Asset Ownership, Climate Variability and Policy Design: Game Theoretic Insights on Tuna Management Outcomes

Kathleen Miller, National Center for Atmospheric Research, Kathleen@ucar.edu
Peter Golubtsov, Moscow State Lomonosov University, pgolubtsov@gmail.com
Robert McKelvey, University of Montana, *emeritus,* rwmckelvey@msn.com

ABSTRACT

Tuna fisheries around the world are governed by Regional Fishery Management Organizations (RFMOs), whose membership includes both harvesting nations and nations in whose waters the targeted fish populations reside. The outcomes of the policies established by an RFMO will depend on subsequent interactions among the fleets, the fishing sites and the RFMO itself – an interplay that can be formally modeled as a multi-party harvesting and management game. This paper uses such a model to explore the consequences of alternative policies that might be pursued by the Western and Central Pacific Fishery Commission in its efforts to manage fisheries for tropical tuna in that region. The analysis indicates that while the RFMO could potentially achieve any given biological objective by in a variety of ways, different types of policies will have very different implications for who benefits from the policy as well as for the overall level of the economic returns that can be obtained under the policy. Furthermore, policy outcomes will vary considerably depending on whether or not coalitions form among the various fishing nations and coastal nations in whose waters harvesting occurs. In addition, climate-related shifts in the distribution of the stocks between EEZ's and the high seas can affect the biological and economic consequences of the RFMO policy choices. Recent policy developments in the region are evaluated in light of insights from model simulations.

Keywords: Policy design, DWFNs, RFMO, Coastal states, multi-player game

INTRODUCTION

As highly migratory species, tuna are vulnerable to capture by fishing vessels operating both on the high seas and within the EEZs of multiple coastal nations. The threats of biological overharvesting and dissipation of resource rents have led the international community to conclude a series of agreements providing the legal basis for cooperative governance of these resources, and this process is continuing as new pressures emerge (FAO, 2009). In particular, the 1993 FAO Agreement to Promote Compliance with International Conservation and Management Measures by Fishing Vessels on the High Seas (FAO Compliance Agreement), and the 1995 United Nations Fish Stocks Agreement (UNFSA) strengthened the basis for the creation of Regional Fishery Management Organizations (RFMOs) (IGIFL, 2008; Munro et al., 2004).

Five RFMOS now govern fisheries for tuna and other highly migratory fish stocks in different parts of the world's oceans. All of the world's tuna RFMOs share similar challenges, in that a large and diverse set of nations and sub-national interests are competing to derive benefits from the tuna and related fish stocks in the area within the organization's purview. Information about the biological status of the stocks, as well as the activities of the fleets is often incomplete, and variable environmental conditions, together with rapid change in the industry compounds the uncertainty facing fishery managers and policy makers.

In addition, there is growing recognition of the need for better coordination across RFMOs, because the large capacity and mobility of global industrial tuna fleets creates the potential for policy "spillovers" between areas. For example, restrictive policies implemented by one RFMO may cause vessels to move to another area, thus increasing fishing pressure there. That is particularly likely if the receiving area lacks clear agreements on allowable harvests and their allocation, or adequate resources to monitor and control fishing activities. Progress towards improved coordination has been a slow, deliberate process that started with the January 2007 First Joint Meeting of Tuna RFMOs in Kobe, Japan. Since then, these organizations are increasingly sharing information[i] and conducting joint workshops on various management topics. For example, there have been four joint tuna RFMO workshops in just the months of May and June 2010 (http://www.tuna-org.org/meetings2010.htm#).

While these RFMOs have had some success, notably in the area of scientific and technical coordination (Cullis-Suzuki, and Pauly, 2010), their record with respect to halting the decline of fish stocks or ensuring economically efficient harvesting practices has been mixed, at best. Many efforts are underway to understand the reasons for such limited success and to promote organizational reforms that might improve performance (Hilborn, 2007; Lodge, et al., 2007; WWF, 2007; Allen, 2010; Allen, et al., 2010). Considerable attention has been given to the difficulty of maintaining the incentives of RFMO member states to cooperate on setting and enforcing joint management measures, and to the problems posed by potential new entrants to a high seas fishery (See e.g., Munro, et al., 2004; Hilborn, 2007). In addition, it has been widely noted that RFMOs are hampered in their ability to pursue aggressive conservation measures by the fact that member governments are reluctant to cede their sovereignty to these international bodies. Stalemates frequently arise when strongly divergent national interests come up against consensus decision-making rules and reliance on member states to enforce agreed upon management measures. For example:

> The commissions are often very slow to accept scientific advice that requires significant management action, and conservation measures are often only applied when there is an appearance of an emergency rather than as a measured response to changes in situations. The management organizations depend on agreements among their members and their decisions are compromised by the mixed incentives of those members, who have to balance their obligations to conserve the resources with the need to support their own industries. The splitting of governments' attention between questions of conservation and allocation often results in more attention being given to securing allocation for their fleets than to overall conservation. As long as this remains the case, the management organizations are not likely to perform well in their primary role of conservation of resources. Allen (2010, p. 41)

Recommendations for moving to "rights-based" management regimes are now receiving considerable attention (Allen, et al., 2010). However, implementation of rights-based management in the international arena will likely be a complicated process both in terms of negotiating the nature and ownership of the rights, and in terms of subsequent enforcement (Allen, 2010). While a major overhaul of RFMO governance arrangements might be desirable (Hilborn, 2007), incremental reforms appear to be a more likely trajectory. To evaluate the merits of either sweeping, or incremental policy changes, it will be important to develop models that can capture the essential features of the incentives facing all relevant actors, the interactions that will arise as each set of actors responds to a policy innovation, and the ultimate impacts of the policy on the economic performance of the fisheries and the biological status of both the targeted fish stocks and other species affected by the harvesting activities.

This paper makes a modest contribution to this effort by describing a multi-player model that sheds light on how the strategic interplay among different types of actors can alter the efficacy and distributional consequences of the available policy instruments. Furthermore, we examine how policy outcomes may be affected by the impacts of natural environmental variability.

Our findings demonstrate that the choice of policy instruments can have significant impacts on the overall economic returns to the fishery as well as on the distribution of fishery benefits between coastal nations and the DWFN fleets. We apply the model to examine the effects of alternative management tools currently used by the Western and Central Pacific Fisheries Commission. In particular, we evaluate the possible consequences of recent policy shifts including the closure of the high seas pockets between the

EEZs of Pacific Island Countries (PICs) to industrial purse seine fishing. This analysis highlights the interplay between coalition formation, policy choice and the subsequent distribution of economic rents.

DISTANT WATER FLEETS, EEZS & THE RFMO: GAME STRUCTURE

Industrial distant water fishing fleets harvest the largest share of the world's tropical tuna catch, and the rapid growth of purse seine harvests of Skipjack, Yellowfin and Bigeye tuna over the past three decades has been largely driven by the increased size and harvesting capacity of fleets owned by citizens of industrial DWFNs (Miyake, et al., 2004). For example, in the Western and Central Pacific, it is estimated that industrial purse seine harvests increased from less than 100,000 metric tons in 1979 to the current average of approximately 1.5 million metric tons per year (Lawson, 2007).

The governments of DWFNs can become full voting members of an RFMO or they may simply agree to act as "cooperating non-parties" and abide by the policies set by the RFMO when fishing in the region governed by that organization.[ii] In either case, international law holds each nation responsible for controlling the actions of fishing vessels flying its flag, but in practice there is considerable variability with respect to the diligence by which fishing nations carry out this responsibility. The ability of any nation to control the activities of vessels owned by its citizens has been further limited by the practice of reflagging vessels to avoid stringent regulations imposed by a vessel-owner's home nation. In some cases, the re-flagged vessels operate as IUU harvesters, and in other cases they continue to fish legally, but just under more favorable terms offered by the new flag state (Miyake, et al., 2010, *in press*).

As previously noted, the governments who are parties to an RFMO tend to champion the interests of the fishing fleets owned by their citizens, but also recognize their longer-term obligations to promote conservation of the resource. Thus, as organization members, the governments are not merely mouthpieces for their respective industries.

Our model recognizes the distinct roles played by nations and fleets by treating the RFMO as the locus for government-level coordination on policy making, whereas the annual sequence of decisions on fleet deployment and levels of fishing effort are made by the fleets. These independently managed "distant water" fishing fleets operate both within the exclusive economic zones (EEZs) of regional coastal states and also in international waters. The terms of access to the EEZs are set by the respective coastal states.

Within a given season, fishery management is decentralized, with each fleet harvesting independently and each coastal state retaining control of access to its individual EEZ. The fleets profit directly by sale of harvested fish and the coastal countries profit indirectly by collecting access payments. Neither the fleets nor the coastal countries are assumed to base their within-season decisions on anything other than expected current-season payoffs.

Thinking about the long-term sustainability and profitability of the fishery is a function reserved for the RFMO. In that regard, our model abstracts from the cumbersome and somewhat dysfunctional policy processes within real-world RFMOs by assuming that the member governments are able to agree on long-term management measures that are designed to achieve a long run steady state which is both economically and biologically sustainable. This is an idealized representation that might be consistent with governance arrangements that provide adequate incentives for both the coastal states and distant water fishing countries to set aside their parochial interests and develop management plans for the long-term common good.

There are thus three distinct types of players in the model – the coastal nations that own part of the available fishing grounds, the distant-water fleets that own much of the modern harvesting capital, and the RFMO, that guides the evolution of the fishery through a series of annual regulations. The fish stock itself is an un-owned resource migrating freely across various EEZs and international waters.

We assume that each coastal state and each distant-water fleet will act within the annual RFMO-mandated constraints to optimize its seasonal return. An actor's choices will reflect its knowledge of the actions of the other actors. In addition, some or all actors may choose to cooperate with others by coordinating their actions. Thus, in effect, the coastal states and distant water fleets participate in an annual (cooperative or non-cooperative) bioeconomic game which is induced by the policies set by the RFMO.

APPLICATION TO THE WESTERN AND CENTRAL PACIFIC

The Western and Central Pacific Fisheries Commission (WCPFC) is the youngest of the world's tuna RFMOs. After several years of negotiations, it was formally established on June 19, 2004 (WCPFC, 2005; Anon, 2005). Currently all of the small island nations in the region and all major harvesting nations are either members or cooperating non-members of the Commission.[iii]

Tuna fisheries in the Western and Central Pacific have long been dominated by DWFN fleets. In particular, the purse seine fishery, which accounts for the largest and fastest-growing segment of the region's tuna harvests, is dominated by DWFN vessels (SPC, 2008). The region's fisheries have undergone several periods of rapid change, stemming from the entry of new fleets, and the adoption of new fishing techniques – such as the use of fish aggregating devices (FADs). There has recently been an increasing trend toward reflagging of previous DWFN vessels to countries within the region (Havice, 2007; Miyake et al, 2010), but citizens of industrialized countries still maintain controlling ownership of most of the harvesting capacity.

DWFN harvesting takes place either within the EEZs of small island nations or in international waters. When fishing within another nation's EEZ, the DWFN (or its nationals who own the fishing vessels) pay for access and that payment can take several forms, including fixed entry fees, payments based on reported harvest taken from the EEZ, payments for the use of a vessel-day of harvesting effort, and implicit payments made in the form of foreign aid (Tarte, 1998; Petersen, 2002). Several authors have argued that the developing Pacific Island Countries could benefit by bargaining collectively with the DWFNs over the structure and level of access fees, and that this prospective gain motivated the creation of the South Pacific Forum Fisheries Agency (FFA) (Hanchard, 1998). There is some evidence that increased competition for access to the tuna stocks within PIC EEZs has put upward pressure on access fees (Gillett et al. 2001), but information on actual payments is closely guarded and the island countries clearly do not yet function as a fully coordinated cartel. For example, Havice notes that:

> "…access agreements come in many shapes and forms, and display variable rates of returns and benefits for PICs. … Data shortages and lack of transparency in access agreements hinder regional opportunities to improve the terms of access agreements. PICs' general practice of not disclosing the terms of access agreements to protect DWF partners does not benefit the ultimate negotiating position of PICs, or protect resource health." (Havice, 2007, p. 51)

Tuna are not distributed uniformly throughout the Western and Central Pacific. In particular, skipjack tuna that constitute the bulk of the purse seine harvest, are heavily concentrated in a narrow band along the equator and (in most years) primarily on the western side of the region. Those island nations located close to the equator and west of the dateline have far better access to these resources than those located east of the dateline or farther north or south of the equator. Munro (1991) characterized these two groups of nations as the "haves" and the "have nots." We would characterize them as the "haves" and the "sometimes haves," because the latter group has "feast or famine" access to the region's tuna resources. In most years, their waters are relatively unproductive for purse seining efforts. However, in El Niño years – and particularly in strong El Niño years, they are in a position to reap a bonanza as the skipjack move sharply to the east, following the retreating tip of the equatorial "cold tongue" (Lehodey, et al, 1997; Lehodey, 2001; Miller, 2007).

This differential pattern of resource availability is reflected in way in which the PICs organize themselves. The island nations in whose waters tuna are most abundant tend to act as a coalition. They played a prominent role in driving the creation of the WCPFC and continue to work as a cooperative block in negotiating the development of fisheries policy in the region. This group is called the "Parties to the Nauru Agreement,"or PNA countries[iv] (The PNA countries are highlighted in Figure 1). In recent years, they are playing an increasingly active role in pushing for measures to reduce overharvesting of yellowfin and bigeye tuna and to constrain the continued escalation of fishing effort in the region.

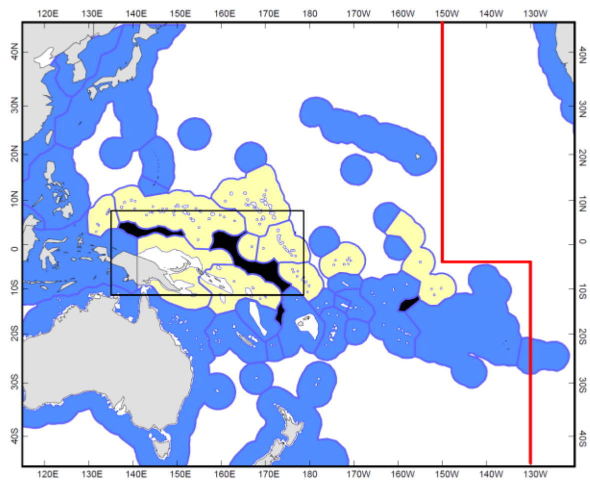


Figure 1

Exclusive Economic Zones in the Western and Central Pacific

Yellow shading denotes PNA member countries; high seas pockets colored black. The 2 pockets within the box are closed to purse seiners effective, January 2010. *Source:* WCPFC, 2008 at p.38.

Even prior to the establishment of the Commission, the island countries had implemented measures intended to control the surge of harvesting capacity into the region. For example, the Palau Arrangement (1992) had established a cap on the number of DWFN purse seine vessels operating in the region (Aqorau and Bergin, 1997; Gillett, et al., 2003, MRAG, 2006), but the cap was too loose, and the controls proved to be largely ineffective. More recently, the PNA countries pushed for establishment of a vessel-day scheme (VDS) to more effectively control purse seine harvesting effort within their EEZs. Under the arrangement, each participating island country is allocated a share of the total stock of capacity-weighted vessel days. DWFNs must negotiate with the island countries to purchase the right to use these vessel days. Total fishing days and country allocations are defined for one year periods, up to three years in advance. Thus, there is a regular review of total allowable effort in PNA waters, and the capacity weighting formula also is subject to revision, as needed. The vessel-days are transferable across EEZs to facilitate the movement of harvesting effort in response to movement of the stocks and encourage optimal placement of fleets with respect to the most profitable harvesting sites. The PNA countries clearly expected to gain by implementing the VDS. Indeed, the following statement appears on the website of the Pacific Island Forum Fisheries Agency:

> By setting limits on the number of days purse seine vessels fish, the VDS is a management tool to limit fishing within sustainable levels. However it also has an economic objective of creating competition between Distant Water Fishing Nations (DWFNs) to purchase units of fishing effort in days, at the highest possible price. (FFA, 2008).

At present, the scheme only applies to the EEZs of the PNA countries. When it was first introduced, it was recognized that such an arrangement might encourage movement of fishing activities into areas not covered by the scheme. Thus, the December 2005 conservation and management measure (CMM) for yellowfin and bigeye tuna that authorized the scheme (CMM-2005-01), also called on non-PNA island countries to take similar measures, and on the Commission was to implement a similar VDS on the high seas (WCPFC, 2005). However, progress on those fronts has stalled (WCPFC, 2009).

PNA frustration with slow progress on implementation of compatible access schemes in other areas and concern about continued access of DWFN fleets to the high seas pockets separating their EEZs led them to advocate closure of those pockets to purse seine operations. In 2008, PNA members began refusing to issue permits to any DWFN vessels fishing in those high seas pockets (FFA, 2008), and at the next regular session of the WCPFC they secured an agreement that two of those pockets would be closed to purse seine vessels as of January 2010 (WCPFC, 2008). Those closures are now in effect.

MODELING INSIGHTS: MANAGEMENT TOOLS, COALITIONS AND CONSEQUENCES

Three primary management tools can be identified in the WCPFC case: limits on capacity, limits on the use of that capacity (VDS), and closures of areas to harvesting – either entirely, in the case of purse seine exclusion from the closed high seas pockets, or partial closures, in the case of a seasonal prohibition of the use of FADs by purse seiners, on the high seas during periods in which juvenile yellowfin and bigeye are particularly vulnerable to that harvesting method. In addition, provisions related to monitoring and surveillance, and control of IUU fishing are important, but we will not consider them here. Rather our model simulations focus on examining the effects of use of capacity controls, fishing effort and closure of high seas areas.

We have chosen to consider here only the simplest basic case, in which harvesting occurs within just two coastal states' EEZs: (α and β) – plus also on the high seas: γ, and is engaged in by just two distant-water fleets: (1 and 2), each of which can divide its harvest effort among all three fishing grounds. Within a given season, the stock is split across these three zones. So, a vessel that is fishing in one area does not have access to the full stock. A schematic representation of this "split-stock" model is shown in following diagram.

$$\mathbf{H}_\alpha = \theta_\alpha \mathbf{R} \longrightarrow \mathbf{S}_\alpha = \mathbf{R}_\alpha - \mathbf{H}_\alpha$$

$$\nearrow \qquad\qquad\qquad\qquad \searrow$$

$$\mathbf{R} \qquad \mathbf{H}_\beta = \theta_\beta \mathbf{R} \longrightarrow \mathbf{S}_\beta = \mathbf{R}_\beta - \mathbf{H}_\beta \qquad \mathbf{S} = \mathbf{S}_\alpha + \mathbf{S}_\beta + \mathbf{S}_\gamma = \mathbf{R} - \mathbf{H}_\alpha - \mathbf{H}_\beta - \mathbf{H}_\gamma \ \longrightarrow\ \mathbf{R}^+ = \mathbf{G}(\mathbf{S})$$

$$\searrow \qquad\qquad\qquad\qquad \nearrow$$

$$\mathbf{H}_\gamma = \theta_\gamma \mathbf{R} \longrightarrow \mathbf{S}_\gamma = \mathbf{R}_\gamma - \mathbf{H}_\gamma$$

Here R is the initial recruitment; S_v = stock accessible in areas α, β, and γ, respectively; H_v = harvest in areas α, β, and γ; and R^+= G(S) = subsequent season recruitment as a function of the remaining unharvested stock. We assume that all parties know the total seasonal stock recruitment and its distribution across the EEZs and high seas:

$$\mathbf{R} = \mathbf{R}_\alpha + \mathbf{R}_\beta + \mathbf{R}_\gamma.$$

We further assume that the RFMO attempts to ensure that subsequent-season recruitment is at or above some desired target, by setting an escapement goal $\mathbf{S} = \mathbf{S}^*$ so that *expected* subsequent-season recruitment will be at or above a specified biomass level $\mathbf{G}(\mathbf{S}^*)$.

$$\mathbf{R}^+ = \mathbf{G}(\mathbf{S}).$$

We assume that the RFMO has the authority to control both harvesting capacity and fishing days. In addition, it may leave the high seas open to harvesting by the vessels that are authorized to fish within the region, or it may close those areas to fishing. Specifically, the RFMO can constrain overall seasonal fleet effort capacity, i.e. by specifying that $\mathbf{E} \leq \overline{\mathbf{E}}$. Alternatively, the RFMO could constrain the use of that capacity by limiting the total number of capacity-weighted fishing days allowed in the season $\mathbf{F} \leq \overline{\mathbf{F}}$. These are allocated to the two sites α and β. Such a restriction could be imposed either alone or in conjunction with restrictions on the effort capacity of the fleet.

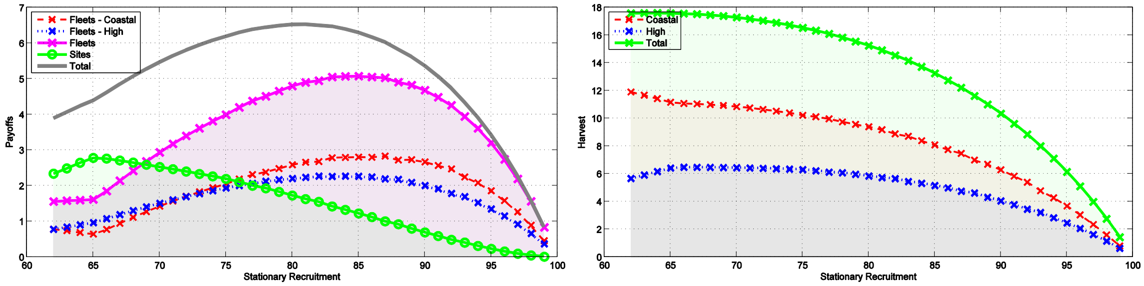
Depending on the RFMO policy, each site has the right to set a pair of fees: an entry fee for each vessel operating in its EEZ and a separate fee for the use of a fishing day. Each site reacts to the other site's policy by optimizing its own payoff. Thus, their optimal policies constitute a Nash equilibrium in the sites' game.

Finally, given **R**, the RFMO constraints and the sites' fees, the fleets choose their policies (distribute their efforts between the sites and allocate vessel-days, i.e. decide how long they will harvest on different sites). Again, each fleet reacts optimally to another fleet's policy and their combined policy is a Nash equilibrium in the game of fleets.

To perform the calculations, we have adopted a highly simplified representation of the fishery and the biology of the targeted fish stock. The model and parameter values are abstractions, but they are designed to imitate real-world bioeconomic relationships, and to qualitatively represent the behavior of the real-world system. Let us start first with the question of the desirable target level at which the stock is to be maintained. The maximum sustainable yield (MSY) population level is often put forward as a desirable biological target, but if harvesting becomes more difficult as the stock is drawn down, the MSY target would not be consistent with the stock level that could yield the maximum economic rent. In our simulations, per unit harvesting costs increase as the stock declines and becomes more diffuse, so if the goal is to maximize MEY – i.e. the sum of the payoffs to the sites (coastal country EEZs) and the fleets, the RFMO should maintain a larger stock-size, and allow smaller harvests than would be consistent with a MSY goal. As the figures below demonstrate, even the simple policy choice of the size of the biological target can have significant impacts on both the size and distribution of the total payoffs. The choice of policy tools to achieve the target is critical. In addition, policy outcomes will depend on the extent of cooperation or competition among the fleets and the sites.

Suppose, for example that the RFMO decides to rely entirely on effort-capacity constraints (limits on E) to achieve different possible targets for sustained recruitment. We will also assume that those vessels can choose to pay access fees to fish in one of the two EEZs or they can fish free of charge in the high seas areas that are under the RFMO's purview.[v] Figure 2 presents the steady-state outcome of this analysis, with alternative target levels of sustained recruitment measured along the X axis. In panel (a) payoffs are measured along the Y axis -- the top solid gray line represents total payoffs. Payoffs to the sites and the fleets are also shown and the latter is further subdivided according to the source of the payoffs (i.e. from harvests taken on the high seas, or from the EEZs). Panel (b) shows the total annual harvest consistent with each recruitment level, and where it is taken. In this example, there is no cooperation among fleets or sites.

In this simulation, the maximum payoff to the sites occurs at a much lower level of stationary recruitment than the maximum payoff to the fleets. In fact, the policy most favorable to the fleets (which is biologically very conservative, R=85) would be distinctly unfavorable to the sites – and vice versa (the policy most favorable to the sites corresponds to the steady state R=65, which is close to the recruitment at MSY). This result raises the question: why would the coastal nations stand to lose from the more biologically conservative policy? The answer lies in how the target is achieved and what that implies for the relative value of the two scarce factors of production that are needed to produce harvested fish. Here, it is assumed that the DWFNS own the fleets, and thus control all of the harvesting capital, while the coastal states control a substantial part (but not all) of a second critical factor – access to the fishing grounds. In the case illustrated, by using capacity controls to achieve the recruitment objective, the RFMO is essentially making harvesting capital a scarcer resource relative to the size of the fishing grounds. Because both factors are needed to produce harvested fish, the non-cooperating sites will be induced to compete against one another by lowering access fees to attract the fleets.



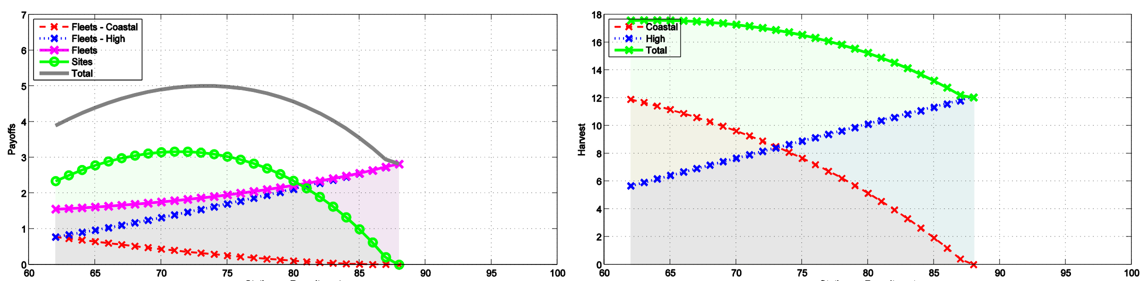
(a)

(b)

Figure 2

RFMO E-control. High seas open. No Cooperation.

Suppose, instead, that the RFMO had agreed to implement a vessel-day scheme by implementing F controls, and had allocated those vessel days to the sites. For the simulation in Figure 3, we examine the case of pure F controls, in which E is left unconstrained. As a result, each site can get as much capacity as it needs and there is no need to "attract vessels" from the other sites. So the sites become independent and it does not matter whether they cooperate or compete. Formally, the single "two fleets on three sites" game reduces to three "two fleets on one site" games: one for each EEZ and the third for the high seas. For such a game, it matters greatly whether or not the high seas areas remain open to harvesting. In Figure 3, we show the case in which the fleets are able to shift effort into the high seas areas, but in the absence of effort-capacity caps, there would many vessels chasing after the few fish in those areas. Furthermore, if the RFMO desired to achieve a high recruitment target using only effort-time restrictions, it would have to clamp down so tightly on the amount of fishing time allowed in the EEZs that harvesting activities there – and payoffs to the sites – would decline sharply.



(a)

(b)

Figure 3

RFMO keeps recruitment at stationary level R^+=R, using F-control. No Cooperation (= Sites Cooperate)

Next, consider the effects of interactions between the policy options and the extent of cooperation or competition among the sites and fleets. Here, the RFMO has chosen the policy target of R+ = 84, which is potentially consistent with achieving MEY. The RFMO can achieve this target in four different ways:

1) control E – effort-capacity;

2) control E and also close the high seas enclaves;

3) control F – days of fishing effort;

4) do that and also close the high seas pockets.

The outcomes of these possible policies under different cooperation structures are displayed in Figures 4 and 5. In each case, the magenta line represents the maximum total payoff from within-season cooperation among all four players (two fleets and two sites) given the policy. The bar-charts show payoffs attainable without cooperation, as well as by coalitions of the two sites and/or the two fleets.

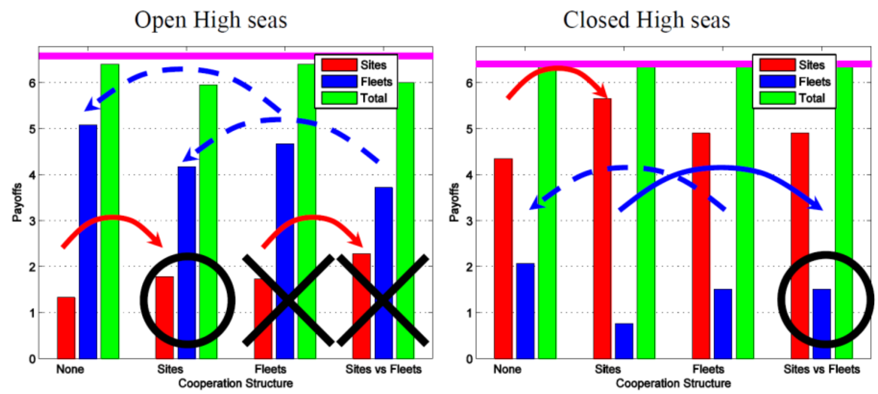


Figure 4

E-controls – Effects of Cooperative Structure
Steady-state recruitment = 84

Open High seas. Starting from the purely competitive case, it can be seen that the sites could gain by banding together to extract higher access fees from the fleets, and that the fleets would be worse off if that happened. The fleets, might be tempted to react by also forming a cooperating coalition, but it would not be possible for them to gain by doing so. The only stable outcome is the case in which the sites cooperate with one another while the fleets compete – and this cooperation structure provides the lowest industry-wide payoff. However, a four-way agreement with side payments could yield a superior outcome.

Closed High seas. If nobody cooperates, the total payoff from E controls is just slightly lower with closure of the high seas – but the distribution is very different. Here, the sites could gain substantially by cooperating on access fees, but that would induce the fleets to form their own coalition. The only stable solution in this case is the two coalition game of sites against fleets– in effect, a bi-lateral cartel. Note that there isn't any further gain to be achieved by four-way cooperation, and that the total payoffs are the same in all of the closed high-seas cases – only the distribution changes.

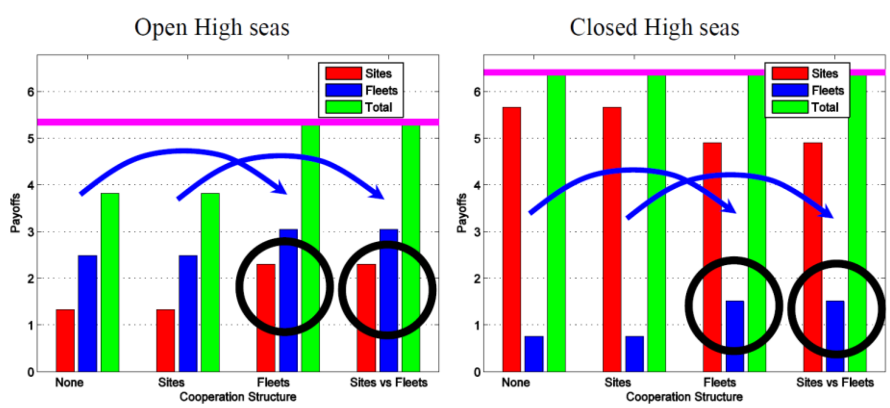


Figure 5

F-controls – Effects of Cooperative Structure
Steady-state recruitment = 84

Open High seas. If pure F controls are used while the high seas remain open, the maximum payoff would be much lower than in the other cases. This occurs because without the ability to restrict the size of harvesting capacity, severe restrictions on total fishing days within the EEZs are the only way for the RFMO to achieve its recruitment goal. Here cooperation among the fleets allows them to increase their share of the returns from fishing within the EEZs while also reducing counter-productive competitive fishing on the high seas. This would yield a stable solution, and because the F-controls are functionally equivalent to site cooperation in the model, further explicit site cooperation would not alter site payoffs.

Closed High seas. The sites would stand to gain significantly from closure of the high seas pockets – especially if the fleets fail to cooperate – but again, that would not be a stable solution. The stable outcome with cooperating fleets would be functionally equivalent to the stable sites versus fleets game when E controls are coupled with closure of the high seas pockets – and thus, these two management options would yield the same total payoff and same distribution of payoffs.

Finally, consider a very simple representation of the effects of a climate-related shift in the spatial distribution of the fish stock. Figure 6 shows the case in which pure **F** constraints are used, with the RFMO adjusting the **F** constraint to keep recruitment at a steady level R=70. Since there is no constraint on **E**, harvesting capital is abundant, putting the sites in a favorable situation. The high seas portion of recruitment is 20%, but the remaining stock is distributed unevenly. Specifically, on the far right of each figure, 70% of the stock occurs on site β, 20% on the high seas, and 10% of it on site α, while on the far left the α and β shares are reversed.

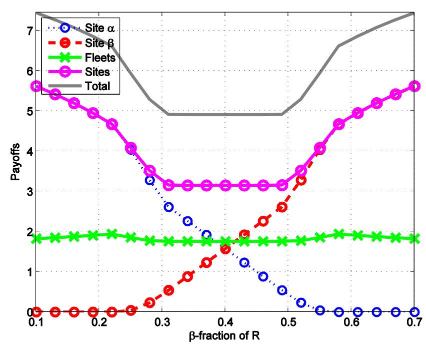


Figure 6

Environmental variability with F controls

When the concentration on one site becomes very high, the unit cost of harvesting there becomes very cheap, while it becomes expensive on the other site. Competition between the fleets allows the environmentally favored site to sharply increase its fees, and to capture the entire gain in rent created by the impacts of stock concentration on harvesting costs. Note that this case assumes that the RFMO aggressively reduces the allowable number of fishing days as the stock becomes more concentrated on one of the sites. In the absence of such active management, a site that is temporarily advantaged by the effects of an El Niño would be tempted to allow a substantial increase in harvests while the period of bounty persists.

SUMMARY AND CONCLUSION

This analysis indicates that while an RFMO can achieve any given biological objective by in a variety of ways, different types of policies will have very different implications for who benefits from the policy as well as for the overall level of the economic returns that can be obtained under the policy. Furthermore, policy outcomes will vary considerably depending on whether or not coalitions form among the various fishing nations and coastal nations in whose waters harvesting occurs. In particular, controls on overall harvesting capacity will tend to be more favorable to the fleets because the coastal nations must attract the fleets to their EEZs in order to benefit from the fishery. On the other hand, restrictions on the allowable number of harvesting days may be more favorable to the coastal nations – especially if they are coupled with restrictions on the movement of harvesting activities into the surrounding high seas.

These distributional effects may help to explain why the PNA coalition in the Western and Central Pacific has pushed so hard to limit vessel-days through the VDS, and why they quickly decided that it was critical to couple that approach with closure of the purse seine fishery in the high seas pockets between their EEZs. This real world case is not fully equivalent to our model simulations because there are still large high-seas areas in the eastern part of the region that remain open, except for a short seasonal closure on the use of FADS by purse seine vessels that has been implemented to protect juvenile bigeye and yellowfin tuna (WCPFC, 2008). It is possible that continued global warming could create a more El Niño-like mean state that would shifts the distribution of the region's skipjack tuna stocks to the east. If that occurs, it would tend to weaken the bargaining position of the PNA. Such an environmental change might require renewed attention to restricting overall harvesting capacity to effectively manage the fishery, or perhaps a shift to an ITQ-type approach. In the latter case, it will be important to pay attention to the distributional consequences of switching to rights-based management to avoid unnecessary conflict.

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ENDNOTES

[i] See: http://www.tuna-org.org/

[ii] MRAG, 2006, notes that: "WCPFC article 32(4) provides that cooperating non-parties (to WCPFC) shall enjoy benefits in the fishery commensurate with their commitment to comply with conservation and management measures and their record of compliance." p. 23

[iii] As of July 2010, the membership in the WCPFC is as follows:

Members: Australia, China, Canada, Cook Islands, European Union, Federated States of Micronesia, Fiji, France, Japan, Kiribati, Korea, Republic of Marshall Islands, Nauru, New Zealand, Niue, Palau, Papua New Guinea, Philippines, Samoa, Solomon Islands, Chinese Taipei, Tonga, Tuvalu, United States of America, Vanuatu.

Participating Territories: American Samoa, Commonwealth of the Northern Mariana Islands, French Polynesia, Guam, New Caledonia, Tokelau, Wallis and Futuna.

Cooperating Non-members: Belize, Indonesia, Senegal, Mexico, El Salvador, Ecuador, Vietnam

[iv] Collaboration among this group resulted in the1983 Nauru Agreement which established a regional fishing vessel register and specified minimum terms of access. The Original 7 members of the PNA are: The Federated States of Micronesia, the Republic of Kiribati, the Marshall Islands, the Republic of Nauru, the Republic of Palau, Papua New Guinea and Solomon Islands. Tuvalu joined the PNA in 1991.

[v] Here, we assume that only RFMO-authorized vessels can fish in those high-seas areas.