Present and future allocation approaches for internationally shared fish stocks

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Abstract

Allocation schemes are one way to combat the tragedy of the commons, the situation whereby individual users of a shared resource put their own interests above the collective good. In the case of shared fisheries, developing equitable and transparent allocation schemes can help to ensure stable cooperative management agreements, which in turn will facilitate sustainable fisheries. Allocation schemes for shared fisheries resources, which have been in existence for decades, have recently been facilitated by Regional Fisheries Management Organizations (RFMOs). These schemes vary in the scale of interested parties, from simple two-country systems sharing Pacific salmon, to multi-country systems sharing Atlantic bluefin tuna. Most RFMOs tend to base allocation schemes on historical catch records, spatial stock abundance estimates, or a combination of these. Socio-economic factors do not appear to influence allocation to any major extent. Unfortunately, previous attempts at creating and enforcing allocations programs have not, by and large, been able to curb the serial depletion of fish stocks, particularly when the number of fishing countries is large. Several RFMOs are currently in the process of initiating or reformulating allocation programs. In this paper, current allocation approaches are reviewed and discussed in the context of their possible transference to new or evolving programs. Specifically, we draw on lessons from game theory, and explore the potential for better incorporation of socio-economic circumstances in allocation decisions, which can incentivize improved compliance. We also draw on conclusions from the relevant literature analyzing international water agreements. We propose a combined socio-economic-ecological construct whereby allocation programs can be based on the sharing of benefits other than catch.

Keywords:
shared fish stocks, straddling stocks, RFMOs, allocation, socio-economics, tragedy of the commons

1. Introduction

Shared fisheries resources are susceptible to the "tragedy of the commons" [1], and although Hardin formally explored the impact of individual shepherds increasing their heads of cattle on a shared pasture, his thesis is just as relevant to shared marine pastures, or the global ocean commons. Fish stocks are common pool resources that face the

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problem of overexploitation due to dynamic [2, 3], market [4, 5, 6] and stock [7, 8, 9] externalities. This challenge to economically and ecologically viable common pool fisheries was identified by an economist in the 1950s [10], before the idea was better-popularized by Hardin. Fellow economists took up the challenge by analyzing the difference between noncooperative and cooperative management of these shared fish stocks, concluding that cooperation could alleviate some of the problems of the overuse of common pool resources [2, 3, 11].

In the case of fish stocks exploited by several fishing nations, a race to the fish fueled by national interests has historically ensued, leading to both biological and economic losses. Some countries recognized the sub-optimal nature of such interactions and formed joint management arrangements to facilitate cooperation and improved fishing strategies. Canada and the United States, for example, formed a joint committee as early as 1923 to improve management of Pacific halibut. In 1982, the United Nations Convention on the Law of the Sea [12] admonished fishing states to seek regional or sub-regional organizational groups to improve management of transboundary and straddling stocks. In 1995, the United Nations Fish Stocks Agreement (UNFSA) furthered this sentiment, and formalized these joint arrangements into what are called Regional Fisheries Management Organizations (RFMOs) [13].

Among other responsibilities, RFMOs are required to perform the function of agreeing "on participatory rights such as allocations of allowable catch or levels of fishing effort" in internationally-shared fisheries [13]. The degree to which an allocation program is seen as equitable and effective can have a large impact on the success of RFMO management, and yet, it is often one of the least-structured elements of RFMO activities [14]. In order for cooperative management to succeed, fishing parties must be confident that they are better off through cooperation than through non-cooperation: known as the individual rationality constraint. The allocation of catches (or other benefits) can largely influence whether or not cooperation is rational.

In this paper, we summarize how the current allocation programs for shared fisheries came to be, and comment on future allocation programs. We begin the analysis with a summary of how game theory, or the study of strategic interaction, has been applied by fisheries economists to the issue of catch (or effort) allocation. Following this, we outline the allocation approaches currently taken by both bilateral and multilateral RFMOs. These results, summarized in Table 1, are split into two Sections, with the second Section being devoted solely to tuna RFMOs. We next outline future considerations for allocation programs, both for new schemes and those schemes that may need to be renegotiated in the near future. The issues present in the management of shared fish stocks are also present in the management of internationally-shared water resources. We therefore draw on various parallels with, and conclusions from, international water agreements. By highlighting current allocation practices, criteria to be considered in the future, and allocation programs present in sharing other natural resources, we propose a way forward for RFMOs with regard to their responsibilities for allocation schemes.

2. Game theory and allocation

Issues surrounding the allocation of shared fisheries resources are some of the most challenging in fisheries management [15, 16]. Two of the formidable barriers that impede international cooperative agreements are the new member problem, by which a new country seeks access to the shared resources [17, 18], and issues related to free-riding, whereby a country not engaging in the cooperative agreement benefits from the conservation measures of compliant countries. Such issues are usually present in fisheries that involve a substantial catch from the high seas, in addition to EEZ catches, such as fisheries for tuna species. Cooperation in such systems is inherently difficult to reach [19, 20].

While RFMOs have often relied only on biological information, economists have been using the theory of games to derive the conditions under which fishing states sharing a resource would be encouraged to cooperate in management, including how effort or catches should be allocated. Most applied game-theoretic analyses, which usually focus on maximizing economic rent from the shared fishery, have concluded that cooperative agreements between fishing nations bring benefits above and beyond non-cooperative management [21]. Two-player systems, where the fisheries resource is shared only between two countries, have been thoroughly analyzed, and economically rational sharing agreements have been identified in theory [22, 23, 24, 25, 26]. Finding acceptable sharing arrangements is hard enough in systems where the resource is shared by only two countries; finding acceptable arrangements in systems with greater than two players has been overwhelmingly difficult in both theory and in practice.

Following the UNFSA, it became evident that the two-player analysis would not be sufficient to tackle one of the most pressing of fisheries management issues, namely, management of straddling stocks [17]. While the bargaining process among two players proceeds in a straightforward manner, the standard game-theoretic models that had been developed for bilateral allocation were not capable of dealing with a larger number of players [17, 27]. So the management of fisheries occurring in both the EEZs of countries and in the high seas calls for a coalition approach due to the potentially large number of interested countries [28]. One conclusion that came out of the early speculation on international fisheries sharing arrangements was that in a repeated game model of infinite duration (known as a supergame), the payoffs to playing non-cooperatively increase as the number of players in the game increases [27]. Thus, there is a large incentive to deviate from cooperation given a sufficiently large group of players. This may be particularly relevant for management of tuna fisheries, as the potential number of interested players can be quite large.

Some of the earliest fisheries studies involving greater than two players, no doubt inspired by [17] and [27], used characteristic-function games, or C-games, which progress in two steps [29, 30, 31]. Firstly, the relative payoff of each coalition is computed and compared, with respect to the payoff when all players cooperate (the grand coalition). Secondly, the sharing imputation is calculated, which is essentially the allocation: what fraction of the benefits should each player in a coalition receive? There are different methods for assigning sharing rules in fisheries, for example, the Shapely value [32], the nucleolus [33], and the Nash bargaining solution [34].

The Shapley value essentially weights players based on their marginal contributions, such that the more a player contributes the more they stand to gain [32]. The nucleolus is a unique solution that maximizes the benefits of the least-satisfied coalition [33]. The Nash bargaining solution is an egalitarian approach, essentially assuming that all players in the coalition are equally important because full cooperation would not succeed without all of them, and thus the payoff should be shared equally [34]. Note that there is no guarantee that all or any of these approaches will lead to a stable coalition structure, that is, one that is rational to all players. However, applying these sharing rules is the way that economists have generally tried to tackle the allocation problem from an economic, as opposed to biological, perspective. A review of a coalitional fisheries games was undertaken in [28].

Even when fair sharing rules could be calculated, the stability of the cooperative solution is questionable [35, 36]. A given coalition is stand-alone stable if and only if no player is better off by leaving the coalition to become a singleton, or free-rider (internal stability), and no player wishes to join the coalition (external stability) [19]. In an early coalitional game of the Baltic Sea fishery, it was concluded that the sum of the players' threat points if operating as singletons was greater than the sum of the grand coalition's payoff [35]. That is to say that fishing parties acting independently were better off than they would be through their allotted allocation in the cooperative game. Consequently, a novel sharing rule was developed to combine cooperative and non-cooperative games, and to explicitly consider free-rider threat points, those payoffs that each player would get if deviating from the grand coalition [36]. This research determined that a large enough increase in benefits through the formation of the grand coalition was possible to satisfy all players, [36]. Here, all players are 'satisfied' if their payoff through cooperation is at least equal to their payoff from free-riding (the individual rationality constraint).

3. Current allocation approaches for non-tuna RFMOs

Having reviewed how economists have developed allocation modelling approaches based on the sharing of economic rent, we now turn to the current allocation schemes that are practiced by bilateral and multilateral RFMOs.

3.1. Pacific Salmon

Pacific salmon are a transboundary resource, shared by the United States and Canada. In 1985, the Pacific Salmon Treaty (PST) was signed by both parties, after 25 years of negotiations. Prior to the Treaty, both countries engaged in "fish wars", intentionally over-harvesting in their own waters in order to deny harvesting opportunities to the other country [37]. The Treaty replaced earlier agreements, such as the 1937 Fraser Salmon Convention, which established the International Pacific Salmon Fisheries Commission (IPSFC) charged with sharing Fraser River sockeye 50/50 between Canada and the U.S.. The 1985 Treaty sets out the long-term management goals of both countries. The Pacific Salmon Commission is the regulatory body put in place to implement the Treaty. There are five species of Pacific salmon managed jointly under the treaty: sockeye (*Oncorhynchus nerka*), chinook (*O. tshawytscha*), coho (*O. kisutch*), chum (*O. keta*), and pink (*O. gorbuscha*). Pacific salmon return to spawn in the streams they were born in, meaning salmon that originate in Canada will eventually return to Canadian waters. The Treaty acknowledges this, recognizing "that States in whose waters salmon stocks originate have primary interest in and responsibility for such stocks" [38].

Annex IV, Chapters 1 to 7 of the Treaty contain agreed management, conservation and allocation measures for each species and interception fishery. These chapters are renegotiated separately every 4 to 12 years. Article III 1(b) requires each country to manage its fisheries and enhancement programs so as to ensure that each country receives "benefits equivalent to the production of salmon originating in its waters", the so-called equity principle. This provision has never been fully implemented because the Parties cannot agree on what constitutes an "equitable balance" [39].

The Commission has long dealt with the issue of "interceptions": those fish originating in one country but being caught by the other. In 1996, for example, Canada estimated that the accumulated interceptions of both countries favoured the U.S. by about 35 million fish, resulting in a loss of about $500 million (CAD) to Canada [38]. Notably, Pacific salmon cannot be fished in the high seas, as per the North Pacific Anadromous Fish Convention [40].

Bilateral interception limits are negotiated periodically between Canada and the U.S.. However, Canada actually has to negotiate with several states (Oregon, Washington and Alaska), the U.S. government, and the Pacific Northwest Tribes, instead of just one federal group. That negotiations must take place between more than two interested parties increases the challenge of reaching cooperation. In spite of this negotiating complexity, however, in 1999, after 7 years of difficult negotiations, agreement was finally reached amongst the 5 U.S. jurisdictions and Canada on renewed fishing arrangements for Annex IV.

For Fraser River sockeye, an annual international total allowable catch (TAC) is calculated as follows [41]:

$$TAC = return - sockeye \quad harvested \quad (test) - escapement \quad target - MA - AFE \tag{1}$$

Here, MA is the management adjustment for each Fraser River sockeye stock, and AFE is the Aboriginal Fisheries Exemption. The U.S. TAC is then a fixed percentage of the international TAC, currently 16.5% [41]. It is unclear how this fixed percentage was formulated.

3.2. *Pacific hake*

North Pacific hake (*Merluccius productus*), also known as Pacific whiting, are found from northern Vancouver Island south to the northern part of the Gulf of California, and are thus shared between Canada and the U.S.. Hake are considered the most populous groundfish species in the California current system. The catch is primarily processed into H&G blocks, fillets or surimi. Prior to 2002, the U.S. was claiming an 80% share of the hake fishery, while Canada was claiming 30%, leading to non-cooperation and overfishing [42]. This was perhaps due to differences in stock assessments performed by scientists within each country. Thus, in 2003, both countries signed the U.S.-Canada Pacific Hake/Whiting Agreement. While the Agreement was ratified in 2003, it was not formally implemented until 2012 [43]. However, from 2003 through 2011, both Canada and the United States operated under the spirit of the Agreement, and complied with the Agreement's national allocations[1]. The document states:

[1]Bruce Turris, Pacific Fisheries Management Inc., personal communication.

“The Agreement establishes, for the first time, agreed percentage shares of the transboundary stock of Pacific hake, also known as Pacific whiting. It also creates a process through which U.S. and Canadian scientists and fisheries managers will recommend the total catch of Pacific hake each year, to be divided by a set percentage formula. [42]”

A TAC is decided upon jointly, with input from scientific advisory panels from both Canada and the U.S., as well as through consultation with the Hake/Whiting Industry Advisory Panel. Allocations of 26.12% and 73.88% of the coastwide TAC go to Canada and the U.S., respectively [42]. This fixed allotment, determined through bilateral negotiation, is in effect for nine years, and will remain fixed unless both Parties agree to change it.

3.3. Pacific halibut

Pacific halibut (*Hippoglossus stenolepis*) are found along the continental shelf in the North Pacific as well as the Bering Sea, and have been commercially harvested by Canada and the United States since the late 1880s. Since 1923, the Pacific halibut fishery has been managed by a joint Canada-U.S. convention. This convention resulted in one of the earliest international groups developed to facilitate conservation-based cooperative management between different countries sharing access to a commercially valuable fish stock. It was initially called the International Fisheries Commission, but today is known as the International Pacific Halibut Commission (IPHC).

Prior to 2006, halibut was managed under the assumption that there were several separate stocks along the Pacific coast with negligible migrations between regulatory areas. Due to an easterly migration of halibut that was originally not accounted for, a disproportionate share of catches were being taken from the eastern areas, notably the waters of Canada and Washington State [44]. Modified stock assessment modelling has led scientists to reformulate this assumption, and now the population is managed based on a single coast-wide stock, although this has not been formally accepted by Canada. Through annual stock assessments, IPHC estimates the coast-wide exploitable biomass. Exploitable biomass by regulatory area (8 areas in total) is then calculated based on survey data, and a fixed exploitation rate is applied to that biomass to obtain an allowable yield (constant exploitation yield (CEY)) for each regulatory area [44]. Presently, an exploitation rate of about 20% of the exploitable biomass is the management target for each area [44]. Allocation is currently done by regulatory area, but the result of this process is a proportion of the stock that Canada is allocated to remove, and proportion of the stock that the U.S. is allocated to remove, essentially a bilateral agreement.

Given that Canada and the U.S share several commercially-exploited fish stocks (salmon, hake and halibut), it is conceivable that bargaining for multi-species instead of single-species allocations could facilitate improved cooperative outcomes for both countries. In this case, by giving up some allocated hake, for example, Canada could then ask for more sockeye salmon or halibut in return. The apparent process of several different Canadian and U.S. interests all acting in their own best interest is probably counterproductive to each country obtaining the best outcome.

3.4. Northwest Atlantic: NAFO

The International Commission for the Northwest Atlantic Fisheries (ICNAF), now the Northwest Atlantic Fisheries Organization (NAFO), initiated allocation schemes in the early 1970s [45]. At that time, the primary stocks of management interest for the Commission were of haddock, cod, pollock, halibut, herring and lobster. Between 1969 and 1972, the ICNAF adopted national TACs for individual stocks based on historical catches [46, 47]. They used an 80% allocation rule, where national TACs were developed based on long-term (40% in proportion to average catches over a 10 year period[2]) and short term (40% in proportion to average catches over a 3 year period) removal histories [45]. Further to this, 10% of the TAC was allocated to Coastal States, with the remaining 10% put aside for special needs [45]. This was referred to as the 40-40-10-10 formula. By 1977, ICNAF had developed nationally-allocated TACs for some 70 different regional stocks [46]. The Commission recognized the need for flexibility in allocation schemes, especially because overfishing was already occurring on some stocks, and TACs needed to be adjusted downward in subsequent years. ICNAF was formally dissolved in 1979, with NAFO being inaugurated that same year [46].

After Canada and the U.S. declared sovereignty over their 200 nautical mile EEZs, many foreign fleets turned their attention to heavy fishing just outside of the EEZ limits, on the so called “nose and tail” of the Grand Banks. Although NAFO continued to recommend annual allocation TACs, these were often exceeded by several European countries [46] and the area has been plagued by overfishing for decades [48]. NAFO was also challenged by non-member fishing fleets, for example those from Panama, Chili and Mexico [46] who fished the resource without being party to the group, essentially free-riders. Today, the NAFO allocation system is based on fixed shares, as a proportion of the TAC [49]. A working group formed to analyze current and possible future allocation programs for NAFO has had difficulty agreeing on a comprehensive set of allocation criteria [15].

NAFO has set out guidelines on how to deal with the new member problem. They simply state that their stocks are fully allocated, and new members should join NAFO with the understanding that their fishing opportunities will be limited, for example, to fisheries that are as of yet unallocated [14]. The setting of NAFO allocations, however, has often been met with resistance. In the 1980s and 1990s, for example, an average of 10 objections per year were launched by member states, which often resulted in unilateral quota allocations being set by the objecting parties [50].

3.5. Northeast Atlantic: NEAFC

The Northeast Atlantic Fisheries Commission (NEAFC) was established in 1959, and is mainly concerned with herring, mackerel, blue whiting and pelagic redfish [51]. Despite recognition in the early 1960s that TACs could serve conservation purposes, the Commission was unable to nudge its members into cooperating in an allocation

[2]It is unclear why 10 years was thought to be long-term. If this was based on biological considerations of the target stocks, then we have the case where biological reference points are used, with disregard to economic criteria. When dealing with climate science and issues of resilience over time, RFMOs will certainly be forced to expand their considerations of ‘long-term’.

scheme prior to the collapse of the Norwegian Spring Spawning Herring stocks in the late 1960s. This led some of its members, specifically the former USSR, Iceland and Norway, to initiate their own allocation program. In 1974, NEAFC was able to institute TACs for North Sea herring along with other stocks on an ad-hoc basis [47, 52]. Like ICNAF, NEAFC used historical catches as the main criteria for their allocation recommendations, along with special considerations for coastal states and new members [47].

NEAFC originally ceased overseeing TAC allocation when countries adopted the 200 nautical mile EEZ, leaving individual nations responsible for conservation through smaller bilateral and multilateral agreements [47]. Today, they recommend a variety of conservation measures, including the setting of TACs and allocations to member nations (called contracting parties, CPs), which include the European Union, Denmark, Iceland, Norway and the Russian Federation [51]. For herring, allocation to CPs is based on the "zonal attachment principle": the stock size in a given zone multiplied by the duration of the stay determines the allowable biomass removals for that zone [51]. Changes in abundance distribution of herring caused a breakdown in cooperation between CPs in 2003, with Norway demanding a higher allocation [51].

NEAFC has also encountered trouble facilitating cooperation between CPs targeting blue whiting. In the 1990s, although fishing nations agreed that a cooperative sharing scheme was necessary to prevent overexploitation of blue whiting, CPs could not agree on how to share the TAC, and often set their own quotas, greatly exceeding the recommended TAC [51]. In the 2000s, CPs presented alternative ways of allocating the TAC based on the zonal attachment principle described above, on catches from a given zone, or a combination of these two, along with an economic dependency argument in some cases. In 2005, an allocation scheme was finally agreed upon, which was heavily facilitated by fishermen's organizations [51]. Currently, NEAFC operates their allocation program based on fixed proportions of the TAC [49].

A promising sign of improved fisheries management in the North Atlantic is communication between NEAFC and NAFO. The two RFMOs have reportedly initiated the development of a pan-North Atlantic list of vessels engaged in illegal, unregulated and unreported (IUU) fishing [51]. IUU vessels flagged on the waters of one RFMO would be reported to the other group.

4. Allocation approaches by tuna RFMOs

Due to their migratory nature, managing tuna stocks in a cooperative manner is remarkably difficult. Several RFMOs exist to do just that, although they have had variable degrees of success in meeting management objectives, be they catch limits or otherwise [53, 54]. This could be partly due to the lack of quantifiable guiding principles on which RFMOs can draw for their allocation decisions [14]. Figure 1 shows the RFMOs that are charged with the management of tuna (and tuna-like) species [14].

Most tuna RFMOs currently have some type of catch allocation or apportionment scheme in place. Although RFMO members are under a legal obligation to cooperate as per the UNFSA [13], groups have often failed to reach agreement on the allocation of catches, and overages have been common [14]. Current allocation schemes fall short in their ability to address the problem of new member allocations, of adequately considering the needs of developing states, and of limiting non-compliance with catch allocations [14, 15].

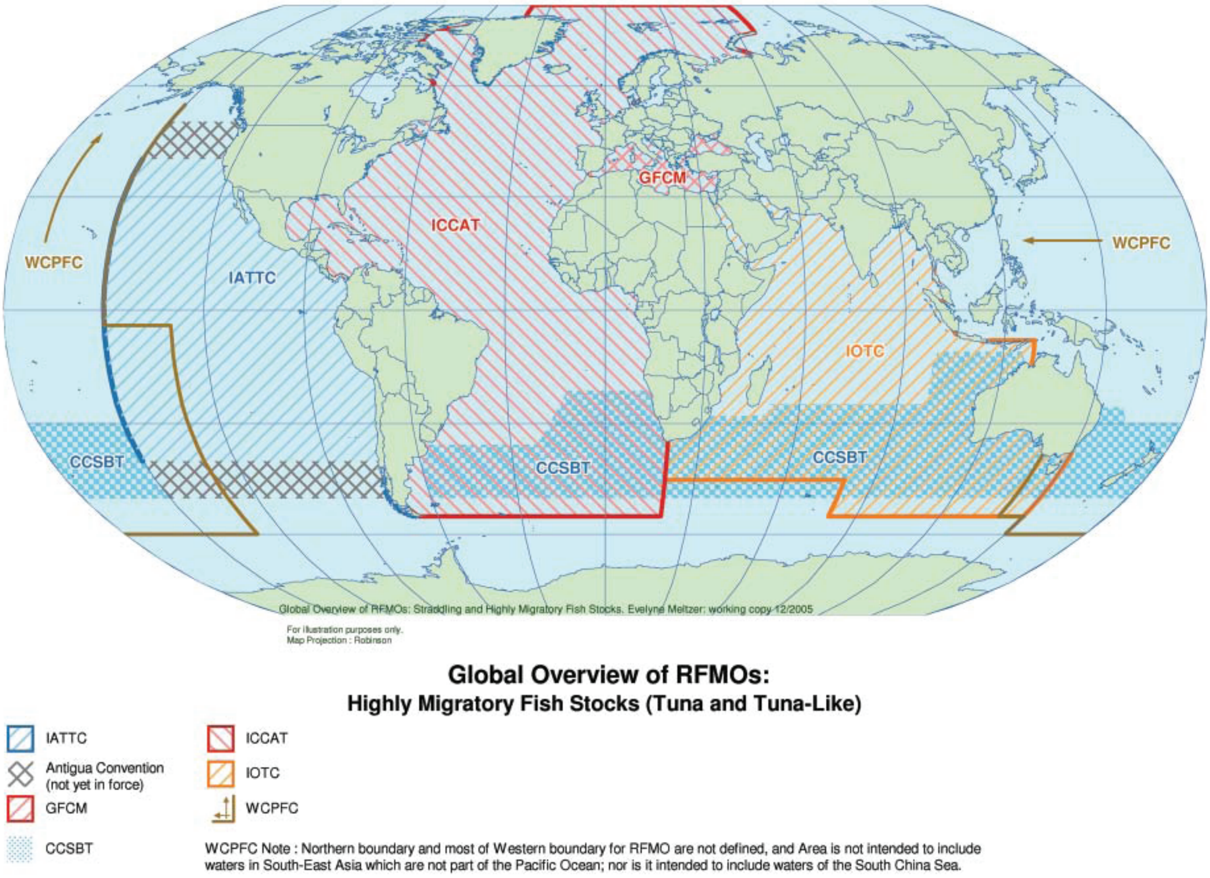

Figure 1: Map of tuna RFMOs [14], © Chatham House.

4.1. ICCAT: Atlantic bluefin tuna

The RFMO in charge of Atlantic bluefin (*Thunnus thynnus*) is the International Commission for the Conservation of Atlantic Tuna (ICCAT). In the early 1970s, tuna fishing nations in the Atlantic began to worry about overexploitation of Atlantic (northern) bluefin tuna. In 1974, minimum size limits were implemented, but by 1981, it was evident that more drastic conservation measures would be required [55]. The United States proposed allowable catches be allocated based on 1970-1974 catch histories, but this was not agreed upon. Further delegations resulted in the TAC being divided among Canada, Japan, and the U.S., with Brazil and Cuba having no catch restrictions. Reportedly, allocations were determined by a combination of historical catches, economics factors, and monitoring needs [55]. These initial bluefin delegations paved the way for further TAC allocation schemes to be developed for other North

Atlantic species, such as swordfish and albacore tuna. For these latter schemes, instead of catches being explicitly allocated, management instead suggested to set the allowable fishing mortality [55]. This resulted in an implicit sharing arrangement. However, problems with uncertainty in mortality estimates and the inability to enforce this measure, meant that catch allocations were eventually favoured. Similar to earlier allocation schemes, sharing was based on historical catches. Pathological underreporting of catches, however, has occurred [14].

Today, ICCAT has developed an extensive set of criteria to inform allocation schemes of individual stocks. The inclusive nature, however, makes consensus difficult, and leaves room for various concessions, and opportunities for ineffective management [49]. One of their more questionable allocation criteria is based on aspirations. For example, in 2002, ICCAT allocated 25 tonnes of bluefin tuna to Mexico and various amounts of swordfish to Morocco, Mexico, Barbados, Venezuela and China, among others, because of the aspirations of these countries [15, 49]. Unfortunately, such practice resulted in the 2002 allocated TAC for bluefin being significantly higher than the scientifically-recommended TAC [15]. ICCAT outlines the conditions for applying their allocation criteria as follows [49]:

1. Applied in a fair and equitable manner;
2. Applied by relevant panels on a stock by stock basis;
3. Applied to all stocks in gradual manner;
4. Takes into account contributions to conservation;
5. Applied consistent with international instruments in a manner to prevent over-fishing;
6. Applied so as to not legitimize illegal, unreported and unregulated catches (IUU);
7. Applied in a manner that encourages cooperating non-members to become contracting parties;
8. Applied in a manner that encourages cooperation between developing states;
9. No qualifying participant shall trade or sell allocated quota.

Some of these criteria appear to be at odds with one another. For example, to apply an allocation program to stocks in a gradual manner (3), may in fact not be consistent with preventing overfishing (5). Interestingly, ICCAT does not assign area-specific TAC allocations, rather, allocation of a TAC to a party allows that party to fish throughout the whole convention area (access to foreign EEZs has to be applied for) [15]. This is due to the migratory nature or tuna (and tuna-like species) and is something for other tuna RFMOs to consider. Agreed-upon ICCAT allocations are valid for three years [56].

4.2. WCPFC: Western Pacific tuna

The Western and Central Pacific Fisheries Commission (WCPFC) is the RFMO responsible for tuna management in the western Pacific. The tuna species of interest for the WCPFC are albacore (*T. alalunga*), bigeye (*T. obesus*), yellowfin (*T. albacares*) and skipjack (*Katsuwonis pelamis*). The Commission was established under the Convention on the Conservation and Management of the Highly Migratory Fish Stocks of the Western and Central Pacific Ocean in 2000, in an effort to more effectively manage fish stocks in the area. It came into being in 2004, after both UNCLOS and FSA, and thus its guidelines are more considerate of the the issues around straddling stocks management, including issues of allocation. The WCPFC has a strong sub-coalition within its membership through the Nauru Group, made up of Pacific Island Countries (PICs) with plentiful tuna resources within their EEZs. They have had success in bargaining together as a group [14], and influence the development and direction of the WCPFC [18].

The WCPFC does not presently allocate specific tuna catches to member states, however, they recognize the need for such a program in the near future, and have therefore developed a list of criteria to be considered [15]:

1. Stock status;
2. Past and present fishing patterns and practices of participants, extent to which catch is used for domestic consumption;
3. Historical catch in an area;
4. Needs of small island states with highly fisheries-dependent economies;
5. Contributions by participants to conservation and management;
6. Record of compliance;
7. Needs of coastal communities;
8. EEZ size, with special consideration for states with limited EEZs due to proximity of neighbours;
9. Geographical situations of island states;
10. Fishing interests and aspirations of coastal states.

Although these practical criteria exist, there does not appear to be any indication of how they would be weighted in an effort to calculate and distribute allocations. The sub-coalition mentioned above, the Parties to the Nauru Agreement (PNA), use the vessel day scheme (VDS), which is an effort allocation program. VDS was adopted by the PNA under the Palau Arrangement for the Management of the Western Pacific Purse Seine Fishery (the Palau Arrangement), to regulate purse seine fishing days in the waters of PNA countries. VDS came into effect in December 2007, and was implemented as a way to provide for effective management in the face of declining fish stocks, and in an attempt to improve economic returns by creating a limit on the number of fishing days. Fishing days are allocated to all bilateral fishing partners, and these days are monitored using Vessel Monitoring System (VMS) technology. Effort allocation is based on equal weighting of historical effort levels and the level of estimated biomass in different EEZs [15].

Work within the WCPFC is ongoing in an effort to develop an allocation approach that will be accepted by its members. A recent analysis outlined four possible allocation schemes for WCPFC tuna [57]:

1. Effort model: calculate allocated shares based on historical effort;
2. Harvest model: calculate relative allocations based on historical harvest data;
3. Biomass model: calculate allocations based on biomass distribution data;
4. Spatial model: calculate relative allocations based on size of EEZs.

Unfortunately, no combination model was analyzed and socio-economic factors were not suitably incorporated. One important element for WCPFC to note, and other RFMOs who are currently contemplating initiation of allocation programs, is that it is easier to meet the needs of members through allocation when the stock status is considered healthy, i.e., prior to overexploitation [14] (or perhaps after rebuilding). In this regard, setting up catch quotas for skipjack, yellowfin and albacore should proceed quickly, as reaching agreement in the future may be harder if conservation measures are not put in force today.

4.3. CCSBT: Southern bluefin tuna

Southern bluefin tuna (*T. maccoyii*) is managed under the Commission for the Conservation of Southern Bluefin Tuna (CCSBT), which came into force in 1994. Prior to the Commission, southern bluefin was managed through a voluntary cooperative agreement between Australia, Japan and New Zealand, but this agreement failed to adequately conserve the resource.[3] Kennedy [22] developed an applied two-player game of the fishery between Australia and Japan, targeting southern bluefin. Due to the heterogenous markets for sashimi (Japan) and canned (Australia) products, the optimal outcome in the early 1980s was joint management whereby Australia was totally excluded from the fishery (compensated through side payments) [22]. In reality, of course, no country was excluded and membership increased instead of decreased. CCSBT was faced with the new member problem when South Korea and Chinese Taipei wanted access to the resources. CCSBT simply increased the total allowable catch for southern bluefin, despite concerns about the health of the stocks [14].

CCSBT originally inherited the allocation scheme that the three founding fishing nations had developed in 1986, but there is no record of how that allocation program was decided upon [15]. In 2005, CCSBT initiated a changing TAC procedure, but this did not change national TAC shares that were initially negotiated in 1986 [15]. In 2009, members agreed on a proportional allocation program based on catches and distribution, however CCSBT is currently in the process of redefining this approach [58]. The new guidelines stipulate that, upon any increase in the calculated TAC, those countries who took voluntary decreases in allocation (New Zealand and Australia) will have the difference in their TAC returned to them, providing a system with some type of incentive for voluntary conservation [58]. Any decrease in the TAC will result in a decrease in national allocation consistent with allocation proportions [58]. CCSBT allows for nations to carry forward any unused TAC in the subsequent year, however it does not allow for transfers between nations. Like ICCAT, fishing nations can fish their allocated TAC throughout the convention area [59].

4.4. IATTC: Eastern Pacific tuna

Tuna and tuna-like species in the eastern Pacific have been managed through the Inter-American Tropical Tuna Commission (IATTC) since 1969. Original allocations were based on historical catches, with disregard for the migratory nature of tuna and stock distribution information [15]. This original program collapsed in the mid 1970s. IATTC has since promoted management measures supplementary to allocations, such as area closures.

[3] $http://www.ccsbt.org/site/origins_o f_t he_c onvention.php$

IATTC manages its purse seine and longline fisheries differently. The purse seine fishery is managed through capacity (effort) allocations using four main criteria [15, 60]:

1. Catch history of national fleets (1985-1998);
2. Amount of catch taken from zones where nations have jurisdiction;
3. Landings of tuna in each nation;
4. Contribution of each nation to the IATTC conservation program.

The longline fishery is managed through a catch limit program. The benefit to allocating catches instead of capacity is that IATTC found some fleets were manipulating their vessel capacity and this resulted in capacity allocation being ineffective [15]. National catch allocations are based on stock abundance and distribution, as well as historical catches during the 2000-2002 period [15].

4.5. IOTC: Indian Ocean tuna

In 1996, the Indian Ocean Tuna Commission was formed and today, consists of 30 Member states. Its stated objective is to promote cooperation among its Members, and to use appropriate management to encourage the conservation and sustainable use of tuna stocks. A total of sixteen tuna and tuna-like species are managed by the IOTC, including southern bluefin, yellowfin, skipjack and bigeye tuna, among others. Similar to IATTC, IOTC has tried to use restrictions on vessel capacity (through measurement of gross registered tonnage) as their allocation program, however the restrictions are reportedly not binding [15]. A resolution was passed in 2006 encouraging members to limit their capacity, but allows for much flexibility in meeting capacity targets [15]. IOTC has, however, produced a report documenting allocation approaches by other RFMOs in an attempt to begin their allocation process [61]. The report documents their struggles with using capacity limits to impact conservation, and discusses the possibility for allocations based on historical catch [61].

In 2012, the IOTC solicited suggested allocation approaches from its Members in response to IOTC Resolution 10/01, requiring the adoption of a quota allocation program (or other suitable approach) [62, 63, 64]. The proposal put forth by the Republic of Seychelles suggests historical catches and catches per area be used as the basis for allocation, but they make note that for some developing coastal states, catch records have not been consistently collected and this could negatively impact their catch allocations [64]. Thus, the proposal suggests that, where catch records are not of good quality, socio-economic factors be incorporated [64]. The EU proposal is also firmly attached to the idea that historical catches should form the basis of the allocation program, but it suggests that a percentage of the TAC be put aside to be redistributed to developing coastal states and new members [63]. Similarly, the third proposal, put forth by Japan, states that allocation should initially be based on historical catches, specifically over the past 10 years [62]. These base allocations are subsequently altered using different mathematical relationships, based on criteria such as if the Member has contributed financially to the IOTC, or has had any occurrences of non-compliance [62]. These proposals all use catch histories as their basis, but also recognize, in different ways, that this singular criteria is not the most effective and equitable strategy.

Table 1: Summary of RFMO allocation information

RFMO	Species	Data for allocation	What is allocated	Penalties for non-compliance	Transferability	Ranking (theory, practice)
NAFO (ICNAF)	Groundfish	Stock assessment and historical catch	Catch	Yes	Allowed	52,53
NEAFC	Herring, mackerel, blue whiting	Zonal attachment principle and historical catch	Catch	Yes	Allowed	52,72
ICCAT	Tuna species	Stock assessment, historical catch, bycatch	Catch and effort	Yes	No sale, exchange ok	57,38
CCSBT	Southern bluefin	Stock assessment and historical catch	Catch	Yes	None	44,0
IOTC	Tuna species	Gross registered tonnage (plus historical catch in future)	Effort	Yes	None	58,78
IATTC	Tuna and tuna-like species	Vessel carrying capacity	Catch and effort	Yes	None	60,33
WCPFC	Tuna and tuna-like species	Stock assessments and historical catches, distribution, economic dependence	No current regional allocation, but sub-regional effort program (VDS)	Yes	Currently being discussed	74,67
PSC	Pacific salmon	Historical catch, bilateral negotiations	Percentage of TAC	Unknown	None	43,NA
IPHC	Pacific halibut	Stock abundance and distribution	Catch	Unknown	None	52, 33

Sources: [15, 49, 54]

5. The future of allocation schemes

Table 1 summarizes the various RFMO approaches to allocation programs. A recent report analyzed the performance of all RFMOs in meeting best practices criteria in theory (based on written mandates) and in practice (based on stock status reports) [54]. These rankings are included in Table 1 to relate the allocation schemes in place with one measure of the effectiveness of RFMO management.

The first question to be addressed in developing an allocation approach is what, in fact, is to be allocated. Despite the efforts of economists in developing and analyzing sharing agreements based on economic value, there is an obvious precedent in internationally shared fish stocks management for historical catches (by proportion) to provide the basis for allocation. The assumption here is that a fair way to distribute shares is based on historical participation, with the added benefit of catches being an easily measured and quantified reference [49]. The PNA countries (a WCPFC sub-coalition) employ an effort allocation scheme, instead of allocating catches, called the vessel day scheme. But apart from this, allocation schemes for existing RFMOs are primarily based on catch tonnage. Using catch histories is not always the most ecologically-sound method [65], and gives an incentive for members to block allocation agreements until they have built up their capacity and catches [14]. Furthermore, the allocation schemes that have been put in place so far, based on catch histories or abundances, have been unsuccessful in facilitating sustainable fisheries.

It may be time to start reconsidering what is being allocated. Although economists have long-studied theorized on how potential rent could be allocated, rent has rarely entered into allocation discussions. One way to expand allocation units beyond merely catch tunnage would be to try to put different types of benefits into equivalent units. This has been suggested several times with regards to the Pacific Salmon Commission, the RFMO put in place to manage Pacific salmon between Canada and the U.S.. Sockeye are the most valuable of the five Pacific salmon species harvested. It was argued that "sockeye equivalents" could be used so that catches, overages and interceptions are measured in a similar fashion, and could perhaps facilitate trading. This type of relativity would allow the two countries to compare apples to oranges, that is, to put all salmon species in the same currency. Unfortunately, this scheme has never been realized because groups within both countries were unable to agree on a way forward.[4] As discussed later in the paper, some international water allocation agreements have explicitly allowed each interested party to develop their own apples- or oranges-based utility function [66].

Currently, no program for internationally-shared stocks is based on revenue or rent allocations. The addition of socio-economic factors into allocation decision-making was argued for as early as 1996 [65]. Several tuna RFMOs have begun using qualitative criteria in assisting with the allocation process, for example economic dependence and domestic consumption. How to explicitly incorporate these into some type of allocation algorithm is a challenging next step. One possible way to incorporate other criteria would be to develop objective functions of resource use for each country and then test possible allocation schemes in their ability to most closely meet both (all) countries' needs. For example, if employment is an important target, then incorporating a layer of fishery dynamics into allocation modelling

[4] Sandy Argue, Argus Bioresources Ltd., personal communication.

could suggest employment outcomes for various schemes. Optimization approaches could be used to calculate the weighting system that best meets nations' objectives. Some possible factors to consider including are: historical catches; species distribution within EEZs; spawning and nursery areas; contribution to habitat and environmental health; contribution to research and monitoring; amount of catch for domestic consumption; and interactions between catch and employment in the fisheries and processing sectors. Currently most RFMOs produce some type of annual report that summarizes stock dynamics, catches, and sometimes effort, for the fishery. Producing an annual report that includes social, environmental and economic assessments of RFMO-managed fisheries, in addition to these biological reports, could help highlight the broader benefits of reaching an optimal sharing agreement [51].

One of the first papers in the literature to start theorizing about the future of allocation schemes suggested an objective framework where national allocations depend on multiple factors which are given different weights by individual parties [65]. As per the Caddy [65] approach, allocation negotiations essentially break down into three parts:

1. What factors are relevant (catch histories, domestic consumption, biomass distribution, employment, etc.)?
2. How do we calculate/measure values for each factor for each interested party?
3. How do we weight the different factors?

One of the drawbacks associated with solely using catch as a way of measuring fleet performance and stock sustainability is that it explicitly ignores human drivers of fishing behaviour and does nothing to illustrate tradeoffs in policy decisions (allocations) with community well-being. This is of course an argument that can be made across many forms of fisheries management and is not at all exclusive to the challenges of internationally-shared stocks, but it is worth mentioning here. Importantly, the incorporation of short-term social, economic and political criteria can also pave the way for opportunities to overexploit and ignore conservation goals [48]. Many allocation schemes do utilize penalties for lack of compliance to discourage TAC overages [49]. For example, NAFO and CCSBT reduce the quotas in the subsequent year of members who overfish their allocation. If countries cooperate in defining their objectives in participating in the joint fishery (above and beyond catch), that could help in developing some sort of tradeoff matrix. What mix of targets is optimal? What costs and amount of risk are communities and governments willing take to promote economically viable fisheries?

Although no RFMOs have taken seriously the task of developing a multi-criteria allocation algorithm, academic studies have been discussing this issue. One such study, involving NAFO fisheries, developed a model linking catches to processing and community livelihoods in Canadian maritime regions, taking into account fleet dynamics of Spanish and Portuguese fisheries [48]. The schematic developed, shown in Figure 2, displays how the annual catch scenario (or allocation rule) feeds into the socio-economics of the communities [48]. In this way, allocations are directly linked with their outcomes to the community at large, and are thus representative of benefits above and beyond catches.

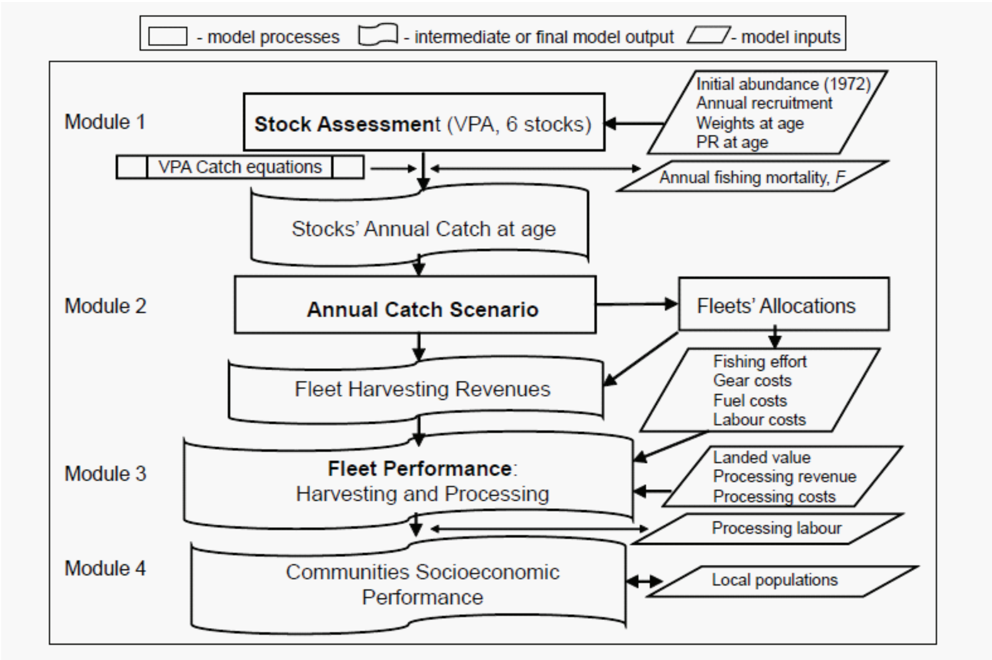

Figure 2: Grand Banks fishery model schematic [48]. © Journal of Northwest Atlantic Fisheries Science.

5.1. *Rationality, flexibility and reviews*

In order for members to agree on a cooperative management solution, they must be better off in doing so than by continuing in a non-cooperative manner, the so-called rationality assumption. Ensuring equitable distribution is an essential component of an agreement, as agreements perceived as inequitable (and thus irrational) often lead to non-compliance [14, 49]. Having flexibility built into the cooperative agreement, often called resilience [67, 68], is of paramount importance to ensure the rationality constraint continues to be met through time. In addition to individual rationality, there is also the notion of collective rationality, or Pareto Optimality. If there exists an alternative solution to a given allocation approach that would make at least one fishing nation better off, without hurting the other fishing nations, then the proposed allocation solution is not collectively rational.

One of the major impediments to long-term stability of allocation agreements is the new member problem. A stipulation in the UNFSA (Articles 10 and 11) states that any party with genuine interests in a fishery can seek to join the RFMO (and thus have access to the resource) at a later date. How to deal with these new members is something that RFMOs to date have not adequately addressed. Most RFMOs have chosen to accommodate new members by increasing the total allowable catch instead of reallocating from within the catch limits [14]. This has been done with disregard to the conservation status of the resource (for example, the case with CCSBT), and thus is at obvious odds with RFMO mandates for conservation.

The scope for bargaining and renegotiation of allocations needs to be widened, and access rights should certainly stop trumping conservation concerns. Both conservation and access are part of RMFO mandates so novel ways of trading them off against each other resulting in the best outcomes are necessary. One possible option would be to put aside part of the total catch allowance, say 5%, for new members. Each year, if no new members have been added to the RFMO, that 5% gets redistributed to existing members, but it should be seen as a bonus, not as a right. An additional, and supplemental, mechanism would be to relax the ban on trading of quota that most RFMOs have in place and allow existing members to lease out or sell part of the allocation to new members [15, 14]. If these methods were combined, new members would be afforded initial allocation (from the 5% surplus) with the chance to increase their share through trading.

A solution to the new member problem was tackled by Pintassilgo and Duarte [69], in which the authors explored three possible solutions, including transferable membership, a waiting period, and a fair sharing rule. The authors point out that in a quota or allocation scheme, transferable memberships in the cooperative group can take on the attributes of individual transferable quotas [69], and thus bring some benefits that quota systems have conferred. One way may be to develop a better understanding of how to negotiate the reallocation of property rights to new RFMO entrants in the future, as called for by [70]. Renegotiation of the allocation scheme should take place, and an appeals process should be developed [65], if one is not already in place. It has been suggested that renegotiation should be considered on a medium to long term basis, for example, every 10 years [15].

Currently, no RFMO has any type of independent review panel in place to assess suitability of catch allocations [49], even though this can be a useful measure [65] and has even been outlined in the UNFSA [13]. NAFO does, however, have an appeals process in place, whereby a contracting party is able to file an objection to any conservation or management measure, along with an explanation for the objective and an alternative policy. This objection can then go to an independent ad-hoc panel, who will make a subsequent recommendation to NAFO. Ad-hoc panels made up of external experts could be a more frequently-used tool.

Anticipated and unanticipated climate shifts can change local fish distributions. If the allocation scheme is fixed and based on distribution, such changes can affect the viability of national fisheries and can give participating countries an incentive to deviate from cooperative agreements. For example, climate shifts impacted the stability of the cooperative agreement formed between Canada and the U.S. to manage Pacific salmon [67]. Warming of coastal waters on the west coast of North America in 1977 led to an increase in the abundance of salmon in Alaskan waters, and a sharp decrease in abundance in salmon found in California, Oregon, Washington and southern Canada [67]. The benefits expected by the southern players at the outset of the cooperative agreement did not materialize, and non-cooperative behaviour ensued [67]. One major criticism to the Canada-U.S. Pacific Salmon Treaty was that it did not explicitly include the scope for side payments [23], which would have been a way to compensate the losing party subsequent to any unforeseen shifts in abundance. This retrospective analysis helps to illustrate why resiliency and flexibility in a cooperative agreement is important for stability. This is becoming of increasing importance as climate forecasts coupled with models of fish stock distributions suggests there could be major shifts in terms of future access to shared resources [71].

Pacific sardine (*Sardinops sagax*) are one such species that exhibits extreme decadal variability in abundance and geographic distribution corresponding to water temperature regime shifts within the California Current Ecosystem. Pacific sardine is a transboundary resource targeted by Mexican, U.S. and Canadian fisheries. Ishimura [72] applied a three-agent game-theoretic model incorporating environmental effects on Pacific sardine abundance and biomass distribution. The author evaluated the stability of full and partial cooperative management of the Pacific sardine fishery, under seven different climate variability scenarios. His results show that ocean climate variability could motivate the formation of stable cooperative management outcomes for Pacific sardine fisheries operated by Canada, the U.S. and Mexico [72], and thus could offer insights into cooperation of other fishing nations in light of climate-induced changes in fish distribution.

5.2. Efficiency and transferability

Ex-vessel prices, fishing costs, and fleet capacity are rarely mentioned in stock assessment reports describing allocation, and thus economic efficiency does not play any kind of role in allocation decisions [49]. One argument that has been put forth in the literature is the possibility for auctioning quota or allocation shares [73] to increase economic efficiency. This has not been taken seriously to date. Given that cooperation must bring benefits above and beyond non-cooperation, the added economic burden of paying for allocation shares could result in non-cooperation being the more economically-sound decision for some states [49]. Most RFMOs do not allow trading or selling of quota among participating members. This is inefficient from an economic perspective, however, as transferability allows for the most efficient vessels or nations to harvest fish [74]. Efficiency gains have been seen through allowing a secondary market for transferring quota [75], and some RFMOs have recognized the future need for transferability of allocated quota [60]. Economic efficiency has probably been ignored to date because efficiency gains from allocation programs are oftne perceived to derive from some loss in equity [76]. A tradeoff between efficiency and equity does not have to occur, or course. A lack of dialogue between economists and non-economists about efficiency and equity has bred continued confusion about this apparent tradeoff. Economists have continually suggested that side payments be utilized to facilitate cooperation. This is one way that equity could be strengthened, while at the same time improving efficiency.

The issues around limiting greenhouse gas emissions parallel those around sharing fisheries resources. Allocated quota and trading programs for greenhouse gas emissions were initiated based on setting national targets. A market for international trading has emerged as the primary policy tool to promote efficiency and benefit those who choose to lower their contribution to the problem, although improvements in the system are still being sought. The allocation schemes in place to deal with greenhouse gas emissions have incorporated economic efficiency as a major objective in their design. There will likely be lessons learned about the international quota markets for carbon trading that could help guide the way towards an international trading mechanism for catches or revenues from shared fisheries.

5.3. Allocation and shared water agreements

Like the United Nations Convention on the Law of the Sea, the United Nations Convention on the Law of the Non-Navigational Uses of International Watercourses exists to provide a framework for allocating water resources that are shared internationally [77]. The Convention states three main rules that govern the conduct of states who share a watercourse [77]:

1. The watercourse is to be used in an equitable and reasonable manner;
2. States are to take appropriate measures to prevent significant harm to another state;
3. States are to consult with, and provide timely notification to, other states about any possible adverse effects resulting from new policies or a change in policy.

A novel approach to negotiations between states sharing a watercourse, called the "Mutual Gains Approach", has been proposed by Grzybowski et al. [78]. The authors outline two possible negotiation scenarios, one in which the *position* of the states is the primary driver of negotiations, and one in which states negotiate based on their *interests*. The conclusions reached suggest that when institutional egos can be left off the bargaining table, mutual gains to all cooperating parties are attainable based on the interests they represent [78]. The authors draw on historical examples of successful cooperative agreements, writing in length about the Columbia River Basin, a watercourse shared by Canada and the U.S.. One of the more interesting, and important, parts of the Columbia River Treaty, is that the responsibility for calculating the benefits and costs of non-cooperative and cooperative management lies with each individual country [66]. In this way, each country calculates and communicates what it is likely to gain through cooperation, but these perceived benefits, or utility functions, need not be comparable between states [66]. Rather, each country lays out what it hopes to get from cooperation, and as long as those hopes are met, cooperation can ensue.

The Columbia Treaty suggests a 50/50 sharing of the benefits of cooperation, but in the event that one party would end up being worse off than through non-cooperation, a renegotiation of the sharing rules takes place [66]. In a more applied assessment not related to the Columbia, van der Zaag et al. [79] suggested three alternative allocation algorithms: equal sharing; shared in proportion to each country's area in the water basin; and equal sharing per capita. The authors report that once equitable allocation has been reached, parties should be free to trade or transfer their allocated water amongst themselves [79].

Subsequently, Paisley et. al (see http://governance-iwlearn.org/) conducted a multi-year, multi-donor United Nations Global Environment Facility (GEF) and private sector sponsored initiative dedicated to facilitating good governance and more effective decision making in the governance of global transboundary international waters including through the identification, collection, adaptation and replication of beneficial practices and lessons learned from international experiences. Among other things the initiative compared, contrasted and critically reviewed 28 different international waters situations according to 18 different criteria including benefit sharing. A searchable data base and report were then created based on primary materials such as international agreements (including treaties and conventions where applicable), protocols or action plans. Where relevant secondary materials were available, (primarily for water bodies with more extensive legal frameworks), those secondary materials were also identified and referenced as appropriate. The report is based on information available as of June 2010. The report also identifies and explains the eighteen criteria that are used to describe the legal and institutional frameworks of each of the water bodies discussed in the report. The report also provides a detailed discussion of the legal and institutional frameworks for each water body identified, organized by global region. As the described frameworks continue to evolve, there may be future revisions of this report, for which supplemental information would be welcome. Both the report and the searchable data base suggest scope for a more de-politicized incentive structure whereby allocations are afforded based on more than just catch histories and abundance estimates is required to address these problems and improve RFMO management of shared fisheries resources. To review the full report online and other details of this project please go to http://governance-iwlearn.org/.

In terms of allocation of shared water *within* a nation, historical usage patterns have been a common starting for allocation programs, although this is as much for political reasons as for any other [49]. Market-based approaches have been employed in Australia, South Africa, the western states of the U.S. and Chile where the highest bidder wins [49], but it's hard to imagine that these can be at all equitable. A two-tiered approach has, however, reportedly been successful in the U.S. and Australia, whereby some amount of reliability or security of the entitlement is combined with the actual allocated amount [80]. In this way, allocations that are highly secure (or can be met 96-99 times out of 100) have priority before general secure allocations are met (those that are to be met 75 times out of 100) [80]. Efficiency is achieved through market-based trading allowances. The implications for fisheries would be as follows: one proportion of the TAC is allocated to nations as fixed, with the remaining quota classified as flexible, distributed on an annual basis to members either through auction or some other mechanism [49].

6. Conclusion

This study has provided a review of allocation approaches used by groups managing internationally-shared fisheries resources. Many RFMOs have found it a tedious and tiring process to formulate allocation programs that are agreed-upon by all members, or have avoided making explicit allocation decisions all together [16]. In most cases, allocation has generally been decided based on historical catches, and more recently, combining historical catches with current biomass distribution trends [15]. Most current programs are based solely on biomass and catch information, without consideration of economic or social factors in allocation decisions. Socio-economic factors can include such items as economic dependency on the fisheries stock, and national economic wealth [55]. Incorporating these may offer alternative allocation possibilities that could increase the scope for cooperation in internationally-shared fish stocks management. And although the United Nations Fish Stocks Agreement states that there should be development of transparent allocation criteria [13], transparency has not been a priority to date [14].

The "Mutual Gains Approach" [78] for shared international watercourses, offers some insights into the future of fisheries management. The authors suggest that the *interests* of nations sharing a resource should be the central tenant that drives negotiations [78], thus de-politicizing the allocaiton process. This is akin to states moving away from what they should be allowed to extract, to why they want to extract, essentially what they hope to gain from participating in a sharing system. Allocation in shared fisheries has invariably been based on a political process [14], something that has not served sustainability well. In the Grzybowski et al. [78] paper, the authors draw on historical examples of side payments (or negotiation facilitators) in shared watercourses, whereby the party who stands to gain the most through cooperation compensates those parties who may not be better off under cooperation. One of the earliest such schemes was contained within the Treaty of Versailles in 1919 [81], one of the post-World War I treaties. Article 358 of the Treaty gives France "the exclusive right to the power derived from works of regulation on the river, subject to the payment to Germany of the value of half the power actually produced" [81].

A more relatable example is the 1911 agreement between the U.S., Russia, Canada and Japan, all of whom targeted fur seals. In the early 1900s, the fur seal population had declined to the point that the economic benefits from the fishery were brought into question. While the U.S. and Russia harvested seals from land, Canada and Japan targeted individuals at sea. To maximize economic returns, all harvesting was to take place from land, essentially removing Canada and Japan from the harvest [82]. All of the catch was taken by the U.S. and Russia, with Canada and Japan compensated, through side payments, with a fixed percentage of the annual sealskins [82]. The need for side payments to factor more heavily in cooperative fisheries schemes is evident today, and has been raised before [2, 14, 21].

Although Hardin's most memorable contribution to our understanding of the problems associated with shared resources is the idea that self-interest almost always trumps collective interest,[5] he also explored briefly the fact that incommensurable goods could in fact be compared, simply through subjective judgement and a weighting system [1]. In this regard, he was encouraging us to combine different objectives with different measurements in a joint utility function to improve the management of common pool resources. His challenge to the future was to "work out an acceptable theory of weighting" [1]. That challenge needs to be taken up and applied to the ocean commons. Allocation models with multiple weighted criteria would be a good starting point.

Further to this, economic efficiency has not routinely been a component of international allocation schemes. Socio-economics have been largely ignored in allocation formulations in part because, although RFMO members are required to report some biological and catch statistics, there is no requirement to report statistics related to fishing costs, employment, or subsidies. In the very least, developing a bioeconomic allocation approach with which to compare the strictly ecological program currently in place would provide an interesting starting point for dialogue among RFMOs.

Clearly, the allocation programs developed thus far, and based on catch shares, have not provided the right incentive structure to promote sustainable fisheries. Most RFMOs, especially those tasked with managing highly migratory fish like tunas, face problems of illegal, unregulated and unreported fishing (IUU), TAC overages, competing sector interests, and challenges associated with multi-species and multi-gear fisheries, such as juvenile bycatch. Perhaps a

[5] It has been argued that Hardin had it wrong [83], and that groups could in fact be counted upon to manage shared resources well [84]. Although it is probably true that Hardin's argument does not always hold its ground, the fact that so many shared resources are mismanaged and overexploited certainly gives credence to his insights.

de-politicized incentive structure whereby allocations are afforded based on more than just catch histories and abundance estimates is required to address these problems and improve RFMO management of shared fisheries resources.

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