Hot Fish: The response to climate change by regional fisheries bodies

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Abstract

This paper explores institutional responses from Regional Fisheries Bodies (RFBs) to climate change. Fisheries management is highly dependent on the stabilityof targeted fish populations. Oceanic changes occurring as a result of climate change will see continuing and potential irreversible deviations from the conditions of fisheries past. These changes present challenges to fisheries management at all scales – from local to international – relating to food security, sustainability, and ecological integrity. Areas of measurably warmer ocean, or 'hotspots', are a very clear indicator of direct climate change effects. RFBs with hotspots in their areas of competence were chosen for this study. Three levels of institutional engagement were developed: Awareness of climate change; Learning about climate change; Action taken by the institutions. While 94% of institutions demonstrated awareness of climate change and 82% demonstrated learning about climate change, only 41% demonstrated some form of action; and these were mainly procedural

and administrative. Only two of the RFBs considered made explicit statements about incorporating climate change into future fishing management plans. The inference is that RFBs are largely practising business-as-usual, with the implication that many exploited fish populations will face additional survival pressure as the sea around them alters.

Keywords: Climate change; Hotspots; Fisheries management; Governance; Regional Fisheries Bodies.

1. Introduction

Climate change is changing the physical nature of the world ocean and from a human use perspective there are three main effects to consider; acidification, ocean warming, and deoxygenation. Ocean warming is the most broadly influential climate change driver. One of its clearest and most immediate effects has been the poleward movement of species [1]. Worldwide, taxa of all kinds have been observed to have shifted their distributions, with the velocity of these shifts typically significantly faster in the oceans [2]. These shifts are restructuring ecosystems at all levels, from phytoplankton through higher trophic levels [3]. This has the potential to lead to substantial changes in fish abundance, due to altered reproductive [4] or recruitment capacity [5]. Current projections of the combined effects of changed primary production and general ecosystem productivity indicates that declines in fish production is highly likely [6,7], as is a drop in fishery yields [8,9]. Observations of regional responses to extant ocean warming concurs with these projections [10,11,12] and indicates that patterns of biodiversity are being altered globally [1].

The pattern of warming is also heterogeneous, leading to 'hotspots' where warming (as observed by sea surface temperature) is increasing much more rapidly than the global average [13,14]. These regions can provide early insight into what challenges marine ecosystems will face more generally as ocean warming continues in the coming decades. For instance, they show that range shifting species can lead to the reorganisation of ecological communities, both as new entrants ('novel species') and as resident species exit an ecosystem. Both kinds of change impact upon trophic levels and food web structure and lead to ecological niche alterations [15,16,17].

Acidification is another increasing pressure on the global ocean. By significantly altering ocean chemistry acidification is expected to alter the distribution and abundance of plankton communities, habitat forming species and the biota relying on them, from zooplankton to coastal, pelagic, and benthic fish communities and top predators [18,19,20]. While hotspots of acidification have received less attention, studies are accumulating, particularly around polar, upwelling, and reef locations [21,22]. The interaction of temperature and acidification in hotspots of either kind can have compound effects, such as making the area hostile to some surface layer planktonic organisms, with consequences for marine ecosystems [23].

Increasing ocean heat also results in increased stratification and the reduction of available oxygen in the ocean, both in coastal seas and the open ocean [24]. Deoxygenation is already evident and is expected to become more widespread by 2030-40 and have a global signature within a few decades after that [25,26]. Deoxygenation affects the metabolic constraints of marine organisms and therefore also their distribution and abundance [19,27,28,].

Not only do these three main climate drivers – warming, acidification and deoxygenation – individually impact distribution and abundance, they can interact synergistically [29] in many cases intensifying effects on habitats, ecosystems, and fish assemblages. Individually and together, these three factors affect the physiological tolerances of both mobile and sessile organisms and will greatly alter the global ocean ecosystems, biological structures, and biodiversity [30-32]; increasing the risk of severe ecosystem perturbation and potentially even ecological collapse in some circumstances [33]. The interaction of these three factors has been involved in major marine extinction events in the past [34].

All of this sets significant challenges for resource managers seeking to maintain sustainable fisheries. These challenges are reinforced by growth in global population and wealth seeing an increasing demand and consumption of fish products [35]. So the question must be asked as to how rapidly regional fisheries bodies (RFBs) are responding to these challenges. Regional Fishery Bodies (RFBs) were a product of the establishment of the Food and Agriculture Organisation's (FAO) Fisheries Division in 1946 [36]; although the Interational Pacific Halibut Commission (1923) and the International Whaling Commission (1946) were first established outside of the FAO. The purpose of RFBs is to manage and distribute the economic benefit of the fishery to the member parties, which include both coastal States and distant water fishing nations permitted to use the fishery. While initially focused on harvesting RFBs have increasingly included the language of sustainability and conservation in their publications, in line with the Reykjavik Declaration on Responsible Fisheries (2001) [37,38].

The management of global marine capture fisheries over the last eight decades has a mixed history. There have been some notable successes such as action on the sustainability of major commercial stocks in the United States, Australia, New Zealand [39] and parts of Europe [40]. Developing and emerging economies have not fared as well but even there have been bright spots [41]. This is not to deny that there has also been overfishing, species depletion, ecosystem depauperation, and fisheries collapses [42,43]. Humanity has fished down [44,45] and through food webs [46] and where this has occurred at scale or to extreme levels there has been loss of community stability [47] and productivity [48]. Fish protein is increasingly sourced further away from consumption locations [49], suggesting at least some instances where demand cannot be met by local ecosystems but also pointing to the contribution of the seafood trade to the global carbon footprint.

RFBs sit within complex socioecological systems dictated by socio-economic and biophysical dimensions. How RFBs respond, and how rapidly, to the biophysical changes in the world's oceans is an important issue. How RFBs respond, and how rapidly, to the biophysical changes in the world's oceans is an important issue; particularly given that these changes are ongoing, and effectively permanent on the scale of most operational or even strategic management horizons for fisheries. Since climate change is demonstrably altering the ocean, the need for an active and adaptive response by RFBs is clear. This paper explores the type and focus of such responses thus far.

2. **Method**

From the global pool of RFBs we chose the 17 RFBs that have ocean warming hotspots (as per Hobday and Pecl [13]) within their area of competence (Table 1). The research purpose was to capture the instances where the decision making body of RFBs addressed climate change in its deliberations. To that end the annual reports of the RFBs were used as the primary source of data. This is because the annual meeting and associated report is the 'voice' of the RFBs and shows the items of note raised and discussed by the organisation, as well as any relevant decisions made. If climate change is an issue noteworthy enough to be considered by the RFBs formally at annual meetings, it should appear in these annual records. Note that annexes, appendices, including appended scientific reports (unless mentioned in the RFBs meeting), and budget statements were not included as these are often subsidiary documents accepted *en bloc* and we wished to focus on the active consideration of climate change in the discussions surrounding the decision making.

In compiling our data set, the annual reports of the organisations listed in Table 1 released in the period 2002 to 2018 were searched for the phrase 'climate change'. To establish how the RFBs were using this phrase and to what level of institutional activity or response, we developed three tiers of usage (2.1, 2.2, 2.3 below) reflecting whether the RFBs showed awareness, was seeking/receiving understanding (learning) or was taking action. Each mention of climate change in the annual reports was contextually analysed and classified as to the most relevant tier.

Table 1. Regional Fisheries Bodies and their listed primary objective.

RFB	Title	Primary objectives
APFIC	Asia-Pacific Fisheries Commission	Promote the full and proper utilization of living aquatic resources.
CCAMLR	Commission for the Conservation of Antarctic Marine Living Resources	Conservation including rational use of Antarctic marine living resources.
CCBSP	Convention on the Conservation and Management of the Pollock Resources in the Central Bering Sea	Conservation, management, and optimum utilization of pollock resources in the Convention Area.
CCSBT	Commission for the Conservation of Southern Bluefin Tuna	Conservation and optimum utilisation of southern bluefin tuna.
IATTC	Inter-American Tropical Tuna Commission	Conservation and management of tuna and other marine fish in the eastern Pacific Ocean to permit maximum sustained catches.
ICCAT	International Commission for the Conservation of Atlantic Tunas	Management and conservation of tuna and tuna-like species in the Atlantic Ocean and adjacent seas to permit the maximum sustainable catch.
IOTC	Indian Ocean Tuna Commission	Conservation and optimum utilisation of stocks covered by the organisation's establishing Agreement

IPHC	International Pacific Halibut Commission	Develop the stocks of Pacific halibut in the Convention waters to those levels which will permit the optimum yield from the fishery and to maintain the stocks at those levels
IWC	International Whaling Commission	Provide for the proper conservation of whale stocks [then] the orderly development of the whaling industry.
NAFO	North Atlantic Fisheries Organisation	Ensure the long term conservation and sustainable use of the fishery resources.
NASCO	North Atlantic Salmon Conservation Organisation	Conservation, restoration, enhancement and rational management of salmon stocks.
NEAFC	North East Atlantic Fisheries Commission	Conservation and optimum utilization of the fishery resources, providing sustainable economic, environmental and social benefits.
PSC	Pacific Salmon Commission	Conservation and rational management to provide for optimum production
SEAFO	South East Atlantic Fisheries Organisation	Conservation and sustainable use of the fishery resources (excluding migratory fish stocks) in the high seas of southeast Atlantic Ocean
SEAFDEC	South East Asian Fisheries Development Centre	Develop and manage the fisheries potential of the region by rational utilization of the resources.
SWIOFC	South West Indian Ocean Fisheries Commission	Promote the sustainable utilization of the living marine resources.
WCPFC	Western Central Pacific Fisheries Commission	Ensure long-term conservation and sustainable use of highly migratory fish stocks in the western and central Pacific Ocean

2.1 Tier One: Institutional Awareness (Awareness)

This tier indicates that on the official record the organisation was aware of the existence of climate change. This sort of awareness was found in welcoming addresses, speeches, delegate statements and submissions by invited participants. These statements are generally broad and not overly detailed. Awareness was also found in the language of the meeting reports where phrase instances were associated with the words, ‘noted’, ‘recognised’, and similar.

2.2 Tier Two: Institutional Learning (Learning)

Learning at the institutional level was indicated when 'climate change' was mentioned in the context of the words, 'informed', 'recalling', 'proposal', and similar. Learning was also seen in technical and other reports to the RFBs that were included/noted in the annual report, and in lectures or seminars involving climate change delivered to the RFBs in the annual meeting.

2.3 Tier Three: Institutional Action (Action)

This was seen in RFBs deeds, decisions, and in active language. For example, actions included placing climate change on the agenda, funding or commissioning research, and making a definitive statement about climate change. Active words were, 'decided', 'concluded', 'urge', 'requested', 'advised', 'recommend', 'endorsed', and similar. Language that was passive, e.g. 'suggested', 'invited', etc. was not recorded as an action. The Oxford English Dictionary was consulted to determine the precise contextual meaning for less clear words.

2.4 Data treatment

If the phrase 'climate change' appeared in a meeting report in the context of the three tiers each appearance was counted in the appropriate tier. No phrase instance could be placed in more than one tier at the same time in this methodology. This design developed a profile of each RFBs engagement with the issue and allowed a baseline analysis of the performance of RFBs in regard to climate change. As we were interested in engagement with the topic our minimum criteria was direct mention of climate change. Consequently, where the phrase appeared in a non-substantive role (a title, paragraph header, within a citation, etc.), it was not counted. As the information was being treated qualitatively and was assessing level of engagement not sheer volume of mentions, when the phrase appeared multiple times within a single context (e.g. a single sentence, agenda item, or paragraph), it was counted once. When 'climate change' did not appear at all in an annual report the result was recorded as '0'. When an organisation did not produce an annual report that was recorded as '-'.

3. **Results**

Figure 1 shows the RFBs cumulative response to climate change issues since 2002. It is clearly an area of rapidly growing attention, even if action is lagging substantially behind other forms of engagement with the topic.

The jump in learning from 2006 to 2007 is unrelated to the Intergovernmental Panel on Climate Change Fourth Assessment Report and is the result of the discussion and debate during the 26th meeting of CCAMLR (2007), relating to placing climate change as a permanent agenda item on the Scientific Committee. If this were omitted the curve in Figure 1 would be initially lower but the general linearity of the curve remains. Finer detail in institutional responses can be seen in Figure 2.

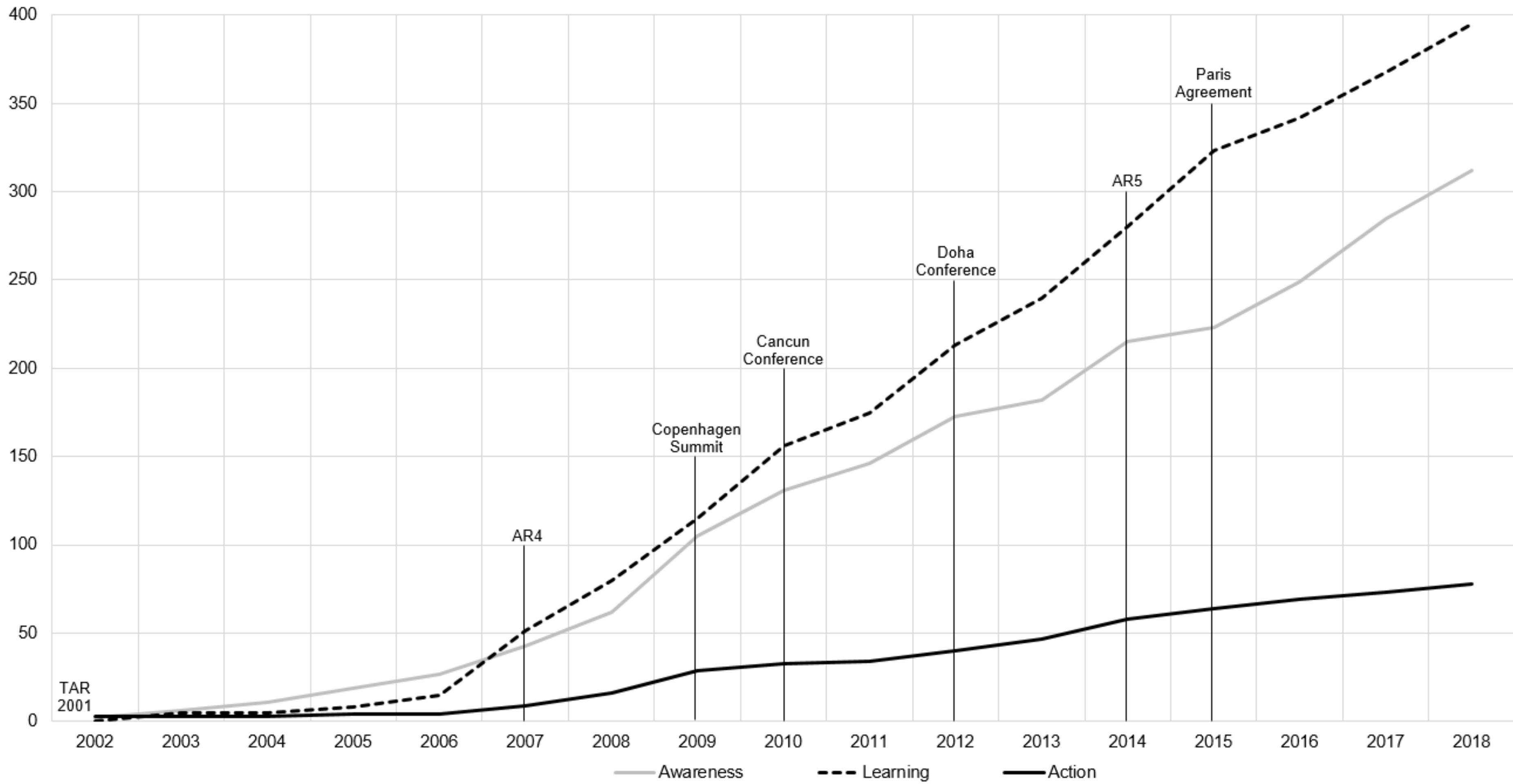

Fig 1. Cumulative count of institutional response by tier.

TAR - IPCC Third Assessment Report; AR4 - IPCC Assessment Report 4; AR5 - IPCC Assessment Report 5.

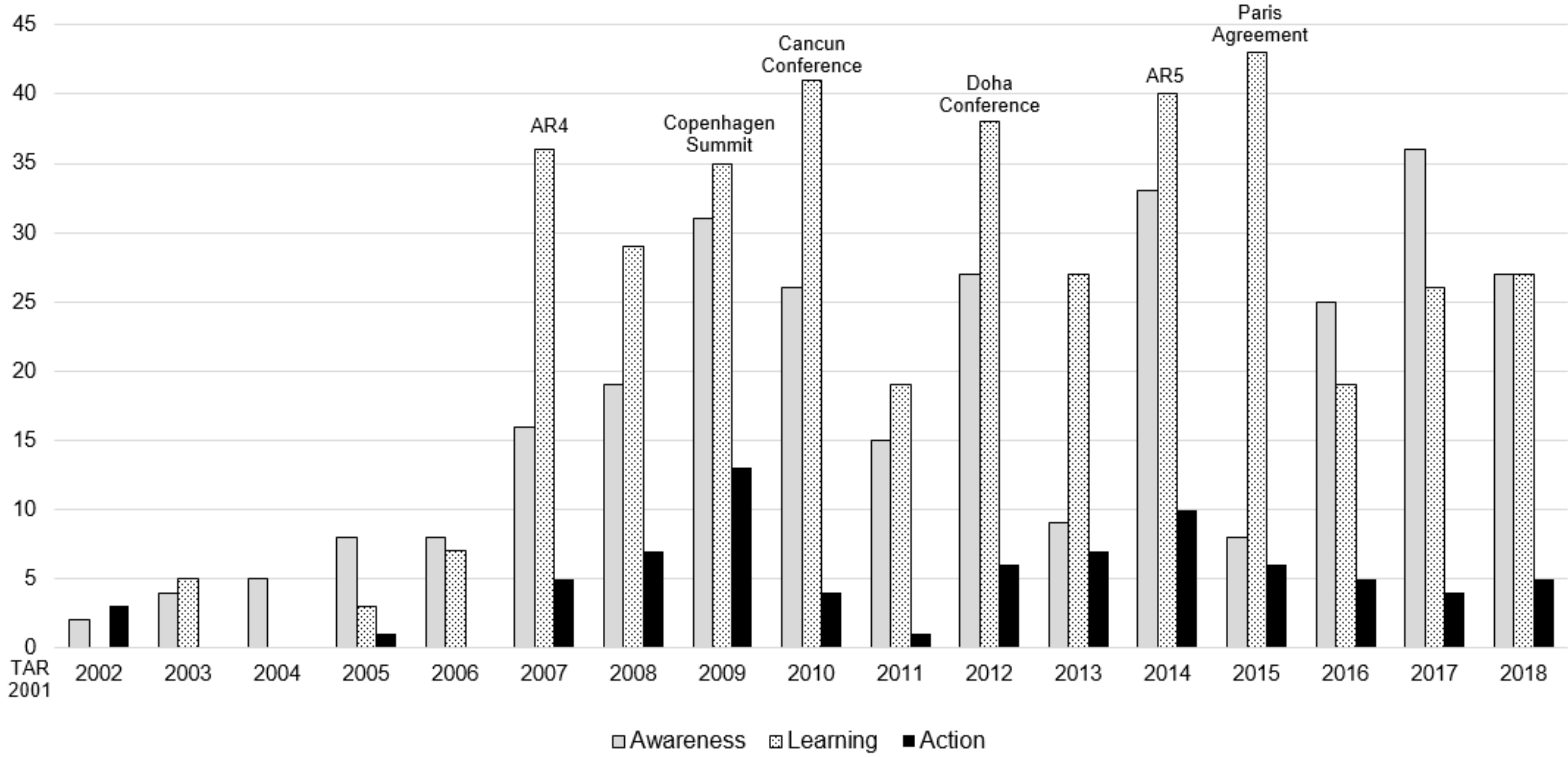

Fig 2. Annual counts of institutional response by tier.

TAR - IPCC Third Assessment Report; AR4 - IPCC Assessment Report 4; AR5 - IPCC Assessment Report 5.

Awareness is low initially but then doubles between 2006 and the release of IPCC AR4 in 2007. Awareness continues to rise to the Copenhagen Summit but then appears to fluctuate, peaking around each new international climate-related event, such as the Doha Conference (2012) and IPCC AR5. The highest peaks of learning then coincide with each major climate meeting or report; Copenhagen, Cancun, Doha, AR5, and Paris. These named years are all annual joint events (the Meetings of Parties of the Kyoto Protocol (CMP) and Conference of the Parties (COP) to the United Nations Framework Convention on Climate Change), that gathered significant public awareness compared to other more technical meetings.

Actions were almost non-existent before 2007 and the growth in actions has been much slower than for the other categories. Concerningly, it does not show sustained growth or even a maintained level of appearance, cycling much as the other categories do – rising to peak at the Copenhagen Summit and then dropping off to a lower level. Of the 17 RFBs considered the majority of actions have been taken by only four – APFIC, CCAMLR, IWC and NASCO (Table 2).

Table 2. Basic descriptive information about RFBs that made an action during the period of 2002 to 2018.

RFB	Year est.	Signatory parties	Action count	Primary objectives
APFIC	1948	21	16	Promote the full and proper utilization of living aquatic resources.
CCAMLR	1980	27	20	The conservation and rational use of Antarctic marine living resources.
IWC	1946	88	13	Provide for the proper conservation of whale stocks [then] the orderly development of the whaling industry.
NASCO	1982	6	11	The conservation, restoration, enhancement and rational management of salmon stocks.
CCSBT	1994	7	7	The conservation and optimum utilisation of southern bluefin tuna.
SEAFDEC	1967	11	7	Develop and manage the fisheries potential of the region by rational utilization of the resources.
SWIOFC	2005	12	4	Promote the sustainable utilization of the living marine resources.

Within the pool of 17 examined organisations there is no apparent relationship between the age of the RFBs, the number of contracting parties, the governing instrument objectives, and response to climate change.

The data suggests socio-political linkages. APFIC, NASCO, SEAFDEC and SWIOFC are RFBs whose member parties are largely artisanal (traditional/subsistence) and small scale fishing nations; in the case of NASCO, there is also an international pool of recreational fishers. In contrast, RFBs made up primarily of industrial fishing are absent from the organisations responding to climate change, with the exception of the CCSBT - which made resolutions in 2014 and 2015 to, 'In the future, the CCSBT could undertake to test the robustness of the MP [management plan] to climate change', with a timeframe of possibly from 2018.

It is also worth noting that the focus of the RFB's may also be contributing. The CCAMLR and the IWC have a long standing and continuing institutional focus on conservation foremost; while the CCSBT is charged with the management of a species (the southern bluefin tuna), which is on the IUCN Red List as 'Critically Endangered'.

In terms of the type of actions taken, the bulk of action events (68 of 78) were internal to the RFBs; mainly requesting more research, proposing education programs, forming committees, working groups, intercessional meetings etc.; requesting reports and developing presentations; placing or proposing climate change be incorporated in future broad scale plans; and the like. However, interestingly, of the 10 actions considered more substantive (listed in Table 3), in that they faced externally or committed the RFBs to an action, half of those occurred in the first half of the period considered (i.e. before 2010) and largely consisted of placing climate change permanently on the annual meeting agenda. Other substantive actions taken in the study period included making climate change considerations part of stock assessments, pushing for management forms resilient to climate change and reaching out to the international community for greater action on mitigation of climate change. For those RFBs that made an action, the median time from awareness to action is four years (range 1-7 years).

Table 3. Substantive Actions made by RFBs in the period 2002 to 2018.

Year	RFB	Substantive Action
2007	CCAMLR	Climate change put on the permanent agenda of the Scientific Committee.
2007	SWIOFC	'The possible effect of climate change on the fisheries of the South West Indian Ocean should be on the Agenda of the fourth session.'
2009	CCAMLR	'4.45 The Commission agreed that climate change is a very important issue and adopted Resolution 30/XXVIII on climate change that urges increased consideration of climate change impacts in the Southern Ocean to better inform CCAMLR management measures.'
2009	IWC	Resolution 2009-1 'Requests Contracting Governments to incorporate climate change considerations into existing conservation and management plans; appeals to all Contracting Governments to take urgent action to reduce the rate and extent of climate change.'
2009	SWIOFC	'Climate change is an item on the Agenda.'
2012	APFIC	'103. The Commission emphasized the importance of raising awareness of climate change, particularly for policy-makers in this region. It encouraged delegates to return to their agencies and engage with relevant people to make sure that fisheries and aquaculture was being incorporated into national planning for climate change mitigation and adaptation.'
2013	APFIC	'The Commission recommended that fish stock assessment models should incorporate climate change considerations.'
2014	CCSBT	'PR-2014-5: In the future, the CCSBT could undertake to test the robustness of the MP [Management Plan] to climate change. It should also take every opportunity to give priority to stock rebuilding above increasing catch.'
2014	CCSBT	'PR-2014-6: Every effort should be made to enhance (speed-up) the rebuilding trajectory in line with the precautionary approach to fisheries ... and improve resilience to fishing and climate change.'
2015	CCSBT	Reiterated PR-2014-5 and PR-2014-6 with a possible implementation timeframe of 2018.

4. **Discussion**

Collectively the 17 RFBs examined cover the entirety of the world ocean (95% without IWC), including all recognsed warming hotspot areas where it is expected attention to climate effects would possibly be more evident due to the level of climate induced change in ecosystems [14]. These are the organisations charged with delivering sustainable renewable marine resources into the future so it is insightful to see how they are grappling with the early stages of climate induced changes to marine ecosystems.

RFBs institutional awareness and learning has largely tracked the wider public awareness of climate change, tending to peak around particular high profile climate events – such as the Doha Conference – rather than showing a sustained response to the input of expert knowledge or on the back of COP meetings (held annually since 1992 and the CMP since 1995). In particular, despite rising awareness and learning, actions have remained low in number, infrequent, and limited to under a third of the RFBs.

The lack of action on the part of RFBs comes from a low baseline, given one class of substantive responses was simply to have climate change placed permanently on the agenda for the attention of an RFB. Taking climate change into formal consideration in fisheries management plans and assessments has been a much slower process, with very few RFBs having taken that step to date.

The physical changes to the global ocean are intensifying and there is a growing body of research that shows the impacts of climate effects will be profound and long-lasting, affecting the distribution, survivability, structure and composition of marine species and ecosystems [50]. It is easy in principle to call for rapid responses, and preparedness given the potentially short time frames involved before substantial ecosystem change is realised (particularly in warming hotspot locations). However, the capacity for RFBs to respond to the biological changes within their areas of competence is dependent on the organisation's ability to define those changes. Modelling a species or regional biological response under climate change has layers of uncertainties which can hamper regulatory action [51,52]. While there are observed and predicted trends that show there will be reductions in abundances, extinctions, regime shifts and ecosystem collapses, extending these trends and effects to specific fisheries and species has been limited and is of uncertain utility for immediate management under the governance of RFBs [52-55].

In the highly structured arenas of RFBs advisory systems, information is often required in specific forms on specific topics, not always easily facilitating input from new groups/disciplines not familiar with the formalities. Where advice is sought more broadly, managers may ask for specific guidance, for prioritised or optimised lists of actions that will be most effective. However, scientists cognizant of the need for co-management or procedural input are often reticent to make prescriptive pronouncements on actions needed for particular stocks. Given the remaining uncertainties involved (e.g. the true and ongoing extent of impacts on survivorship and recruitment, on food web restructuring, evolution and acclimation) scientists are more confident around highlighting where risks exist, on the kinds of additional information that can confirm a specific effect is occurring, or on broad classes of options that may assist with mitigation or adaptation [56]. The difference between the actions of the decision makers and the advice from science remains an issue [57]. Consequently, it is imperative the two groups – scientists and policymakers – come together to highlight reliable means of injecting science on climate change into RFBs processes and to highlight the no regrets actions that can be made now and built on into the future as more information is gathered.

Historically and presently RFBs manage fisheries on behalf of parties with an interest in the resource being exploited. They include organisations made for the management of highly migratory and straddling stocks and organisations made for managing geographical areas. Since the 1970s conservation and ecosystem management efforts have been slowly introduced to try and manage the effects of industrial fishing to varying degrees of success [58] and it can be argued that inclusion of climate is yet another step in that evolution. Nonetheless despite the ecosystem perspective, the core business of RFBs still largely remains fixed on regulation built around the Maximum Sustainable Yield concept, which has limited scope to easily introduce broader system perspectives [59,60]. The mixed success of fisheries management more broadly indicates that systemic problems persist with the application of single species approaches when considering multispecies fisheries and ecosystems [61,62]. There has been progress with ecosystem-based fisheries management, typically within national jurisdictions (e.g. [63,64]), but much more remains to be done, particularly within the context of RFBs and especially in the context of taking on adaptive, dynamic, and system perspectives that can pragmatically deliver when rapidly changing ecosystem states collide with limited logistical resources. Unfortunately, the tight timeline for delivering sustainable food security that climate change has put the globe on means the ability of RFBs to manage their areas of competence under climate change is now a critical issue.

The governance behaviour and decision-making processes of RFBs seem to preclude rapid, comprehensive, and effective decisions on matters not relating to negotiations concerning immediate tactical management decisions [65]. However, the instruments that constitute RFBs (treaties, agreements, etc.) theoretically have the capacity to fit in a response to climate change, uncertainty, and species range shifts if there is the political will to do so [66-69].

The role of RFBs in determining resource allocation means that governance and decision making are by nature political [70]. RFBs negotiations need to manage and mediate tensions between the needs of delegations to maximise their nation's quota and a focus on sustainability [70]. The political dimension of RFBs can be exacerbated where there is a high level of industry participation (including where industry members attend as delegates for member states) whereas civil society organisations generally have observer status [71]. The acceptance of best practice scientific advice in the face of economic interests has been problematic [55], with some RFBs following scientific advice 39% of the time or less [72]. While RFBs are addressing the wider domains of sustainability and biodiversity in management [73], the political pressures in shaping scientific advice to suit the agenda of members [74] or, as Axelrod notes, to maintain the *status quo* [75] is likely to be accentuated as fisheries are affected by climate change.

Conclusion

This assessment shows that while there is evidence of broad scale awareness of climate change and a desire to learn more about it and its implications amongst RFBs, resulting actions have so far been largely procedural and infrequent in number. Extant actions have served two main functions; keeping institutional awareness of climate change on the agenda and to consider climate change in planning. There is very little indication that climate change has yet appeared in the RFBs fisheries policy, annual decision making, or operational regulation. RFBs are apparently continuing with business-as-usual approaches and are yet to seriously prepare for coming change or, in the case of RFBs in climate change hotspots, respond to current changes. Two factors contributing to this inaction are, first, uncertainty and imprecise knowledge around the effects on fisheries within the RFBs competence and second, the lack of political will to take management decisions that curtail resource extraction.

There is extensive research showing that the global ocean is changing and marine life is responding; there is also an increasing information on what future changes will entail. Based on their formal structures, RFBs have the capacity to negotiate a path to respond constructively to climate change effects, but are as yet to actually begin to do so. The seriousness with which the RFBs take the topic will be evident once clear actions (such as policy adjustments or regular assessment inclusions) that address climate change and its effects become commonplace within RFBs meetings and reporting. This is achievable if there is the political will, awareness, and a recognition that the current policy vacuum and stasis should end. This will require a coming together of both scientists and policymakers, so that they can work together to ensure the immense volume of relevant science can be communicated in a way that facilitates the rapid and adaptive action required by RFBs in response to the world's changing oceans.

Authorship contribution statement

Jonathon Sumby: Conceptualization, Investigation, Methodology, Visualization, Writing - original draft. Marcus Haward: Conceptualization, Writing – review and editing. Elizabeth A. Fulton: Writing – review and editing. Gretta T. Pecl: Conceptualization, Funding acquisition, Writing – review and editing.

Gretta T. Pecl was supported by an Australian Research Council Future Fellowship (FT140100596)

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