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# Decision-Making and Action Taking: Fisheries Management in a Changing Climate

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# Abstract

## Decision-Making and Action Taking: Fisheries Management in a Changing Climate

*by*

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Decision-makers in fisheries management are confronted with the challenge of how to respond to existing and predicted changes in ocean conditions that are likely to affect the stocks of fish they manage. In order to address climate change most research and thinking advises decision-makers to ensure that fisheries are well-managed and abundant in an ecosystem context. These policies can best allow fisheries to adapt to changing climate. To address climate change, decision-makers should carefully monitor changing conditions and potential changes in factors affecting fish stock abundance. An adaptive approach to fisheries management under conditions of climate change requires that decision-makers engage with fishing interests in a transparent manner and in ways that respect the input of fishing interests and in ways that acknowledge the levels of uncertainty. This approach implies a governance approach to management that is closer to co-management or shared management responsibility than in most hierarchical processes that characterize fishery management to date. The answer to the question of when fishery decision-makers should begin to incorporate climate change into decision making processes is that they should have started yesterday. The justification for this is that even today, climate variability can affect fishery management decisions and the sooner this is understood and incorporated into the management process the better. In economic terms, a conservative decision relative to fisheries management is likely to produce a positive long term benefit whereas the failure to recognize the need to act in time may have serious immediate negative consequences especially when compounded by inadequate management. While climate change can also produce positive consequences for some species a note of caution is still advised in anticipating and responding to such opportunities

***Keywords***: Fisheries management; climate change; fishery policy; governance; ecosystems; global warming; international fisheries.

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## Introduction

It is accepted as a given that climate change (likely global warming) will have impacts on fisheries and aquaculture in various ways (*e.g.*, primary production, growth, recruitment, mortality, distribution, migration pattern, species composition of the fish stocks, seasonality and productivity of marine and freshwater systems, increasing input costs, etc) and is likely to increase in intensity in the coming decades (Kotchen and Young, 2007). Fisheries management is assumed to be able to play a crucial role in adapting fisheries to changing climate. Some have argued that the management system should be adaptive and flexible, be based on a precautionary approach and to incorporate an ecosystem approach to fisheries management (EAFM) (Johnson and Welch, 2010; Cheung, 2009). However many challenges exist in order for this to happen. Chief among these are the uncertainties and complexities in understanding and forecasting the interactions between climate change and fisheries and how fisheries respond to management measures which might be adopted to adapt to changing circumstances. What should fisheries policy makers do in order to develop adaptive and flexible fisheries management regimes in order to assist the transition of fishing industries and communities to changing circumstances? If inappropriate measures are adopted the results could be economically detrimental to millions whose food security and livelihoods depend on fisheries and aquaculture (Badjeck *et al.*, 2010; Kullenberg, 2010).

This paper addresses the question of how to select management options and pathways to address climate change. More specifically, the paper addresses the question of "What should policy makers do to address climate change?" by laying out what fisheries management options can address climate change, taking into consideration that the question of whether the current fisheries management toolbox is sufficient to address climate change. It also addresses the question of "How should policy makers take action to address climate change?" *e.g.*, how fisheries decision making processes can be enhanced so that the decision making can contribute to increased flexibility, adaptability and resilience of fisheries management. This requires that we take into account the dynamics of interaction among different players, institutions and stakeholders in the fisheries management process. Similarly it is critical to address "How can fisheries governance affect decision making for coping with climate change in fisheries and how can those aspects of governance be strengthened?" In this instance fishery governance should be understood broadly to be, "a systemic concept relating to the exercise of economic, political and administrative authority that is characterized by:

- guiding principles and goals, both conceptual and operational;
- the ways and means of organization and coordination;
- the infrastructure of socio-political, economic and legal institutions and instruments;
- the nature and modus operandi of the processes;
- the actors and their roles;
- the policies, plans and measures that are produced; as well as
- the outcomes of the exercise (*http://www.fao.org/fishery/topic/2014/en*)."

Our focus here is on fisheries managed in the context of large marine ecosystems under national jurisdictions of developed countries (Hennessey and Sutinen, 2005; Payet,

2006) and not artisanal fisheries (Kalikoski *et al.*, 2010; Njock and Westlund, 2010; Allison and Ellis 2010) or fisheries on the high seas (Miller 2007; Schechter *et al.* 2008) or in freshwater (Crook *et al.*, 2010).

Finally, we address the question of "When should policy makers act?" Given the uncertainties and complexities involved in the interaction between climate change and fisheries, what sort of framework that can provide advice to policy makers in determining the timing of setting up and implementing policies? In other words, should we change current management systems to be more flexible and adaptable systems, or we should wait until climate change imposes more direct impacts on fisheries. In addressing this issue, it is important to identify economic costs and benefits of each set of policy decisions as well as trade-offs between short term costs and long term benefits or vice-versa (Shertzer and Prager, 2007).

In developing this paper, the discussion has benefitted from Grafton (2009) supplied by the OECD Secretariat and Grafton (2010). However, those papers leave open some opportunities for expansion, especially with respect to empirical responses. In this paper we examine ways to advance some of the components of the previous literature and use the Northeast Pacific region as an empirical front for exploration of fishery management decision making that appears to follow successfully the policies advocated for fishery management response to climate change.

## What should policy makers do to address climate change?

In order to answer this question it is critical to ask a series of other questions, "Who are the decision-makers relative to fisheries and climate?" What are the decision processes?" "What are the climate change challenges to fisheries management?" "What decisions need to be made with climate in mind?"

The goal here is to identify actors, processes and actions that can support adaptation to climate change. Note that no effort to address mitigation within the fisheries sector is made in this paper (Rees and Wackernagel, 1994; Rees and Wackernagel, 1996; Watson *et al.*, 2004). The rationale for this decision is because avoiding the unmanageable consequences of climate change requires a global mitigation approach while managing the unavoidable consequences of climate change can be handled in an adaptive approach applied at local and regional scales in fisheries management. This is not to deny that there are win-win strategies that could encompass both mitigation and adaptation or that many adaptation strategies are actions that represent improvements in fishery management that would produce significant economic or management benefits in and of them (Sigma Xi Scientific Expert Group, 2007). This approach underscores the need for fishery managers to be able to recognize the conditions under which fisheries values are sustained by conservative decision-making and when more flexibility can be realized.

### *Decision-makers and decision processes*

So far we have identified the locus of climate change mitigation and fishery adaptation decision-making in this paper as being at a national level decision making. With respect to either action arena this approach is justified because it is a legitimate role for government to provide monitoring, scientific research, management and enforcement in support of local and regional government and private sector decision-making with respect to common access resources, *i.e.*, the atmosphere and fisheries. In most countries there are distinctly different sets of decision-makers and processes for decision making with regard to climate mitigation and climate adaptation. Decision-making about mitigation strategies is led (or blocked) by either legislative bodies or by the administrative branch if such authority is granted. Multiple agencies within the administrative branch are involved with developing strategic responses for adapting to climate change usually in response to a legislative mandate or as part of a coordinated national administrative strategy. Fisheries decision-making generally falls in this sectoral adaptation strategy where a national directive may be set and the agencies respond. Beyond sectoral agency level it is difficult to generalize on how specific decisions are made because some countries perform this function centrally and others do it on a regional basis, *e.g.*, for setting total allowable catches, setting seasons, etc. Further complicating matters for decision making, within regions there may be split authority for fisheries in coastal fisheries performed at the state or provincial level and nearshore vs. offshore level. In addition, there are some cases where jurisdiction is assigned on a species by species basis, which, in the case of an anadromous fish like salmon, means different management decision making in freshwater and marine environments.

Processes for decision-making on climate mitigation involve national level agenda setting that is strongly influenced by the engagement of the country in international efforts like the Kyoto Protocol and the Intergovernmental Panel on Climate Change. This involves a complex interplay among legislative bodies, administrative agencies and the highest levels of political leadership and the affected interests that seek to influence the outcomes. Decisions are not so much "made" by an individual but a position is "negotiated" to represent policy. This is a constantly evolving discourse that takes place gradually over multiple years (*in sensu* Young, 2002).

With respect to adaptation, a similar complex interplay may occur but at a considerably lower policy level and with a constellation of participants that focuses on the decision processes and opportunities for scoping or input and response. If fisheries are a significant part of a national or regional economy, then the policy level would be commensurately higher than where they represent a small portion of the national economy (Smith *et al.*, 2010). Fishery management decisions are almost exclusively based on annual cycles where stock sizes are assessed and total allowable catches and regulations are modified to take into account current trends. With the move toward incorporation of a broader ecosystem framework in fisheries decision making scientific information on fishing effects and affects of other environmental factors on fisheries are taken into account and may inform and modify decisions made. Taking ecosystem aspects into account tends to expand the timescale from an annual cycle to consideration of the long term as well. Within this framework, the decision processes for centrally managed fisheries tend to have formal mechanisms for interest group and public participation which can result in lower transparency. Similarly, where co-management is the process for decision-making, the level of participation and responsibility increases proportionally and transparency is enhanced (OECD 1997).

This brief effort to characterize the decision makers and decision processes shows considerable diversity exists depending on if the focus is on climate mitigation or fisheries sectoral decisions to adapt to changing circumstances. In closing this section, it is necessary and important to identify a critical linkage that needs to exist between these two decision arenas. With respect to provision of forecasts and climate scenarios on which fishery management depends, fisheries management is a client/stakeholder in the broad scheme of decisions about climate forecasts. Conversely, climate science needs to be relevant to the questions of climate change and fisheries. Thus, mechanisms for communicating forecasts and forecast needs from the fisheries sector to the climate sector monitoring and forecasting change must be established.

In practice, the response of fishery management to climate change so far is extremely diverse, *i.e.*, some managers assume that natural variability already encompasses climate change, others deny that climate change is occurring in ways that could affect fisheries, while still others are stymied in developing a response because of lack of information, capacity and high level uncertainty. Finally, other fishery managers are developing reasoned responses in light of observed changes in fisheries and concern about predicted trends that would further impact fisheries. In general, this latter approach is found in regions which experience the El Nino/Southern Oscillation (Wooster and Fluharty, 1985) and the Pacific Decadal Oscillation (Mantua *et al.*, 1997; Hare *et al.*, 1999, Stram and Evans, 2009) as well as other regions with similar variability affecting marine resources (Glantz, 1988; Glantz and Feingold, 1992). The social limits to adaptation to climate change are rooted in values and ethics, risk, knowledge and culture in diverse but possibly mutable ways (Adger, 2009) a topic to which we will return.

Throughout the world's fisheries there are many different approaches to fisheries decision-making and these factors may, in the short run, be more important to identify even though they are not associated with climate per se (Alder *et al.*, 2010). Furthermore, regional differences and varied and variable responsiveness of organisms to climate change are not well understood. Response times can be slow or fast so that it is not easy to either generalize or to be specific about the need for and the impact of direct or indirect management response.

### *Fishery management systems and climate change*

Challenges to fisheries management systems are myriad (Longhurst, 2010). From the standpoint of social system dynamics and their impacts on fisheries management it is useful to consider such factors as cost of inputs like fuel, labor, construction and repair into the fishery. Similarly in an increasingly global market, factors that affect revenue like volume and value of catch promote competition that generates positive or negative feedbacks to fisheries communities independently of climate change (Smith *et al.* 2010). Changes in technology affect the productivity of individual fishing operations as well as fish processing and distribution. Illegal, unreported and unregulated fishing can perturb markets and increase competition in ways that encourage cheating (Flothman *et al.*, 2010). This is a "not so natural, natural disaster" but real natural disasters like impacts of storms on fishing infrastructure can be extremely problematic. Most important, human values and how they resist or respond to changes in climate are poorly known (Turner *et al.*, 2009). While this paper focuses on the direct benefits from fisheries and economies but it should be noted that others are exploring the broader valuation questions related to natural capital and ecosystem services (Daily 1997; Hawken *et al.*, 1999; Bryan, 2010).

Global climate change in the marine environment that are occurring include rising sea levels [in most areas], warming water temperatures, increasing acidification and differences in patterns of precipitation all of which can impact productivity and structure of marine ecosystems. Concomitantly "global changes are taking place in human systems which impact the oceans, including changing lifestyles, intensive fishing, the globalization of trade and, as food prices continue to rise, the need to feed the world's population" (Perry and Ommer, 2010).

From the standpoint of the ecosystem the challenges of climate change to fisheries management systems are also myriad. Most critical is the determination of how much harvest can be taken on a sustainable basis over time and then measuring and estimating how that result can be obtained. Given that fisheries themselves are ecosystem change agents, fisheries management is also expected to determine and utilize information on the life history parameters, distribution, and response of fish to their environment and to fishing and other factors (Planque *et al.*, 2010). The acceptable level of change in marine ecosystems that can be attributed to fisheries is becoming a more and more hotly contested as complex aspects like shifting baselines, fishing down or through foodwebs and impact of fishing on biodiversity and habitats enter into fishery management decisions. While these are difficult scientific questions that must be addressed, fishery management continues to make decisions in the face of uncertainty about the ecosystem. However, it must also make decisions on what is the appropriate fishing effort and how can it be applied to achieve the management targets. This requires setting and enforcing fishing regulations and allocations that are effective at achieving the target biological catch which is difficult under open access conditions. Indeed, even when entry is limited, technological progress and investments in more efficient harvesting can compound control efforts. Increasingly, some form of catch shares in the commercial fisheries is being seen as a necessary tool in fisheries management decision-making (Sanchirico, 2009). Thus, even without the complications of climate change, fisheries management is an increasingly complex and contentious process.

The challenges that climate change adds to fisheries management decision making processes can be summarized along the following lines. First, climate change increases the management uncertainty concerning fish stock productivity, migratory patterns, trophic interactions and vulnerability to fishing pressure (Ling *et al.*, 2009; McIlgorm *et al.*, 2010). Secondly, the effects of fishing, especially overfishing and degradation to the essential habits may also exacerbate the difficulty of fisheries management to take actions that respond to climate change signals, *e.g.*, be slower to recover or less resilient (Turner *et al.*, 2010). Third, where fishing has already exceeded thresholds major shifts may have occurred in ecological systems (Casini, 2009) and climate change may produce additional surprises for management (Peters *et al.*, 2004, Lindenmayer *et al.*, 2010). Fourth, social and economic constraints on fishery management may also add to the complexity and uncertainty about fishing effects (Robards and Greenberg, 2007) but they also raise issues of food security in livelihoods (Badjeck, 2010). Finally, climate change now charges fisheries managers to manage for resilience in ecological and social systems, however, our ability to define what makes a natural or social system resilient is limited (Gibbs, 2009). In review of literature for climate change adaptation in fisheries there did not appear to be any source that indicated that fishery management decisions would become easier as a result of climate change. All seemed to concur that fishery management processes and resulting fishing policies would be more difficult to set and monitor.

## How should policy makers take action to address climate change?

In the previous section we explored the status of fisheries management to manage fisheries absent climate change and with climate change. Fundamentally, the tools are relatively well developed but there remain high levels of uncertainty of how to apply them or if they should be applied. It is not a direct analogy but it may be useful to think of climate change in the context of the adoption of the Law of the Sea III in 1982. The new regime under the Law of the Sea II fundamentally changed the nature of fisheries management from wide-spread distant water fishing and management of restricted coast zone fisheries to much constrained deployment of distant water fleets and national management applied to a 200 mile. Exclusive Economic Zone (EEZ). This required significant changes in the science and management and how it was implemented (OECD 1997; de Fontaubert and Lutchman, 2003). Transition to fishing under the UN Straddling Stocks and Highly Migratory Fish Stocks adopted in 1995 and the companion Code of Conduct for Responsible Fisheries (1995) also required sophisticated and sometimes painful decisions to be taken involving output, input and technical measures (OECD 2000). These measures could be quite broad as would be necessary for climate change as well. They include, fisheries labor adjustment, post-harvest management practices, government financial transfers, and investment in modeling the transition (OECD 2000). In most cases, new legislation for reorganization of fishery management institutions and setting the legal framework for EEZ fisheries management had to be passed and significant investments were made in both human capital and budgeted expenses.

Adapting fisheries management to the vagaries of climate change does seem to have some commonalities with the measures that had to be developed and adopted for major changes in the global fishing regime. The new global fishing regime was a set of agreed norms for how fisheries at the national and international levels were to be carried out. There are significant differences relative to climate change. Global warming has a significant anthropogenic component but it is mediated throughout the global ecosystem and ecosystem processes. These processes operate at different spatial and temporal scales so that what constitutes an appropriate response in space and time for one country or region may be right in another (Cheung *et al.*, 2009). There are not shared norms for adapting to climate change. Without international standards, there is no requirement for adjusting national legislation. Fisheries managers do get the opportunity through the legislative process to make the necessary pitch for the resources needed to deal with climate change planning. In addition, because climate change is operating at ecosystem scales it should be treated in fisheries management as part of plans for implementing ecosystem based management in a social-ecological system. The two are inherently joined. Efforts to develop an ecosystem based approach without taking into account climate change would lead to unfortunate results.

In developing an adaptive plan for fisheries management to be robust in the face of climate change, it is useful to incorporate what some have characterized as an adaptive management cycle into the fisheries management plan (Grafton, 2009 and 2010). While it is possible to informally adapt to changing circumstances (Grafton, 2009), it can be argued that the need for strategic planning in the case of fully implementing best management practices and a climate informed ecosystem based management approach requires a more formal planning approach. As with any planning process it is necessary to determine policy goals. How these policy goals get set in light of climate change and other interacting factors is critical because these relate to fundamental values and ethics, appreciation of risks as well as knowledge and culture (Adger, 2009). These policy goals are arguably best set through interaction between science, management and stakeholders in a transparent process (Miller *et al.*, 2010). In terms of planning it makes a huge difference if maximization of revenue is adopted as a goal or if the goal is something like maximization of employment. Neither of these goals is negated by the impacts of climate change yet each leads to vastly different choices of management measures. Critical to goal setting is to select goals that are not mutually exclusive.

One of the frequently mentioned goals for fishery management is to manage for resilience. This is an elusive concept so it warrants some discussion at this point. The two most widely used definitions of resilience are: “Holling resilience” that refers to how capable is a population or system to stay within a set of boundaries and maintain its "identity" following a shock (citing Holling 1973) and "Pimm-resilience", which refers to how quickly a system returns to within some neighborhood of its previous state following a shock (citing Pimm 1984)" (Grafton, 2009 p. 9). However, a third type of resilience might be defined as the capacity of governance systems to accommodate change in ways that support societal development and environmental linkages for generations to come (Folke, 2006; Robards and Greenberg, 2007). This definition accepts the possibility that a coupled socio-ecological system could move to a entirely different state, *i.e.*, not remain the same or return to something like its original state, if climate change or some other combination of factors crosses a threshold over which there is no return (Schnellnhuber, 2009; Washington-Allen, 2010). In such a case a functioning ecosystem in an altered state is seen as demonstrating resilience in both natural and human systems. Even within marine ecosystems this is a formidable challenge to our current management capacities much less when considering the interacting global system (Fiksel, 2006).

Once overarching policy goals have been set, a more detailed process of developing management objectives to which performance indicators or standards are assigned. This seemingly logical step to hold the process accountable is critical to the concept of adaptive management (Walters and Hilborn, 1976). While this step can become onerous and difficult to implement if taken to the extreme, the fundamental intent is to identify metrics that allow fishery managers to ask if the measures they have selected are producing the results that were targeted and if not, why not? Identifying these metrics at the outset through a stakeholder engaged process enforces a systematic review of the outcomes, *i.e.*, the adaptive process.

Given policy goals and measurable objectives it is then necessary to select management strategies that are reasonably calculated to achieve them. It is necessary to actually turn these strategies, *e.g.*, conservative stock assessments, designation of marine reserves, or setting of seasons, into management tactics that specify exactly what would be done. Following that the next step in the adaptive management cycle is to develop indicators and performance measures that would allow comparison of the outcomes with the management actions (Rice and Rochet, 2005; Cury and Christensen, 2005). The final step would be after a specified amount of time to review the performance in light of the goals and objectives and to assess the management strategies and tactics for effectiveness (management strategy review). Based on this review goals and objectives may be revised and different management strategies and tactics employed. Throughout each step in the process stakeholders are to be involved either formally or informally.

This adaptive management cycle appears to be a linear approach to fisheries management. Others working in this field offer some additional ideas on how to create adaptive policies (Swanson *et al.*, 2009) that can be usefully incorporated. Inherent in adaptive management is the idea that management should be considered as an experiment and that during an experiment one does not change the parameters being examined even though preliminary results point strongly to some other outcome or design for the experiment to produce more useful results. By deliberately designing the experiment itself to be adaptive from the beginning so that parameters could change, would allow for more rapid accumulation of relevant information and not delay management response. Thus, if an adaptive management plan is being developed, it is useful to think in terms of the ability of the policy to adapt to unanticipated outcomes as well as to anticipated outcomes. The adaptive policies anticipate an array of the conditions that lie ahead by incorporating them in the design, *i.e.*, integrated and forward-looking analysis, multi stakeholder deliberation and monitoring of performance indicators that trigger automatic policy adjustments. To cope with the unknowns creative adaptive policy takes advantage of the inherent self-organizing and social networking capacity of communities, it seeks to decentralize governance to the lowest jurisdictional level, it promotes variation in policy responses and it relies, like the adaptive management cycle on formal policy review and continuous learning (Swanson *et al.*, 2009).

The approach advised here is to incorporate climate change into development of ecosystem based management for fishery management planning. The focus is on what Johnson and Welch (2010) "high adaptive strategies" could be used by those countries, mostly OECD members, who already incorporate many or most of the precepts of current fisheries management that could be termed to be "best management practices" [see below] and who are seeking to implement ecosystem based management for fisheries in a social-ecological system. These countries would examine opportunities to adopt further best management practices or more fully incorporate ecosystem based management including climate change through the development of a strategic management plan. There are many planning tools and approaches that can be utilized according to country capacity and circumstances. These proposed strategic management plans may be quite different in scope and approach, but it is likely that they must address all aspects of the fishery management system.

Best practices of current fishery management are recognized to include, investing in scientific understanding and monitoring of fish and their habitats, setting conservative catch limits, accounting for bycatch, maintaining effective catch monitoring and enforcement system, placing limits on the level of fishing effort, integrating science and management for long term sustainable management which includes active consideration of ecosystem dynamics, and a transparent decision process that engages stakeholders (Alder *et al.*, 2009; Worm *et al.*, 2010; Mora *et al.*, 2009). More and more there is recognition that fisheries management and ocean management more generally is management within a coupled human-natural system (Perry and Ommer 2010; Garcia and Charles, 2008; Perry *et al.*, 2010; Miller *et al.*, 2010). Thus, the best practices for fishery management should now include much more robust social and economic components and dynamics especially the behavior of fisheries adapting to changed circumstances (Salas and Gaertner, 2004). The unintended and usually negative consequences of ignoring human dimensions and biophysical linkages in fisheries systems are potentially dangerous (Dengbol and McKay, 2007). In point of fact, only a few fishery management systems come close to this set of best practices (Worm *et al.*, 2010, Pitcher *et al.*, 2009; Rosenberg *et al.*, 2009). Far more common is "quasi-functional" fishery management which accomplishes some of the elements of best practices and dysfunctional fishery management is prevalent (Longhurst, 2010).

## How can fisheries governance affect decision making for coping with climate change in fisheries and how can those aspects of governance be strengthened?

It is difficult to make generic recommendations with respect to governance of fisheries and coping with climate change because each management context is different and the impacts of climate change are likely to be experienced differently as well. Diverse approaches to fisheries governance bear repeating as a way to inspire out-of-the-box thinking about alternative governance approaches and how governance can be strengthened.

Johnson and Welch (2010) recommend that for high adaptive strategy countries advancing best practices would be appropriate. This would include countries incorporating larger margins of safety into harvest and effort targets. It would also shift management priority, in their view, from economic profit to ecological stability by taking an ecosystem based approach that includes climate variability. This approach is consistent with that proposed above.

McIlgorm *et al.* (2010) argues that fisheries governance should take into account increased levels of uncertainty due to climate change in the ecosystem and the governance system. The way forward in governance for climate change suggests that more flexible fishery management regimes are desirable and that capacity adjustments, catch limitations are necessary as are alternative fishing livelihoods for fishers. They note that existing fisheries arrangements, especially between and among countries, may have to be modified depending on the eventual distribution of fish. Additionally, they point out that the success of fishery management depends on the rate of change in fisheries. If the rate of change is gradual and predictable existing governance arrangements are likely to be able to adjust. If the rate of change is abrupt and not predictable then governance systems will fail. In any case, success in management adaptation is measured by effectiveness, economic efficiency, equity and legitimacy all of which are at risk due to climate change (McIlgorm *et al.*, 2010). Consistent with this approach Martin *et al.* (2009) have developed a process for structured decision making that may have utility in sorting through alternatives

From Grafton (2010) who is not addressing governance per se offers the perspective that developing an approach to risk management that "1) incorporates and assessment of current and future vulnerabilities: 2) engages stakeholders; and 3) models and simulates different state of the world and strategies, should be used to guide decision-makers when responding to climate change" (Grafton 2010, p. 615). So far the development of methods for systematic assessment of risks relative to climate change is in early stages. In the future it would be invaluable to have ways to compare what Grafton (2010) suggests are "ex ante" measures to promote resilience and ex post measures that are actively adaptive and intended to make rapid response to perturbations. In many cases, win-win interventions like ex-ante actions to rebuild fisheries fall in this category as well as appropriately designed no-take areas. Grafton (2010) acknowledges the need to provide transfer payments as part of this kind of adjustment of fishery management from the current approach to a longer term sustainable form of fishery management (governance).

Miller *et al.* (2010) suggest that climate change adds to the inherent uncertainty of fishery management systems and that the solution is a stronger focus and support for "integrative science" methods and processes. In their view, integrative science can assist in evaluating sources of uncertainty and allow "better assessments of behavioral responses of fish, humans and institutions" (Miller *et al.*, 2010 p. 2).

Current fisheries management in OECD member countries provides a convenient test case for the status of implementation of climate informed ecosystem based management for fisheries. At present the EU does not employ all of the best management practices and, so far, commitments have not been made to develop the planning approach advised in the previous section for fisheries management in the EU. For many member states who are also members of the European Union (EU) fisheries management is largely a function of the EU Common Fisheries Policy (CFP). The CFP is under EU review because it is seen as largely failing to meet its objectives (Wakefield 2010). At the same time the CFP may be moving from a top-down command and control system to one that is more oriented to a regional and co-management approach (Symes, 2007) however the "tensions between European and national institutional frameworks continue to hamper the development of effective management strategies for Europe's fisheries" (Symes, 2007 p. 780). While Symes (2007) sees improvements in regional co-management, Wakefield (2010) argues that such approaches are undercutting the implementation of the EU's integrated maritime policy.

The EU situation seems particularly a difficult one from the perspective of an outside observer -- especially in comparison with extremely large ocean states like Canada and the US and major island states like Australia, New Zealand and Japan with their extensive EEZs. World class formal scientific advice is available from the International Council for Exploration of the Sea (ICES) to decision-makers who may or may not have followed the advice. The scientific advice is constructed on ecosystem scales and it is clear that a reversion from EU management to country managed EEZ would not be ecologically sound. Unless fishery management decision makers and processes can produce a long-term sustainable EU fisheries, the likelihood of the CFP becoming subservient to the Integrated Maritime Policy seems to increase. Improvements in governance arrangements for fisheries are possible. There are a variety of choices available. While each must be tailored to the particular region and country context the tools exist.

## When should policy makers act?

This section explores the timing of management decisions using the three categories of proactive precautionary approach, the *ad hoc* reactive approach and post hoc recovery approach applied to the issue of climate change adaptation. It should be of no surprise that each approach has a role in fishery management although they have very different rationales and serve different and complementary purposes.

### *Proactive precautionary approach*

This approach is broadly advocated for current fishery management, as well as for fishery management in the face of climate change (Lutchman, 2003). It requires an ability to forecast many ecological and social unknowns which at present is only emerging. However, the precautionary component tends to ensure that management decisions are hedged in ways that reduce the cost of a false prediction. It requires a fishery management system that is sufficiently capable and responsive to address short and long term changes in a comprehensive manner. As part of that system, there must be arrangements with fishermen and other stakeholders that agree on a precautionary approach and adaptation strategies that are appropriately designed. The approach sets high expectations but not impossible conditions for management

### *Ad hoc reactive approach*

Even with an ex ante precautionary approach, new information or understanding may indicate management changes need to be made during the fishing season and may indicate a need to tweak management actions. If fishing mandates and management processes do not allow changes to be made the potential for loss of benefits or failure to avoid costs may occur. In some fisheries like Alaska salmon runs, the potential for adjusting management actions to the timing of the run, the rate of harvest and other factors is a well-developed but imperfect art (Hilborn, 2006). Similar measures have also been adopted in management of bycatch in fisheries whereby "hot spot" authority allows the fishing fleet options for voluntary actions to avoid bycatch which, in turn reduces bycatch and does not trigger a closure based on a fixed decision rule. Thus, it is possible to build in some aspects of flexibility into fishery management frameworks. Again, as part of that fishery management system, fishermen and other stakeholders have had to agree that in season adaptive measures are beneficial and necessary.

### *Post hoc recovery approach*

Despite best efforts, mistakes, unintended consequences of actions, etc. may require response after impacts are experienced. The swifter and more on target the management action to recover the more likely there can be biological response to management efforts. Actions to recover fisheries can be taken but the range of alternatives is more likely limited and costs likely to be higher (Shertzer and Prager, 2007).

Fishermen and other stakeholders need to be on board for how to handle post hoc actions.

Ideally, the advice for when to act is that fishery managers should prepare act in advance of experiencing climate change impacts. Policy makers should be prepared to act in anticipation of unusual conditions or conditions that are "normal" but require decision-making to avoid harm. Finally, even best plans and implementation efforts are beneficial but cannot be expected to prove infallible or necessarily successful.

With respect to climate change it is best to anticipate changing conditions in order to have the flexibility to act ex ante, ad hoc, and ex post through a series of adaptive actions.

## Northeast Pacific Ocean: A case study in climate change adaptation

The Northeast Pacific Ocean fisheries management experience by the North Pacific Fishery Management Council (NPFMC), the National Marine Fisheries Service (NMFS) and the State of Alaska (AK) provides an illustration of how fishery management decision making can occur in the proactive precautionary mode (Stram and Evans, 2009).

Uncertainty about global warming trends, rising sea level, loss of sea ice and ocean acidification in the Arctic Ocean, the Bering Sea and Aleutian Islands and the Gulf of Alaska have been of significant concern to fishery managers in the North Pacific. The fishery management system in the Northeast Pacific is recognized as meeting most of the "best management practices" and promoting an ecosystem-based approach to management (Witherell, 1999 and Witherell *et al.*, 2000). Since 1994, for example, an annual ecosystem status and trends document has been prepared to inform the fishery management process – especially with respect to stock assessments.

As a result of study of *El Nino* and its effects on salmon fisheries, in particular, fishing interests and fishery managers have been keenly interested in climate variability in the region (Wooster and Fluharty, 1985). Definition of a longer term apparent Pacific Decadal Oscillation (Mantua *et al.*, 1997) provided explanation for inverse production regimes for salmonids on the West Coast of North America (Hare *et al.*, 1999). These and other studies have led to detailed multi-national efforts to document climate variability in the Northeast Pacific through Fisheries-Oceanography Coordinated Investigations FOCI (Macklin, 1998), the North Pacific Science Organization (PICES), and the North Pacific Anadromous Fisheries Commission (NPAFC) (Beamish. ed. 2008; Farley *et al.*, 2009; NPAFC 2010; Batchelder and Kim, 2008).

In recent years as the Northern Bering Sea has suffered a decline in productivity of several seabird species and the grey whale possibly as a result of a major ecosystem shift (Grebmeier *et al.*, 2006). These warning signs prompted the NPFMC to close significant portions of the Northern Bering Sea to fishing in order to avoid conflicts with other agencies over listings under the Endangered Species Act (NMFS 2008). This action designated extensive habitat closure areas in Northern Bering sea as no bottom trawl zones (112,000 sq.nmi). Even though fisheries were not very large in this area the closure is not insignificant because a northward shift has been observed in the biomass of Alaska Pollock, snow crab and other species. This action to close the area is done with the support of the fishing industry and fisheries communities as well as the environmental non-governmental organizations.

A second major precautionary effort by the NPFMC is to close US Arctic waters to commercial fishing until research provides sufficient information on which to base management decisions 2009. In order to accomplish this staff prepared a discussion White Paper which led to a Council decision to pursue development of a fishery management plan under which management measures could be prescribed (NMFS 2009) for the full US EEZ in the Arctic Ocean.

As part of its actions to close fisheries in the Arctic Ocean, the NPFMC requested that the US Congress initiate a joint resolution calling on US Department of State to convene Arctic fishing nations in order to discuss management of fisheries in the Arctic Ocean. The 110TH CONGRESS in its 1$^{st}$ session passed Senate Joint Resolution 17 in October 2007 directing the United States to initiate international discussions and take necessary steps with other Nations to negotiate an agreement for managing migratory and transboundary fish stocks in the Arctic Ocean. In 2008 preliminary talks began.

The NPFMC continued its actions better understand the Northeast Pacific ecosystem by developing and adopting a Fishery Ecosystem Plan for the Aleutian Islands (NMFS 2009). Currently the Essential Fish Habitat Management Plans are up for review and these cover the entire EEZ.

## Concluding observations

Many tools and opportunities exist in fisheries management to adopt measures to increase the resilience of fisheries to climate change. Many of the management actions that assist in coping with climate change are consistent with best management practices for fisheries today. Climate change is another justification for making fishery management policies more resilient and thus resistant to climate change or other alterations. Climate change is a key driver for developing an ecosystem based fishery management system as it exerts a pervasive influence over the whole fished system. Management approaches and policies should be expected to differ in detail due to regional differences. Still they will have an overarching functional similarity as a result of responding to climate drivers of change. Fishery management systems that have already implemented most if not all of the best practices are the most capable to produce positive results from climate adaptation measures. Fishery management systems that lack some elements can still benefit from management actions although the options are more limited and the condition of the ecosystem may limit responses.

It is not clear if fishery management responses can be adequate to adjust to all multiple stressors related to climate change, however it is too early to concede the contest. The fundamental question is whether or not fisheries decision makers can be any more successful in dealing with the challenges of climate change than with other fishery management issues which show mixed results in responding to challenges and opportunities. The UN Environment Program, for example, estimates in a preliminary report on its Green Economy initiative that a global investment of USD 8 billion per year to rebuild the world's fisheries could result in benefits to the global economy of USD 1.7 trillion over the next 40 years (UNEP 2010). The annual investment would be used to reduce excess capacity in the world's fishing fleets, train fishers in alternative livelihoods, set up tradable quota management systems, and designate and manage marine protected areas. These measures are projected to lead to the increase of sustainable harvests in fisheries to 112 million tons annually. This level of investment could be covered by diverting a portion of the USD 27 billion spent in subsidies (UNEP 2010). Despite what appear to be significant economic and social benefits projected in a move from dysfunctional and quasi-functional fisheries management to functional management there does not appear to be much attention being paid to making the modest investments that UNEP suggests. With such response, it is hard to be sanguine about what to expect when one considers that climate effects on fisheries as we know them are generally expected to be disruptive at best and largely negative in both ecological and social and economic terms (Cheung *et al.*, 2008). Thus, even though the incentive to avoid costs of climate change through adaptation (Costello *et al.*, 2010) seems equally compelling as the incentive to obtain significant benefits by investing in fishery management measures yet it remains to be seen how fisheries management respond.

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