

Vulnerability of freshwater fisheries and impacts of climate change in south Indian states economies

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Abstract: We compare the vulnerability of 5 states in India national economies to potential climate change impacts on their capture fisheries using an indicator-based approach. States in India (e.g. Karnataka, Tamilnadu, Andhrapradesh, Kerala and Maharashtra) were identified as most vulnerable. This vulnerability was due to the combined effect of predicted warming, the relative importance of fisheries to national economies and diets, and limited societal capacity to adapt to potential impacts and opportunities. Many vulnerable states were also among the country's least developed states whose inhabitants are among the poorest and as twice as reliant on fish, which provides 32% of dietary protein compared to 12% in less vulnerable states. These states also produce 25% of the country's fish exports and are in greatest need of adaptation planning to maintain or enhance the contribution that fisheries can make to poverty reduction. Reducing fish mortality in the majority of fisheries, which are currently fully exploited or overexploited, is the principal feasible means of reducing the impacts of climate change.

Key words: climate change, fisheries, vulnerability, poverty

Reference to this paper should be made as follows: Sannadurgappa, D. (2010) “Impacts of climate change on fisheries and vulnerability of southern Indian state economies”, *Interdisciplinary Environmental review*.

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1 Introduction

The North Sea ecosystem provides 5 per cent of the global fish harvest and has been fished heavily with a particular effect on cod (*Gadus morhua* L.) (Hulme et al., 2002). It is previously shown that temperature is more important than wind intensity and direction, salinity, nutrients and oxygen in determining the North Atlantic and North Sea ecosystem dynamic regime (Smit and Wandel, 2006). During the 1980s, the North Sea experienced a change in hydro-climatic forcing that caused a rapid, temperature-driven ecosystem shift (Newton et al., 2007). Because of the unrealized response of the climate system to historical greenhouse gas emissions, the planet is committed to at least as much warming over the 21st century as it has experienced over the 20th century ($\approx 0.75^{\circ}\text{C}$) regardless of possible future actions to reduce emissions. Failure to slow the increase in atmospheric greenhouse gas concentrations only increases the warming. Adaptation to the anticipated warming is essential.

As the planet's climate changes so too will populations, species and ecosystems, with profound consequences for fisheries change (Smit and Wandel, 2006). Where will climate change impacts on fisheries have greatest social and economic significance? This is a simple question, but a comprehensive answer would require predictions of the geographic patterns of global warming (from global circulation models) and predicted impacts of atmospheric warming on climatic, hydrological and oceanographic processes (from physical models). These changes in physical processes would then need to be linked to ecological processes using coupled physical-ecosystem models – if they were available (Brander, 2007). Yet informed predictions at these scales are urgently needed, because most policy responses relating to planned climate change adaptation and fisheries management are or will be implemented at national levels and even those at local levels will be derived from decisions made at national levels. Until the development of detailed global-scale 'physics-to-fish-to-fishers' models, one pragmatic approach is to use indicators in combination with a risk-assessment or vulnerability framework (Newton et al., 2007).

Ecosystems exist as dynamic regimes controlled by the interplay among species, the environment and how they interact with external forces such as climate. Many studies have reported the rapid alteration of marine ecosystems throughout the world (Jennings and Blanchard, 2004). Although human activities and especially fishing are often held responsible for these abrupt ecosystem shifts, the oceanic biosphere is now also experiencing rapid global climatic change. But all of this takes us only half way to an answer; predicting the impacts on people would further require an understanding of the social and economic dynamics of fishing fleets and fishing communities, and their capacity to adapt to change. Such integrated predictions of the impact of climate change are beyond the current frontiers of our knowledge, particularly at national or smaller scales. In the meantime, fishers are already being affected by changes that are ultimately driven by rising global atmospheric temperatures. For example, coastal fishers in Bangladesh face increased frequency and severity of hurricanes, coupled with the greater penetration of saline water into coastal land due to thermal expansion of the warming oceans (Unnikrishnan et al., 2006) the people of the Chad basin converge around their shrinking lake, as regional warming drives decreased rainfall and increased evapotranspiration and the coastal fishers cope with bleached coral reefs as atmospheric warming leads, in turn, to warmer seas and higher bleaching susceptibility. Set within a context of overexploitation of many of the world's fisheries (Mullon et al., 2005; Newton et al., 2007), policy makers urgently require information and analysis to guide investments and initiatives in climate change mitigation and adaptation.

Additionally, little attention has been given to the consequences of changing fisheries ecosystems on people, particularly so for the millions of small-scale fisher folk (fishers, fish processors, traders and ancillary workers) in the developing world who are among the most vulnerable to climate change (McClanahan et al., 2008). While there is a growing body of case studies on the observed effects of climate change on the distribution and production of individual fisheries (Brander, 2007), it is difficult to estimate or predict the broader or aggregate effects of climate change at national and regional scales (Brander, 2007). To date, global and regional climate vulnerability assessments have focused on agricultural production; fisheries have not yet been systematically evaluated (Tubiello et al., 2007).

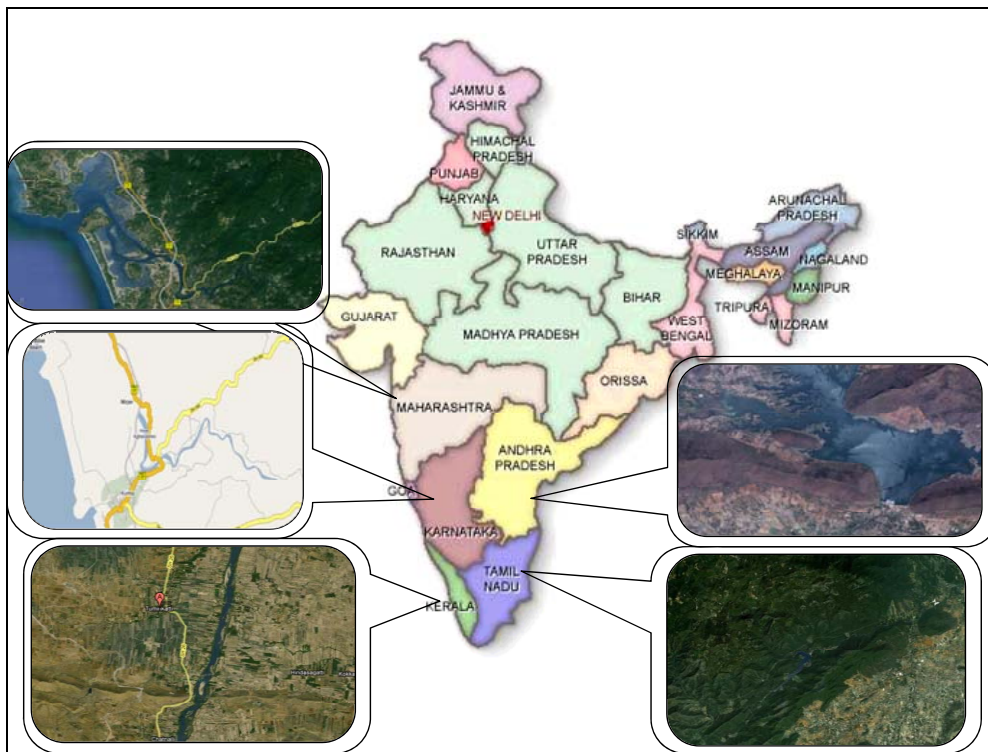
Vulnerability is typically defined as a combination of the extrinsic exposure of groups or individuals or ecological systems to a hazard, such as climate change, their intrinsic sensitivity to the hazard, and their lack of capacity to modify exposure to, absorb, and recover from losses stemming from the hazard, and to exploit new opportunities that arise in the process of adaptation (Smit and Wandel, 2006). This analysis is the first systematic attempt to compare the relative vulnerabilities of national economies to potential climate change impacts on fisheries at a global-scale. In this paper, we provide an indicator-based analysis of the relative vulnerabilities of 5 states to climate change impacts on fisheries.

We use a vulnerability assessment framework developed to identify states highly exposed to hazards related to climate change, where livelihoods and economic growth depend on climate-sensitive industries, such as agriculture, fisheries, forestry and tourism, and where limited resources, infrastructure and societal capacity constrain adaptation (Smit and Wandel, 2006). The increase in carbon dioxide emissions has resulted in an increase in CO₂ concentrations in the oceans (IPCC, 2007), reducing oceanic pH and changing the saturation horizons of aragonite, calcite, and other minerals essential to calcifying organisms (Newton et al., 2007).

2 Study Area

The study areas selected are 1) Aghanashini river in Karnataka. 2) Lakshmipuram reservoir of Vishakapatnam district in Andhrapradesh. 3) Kempanayakana palya of Coimbatore district in Tamilnadu. 4) Periyar river in Kerela and 5) Tansa river in Thane, Maharashtra shown in Figure 1.

Figure 1 India map showing study area of five states i.e. Karnataka, Tamilnadu, Kerala, Maharashtra and Andhrapradesh.



3 Methods

3.1 Climate vulnerability assessment

While this analysis may have greatest relevance to the national policies in India that facilitate climate adaptation processes and management of fisheries systems, our approach complements local site-specific assessments looking at individual and fisher folks' community adaptation, as well as case studies investigating the impact of climate change on particular states. We focus on the vulnerability of state economies to potential impacts of a single large-scale driver, climate change. While additional drivers such as fishing pressure, fuel prices, future changes in trade flows and consumption patterns are important in shaping fisheries production systems. We choose to focus on a state scale, mainly because appropriate policies are generally formulated and implemented at this scale, but also because many global indicators are available only at states and national scale. State-level assessments provide a broad view of vulnerability patterns and may be used to identify particularly vulnerable regions and eventually facilitate comparison of vulnerability assessments across natural resource-dependent industries, potentially providing insight into processes that cause and exacerbate vulnerability (Yohe et al., 2006).

3.2 *The three components of vulnerability*

Vulnerability to climate change depends upon three key elements: exposure (E) to physical effects of climate change, the degree of intrinsic sensitivity of the natural resource system or dependence of the national economy upon social and economic returns from that sector (S), and the extent to which adaptive capacity (AC) enables these potential impacts to be offset (IPCC, 2001a). There are no objective, independently derived measures of exposure, sensitivity, or adaptive capacity, and so their relevance and interpretation depend on the scale of analysis, the particular sector under consideration and data availability (Sullivan and Meigh 2007).

We chose measures of exposure, sensitivity and adaptive capacity that likely to best capture the properties of interest, based on previous vulnerability studies (O'Brien et al., 2005). The choice of variables is similar to that of other constructed indices such as the Disaster Risk Index, Water Poverty Index and the Hotspots program (Sullivan and Meigh, 2007), and was driven by a consideration of a number of factors including: the number of states for which data were available, the availability of recent data, and the degree of direct relevance to the phenomena that the indicators are intended to represent. As this is the first study that specifically addresses the sensitivity of the fishery sector, we identified indicators of economic dependence on fisheries based on a review of the scientific literature (Adger et al., 2005). For the three key elements of vulnerability (i.e. Exposure, Sensitivity, and Adaptive Capacity) the derivation of each indicator is detailed below.

3.3 *Effects of fishing*

Fisheries might interact with climate change in causing changes in fish populations, through various mechanisms. Climate change could affect the distribution of particular species and hence their susceptibility to particular fishing fleets, becoming more or less "catchable" as a result. Similarly, climate-related distribution shifts may affect the protective capabilities of closed-areas, because species or life stages may shift outside the boundaries of the protected area and hence become vulnerable to fishing (O'Brien et al., 2000).

Extensive fishing may cause fish populations to become more vulnerable to short-term natural climate variability (O'Brien et al., 2000), by making such populations less able to "buffer" against

the effects of the occasional poor year classes. A major implication is that fishery-induced impoverishment of stock structure (reduced and fewer ages and smaller sizes) can increase the sensitivity of a previously "robust" stock to climate change. Conversely, long-term climate change may make stocks more vulnerable to fishing, by reducing the overall carrying capacity of the stock, such that it might not be sustained at, or expected to recover to, levels observed in the past (Bakun, 1990).

Fishing will have a major influence on the size structure and species composition of fish assemblages and thus will affect predator-prey relationships (Barange, 2002). Fishing will interact with global warming, because body size generally increases with latitude (CWP, 2004) and small fish species may take advantage of the removal of the larger predatory fish (Edwards et al., 2002). Fishing may also affect ecosystem control causing bottom-up systems to become top-down controlled systems (see the section "Ecosystem response"). How climate change will interact with fishing will depend on the species affected and eventually on the prevailing patterns of ecosystem structure and function (Handisyde et al., 2006). Hence, the response of ecosystems under climate and fishing pressure is currently difficult to predict.

3.3.1 Sensitivity

Table 1 Relative vulnerabilities of state economies and climate change-driven impacts on fisheries.

Rank	State	Vulnerability	E	S	AC
			0.72	0.60	
1	Kerala	0.74	(36)	(32)	0.94 (2)
			0.66	0.67	
2	Karnataka	0.72	(54)	(22)	0.91 (5)
				0.64	
3	Andhrapradesh	0.71	1.00 (2)	(24)	0.55 (76)
			0.73		
			(28)	0.59(47)	
4	Maharashtra	0.71	0.75		0.84 (12)
5	Tamilnadu	0.70	(25)	0.45(42)	0.56(45)

Index values (rankings) of exposure (E), sensitivity (S) and adaptive capacity (AC). All rankings are relative to the entire dataset (n = 5 states).

Two metrics of the contribution we used for fisheries to national employment: total number of fishers and the number of fishers expressed as a proportion of the economically active population (EAP). These two variables are only weakly correlated (Spearman's $\rho = 0.40$) and they capture and represent different elements of sensitivity, because strong dependence on fisheries for employment may reflect either high absolute dependence (i.e. a large number of fishers) or relative dependence (i.e. a large proportion of the national workforce), or in some cases, both. Estimates of fisher numbers were derived from the most recent national census data; we caution that these values probably underestimate true numbers because of the recognized difficulties in enumerating fishers (CWP, 2004). Sensitivity is usually defined as the intrinsic degree to which biophysical, social and economic conditions are likely to be influenced by extrinsic stresses or hazards (IPCC, 2001a). However, because climate change may influence ecological and human aspects of fisheries in complex ways, we considered sensitivity in a slightly different context. Instead we assume that the sensitivity, in this context, is represented by the fisheries dependence which we consider to be the importance of fisheries to national economies and food security. The nutritional dependence of the human population on fisheries was represented by the total fish available for consumption per country expressed as a proportion of all consumed animal protein. Fish consumption was estimated as annual total supply (production + imports - exports - non-food uses) from FAO food balance sheets, and expressed as grams of product consumed per person per day (FAOSTAT, 2004).

3.3.2 *Adaptive capacity*

Elements of adaptive capacity comprise such as levels of social capital, human capital and the appropriateness and effectiveness of governance structures (Vincent, 2007). The adaptive capacity index in this study was a composite of four human development indices (healthy life expectancy, education, governance and size of economy). These variables were chosen on the assumption that states with high levels of economic and human development have the resources and institutions necessary to undertake planned adaptation. CAIT is an information and analysis tool on global climate change, providing a publicly available database of comparable climate-relevant indicators, which are drawn from reputable international and national sources. The Climate Analysis Indicator Tool (CAIT) developed by the World Resources Institute was used to combine these four variables (CAIT, 2005).

3.3.3 *Economic impacts*

A key factor concerning future economic impacts is the need to identify which countries and regions are most vulnerable. Modeling studies have assessed country vulnerability on the basis of exposure of its fisheries to climate change, high dependence on fisheries production, and low capacity to respond. The studies show that climate will have the greatest economic impact on the fisheries sectors of central and northern states of India. Indirect economic impacts will depend on the extent to which local economies are able to adapt to new conditions in terms of labour and capital mobility. Change in natural fisheries production is often compounded by decreased harvest capacity and reduced access to markets. Country's fish production is forecast to increase more slowly than demand to 2025, and the proportion of production coming from aquaculture is forecast to increase. Therefore, zero growth in capture fisheries production will not threaten total supply unduly, but a decline could affect countries fish consumption (Hulme et al., 2002).

4 Results

4.1 Present fisheries production, trends, and threats in southern India

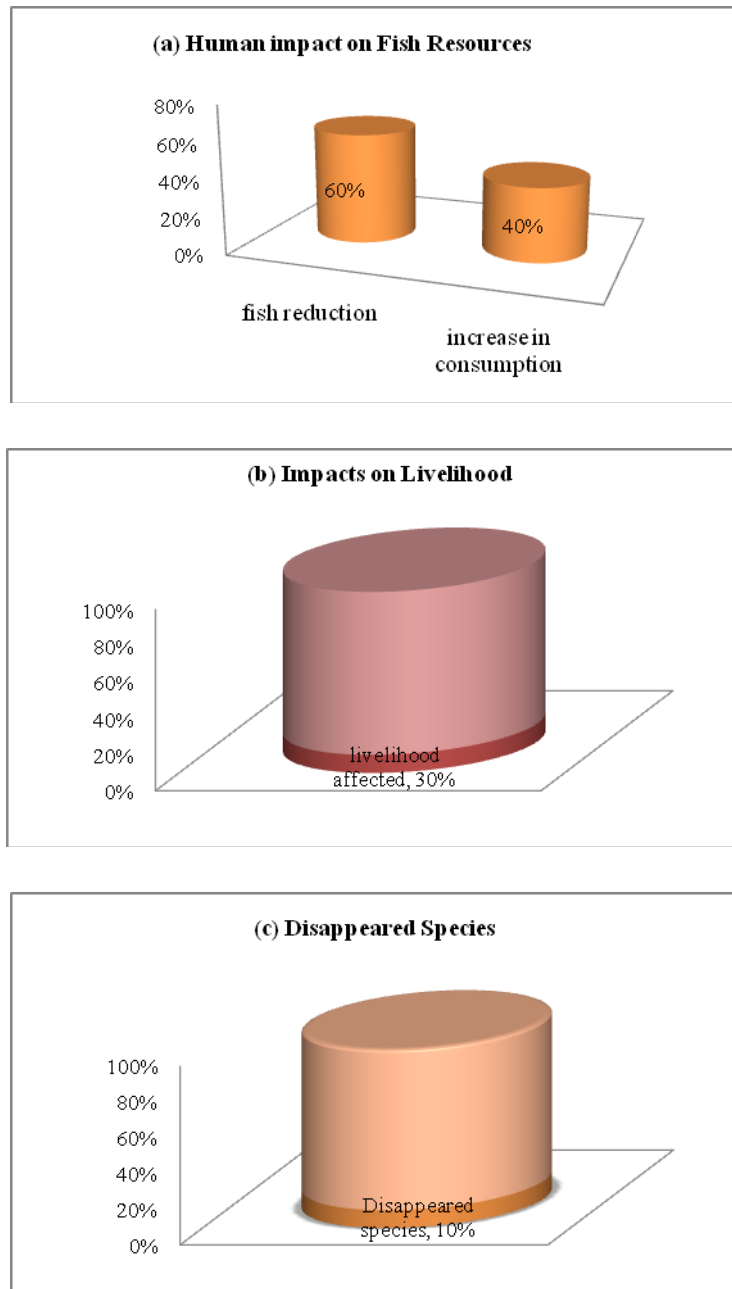
4.1.1 Production and trends

Sixty one percent of the 78 million tons total country's aquatic production in 2006 was from marine systems, and the remaining 22% was from inland waters. Aquaculture production is rising rapidly, and by 2030 it is estimated that aquaculture production will be close to that of capture production in southern India (Newton et al., 2007). Human impacts on fisheries production and consumption represented in ratio, consumption increased in faster rate than production and 30% of livelihood is affected and 10% of fish species reduced. These trends are shown in the Figure 2.

4.1.2 Threats

The principal threats to future fisheries production identified here are expected to act progressively (i.e., a linear response) and to interact with each other. However, marine ecosystems can also respond to changes in physical or biological forcing in a nonlinear way (Hulme et al., 2002,), e.g., when a threshold value is exceeded and a major change in species composition, production, and dynamics takes place. We know that such nonlinear responses occur but do not yet understand how or under what conditions. This is a key limitation in our ability to forecast future states of marine ecosystems.

Figure 2 Trends of fisheries in southern India (a) Human impact on Fish Resources, (b) Impacts on Livelihood, (c) Disappeared Species



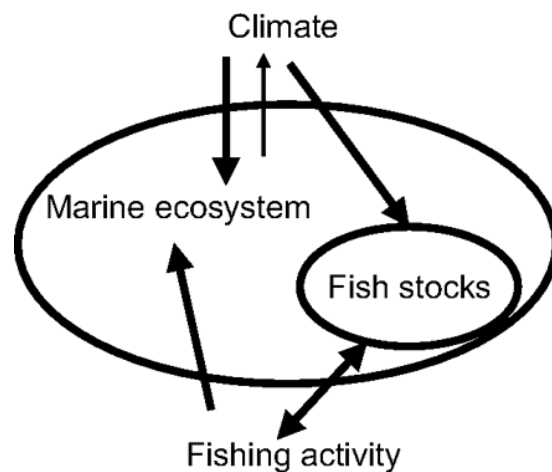
4.2 Fishing activity

Fishing is the greatest threat to future fish production; however, the impacts of fishing and of climate change interact in a number of ways, and they cannot be treated as separate issues. Fishing causes

changes in the distribution, demography, and stock structure of individual species and direct or indirect changes in fish communities and marine ecosystems. These changes have consequences for other ecosystem services (such as nutrient cycling and recreational use) and for sustainability, resilience and ability to adapt to climate change, and other pressures. Figure 3 shows the relationship between the impacts of climate change and fishing activity on the marine ecosystem and its fish component. Future sustainable fisheries depend on effective management of fishing activity, which in turn requires an understanding of the effects of climate change on the productivity and distribution of exploited stocks. Management must take into account the interactive effects of fishing, climate, and other pressures.

Fishing is size-selective and causes changes in the size and age structure of populations, which results in greater variability in annual recruitment in exploited populations. The truncation of age structure and loss of geographic substructure within populations makes them more sensitive to climate fluctuations (Newton et al., 2007). To sustain the resilience of fish populations, in particular when they are confronted by additional pressures such as climate change, their age and geographic structure must be preserved rather than relying only on management of their biomass. We are currently fishing most stocks at levels that expose them to a high risk of collapse, given the trends in climate and the uncertainty over impacts.

Figure 3 schematic representations of impacts of climate change and fishing activity on the marine ecosystem and its fish component.



Fishing is one of a number of human pressures that have resulted in a global decline in biodiversity. This raises concerns over the role biodiversity plays in maintaining ecosystem services and, in particular, resilience to climate change. A recent meta analysis concluded that the oceans' capacity to provide food, maintain water quality, and recover from perturbation has been impaired through loss of biodiversity (Vincent, 2007), but other studies of the relationship between biodiversity and ecosystem functioning and services produce a more nuanced picture.

4.3 Direct and indirect effects of climate change on distribution, productivity, and extinction.

In India climate change has both direct and indirect impacts on fish stocks that are exploited commercially. Direct effects act on physiology and behaviour and alter growth, development, reproductive capacity, mortality, and distribution. Indirect effects alter the productivity, structure, and composition of the ecosystems on which fish depend for food and shelter.

The effects of increasing temperature on marine and freshwater ecosystems are already evident, with rapid pole ward shifts in distributions of fish and plankton in regions, where temperature change has been rapid (Sullivan and Meigh 2007). Further changes in distribution and productivity are expected due to continuing warming and freshening. Some of the changes are expected to have positive consequences for fish production (Vincent, 2007), but in other cases reproductive capacity is reduced and stocks become vulnerable to levels of fishing that had previously been sustainable. Local extinctions are occurring at the edges of current ranges, particularly in freshwater and diadromous species (Adger , 2000).

4.4 Exposure to climate change

Warming will be moderate in southern parts of India. Relatively smaller temperature increases are predicted for nations in northern part. Predicted temperature increases for the final 5 states in the dataset were very highly correlated between the two scenarios.

4.5 *Sensitivity or dependence of national economies upon the fisheries sector and adaptive capacity and vulnerability*

The largest fisheries in terms of total capture production and employment were in the Kerala and Tamilnadu. As expected, the largest reported landings were associated with those states traditionally considered the countries major fishing nations (FAO, 2007). The lowest levels of production were mainly associated with landlocked states (e.g. Karnataka). The states with the lowest adaptive capacity were concentrated almost exclusively Tamilnadu, and Kerala. Virtually all south Indian states, except Karnataka, had low adaptive capacity. The only highly vulnerable states in the higher latitudes were Tamilnadu, Andhrapradesh and Kerala, reflecting their relatively important fishing fleets, high level of exposure to predicted climate change and relatively low adaptive capacity. The region's most vulnerable to climate-induced changes in fisheries were particularly Tamilnadu, Andhrapradesh and Kerala.

5 Discussion

The high vulnerability in Indian states reflects different combinations of climate exposure, sensitivity or fisheries dependence and adaptive capacity (Table 1). Understanding how these various factors combine to influence vulnerability provides a useful starting point for directing future research and climate change adaptation and mitigation initiatives. This study is the first to identify states whose economies are potentially the most vulnerable to future climate change impacts on the fisheries sector. Although warming will be most pronounced at high latitudes, the states with economies most vulnerable to warming-related effects on fisheries lie in the tropics.

South Indian states fisheries are important to the poor, and regional assessments indicate that fishery production in both continental and marine waters is closely tied to climatic variation. West Coast states have large coastal populations that rely upon exploitation of rich marine upwelling fisheries, landings from which are largely driven by irregular low frequency oscillation in oceanic and atmospheric climate conditions (Dulvy et al., 2009). Fish are an important protein source for some of these West coast states, comprising nearly two-thirds of daily animal protein intake (FAO, 2004). Many of these fisheries are already subject to overfishing by both local, Indian fishing fleets with access agreements (Mitchell et al., 2004). In Eastern fisheries, landings are derived largely from freshwaters (FAO, 2004). In the deeper Rift Valley lakes, such as Lake Tanganyika, climate change has been

associated with increases in surface water temperature, reduced primary productivity and reduced fish catch rate over the last century (Metzger et al., 2005). Water levels and surface areas of some large shallow African lakes (Lakes Chilwa, Bangweulu and Chad) fluctuate with regional rainfall anomalies (Reid et al., 2007), these climatic and hydrological fluctuations are mirrored by changes in fishing activity and catches. Vulnerable Asian countries face combinations of three issues: high fisheries dependence, heavily-exploited marine ecosystems, and high exposure of major riverine and coastal fisheries to climate change.

Fish constitute a high proportion of export income in parts of South and Southeast Asia, and a major source of dietary protein – typically 40% of all animal protein consumed per year. The consequences for the region's highly productive river and floodplain fisheries – a vital component of the rural economy - are uncertain and depend on the interaction between local rainfall and glacier melt profiles, the importance of dry vs. wet season water levels for fish productivity, and increasing irrigation demands for domestic, agricultural and industrial use (Vorosmarty et al., 2000; Alcamo et al., 2003). Fisheries production of some of the more vulnerable countries in Asia relies on rivers that arise in the Himalayan Mountains - the Indus, Brahmaputra, Ganga and Mekong. Climate change is likely to cause earlier season peak flows and possible reductions in flow, attributable to reduced snowfall and melting glaciers (Barnett et al., 2005). For example, predicted summer flows in the Ganges will be reduced by two-thirds (WWF, 2005). Southeast Asian coral reef fisheries already appropriate four times their sustainable catch and their reefs are heavily at risk from coral bleaching induced by climate change (Bryant et al., 1998; Warren-Rhodes et al., 2003; Newton et al., 2007). Climate shocks on these Asian fisheries are predicted to have significant economic consequences for the poorest consumers (Briones et al., 2005).

Knowledge of the eco-physiology will provide a strong basis to infer the response of a species to a change in temperature (and other climate-driven changes in abiotic factors). It will allow us to define the bioclimate envelope and evaluate the change in habitat suitability (Perry et al., 2007), or evaluate whether observed temperature changes may be responsible for the change in the population abundance, such as for the eelpout in the Wadden Sea (Pauly et al., 1987). Although we have mainly dealt with temperature, climate change may also affect oxygen, salinity, and ocean pH. These factors may load the metabolic scope and decrease the tolerance range of the organism (Sims et al., 2001), subsequently making it more vulnerable to climate change.

6 Conclusions

While the detailed effects of climate change and direction of change on the physical and biological processes that affect individual fisheries are uncertain. An important element of climate change that could represent 'dangerous anthropogenic interference' (UNFCCC, 2006) is the vulnerability of the economies of some of the countries fishing states to climate change impacts which could affect their food security and levels of poverty by elevating stress on fisheries production. In addition to the effects of climate change, fisheries production systems are already under considerable stress from overfishing, habitat loss, pollution, invasive species, water abstraction and damming. Overall the large-scale climate-related changes in fisheries are likely to bring either increased economic hardship or missed opportunities for countries that depend upon them but lack capacity to adapt. Fortunately most climate change adaptation measures thus go hand-in-hand with attempts to reduce both poverty and overfishing through strengthening livelihoods, economies and environmental governance.

Building adaptive capacity is a necessary response, both for countries where climate change may bring improved fishing opportunities and for those where detrimental impacts are foreseen. Countries with weak economies and poor governance are less able to translate improved fishery productivity into reduced poverty. In the absence of enhanced capacity to cope with and adapt to the impacts of climate change, the disruption of fisheries by climate change is likely to affect large numbers of poor people, and reduce the options for future economic growth in those states for which fisheries are important sources of food, employment and export revenues. South Indian states that are most vulnerable to climate change impacts on their fisheries are also the poorest: The inhabitants of vulnerable states are twice as dependent upon fish for food as those of other states, with 32% of dietary protein derived from fish compared with 12% elsewhere. Yet a considerable proportion of fish captured by the most vulnerable states is exported. The most vulnerable states produce 25% of counties fishery exports.

Given the complexity of the problem, where climate change is a multifaceted driver and the response of affected fish population too is multifaceted, we believe that scientific progress will benefit from an approach where *a priori* hypotheses are formulated based on first principles of the relevant levels of organization. The hypotheses proposed here are by no means complete. They should rather be regarded as a first set of hypotheses. These hypotheses seek to compare species and species-groups that

have contrasting ecological characteristics and are thus likely to differ in their sensitivity to climate change. The classification of species into ecotypes based on bio geographic affinity, habitat requirement, and life-history characteristics may be an important starting point. The review of a number of well-studied fish species in the south India did not allow us to test all working hypotheses, but supported the hypothesis that species exhibited distributional shifts (latitude and depth) in response to a temperature increase and that the response of pelagic species is stronger than that of demersal species, corroborating a number of recent studies of changes in fish assemblages (Andrew et al., 2007; Brooks et al., 2005).

Given the complexity and regional variability of marine ecosystems and their responses to climate change, it is difficult to provide detailed management and adaptation strategies for fisheries management. However, it is possible to suggest attributes of management that are likely to be helpful. These include flexibility, adaptability to new information about the marine ecosystem, reflexivity (i.e., continuous evaluation of the consequences of management in relation to targets), and transparency in the use of information and in governance. Fisheries have always been subjected to large natural variability, and fishing communities have in most, but not all, cases been able to adapt to these changes. Management measures should seek to accommodate such autonomous adaptation by retaining flexibility in transitions between alternative livelihoods. Management measures should also avoid historically based schemes (e.g., catch quota allocations) that cease to correspond to changing distributions and population levels. Objectives for sustainable management of fisheries should build-in expected climate change. Changes in the amplitude of climate variability are very likely to have greater consequences than changes in mean values. Extreme climate events have significant consequences for fisheries production in both marine and inland systems.

Acknowledgements

This research was financed by Indian Institute of Science, Bangalore, India in 2006-2009. We thank our senior Scientists for commenting on earlier drafts, and two anonymous referees for their careful critical reading of the manuscript and their many constructive suggestions. The authors are grateful to the editorial board of *Interdisciplinary Environmental Review (IER)* for their valuable suggestions and the reviewers for their valuable suggestions. All errors remain to the authors.

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