

## MELTING OF POLAR ICECAPS – IMPACT ON FISHERIES

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### Summary

Marine capture fisheries currently constitute approximately 60% of the world's total fisheries production. Overfishing is currently considered to pose the greatest threat to the future sustainability of world marine fish production. However, climatic variability is also known to drive fluctuations in the productivity of marine ecosystems and there has been concern that recent rapid climate change caused by the increase in atmospheric greenhouse gasses could have a negative impact on the productivity of the world's marine capture fisheries. The increased rate of melting of the polar ice caps is one of a range of climate change effects that are likely to impact on world fisheries. Sea level rise, the temporal and spatial loss of sea ice in the polar regions and the possible slowing down or stopping of the oceans' thermohaline circulation system all of which could occur as a result of the melting of the polar ice caps, are considered to pose the greatest threat to the sustainable management of the world's marine fisheries.

Fisheries and fishing communities in less developed regions of the world are less likely to be able to respond to climate induced changes in fisheries and therefore are most at risk from them. Coastal, estuarine and near shore fisheries targeting species that depend on these environments for at least part of their life cycle are considered to be most at risk from sea level rise. Conversely a reduction in sea ice cover, although possibly making some fishing grounds more accessible, is more likely to have a detrimental

effect on high latitude, distant water fleets targeting species such as krill and krill dependent species. The issues associated with the melting of the polar ice caps shouldn't be viewed in isolation but should be considered with the whole range of potential climate induced impacts on fisheries. Future management of marine fishery resources should consider the influence of climatic variability when attempting to manage them sustainably.

## **1. Introduction**

Despite a gradual decline over the last few years marine capture fisheries currently account for around 60% of the world's total fisheries production (81.3 million tonnes out of a total of 132 million tonnes in 2003 - FAO), that in total provides an estimated 16 kg<sup>-year</sup> of fish per capita for the world's population. Between 70 and 75% of the world's capture fisheries are currently assessed by the FAO as being either fully or over exploited. Over-fishing of the world's marine resources is considered to be the most significant threat to their continued existence. A recent global study of world fisheries has gone as far as predicting a collapse of all of the world's major marine fisheries within 50 years at current rates of exploitation. However, in addition to overfishing, the impact of climate change, caused most notably by the anthropogenic increase in atmospheric greenhouse gases, is also likely to exert a major influence over the future sustainability of marine fisheries across the globe.

It is well documented that cyclical changes in climatic conditions around the world play a major role in forcing the productivity of marine ecosystems. Perhaps the best documented is the ENSO (El Nino Southern Oscillation) which causes huge fluctuations in the catches of marine fish species on the Pacific coast of South America. As the linkage between fisheries productivity and climate appear to be so strong there are major concerns that relatively small changes in climatic conditions could strongly influence the productivity of marine ecosystems.

As with all predictions concerning the possible impacts of climate change on the earth system, the impact on the marine environment and therefore on fisheries is subject to a high degree of uncertainty and speculation with conflicting but plausible outcomes often cited. This contribution looks at the most likely impact on the world's marine capture fisheries of just one of the major consequences of climate change, namely the melting of the polar icecaps. It is noted that climate change will exert many other influences over the marine environment and that it is difficult to view the melting of polar icecaps in isolation.

## **2. Climate change and the melting of polar icecaps**

The polar icecaps are comprised of the vast Antarctic and Greenland ice sheets and the associated glaciers, ice shelves and the floating pack ice (sea ice) of high latitude regions. The Antarctic icesheet alone, which covers an area of over 14 million km<sup>2</sup>, contains around 70% of the world's freshwater and 90% of its ice. The Greenland ice sheet measures over 1.71 million km<sup>2</sup> and covers 80% of the landmass of Greenland.

There is now a large body of evidence that has demonstrated that global warming (the average warming of the surface of the planet) is leading to the ubiquitous and accelerated melting of ice in the Polar regions, resulting in one of the most obvious signs of climate change. In the Antarctic peninsular region and at Greenland there has been rapid recent retreat of glacier fronts and an overall thinning of the majority of glaciers. The recent observations of the rapid collapse of many ices helvets that fringe the Antarctic peninsular has coincided with a rise in mean sea surface temperature of approximately 1 °C and rising atmospheric temperatures over recent decades.

The Intergovernmental Panel on Climate Change (IPCC) has determined that global warming was  $0.6 \pm 0.2$  °C during the twentieth century and that most of the observed warming over the last 50 years is likely to have been due to the increase in atmospheric greenhouse gas concentrations of anthropogenic origin. In addition, there is now strong evidence that in certain high latitude regions such as the Antarctic peninsular and Greenland, regional warming has been far greater over the last 50 years than the global average, with temperature increases in the region of 3 °C reported for both regions, as much as 10x the global average. There is real concern that the loss of polar ice would further accelerate climate change, as there would be a significant positive feedback effect. Reduced ice cover would mean that less solar radiation is reflected from the earth's surface leading to further warming.

### **3. Impacts on marine fisheries**

The predicted impact of global warming on the icecaps of the polar regions is, as with all areas of climate change, likely to be highly regional and subject to considerable variability and uncertainty. Consequently, the impact of the melting of the polar icecaps on marine fisheries will be highly dependent on both the rate and geographical area in which they occur. The degree to which different fisheries are impacted will depend greatly upon the nature and location of the fishery and their ability to respond to change. Consequently, fisheries operating in developed industrialised nations may be better placed to respond more rapidly and effectively to the threats from climate change than those in developing nations.

It is impossible to view the impacts of polar icecap melt on world fisheries in isolation and they must be considered alongside other potential impacts of climate change upon marine ecosystems. These include such factors as:

- Sea level rise caused by thermal expansion of seawater
- Physiological intolerance of organisms to a rise in environmental temperature
- Increased wave action and storm surges
- Increased turbidity due to increased precipitation and runoff at mid and low latitudes
- Changes in ambient salinity due to increased/decreased evaporation and /or increased runoff
- Acidification of oceans due to carbon dioxide uptake

Further information relating to the impact of the above of fisheries can be found in *Climate Change - Impact on Fisheries*). The present contribution, however, has been

restricted to an assessment of the potential impacts to marine fisheries that that could be directly attributable to the melting of the polar ice caps. These are:

- A contribution to sea level rise
- A reduction in sea ice cover
- A reduction /disappearance of ice shelf (freshwater ice) cover
- Changes to the oceans thermohaline circulation (THC).

#### **4. Sea-level rise**

An estimate of the increase in sea level over the last 100 years has been made from data derived from tide-gauges and satellites. This rise is the sum of many processes going on in the earth system that contribute to global sea-level change, including thermal expansion of the oceans, an overall contribution of ice from glaciers, and human changes in storage of water on and under the land. The contribution to sea level rise of ice sheets in Antarctica and Greenland over this period is not well established and is the subject of conflicting assessments, but it is generally thought that it could account for around one third of the present rate of sea level rise which is estimated in the region of 2 mm per annum. Icecap melt will only cause an increase in sea level when the rate of melt (ablation) is greater than the rate of accumulation due to precipitation (snowfall) and accurately measuring this flux has proved to be very difficult. It is also recognised that melting ice will only contribute significantly to a rise in sea level when it has originated from a terrestrial source. When sea ice or floating ice shelves melt there is no change in volume and hence no significant rise in sea level.

Estimates of projected sea level rise due to polar ice cap melt are highly variable and uncertain due to the inherent complexity associated with its modelling. Great uncertainty exists regarding regional variation in the mass balance of the polar icecaps (the difference between accumulation and ablation of ice due to snowfall and melt) and the probability of the rapid collapse of the Western Antarctic ice sheet (WAIS) and its associated rapid sea level rise. However current estimates from the IPCC suggest that sea level rise from all causes including thermal expansion and glacial melt will be between 9 and 88cm between 1990 and 2100 (assuming a global average surface temperature rise of between 1.4 and 5.8 °C), but the degree to which polar icecap melt contributes to this figure is unclear. It has been predicted that were the Greenland icecap to melt completely there would be an associated global sea level rise of 7.2m whilst complete melting of the Antarctic ice sheets would lead to a rise in sea level of approx. 70m. Outputs from recent models also have predicted that if all the glaciers on the Antarctic peninsular were to melt (75% of glaciers are currently in retreat) it would lead to a sea level rise of 30cm whilst the collapse of the WAIS would lead to a sea level rise of approximately 5m.

#### **5. Impact of sea level rise on marine fisheries**

Any future sea level rise, regardless of magnitude, is likely to have a detrimental but highly variable impact on marine fisheries around the world. Impacts are likely to occur to both the ecosystem to which a fishery belongs and to the infrastructure that supports it. Coastal, and estuarine fisheries which currently account for around 70% of the world

capture fishery production are therefore the most likely to be affected by rising sea levels. Artisanal fisheries conducted in developing nations lying in the tropics and sub tropical regions of the world are more likely to be adversely affected than highly mechanised deepwater fisheries prosecuted by developed nations.

### **5.1. Ecosystem impacts**

Coastal zones are among the worlds most diverse and productive marine environments. They are also areas that are already threatened by habitat loss (for example by coastal development, building of sea-defences and aggregate extraction), over fishing and by marine and terrestrial pollution. The detrimental impact of sea level rise in these areas will be greater than in other marine environments. The impacts of sea level rise likely to be experienced by coastal ecosystems are likely to include the following:

- Increased level of inundation and storm flooding
- Accelerated coastal erosion
- Encroachment of tidal waters into estuaries and river systems

The threat of habitat loss caused by the factors outlined above is most acute on gently shelving shallow coastlines and estuaries. Consequently the greatest risk to fisheries is to those that either target species which inhabit these regions or which depend upon these environments for at least part of their life cycle. Even relatively small sea level rises are likely to cause major flooding in unprotected areas at all latitudes. Low lying, shallow gradient, low energy coastal habitats including mudflats, salt marshes, coral reefs and mangrove forests are thought to be particularly vulnerable to a rise in sea level. Fisheries that are conducted on inter-tidal species such as sessile molluscs (clams, mussels, cockles etc) are particularly at risk as they are prosecuted on species that are uniquely adapted for the intertidal zone and are less able to adapt or move to other areas. The rate at which sea level rise occurs is also of great importance as a slow increase may enable species to adapt and move to newly formed intertidal habitats. In some areas, particularly in developing and sparsely populated regions of the globe it is thought likely that there would be some inland migration and colonisation of suitable coastal habitat as low lying coastal areas become submerged and new inter-tidal habitats become established. However, in areas in which there has previously been a high degree of human coastal development there is very little scope for the inland movement of new habitats and they are far more likely to be lost. Coastal defences and developments not only create a barrier to the inland movement of coastal habitat but may also prevent the accumulation of sediment that is necessary for new pioneer aquatic vegetation to become established. There has been some suggestion that in regions where there is little or no human coastal development and hence no barrier to inland migration, small increases in sea level may actually lead to a short term increase in available estuarine and coastal habitat. Such increases could benefit localised fish and shellfish populations and hence any fisheries on them.

In addition to direct habitat loss, a rise in sea level is also likely to have a range of other consequences for vulnerable coastal marine habitats. These include increased coastal erosion (with an associated increase in turbidity) and the loss of submerged aquatic vegetation within estuarine and deltaic environments. Increasing salinity and changes to

hydrological flow within estuaries (due to changes in the cross sectional area of the estuary with increasing water depth) are also potential consequences of a small rise in sea level. Estuarine environments are hugely important as spawning and nursery areas for a vast array of commercially important vertebrate and invertebrate species throughout the world. It has been estimated for example that estuaries provide habitat for more than 75% of America's commercial fish catch, and for 80-90% of the continent's recreational fish catch. Any changes to the physical and chemical properties of the estuarine environment carry a high risk of adverse impact on the fisheries for these species.

Recent studies on the eastern seaboard of USA suggest that accelerated sea level rise has led to a degradation of as much as 50% of the tidal marsh area of Chesapeake Bay. Increased sediment load caused by erosion is thought to be responsible for the rapid loss of sea grass beds in the region. Reductions in the tidal marsh and submerged vegetation will directly affect the Bay's fisheries because many commercially important fishes and crustaceans such as mummichog *Fundulus heteroclitus*, striped bass *Morone saxatilis* and blue crab *Callinectes sapidus* utilise these habitats as nursery areas and foraging grounds.

The impacts of climate change on coral reef habitats and therefore on the widespread artisanal commercial fisheries that depend upon them have been reasonably well documented. Increased sea surface temperature (SST) leading to bleaching and accelerated erosion due to increasing wave action will have a detrimental impact on reef ecosystems, but the impact of rising sea level, and particularly that which can be attributed to the melting of the polar ice caps is less clear. It is currently thought that small increases in sea level may actually increase the productivity of some coral reefs and stimulate shoreward growth and accretion. This could potentially increase the fishable biomass of a particular reef but it is noted that as in other coastal systems the shoreward advance would be restricted by human coastal development. As with all fisheries discussed, the current threat from over fishing and destructive fishing practices is probably far greater than an as yet, unquantifiable threats from rising sea levels.

In contrast with the direct impacts upon fisheries targeting estuarine and coastal species, those operating in deeper water over continental shelf and slope waters are less likely to be directly impacted by rising sea levels. The predicted increase in sea level of 9 to 88cm by 2100 is unlikely to lead to the direct loss of habitat in deeper sub-tidal ecosystems, with direct impacts most likely to decrease with increasing depth. However, the indirect and ecosystem impacts described above may still have a detrimental effect on these fisheries.

Increasing turbidity resulting from increased rates of coastal erosion could lead to a degradation of deeper water habitats as the deposition of sediment would increase. This could result in the smothering of benthic food sources such as infaunal invertebrates or leading to the loss of specific habitats that are required for spawning. Ecosystem impacts are, however, likely to be of the greatest significance to deeper water fisheries. It has already been observed that many commercially importance species rely on estuarine and coastal habitats for at least part of their life cycle. Any disruption or degradation to these vulnerable environments by sea level rise will undoubtedly have

knock on effects for those species that spend the majority of their life in deeper water environments. Impacts are likely to be felt directly by target species as larval and juvenile habitats are impacted but also by dependent prey and predator species that are reliant on estuarine and coastal habitats for at least part of their life cycle.

Looking at the commercial finfish fisheries operating over on the shelf seas of the British Isles as an example, it is clear that degradation to near shore environments are likely to have a detrimental impact on a range of fisheries. Numerous commercially important fish species including the flatfish species plaice (*Pleuronectes platessa*) and Dover sole (*Solea solea*), herring (*Clupea harengus*) sprat (*Sprattus sprattus*), Bass (*Dicentrarchus labrax*), whiting (*Merlangius merlangus*) and brown crab (*Cancer pagurus*) all are dependent on coastal or estuarine environments for at least part of their life cycle. It is predicted that yields of these species would decrease substantially if their nursery habitat became significantly degraded.

Deep water and oceanic fisheries targeting demersal or highly migratory species (e.g. orange roughy (*Hoplostethus atlanticus*) or tuna fisheries respectively) are far less likely to be affected by relative small increase in sea level although ecosystem impacts may have some knock on effect. Deep-sea fisheries are buffered to some extent from what is occurring in shallower shelf and coastal areas. However, it should be noted that even some deepwater fish species utilise coastal areas during their early life history stages and could therefore be impacted in the same manner as shallower water species.

Taken in isolation, the impact to fisheries of sea level rise could see significant reductions of yields over the long-term, although the potential short term increase in productivity of undeveloped inter tidal areas is noted. However, these impacts should not be viewed in isolation and the other predicted impacts of climate change on fisheries, that are likely to occur regardless of ice cap melt, must also be considered.

## **5.2. Infrastructure impacts on fishing communities**

Sea level rise presents considerable risk to human habitation and infrastructure in low-lying coastal regions. Increased coastal erosion, coastal flooding, loss of coastal wetlands and increased risk from storm surges will affect most regions of the globe but impacts are likely to be more keenly felt in developing nations that have less adaptive capacity for change than more developed regions.

Fishing communities on low-lying islands and coastal areas obviously face the greatest risk within these regions. The capacity for artisanal fisheries to operate from many African, South East Asian, Latin American and Pacific and Indian Ocean island states may be drastically reduced or disappear altogether.

The ability of the population to adapt or protect low-lying coastal environments in the developed world suggests that the impact on fishing communities in such areas will be far less. Communities serving highly mechanised industrial, shelf sea and deepwater fishing fleets are far less likely to be impacted although the costs associated with all aspects of climate change are expected to rise.

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### Bibliography

Anon (2004). ACIA, *Impacts of a warming Arctic*, Arctic Climate Impact Assessment, Cambridge University Press. Available in pdf at [www.acia.uaf.edu](http://www.acia.uaf.edu)

Dickson B., Yashayaev I., Meincke J., Turrell B., Dye S., & Holfort J. (2002). Rapid freshening of the deep North Atlantic Ocean over the past four decades. *Nature*, **416**, 832-837.

Everson I. editor (2000). *Krill: biology, ecology and fisheries*. Blackwell Science, Oxford

Glantz M.H. editor (1992). *Climate Variability, Climate Change, and Fisheries* Cambridge University Press, Cambridge

IPCC (Intergovernmental Panel on Climate Change) (2001). *Climate Change 2001: The IPCC Third Assessment Report* (3 vols.: *The Science of Climate Change; Impacts, Adaptations and Mitigation of Climate Change: Scientific-Technical Analyses; and Economic and Social Dimensions of Climate Change*). Cambridge University Press, Cambridge

Knight P. (ed.) (2006). *Glacier Science and Environmental Change* Blackwell Science, Oxford.

McGinn N.A. (ed.) (2002). *Fisheries in a changing climate*. American Fisheries Society, Symposium 32, Bethesda, Maryland.

Schellnhuber H.J. (ed.) (2006). *Avoiding Dangerous Climate Change*. Cambridge University Press, 2006 392pages.

Schmitter A. (2005). *Decline of the marine ecosystem caused by a reduction in the Atlantic overturning circulation* *Nature* **434** 628-633

Worm B., Barbier E.B., Beaumont N., Duffy J.E., Folke C., Halpern B.S., Jackson J.B.C., Lotze H.K., Micheli F., Palumbi S.R., Sala E., Selkoe K.A., Stachowicz J.J., and Watson R. (2006). Impacts of biodiversity loss on ocean ecosystem services. *Science*, **314**, 787-790.

### Biographical Sketch

**Mark Belchier** is a marine fisheries ecologist with the British Antarctic Survey (BAS). Following completion of a degree in marine zoology from Bangor University (UK) and a PhD in the field of crustacean fisheries ecology at the University of Leicester (UK), he worked on Northern European fish and shellfish species at the University of Liverpool's Port Erin Marine Laboratory. He joined BAS in 2000 in the position of scientific coordinator for a new applied fisheries research station on the sub-Antarctic Island of South Georgia. He is a regular visitor to the Southern Ocean and South Georgia, carrying out ship-borne surveys and laboratory research on commercially important Antarctic fish species.