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How will climate change alter fishery governance? Insights from seven international case studies ☆

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ABSTRACT

We examine the implications of climate change for fishery governance using seven international fishery case studies in low, mid and high latitudes, including eastern Australia, the western Pacific Ocean, Alaska, west coast United States, Hawaii, west coast Canada and France. Climate change adds uncertainty about fish stock productivity, migratory patterns, trophic interactions and vulnerability of fish populations to fishing pressure.

Fishery governance has to address additional uncertainty from climate change in both the system being governed and the governance systems. The case studies reveal governance issues that indicate adaptation will involve more flexible fishery management regimes, schemes for capacity adjustment, catch limitation and alternative fishing livelihoods for fishers.

Where fishery governance systems have been less developed, fisheries are less able to adapt to climate change impacts. Adaptation involves addressing some of the most intractable allocation issues of fisheries management.

1. Introduction

In their 2007 assessment the Intergovernmental Panel on Climate Change (IPCC) concludes that warming of the climate system is unequivocal [1]. The report also notes that "Impacts of large-scale and persistent changes… are likely to include changes in marine ecosystem productivity, fisheries, ocean CO_2 uptake, oceanic oxygen concentrations and terrestrial vegetation" [1].

The IPCC projects a global average temperature increase of about 0.2 °C per decade for the next two decades, which will cause major changes in the world's ocean and fresh water environments. Ocean surface water temperatures will continue to increase, sea levels will continue to rise, and sea ice in the Arctic and Antarctic will shrink [1].

Scientific evidence supports the conclusion that climate change is already altering marine ecosystems. Primary and secondary productivity and the structure of marine communities are affected by the increases in ocean temperature, increased stratification of the water column, and changes in the intensity and timing of coastal upwelling with consequent impacts on fish migration patterns, recruitment, growth, distribution, abundance and predatory-prey relationships [2,3].

Fisheries are among the human activities most exposed to and affected by climate change; exploited fish populations are more susceptible to its associated stresses [4]. Mitigation options are limited; fisheries are often location-specific and are operating at levels of utilization that preclude substitution flexibility by fishers [5].

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Adaptation to climate change by the fishing industry and fishery governance is necessary and inevitable; but autonomous and rapid adaptation is impeded by the public ownership and management of fisheries. The fishery governance process is slow moving, built upon the foundations of a stable decision environment and consistent expectations [6]. The flexibility of governance adaption to climate requires a reconciliation of the stability goals of fishery management with the large-scale alterations of climate change. Governance will have to acknowledge the uncertainty about system states and processes, accommodate a new range of conditions, and adjust to episodic change.

In this paper we address a number of fundamental issues related to climate change's impact on fisheries governance. We discuss the way in which uncertainty in environmental conditions, scientific information and governance will affect the context within which fisheries are managed. We summarize ideal attributes of governance and contrast these with the modified attributes of governance in practise. We then address mechanisms through which climate change will alter fishery governance, and the options for governance adaptation. Case studies of seven fisheries that illustrate the likely impacts of climate change and governance adaptation possibilities are presented. We conclude with a synthesis of insights from the case studies that suggest ways fishery governance can best equip itself to adapt to climate change.

1.1. Types of uncertainty in the fisheries environment

Climate change will add to the natural variability of the ocean environment and pose new uncertainties for governance. Stock assessment models typically assume stable environmental conditions with random inter-annual variability and become unrealistic in conditions of larger-scale change. The environmental uncertainty created by this variability leads to scientific uncertainty, which in turn and in combination with political factors, creates governance uncertainty.

Governance uncertainty creates confusion about which actions should be taken in response to large-scale change, and so complicates the development of incentives to promote those actions. It is exacerbated by the difficulty of maintaining management control. Fishery participants represent diverse conceptual foundations that often result in poor communication and conflict at the governance level [2,7]. Stability-based approaches have been shown to be unsustainable in variable environments, especially when expectations about harvest are formed at the high end of the range of natural variation [7].

Effective governance is further hindered by public skepticism about climate change, the view that climate change is a long run issue less urgent than more immediate issues, and the fact that there are likely to both negative and positive effects on fisheries. With "winners" and "losers" nobody wants to be in the losing group when others gain.

1.2. The governance ideal

Fishery governance relates to the complex of decisions to achieve social objectives for the use of resources. Governance is implemented through organizations of various types, nested within a mix of institutions. Institutions are the mechanisms that integrate the human and ecological spheres in ways that contribute to, or detract from, their mutual sustainability. Institutions in their broadest meaning are the rights, rules, and responsibilities of organizations and individuals [8]. They shape the way people interact with each other and with their environment, and they integrate economic, legal, social, and ecological systems in formal and informal ways [7].

The "institutional fit" between ecosystems and human systems is of central and continuing importance to governance [9] made even more so by the uncertainties and possible need for drastic action introduced by climate change. As Dietz et al. [10] note, the ideal conditions for governance are increasingly rare. The central governance challenge is to redirect human behaviour toward long-term production approaches that also support the non-consumptive values of ecosystems.

Ideally fishery governance should coordinate decisions over different scales, reconciling actions taken at one level with those in other "nested" levels. It should accommodate diverse objectives of multiple resource use and develop processes for assessing trade-offs among alternatives. It should address the uneven distribution of the costs and benefits of management actions and, critical to the issue of climate change, it should be flexible enough to respond to varying conditions in ways that maintain fishery sustainability [11].

1.3. Governance in practise

The governance ideal becomes modified in practise. In the struggle for authority, decisions often conflict at different scales rather than coordinate in a nested way. Communication is complicated by the diverse belief systems, assumptions, and principles of the people it governs. Conflicts are created by the uneven distribution of management costs and benefits. In attempts to minimize these conflicts among competing interests, managers often avoid explicitly assessing trade-offs among alternatives. Governance tends to be deliberate and ponderous rather than flexible, following a path of increasingly restrictive operating flexibility for fishers.

Jentoft [12] distinguishes between the "governing system" (the social structure of governance) and the "system to be governed" (the natural-social system of marine ecosystems and human infrastructures), noting the difficulty in reconciling the two. We will use this approach to examine how climate change affects fishery governance.

1.4. Climate change alterations to fishery governance

1.4.1. The systems to be governed under climate change

A recent review of research on climate change and fisheries advocates an acceleration of "policy relevant research on impact and especially adaptation responses of fish, fisheries and aquatic resources to climate variation and change" [13]. It is estimated that up to 75% of total stock availability may be due to climate processes, including ocean currents. Climate change may also create conditions beyond those which have occurred in the past [14–16], Mantua [15] advises "Management strategies that rely upon accurate predictions of climate impacts on salmon are doomed to failure—they should be avoided".

Climate models may not be able to adequately forecast changes in ocean temperatures, particularly in the mid latitudes. Small changes in environmental conditions, such as temperature, salinity, wind, and ocean currents, can change the abundance, distribution, and availability of fish populations. Fish stocks have been shown to be very sensitive to temperature changes [17]. "Changes in fish stocks and their distribution may not only be sudden, but will occur abruptly … and the fluctuations may be large" [14].

1.4.2. The governance system and climate change

A governance system reflects the expected configuration of human participants, including access rights and conditions, regulatory impacts and regulatory effectiveness. Climate change is likely to require the modification, elimination or reconstitution of national policies and international agreements. With considerable uncertainty about the impacts of climate change on marine ecosystems, fishery governance institutions must be structured and managed such they can function effectively even with uncertainty [18]. Additionally, climate change may change a fish stock's distribution from being wholly within the jurisdiction of one country or, vice versa, to become a straddling or highly migratory stock, requiring an international agreement for effective management [3,18].

National and international governance systems have been established on the basis of existing conditions and may not be able to deal with the significant changes in fishery resources due to climate change. Gradual, consistent, and predictable changes may be handled by existing governance systems up to a point, but after some threshold current management systems may be inadequate and overwhelmed, and subsequently fail [19].

Governance will need adaptive capacity to address climate change. Adaptation may be anticipatory, or reactive. Adaptive capacity should reduce exposure to climate change, reduce sensitivity to climate change, and increase resilience and the ability to cope with climate change. Building adaptive capacity may require providing the appropriate legal and regulatory environment, providing the correct incentives for change, removing constraints to change, and removing market imperfections such as externalities and a lack of information [20,21]. However, those rigid and complex management controls currently in place may restrict the ability of management authorities, individuals and communities to adapt to change [22].

While the "overriding goal for fisheries managers is to ensure resilient marine ecosystems and sustainable fish stocks" [23], fishery managers usually strive to fulfil a number of, often incompatible, objectives: biological (maintaining long run sustainable yields, protection of ecosystems, maintaining biological diversity), economic (achieving efficiency, maximizing economic rent), social (providing employment, preserving communities) and political (minimizing conflicts and complaints) [25,26].

Success in any management adaptation is measured by its effectiveness (achieving fishery management objectives while minimizing impacts and reducing risk), economic efficiency (minimizing costs or maximizing benefits), equity (comparing winners and losers), and legitimacy (the acceptability of decisions and actions) [21].

1.5. Management adaptation

Given the impacts expected from climate change management actions are required to support mitigation and adaptation in fisheries [24]. The principles suggested for successful adaptation to climate change are derived from fisheries management. Management success has been observed to occur with effective, appropriate and sufficiently strong institutional capacity; flexibility to deal with complexity and change; the creation of incentives that encourage conservation, reduce over-exploitation, and emergence of resource rent; cooperation both horizontally between fishers and vertically between fishers, the wider industry, and government; and a holistic approach that recognizes that both the fishers and the fish stock are members of communities [27]. These features reflect a general trend in public management, moving from rule-based hierarchies to a quality and performance orientation [28].

2. The case studies

The review of the climate change literature has identified and examined the governance issues facing marine systems and the challenges for governance of these systems. The Food and Agriculture Organization workshop [24] suggested that "past management practices in response to existing climate variability and extreme events relating to different regions and resources can provide useful lessons to design robust and responsive adaptation systems, even though they will have to be placed in context of greater uncertainty".

In this section we present information from seven fishery case studies in different hemispheres that cover the three latitude categories used by IPCC. Each case study is an extract from a recent presentation and the case studies are followed by a section comparing the governance issues attributes and trends across these seven fisheries.

Case 1: *Climate change and fishery governance in the Pacific Northwest US*: *Columbia River Basin salmon. Susan Hanna*, *Oregon*, *adapted from* [11]. Climate change will cause significant alterations in the biophysical environment of freshwater and marine aquatic habitat that will affect the growth, productivity, survival, and migration of salmon. There will be wide-scale variability in the availability of salmon to existing fisheries. Accordingly, governance must be redesigned to accommodate this increasing uncertainty under conditions of biological stress.

In the Columbia River Basin, thirteen salmon and steelhead runs are now listed for protection under the US Endangered Species Act. Ocean and in-river salmon fisheries on Columbia Basin stocks are governed through a complex management system that coordinates state, inter-state, tribal and federal authorities, as well as international agreements. Management is designed to provide stability and predictability and depends on an information base largely devoid of climate data.

Climate change will lead to changes in the timing and quantity of water delivery with higher average, but more concentrated, levels of precipitation and resulting losses of salmon habitat. Ocean survival will be diminished through higher sea-surface temperatures (SST) at the entry point of migrating salmon.

The effects of climate change will diminish the effectiveness of the existing approach to salmon fishery governance and will require new governance based on four key principles; planning for variability and uncertainty, broadening the information base, integrating management actions at the ecosystem level, and promoting flexibility. Governance will focus on mitigating for loss of habitat and new approaches for allocating increasingly limited yields.

Case 2: *Principles for managing fisheries to facilitate adaptation to uncertain effects of climate change. Gunnar Knapp*, *Alaska*, *adapted from* [29]. Climate change may cause significant changes in the distribution, abundance, and species mix of Alaska's commercial fishery resources. In any given area stocks of some species may decline; stocks of other species may increase; and new species may appear in commercially significant volumes. However, it is difficult to predict what specific changes may occur or when they will occur.

The principles for managing fisheries in ways that facilitate adaptation to uncertain future effects of climate change include: (1) reduce uncertainty by researching and disseminating the best available information about how commercial fishery resources may change in the future; (2) allocate fishery resources in ways that reduce risks associated with resource changes; (3) reduce restrictions on the mobility of fishermen and processors to reduce vulnerability to changes in the geographic distribution of fishery resources; (4) facilitate development of new fisheries by having mechanisms in place to allow responsible utilization of new species or new fishing grounds; (5) plan for potential resource decline so that governments, communities and individuals understand what kind of assistance and compensation will or won't be available if resource decline occurs. Knapp [29] reviews the extent to which these principles are being followed in major Alaska fisheries.

Case 3: *Canada and US salmon fishery and institutional adaptation to climate change*, *Frank Millerd*, *Canada*. The commercial fishery is managed by limiting the number of licences, area licences, and restrictions on fishing gear, areas, and seasons. Several buy-back schemes to reduce the number of licences have been instituted. The recreational fishery is managed by-catch limits and closed seasons and areas.

Climate change is and will affect both the ocean and fresh water environments of salmon, positively or negatively affecting salmon stocks depending on where they spawn and their ocean migration route. Recent changes in ocean temperatures resulted in large and rapid changes in abundance, changes which could occur again in the future.

Climate change may impact fisheries governance as fisheries management science struggles to assess the impact of climate change on Pacific salmon, having to depend less on science than in the past.

The most likely management structure in the foreseeable future involves continuation of the current system of a limited number of licences for each area and type of fishing gear.

Management has tended to focus on maximizing the sustainable yield allowing as much fishing pressure as possible. Although the total number of licences is limited by area and gear type, fishers have responded by increased investment and effort. The values of the limited number of transferable licences are significant.

The salmon treaty between Canada and the United States allocating the migratory salmon may need to be re-negotiated, even with uncertainty about future migration patterns. Agreements on fishing rights with aboriginal groups may also have to be re-negotiated.

Case 4: *Long-term changes in marine fish communities*; *investments and capital dynamics of French fleets exploiting the Bay of Biscay fisheries. Pascal Lefloc'h*, *France*, *adapted from* [30]. A set of nine commercial species represent the targeted production of the French fleet in the Bay of Biscay: two pelagic species (anchovy and sardine), four demersal (cuttlefish, seabass, pollock and hake), and three benthic (monkfish, nephrops, and sole). The Bay of Biscay fisheries are mainly managed under conservation measures (TACs allocated under the Common Fishery Policy). Governance measures have been defined through capacity reduction programs since 1990. One of the main access regulation measures that were setup in the French context at the end of the 1980s was the adoption of the "Permis de Mise en Exploitation" or operation permit system, leading to a *de facto* limited entry scheme.

Several studies of the Bay of Biscay shelf ecosystem have shown warming of surface waters during the last three decades [31]. From recent research it appears a positive potential impact of climate change for anchovy and a negative potential impact for Pollack and monkfish [32]. However, it is not possible to clearly separate the relative role of fishing impacts and the climate induced changes on the community. For the two "boreal species" (monkfish and Pollack), the impact of climate warming might be expected as cumulative with negative effects of fishing. For anchovy fished in the Bay of Biscay, the exploitation depends to a large extent on the yearly recruitment success, counteracting the potentially positive effect of global warming.

Case 5: *Fishery governance and climate change—Western Pacific ocean fisheries. Alistair McIlgorm*, *Australia*, *adapted from* [33]. The Western and Central Pacific is a complex ocean fishery with island nations and foreign fishers taking purse seine and longline tuna catches in area to the north of Papua New Guinea.

Independent states in the Pacific have several regional organizations such as the South Pacific Forum Fisheries Agency (FFA) and the Western Pacific Fishery Commission (WPFC). The majority of fishery production is by Distant Water Fishing Nations (DWFNs) under access agreements to FFA member states. Gaining economic benefits from domestic tuna fishery processing by island states is a priority to supplement income from access licence fees. The WPFC need sustainable regional catch limits for long term prosperity.

A massive ocean West to East water movement is related to La Niña years and will increase with the frequency and intensity of El Niño conditions [34]. The purse seine tuna fishery coincides with movement of the warm water front, strongly suggesting that there will be changes to this ocean fishery as ocean temperatures rise.

Climate change will impact all industrial fishers and processors due to changes in the location of fishing sites with vessels spending several months of the year inside a national EEZ, as fish move to the high seas, or to an adjacent EEZ. This movement has implications for licensing of foreign fishing vessels and tuna canneries using local suppliers. The increased risk of fish availability will have implications for past and future capital investment past and future and labour requirements. Fishery governance systems need to be aware of potential climate change impacts in annual catches and the location of fish schools, increasing the variability in an already complex system.

Case 6: *Alistair McIlgorm*, *Fishery governance and climate change—East Australia. Alistair McIlgorm*, *Australia*, *adapted from* [33]. The East Australian tuna longline fishery operates under the southerly influence of the East Australian Current (EAC) catching yellowfin, albacore, swordfish and striped marlin. The fishery is managed by the Australian Commonwealth government since the mid 1980s when the Australians developed a small inshore longline fishery, eventually displacing Japanese longline vessels admitted under access agreements in the 1990s. The fishery had gross revenue of $32 m Aud. in 2006.

Oceanographers note the southward penetration of the EAC has increased over the last 60 years with changes in temperature and salinity and predict a further poleward movement south by the EAC of 180 km in the next 30 years [33].

The additional southward movement of the EAC will have fishery impacts on the tuna and marlin which can travel as far south as Northern Tasmania in warm water eddies developed from the EAC. This change may require changes in the delimitations of the Federal fishery and consultation with the Tasmanian State Government regarding jurisdictional limits.

The East Australian area may also benefit, (or lose) from ocean current changes in the Western Pacific, bringing (or not bringing) fish into the East Australian region. Both changes in fish movements and in biological processes could have economic impacts through changing the cost to catch fish and impacting species reproduction and recruitment in unknown ways.

Fisheries governance in the area is implementing a transferable effort based regime in 2009 and then an Individual Transferable Quota (ITQ) system in 2010. The climate induced changes need to be part of the planning horizon for both industry and government so as to address uncertainty. This fishery will likely show rapid climate change impacts due to the changes in the East Australian Current.

Case 7: *Minling Pan*, *Hawaii. Fishery governance in response to climate change in the Hawaii based pelagic long line fisheries Minling Pan*, *Hawaii*, *adapted from* [35]. Like many global pelagic fisheries, the Hawaii-based longline fishery continues to face increased pressure to reduce the incidental catch of endangered sea turtles and/or other sensitive species. Aggregation and movement of both sea turtles and fish are directly associated with climatic variations and oceanographic conditions. As a result, both targeted species and incidental catch rates vary spatially and temporally. Accordingly, successful policy designs of fishery management in terms of effectiveness in turtle avoidance and commercial viability need to consider and adopt the spatial and temporal variations of oceanographic and climate conditions. A spatial bio-economic model was developed to incorporate sea-surface temperature, lunar phase, and other variables with temporal and spatial variations [36].

Through the application of this model, the study explores the trade-offs between turtle interaction reduction and the economic return in the Hawaii-based swordfish fishery in relation to the climate variation and fishing behaviour changes. Hence, the model can be used to evaluate impacts of management choices on fishing opportunity and sea turtle interaction.

2.1. Case study comparisons

The availability of seven cases studies affords an opportunity to compare the estimated impacts of climate change on fisheries governance [36]. In these papers the authors summarize key aspects of climate change impacts and the likely governance response whether it is implemented or not. Table 1 synthesises key aspects of climate change and governance response across freshwater watersheds, rivers and estuaries, inshore, offshore and oceanic areas at a wide range of latitudes. They include demersal, anadromous and highly migratory species. Table 1 assumes that all fisheries have additional uncertainty over levels of biological production and changes in the ocean environment. In all fisheries, governance recognizes the need to plan for variability and uncertainty and to be flexible in adapting to changing conditions.

2.2. Results

The envisaged climate change impacts in each fishery and the government response are presented in Table 1. In the seven fisheries there are a range of possible climate change impacts from temperature change and ecosystem uncertainty across fisheries for different species at different latitudes.

For the ocean fisheries the change of species distribution is a major concern, given the behaviour of the highly migratory species under consideration. Changes to the location of fish stock abundance is a common concern in mid latitude fisheries also. It is noteworthy that the salmonid fisheries, with inland life cycle stages, have additional water temperature and watershed issues.

Table 1
Climate change impacts and fishery governance responses in seven case studies.

Case study	Impacts of climate change	Possible governance response
(1) Columbia River and the Pacific Northwest: river, inshore/offshore, IPCC mid latitude	Altered hydrology, fresh water habitat	Implement ecosystem management
	Warmer sea surface temperatures Variability in salmon distribution Reduced biological predictive ability Allocation conflicts among salmon interest	Broaden the information base to include climate data Reduce harvests Develop new allocation tools
(2) Alaska: inshore/offshore, IPCC high latitude	Alaska commercial fisheries face increased operational risk Spatial change of fisheries Reduced catches	Allocate fishery resources to reduce risks associated with resource changes Reduce restrictions on mobility of fishermen and processors Facilitate new fishery development Plan for potential resource decline and types of assistance available
(3) West coast US/Canada: river, inshore/offshore, IPCC mid latitude	Inability to make preseason run predictions	Ecosystem approach to management
	Fluctuations in salmon abundance Higher temperatures and altered stream flows are detrimental Changes in migration routes	Continuous monitoring In-season flexibility to respond to fish run sizes and distributions Reduced harvest rates to provide buffers against unexpected change Fresh water habitat restoration Re-negotiation of treaty with the United States
(4) Europe, Bay of Biscay French fisheries: inshore/offshore, IPCC mid latitude	Changes in the physical environment	Development of an economic model as a tool to help fisheries adjust to climate change impacts
	Impacts noted on smaller fishers	Modelling gives capacity adjustment options for management
	Economic capacity and adaption to climate change Change in fish species abundance	
(5) Western Pacific: ocean, IPCC high latitude	Stocks of highly migratory species move between the high seas and national jurisdictions Domestic industries impacted Patterns of foreign fishing to change	RFMO and national management regimes to adapt to climate change Assist local industries by policy change Review access allocation and domestic fishery development
(6) Eastern Australia: ocean / offshore, IPCC low/mid latitude	Ingress of highly migratory species from SW Pacific may alter East Coast Tuna industry impacted by EAC moving south	Management regimes to adapt to climate change introducing ITQs Local industries assisted by policy in face of changes Jurisdictional changes
(7) North Pacific, Hawaii: mid-ocean, IPCC low/mid latitude	Managing by-catch issues and climate change impacts	Altering policy design to climate conditions to optimize economic return to the fisheries and reduce the by-catch of protected sea turtles (by-catch)
	Consider the economic costs of alternative policies	

Table 2
The envisaged climate change impacts in the seven case studies using governance criteria after FAO (2008).

Governance criteria for CC impacts	1. Columbia River, Pacific NW	2. Alaska	3. West Coast US/ Canada	4. France, Bay of Biscay	5. Western Pacific	6. East Australian Longline	7. Ocean-Pacific North (Hawaii mid-ocean)
Spatial displacement	Alter distribution and abundance of salmon. fishery locations will change	Research future fishery changes	Negative impact in south and increase in north	Changes in pelagic fish location	Tropical tuna and HMS move from past areas	Tuna move south to new areas due to the EAC	Swordfish and sea turtle spatially sensitive
Adjustment mechanisms	License buy-back or market-based tradable quota shares possible	Potential resource decline assistance available	Buy-back/retiring licenses, limiting licenses by area	Structural adjustment for fleets facing fuel prices	Mechanisms needed to retire vessel capital	Move to ITQs for autonomous adjustment	Moving time-area closures to adjust climate change
Flexible management systems	Tradable share systems allow fishers to respond to changes in the fishery	Allocate fishery resources to reduce change risk	Limited licenses. Area and gear restrictions	From national quotas toward IQs or ITQs ?	Management need effort cap or TACs	Moving to ITQs in 2010	Dynamic policy design
Promoting alternatives	Alternatives to salmon are difficult to develop. Tribal treaty rights are fixed	Facilitate new fishery development	Aquaculture, target other species, develop eco-tourism	Promote low energy inputs	Domestic fishery development	Few other fishing options	Avoiding by-catch
Account for variation in catches	In-season real-time monitoring. Shorter openings and strict incidental catch controls	Reduce the restrictions on mobility of fishers/processors	In-season monitoring of catches. Time limits on permitted fishing areas	No efficiency in controls and more selective fishing techniques	Poor catch controls, some TACs at aggregate level	Setting fishery catch limits (TAC setting) in ITQs	Multiple-years catch quotas
Altering legal and policy frameworks	The Pacific Salmon Treaty with Canada might be re-negotiated	Need for additional fish right provisions	Possible re-negotiation of Pacific Salmon Treaty and aboriginal agreements	A South Western Waters Regional Advisory Council created in 2007	Prepare to diffuse national legal disputes between fishing nations	State/Federal legal issues arise	International cooperation to reduce sea turtle by-catch

Each author also summarized relevant governance responses to climate change impacts.

The primary trend in governance responses is to adopt an ecosystem approach rather than the previous single species management. Managers will also allocate resources to reduce the risk associated with changes in fish resources.

There is a common need to plan for the greater variability and uncertainty in the fisheries, usually by building greater flexibility and adaptation into the governance system. Altering fishery access is common adaptation tool which leads to fishery adjustment and the need to have alternative fisheries available. Table 1 shows the need to adopt new allocation tools to use in allocation issues facilitating fishery adjustment.

The seven fisheries can also be examined against a list of key criteria in policy, legal and implementation frameworks identified by a recent FAO workshop [24]. Table 2 compares the case studies according to the categories of governance issues identified by this workshop:

- spatial displacement of fisheries and fishers;
- adjustment of vessels capacity and infrastructure;
- flexible management systems;
- promoting alternative fisheries or employment for fishers;
- account for variation in sustainable fishery regimes (TAC setting);
- altering legal and policy frameworks.

These categories were used to test the seven fishery case studies. The spatial displacement of inland, inshore and ocean species is clearly seen at in high, mid and low latitudes. The need for governance to have improved adjustment mechanisms means having additional tradable quota shares, buy-back and licence retirement, though the capacity to implement these options is related to the current governance arrangements in place.

Flexibility in the governance system is interpreted as having tradable shares or other allocation methods to reduce resource risk. The East Australian tuna fishery is moving to Individual Transferable Quotas in 2010, but the Western Pacific tuna fishery is being managed by total effort caps and total allowable catches (TACs). Those in governance need more flexibility in the control of fishing activity in the face of climate induced stock changes.

Advocating alternative fisheries for displaced fishers assumes there are other fisheries available. Governance of capacity adjustment schemes and alternative fisheries for fishers is an emerging issue.

Accounting for variation in catches, may lead to shorter, more intense, fishing seasons producing lower total catches in shorter periods and may increase the need for close monitoring. With increasing flexibility in governance there comes a need to enable fishers and processors to be more mobile. The lack of malleability in fishing and fish plant capital may be a constraint in some fisheries. In ocean tuna fishing, more mobility may open up jurisdictional issues, as fishers may cross jurisdictions to take fish. In ocean tuna fisheries the need to contain fishing effort and catch limits also requires the development of bycatch strategies [35].

Legal changes arising from climate change requires attention by those in fishery governance. The specification of fishery boundaries is a first step in management and with climate change these assumptions will need to be revisited, for example within the Pacific Salmon Treaty between the US and Canada. In the western and central Pacific the existing and developing governance regimes need to have the capacity to minimize and diffuse national disputes over fishers following fish stocks to new jurisdictions. The East Australian case shows the potential for intra-national issues to arise from fish moving between state jurisdictions; the tuna species now in Queensland and New South Wales waters will move south to Victoria and Tasmania requiring adjustments in management arrangements.

2.3. Discussion—fishery governance and climate change

The analysis of seven case studies against the FAO criteria has enabled some of the presenting problems in climate change and fisheries governance to be identified. However, there are also some serious governance capacity issues to be addressed. Nearly all of the responses to climate change call on the fishery governance regime to alter policies which have been at the core of the management approaches used to achieve sustainable harvests. Revisiting legal boundaries and agreements, altering licences and conditions of operation, and reducing fishing effort and limiting catch through output regimes are known processes. Governance, however, now faces a new era of capacity adjustment and vessel reduction programs against the background of limited scientific information on fish stock biomass and uncertain rates of climate induced changes.

The seven international case studies enable us to envisage some variations in climate impacts by latitude. For example a rise in the ocean temperature in the low latitude tropics would impact the location of tuna and highly migratory species with implications for spatial management. A similar rise in ocean temperature at high or mid latitudes may also affect the migration locations of salmon stocks. For anadromous species like salmon the inland freshwater life history stage may be more vulnerable to climate change impacts through alterations in aquatic habitat availability and temperature. For pelagic tuna, recruitment areas may also be subject to temperature impacts.

As identified previously, it is important to distinguish between the governance of the natural systems and the systems of governance being used [12]. The appraisal of the climate change issues for the seven fisheries are issues in the governance of the natural system. In the analysis against the FAO criteria there are a mix of governance changes that could be invoked to respond to climate change. Following Jentoft's observation, does the change of a limited entry fishery to manage byment an ITQ system represent an improved way to govern a fishery or is it a significant some changes in governance in the system of fisheries governance due to climate change alone? This suggests some changes in governance may have happened under previous sustainability paradigms anyway, but now the catalyst may be climate change. In the longer term we may see significant changes in the systems of fishery governance, probably emerging from perceptions of current systems being unable to meet the governance challenge.

Familiarity with historical fishery data, existing fishery management systems and their economic/social/governance drivers is an important base from which to alter governance. Additional basic information may be required on fishers, processors and their communities in order to predict impacts and to plan for governance responses.

In summary, climate change will exacerbate the challenges already faced by fishery governance. Redesigning governance will require strategic planning for variability and uncertainty, a broader information base, integration of information at the ecosystem level, and the promotion of flexibility.

At the same time, the uncertainty of climate change creates barriers to re-design. Uncertainty encourages the use of short planning horizons that focus on immediate problems, and supports the delusion that mitigating actions can wait until more information is available. The global scale of the climate change issue means that the benefits of taking local action are uncertain. The effect of climate change may be experienced as a slow "squeeze", exacerbating existing problems rather than a push generating new action. Fisheries governance can mitigate the effects of climate change by explicitly addressing these effects, but it will take considered action.

The paper has also considered governance to be a uniform commodity. Aspects such as involving the fishing industry more fully in co-management and self-governance initiatives may assist government to meet the new requirements arising from climate change impacts more effectively.

2.4. Conclusions

We examined and summarized climate change impact information from seven fisheries in high, medium and low latitudes to see common issues for fishery governance. The major issue for all fisheries is the new level of uncertainty introduced by climate change and the low level of information on the future size of climate change and its impacts. There appear to be few new tools available to address these uncertainties. Adaptation in the fisheries takes the form of revisiting some of the core functions of fishery governance, such as the collection of data on stocks and the environment, adjusting fishing effort, reducing catch and emphasizing management tools that facilitate greater flexibility in production. With climate change impacts there are now new reasons for capacity adjustment and for finding alternative fisheries for displaced fishers, in a world with many overexploited fisheries and few new fishing opportunities.

The comparison of fisheries internationally shows that governance regimes with a sound basis for securing fishery sustainability also have the basis to adapt to climate change and the momentum to address the challenges. Where the management history has been less effective many of the changes required will be daunting. Given the degree of uncertainty facing those responsible for fishery governance, many of the decisions required will not readily be taken, especially where governance has been under-performing in the past.

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