Game Theory and the Evolution of High Seas Fisheries Management Policies

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Abstract. This paper is not concerned with advances in game theory. Rather, the paper is concerned with the relevance, if any, of game theory to a major resource management issue, namely the management of internationally shared fishery resources, particularly those to be found in the high seas. It is argued that the economics of the management of such resources cannot, in fact, be understood, other than through the lens of game theory. The paper discusses several elementary game theory concepts that are of utmost policy relevance, but which are, as of yet, imperfectly understood by most policy makers. The paper does, in addition, discuss a key policy problem in the management of shared fishery resources that demands a game theoretic analysis. The required analysis, however, has yet to be developed.

I Introduction

This paper is, to a great extent, a revision of an invited paper that I gave at the 6th Meeting on Game Theory and Practice in Zaragoza, 2006.[1] In that paper, I confessed that the paper, unlike the overwhelming majority of papers at the meeting, was not focussed on recent advances in game theory. What was true of the Zaragoza paper is true of this one.

This paper is focussed primarily on the impact, actual and potential, on policy makers concerned with a major resource management issue, namely the management of internationally shared capture fishery resources, particularly those to be found in the high seas .

To continue this confession, let me state categorically that I am not a game theorist. Rather, I am a resource economist, who has found himself compelled to attempt to apply game theory to a particular set of resource management issues. This attempt has led me to collaborate with several, who can, by way of contrast, legitimately lay claim to the title of applied game theorist. My debt to these collaborators has steadily increased over the years. I am currently working with two European economists, who I have described in other papers as being at the cutting edge of the application of game theory to fisheries economics.[2]

I entered the field of fisheries economics some thirty plus years ago. As I was coming into the field, the UN Third Conference on the Law of the Sea, 1979-1992, was just getting under way. The Conference was to have a revolutionary impact on the management of world marine capture fisheries.[3] Having come from an international economics background, I was quickly drawn into fisheries management issues raised by the Conference. In so doing, I benefited enormously by my collaboration with an applied mathematician, Colin Clark.[4]

The UN Third Conference on the Law of the Sea brought forth the UN Convention on the Law of the Sea (1982 UN Convention, hereafter), which achieved the status of

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[1] The paper is: "Game Theory and the Development of Resource Management Policy: The Case of International Fisheries'' (Munro, 2006). Versions of this paper are to be published, in due course, in *Environment and Development Economics,* and Dinar, Albiac and Sánchez-Soriano, forthcoming.

[2] They are: Marko Lindroos, University of Helsinki; and Pedro Pintassilgo, University of the Algarve.

[3] The negotiations on fisheries issues were more or less completed by 1975.

[4] Author of the very well known *Mathematical Bioeconomics : The Optimal Management of Renewable Resources* (Clark, 1990).

international treaty law in 1994, and which has come to serve as the bedrock source of the "rules of the game" for the management of world marine capture fisheries resources (UN, 1982).

Under the 1982 Convention, coastal states (states with significant marine coast lines, e.g. Canada) are given the right to establish 200 nautical mile Exclusive Economic Zones (EEZs) off their coasts. To all intents and purposes, coastal states have property rights to the fishery resources encompassed by the EEZs (McRae and Munro, 1989). It was estimated at the time of the UN Third Conference on the Law of the Sea that the EEZs, if spread throughout the world, would encompass fishery resources accounting for 90 per cent of the world's marine capture fishery harvests (Alexander and Hodgson, 1975).

Capture fishery resources are, with few exceptions, mobile. Consequently, it was quickly recognized, during the 1973-1982 UN Conference, that the typical coastal state would find that it was sharing some of its EEZ fishery resources with neighbouring coastal states, or with so called distant water fishing states (DWFSs) operating in the remaining high seas adjacent to the EEZ.

Since the close of that conference, it has come to be recognized that the management of internationally shared fishery resources is one of the major resource management issues to have arisen under the EEZ regime. The Food and Agriculture Organization of the UN (FAO) estimates that as much as one-third of world marine capture fishery harvests are based upon such shared stocks (Munro, Van Houtte and Willmann, 2004).

The FAO goes to categorize these internationally shared fish stocks as follows:

A. Transboundary fish stocks – fishery resources that are to be found in two or more neighbouring EEZs.
B. Straddling fish stocks – fish stocks that are to be found both within the EEZ and the adjacent high seas.[5]

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[5] The UN makes a distinction between highly migratory fish stocks and straddling fish stocks (e.g. UN 1995). Highly migratory fish stocks, tuna primarily, are, because of their highly migratory nature, to be found both within the EEZ and the adjacent high seas. Straddling fish stocks are all other fish stocks(except anadromous and catadromous stocks) to be found both within the EEZ and the adjacent high seas. The distinction was made largely for political reasons and can be defended on neither biological nor economic grounds (Munro, Van Houtte and Willmann, 2004). Hence, we merge the two into what we call straddling fish stocks broadly defined.

C. Discrete fish stocks – fish stocks that are confined to the high seas (see: Munro, et al., 2004).

At the close of the 1973-1982 UN Conference, only Category A fish stocks were taken seriously. With only 10 per cent of the commercially exploitable capture fishery stocks in the remaining high seas, Categories B and C seemed of little importance. This view of the world proved to be wholly unfounded. Serious overexploitation of straddling stocks (broadly defined) in the high seas occurred during the remainder of he 1980s and early 1990s. The overexploitation of the stocks in the high seas undermined attempts to manage the intra-EEZ segments of the stocks.

In response, the UN convened a second conference in 1993, popularly referred to as the UN Fish Stocks Conference.[6] This second conference, which concluded in 1995, brought forth an agreement, popularly referred to as the 1995 UN Fish Stocks Agreement[7] that was designed to buttress the 1982 Convention. Under the terms of the 1995 Fish Stocks Agreement, relevant coastal states and DWFSs are to come together to manage straddling stocks, on a region by region basis, through Regional Fisheries Management Organizations, examples of which are the Northwest Atlantic Fisheries Organization (NAFO) and the Northeast Atlantic Fisheries Commission (NEAFC),

I began doing research on the economics of the management of shared fish stocks around 1976/1977, well before the close of the UN Third Conference on the Law of the Sea. Since I began this research, I have had the opportunity to study in detail attempts to manage such resources in the North Pacific, the Western and Central Pacific, the North Atlantic and the Southeast Atlantic. I worked for the FAO, as a consultant in the mounting of the Norway-FAO Expert Consultation on the Management of Shared Fish Stocks, 2002, and then served as a participant in the Expert Consultation. I recently served on an independent panel, based at the Royal Institute of International Affairs, London, established to develop a model for the improved governance of RFMOs.[8]

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[6] United Nations Conference on Straddling Fish Stocks and Highly Migratory Fish Stocks.

[7] The full title of the Agreement is: Agreement for the Implementation of the Provisions of the United Nations Convention on the Law of the Sea of 10 December 1982 Relating to the Conservation and Management of Straddling Fish Stocks and Highly Migratory Fish Stocks (UN, 1995).

[8] The Independent Panel on Regional Fisheries Management Organizations. See: Lodge, Anderson, Løbach, Munro, Sainsbury and Willock, 2007.

In so doing, I have been given an opportunity to assess the value of game theory concepts and insights to the solving of real world resource management problems. I have also been put in the position of having to "sell" game theory concepts to practitioners. One of my first experiences, in so doing, came when I gave a seminar, in late 2001, on the application of game theory to international fisheries management, at FAO headquarters in Rome. What I have been able to argue at FAO, and elsewhere, such as the aforementioned panel, is that game theory – which I present as the theory of strategic interaction – provides not just a useful framework, but the essential framework, for the examination of the policy problems arising from international fisheries management.

My years of work on internationally shared fishery resources issues have led me to discover that there are several game theory concepts, which every game theorist regards as elementary, if not obvious, that do have significant, if not profound, policy consequences in the real world of fisheries management. These elementary concepts have, until recently, been poorly understood by policy practitioners, but I do see some encouraging signs that they are coming to be accepted.[9] There are, in addition, some distinctly non-elementary concepts that are of direct, and immediate, relevance to the management of high seas fisheries. Work on the application of these concepts to high seas fisheries management by game theorists is underway at the present time.[10] Finally, there is one important issue of relevance to shared fish stock management in general that has yet to be addressed adequately by game theorists.

We commence with two background sections designed to provide an outline of the relevant resource management issues, accompanied by a brief survey of the development of the economic analysis designed to address these issues. While the focus of the paper is on high seas fisheries management issues – straddling stocks and discrete high seas stocks, we commence the review with a discussion of transboundary – EEZ to EEZ – fish stocks. Transboundary fish stocks were seen as <u>the</u> shared fish stock management problem at the close of the UN Third Conference on the Law of the

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[9] The RFMO Panel Report reads:

> A fundamental feature of the management of straddling and highly migratory fish stocks is the fact that … there will be a **strategic interaction** among the States exploiting these stocks --- Economists learned 30 years ago that they could make no progress in analyzing the economics of the management of these fishery resources unless they took this strategic interaction into account explicitly (Lodge, et. al., 2007, p. 10).

[10] See, for example: Pintassilgo and Lindroos, forthcoming.

Sea, 1982. As a consequence, the economics of the management of such shared stocks was developed well before the economics of high seas shared stocks management. The economics of high seas shared stock management is, to all intents and purposes, an extension of and elaboration upon, the economics transboundary stock management.

II. A Review of the Economics of the Management of Internationally Shared Fish Stocks: Stage One – The Foundations: Transboundary Stocks

We begin with the fundamental fact that world capture fishery resources have historically been seen as the quintessential "common pool" resources. In the past, at least, it was deemed to be too costly to put in place effective property rights to the resources. The "common pool" aspects of the resource have been seen to lead to resource overexploitation and economic waste.

Economists have traditionally dealt with the capture fishery confined to the waters of a single state, by contrasting the management of the fishery by an all powerful social manager – the ideal, the target – with a pure open access "common pool" fishery, in which the resource is exploited by a very large number of fishers. Thus, perceptible interaction is completely absent from the analysis. Consider the following commonly used dynamic model (Bjørndal, Kaitala, Lindroos and Munro, 2000; Clark, 1990; 2007).

The resource dynamics, given harvesting, are described by the following deterministic model:[11]

$$\frac{dx}{dt} = F(x) - h(t), x(0) = x_0 \tag{1}$$

$$h(t) = qE(t)x(t) \tag{2}$$

where x(t) is the non-negative state variable representing the fish biomass F(•) is the growth function of the resource, h(t) is the harvest rate, E(t) is fishing effort, defined as the combined flow of labour and capital services devoted to harvesting, and q, a constant, is the catchability coefficient. It will be assumed from here on in that q = 1. It is further assumed that F(x) is concave in x, such that F(0) = F(Z) = 0, for some Z > 0, and F(x) > 0 for 0 < x < Z. The biomass Z is

[11] The following is based upon the famous biological fishery developed by M.B. Schaefer. See : Clark (1990).

the equilibrium level of the biomass, in the absence of harvesting. It is assumed further that $0 \leq E(t) \leq E^{max}$.

At any given point in time, the net revenue, or resource rent, is given by:

$$\pi = (px - b)E \tag{3}$$

where p, a constant, denotes the price of harvested fish, and b, a constant, denotes the average (unit) cost of fishing effort, E.

The objective of the social manager is to maximize the present value of the net revenue (resource rent) from the fishery through time, to $t = \infty$. The objective functional can be expressed as follows:

$$\max J(x_0, E) = \int_0^\infty e^{-\delta t}[px(t) - b]E(t)dt \tag{4}$$

s,t. Eq. (1), and where δ denotes the social rate of discount.

We are presented with a linear optimal control problem, where x(t) is the state variable, and E(t) is the control variable.

There exists an optimal steady state biomass, x^*, which is given by the following equation:

$$F'(x^*) + \gamma(x^*) = \delta \tag{5}$$

where $\gamma(x^*) = \frac{-c'(x^*)F(x^*)}{p - c(x^*)}$, and where c(x) denotes the unit cost of harvesting: c(x)=b/x.

Given that the vessel (and human) capital employed in the fishery is perfectly malleable, the optimal approach path is given by:

$$E^*(x) = \begin{cases} E^{max} & \text{for} \quad x(t) > x^* \\ F(x^*)/x^* & \text{for} \quad x(t) = x^* \\ 0 & \text{for} \quad x(t) < x^* \end{cases} \tag{6}$$

Think of x(t) as a form of "natural" capital. Eq. (5) can then be seen as a Modified Golden Rule of Capital Accumulation determining the optimal stock of "natural" capital, while Eq. (6) sets out the optimal resource investment program.

In the contrasting pure open access "common pool," case the resource will be driven down to a level at which current resource rent is equal to zero:

$$p - c(x^\infty) = 0 \tag{7}$$

which H. Scott Gordon (1954) characterized as Bionomic Equilibrium. Thus, x^{∞} denotes the Bionomic Equilibrium biomass. It can be shown (Clark, 1990; 2007) that we shall have $x^{*} = x^{\infty}$, if and only if $\delta = \infty$. The implications are two fold. The first is that, under pure open access, the fishers are given every incentive to discount fully all future returns from the fishery. The second is that, since $\delta = \infty$ is all but inconceivable, pure open access leads unquestionably to excessive disinvestment of the "natural" capital (overexploitation of the resource) from society's point of view. Bionomic Equilibrium is taken as a benchmark of resource management undesirability.

While the overexploitation of particular local fisheries has been a matter of concern for many centuries, the overexploitation of the great ocean fishery resources was not a concern until the first half of the 20th century, because these resources were seen as being inexhaustible. Perhaps pure open access would lead to the loss of some economic benefits, but at least the resources were safe from dangerous overexploitation, as seen from a biological standpoint. Attempting to regulate such fisheries was hardly worth the effort, or so it was argued.

This point of view found its clearest expression in the doctrine of the Freedom of the Seas (Mare Liberum), as propounded by the 17th century Dutch jurist, Hugo Grotius. Under this doctrine, the oceans were divided between the coastal state territorial sea and the remainder, the high seas. The territorial sea was, and is, a narrow strip of water, by tradition no more than 3 nautical miles.[12] The resources in the high seas were to be deemed *res communis*, the property of all, and thus open to exploitation by all.

The doctrine of the Freedom of the Seas, as it pertained to fisheries, rested upon two premises:

1. the high seas fishery resources are inexhaustible
2. coastal states are unable to control effectively resource exploitation activities beyond their territorial seas

These premises were defensible, in Grotius day. Given the state of fishing technology, for example, the high seas fishery resources were, by and in the large, safe from overexploitation (Orrego, 1999).

Since the 17th century, and in particular since the late 19th century, both of these premises have become increasingly untenable. This decline in tenability has, in turn, led to a steady erosion of the Freedom of the Seas, as it pertains to fisheries. The erosion is not complete, however. A residue persists, which continues to exacerbate the difficulty of managing international fishery resources.

Rapid advances in fishing technology, e.g. shift from sail to steam, increased the vulnerability of ocean fishery resources. By the end of the Second World War, it was obvious to all that the great ocean fishery resources were anything but inexhaustible. The erosion of the Freedom of the Seas appears first in the form of international conventions designed to put restrictions on fishing activities in certain segments of the high seas. The International Commission for the Northwest Atlantic Fisheries (ICNAF), which attempted to impose some management rules over Atlantic high seas fisheries off North America, from Greenland to the Carolinas in the United States provides one example.

Following the end of the Second War, several coastal states attempted, unilaterally, to extend their jurisdiction over seabed resources beyond their territorial seas. In order to prevent a chaotic extension of coastal state marine jurisdiction, the UN convened a series of the Law of the Sea conferences. Conferences One and Two did little to address fisheries issues. Conference Three (1973-1982) did, as we have seen, revolutionise marine capture fisheries management, and, did, through the establishment of the EEZ regime, lead to a massive erosion of the Freedom of the Seas, as it related to fisheries. With only 10 per cent of capture fishery harvests being accounted for by fishery resources in the remaining high seas, the Freedom of the Seas did, in a fisheries context, seem to be all but irrelevant in 1982.

As we have noted, negotiators in the UN Third Conference on the Law of the Sea, and outside observers, were quick to observe that the coming EEZ regime would carry with it the problem of management of shared fish stocks. As we have also noted, the only shared fish stocks that seemed worthy of consideration at the time were EEZ to EEZ – transboundary - stocks.

I developed an interest in this issue in the mid-1970s, well before the close of the UN Third Conference on the Law of the Sea. Since Zara, Dinar and Patrone (2006) claim that I was the first to apply game theory to this problem, it is perhaps worthwhile recounting how I came to do so.

In 1976, I was encouraged to prepare a conference paper on fisheries management issues likely to arise through Canada's establishment of an EEZ off its

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[12] It now extends to 12 miles (UN, 1982, Article 3).

Pacific coast. In contrast to Canada's establishment of an EEZ off its Atlantic coast, this was likely to be a tame affair. The one issue that I could find of interest arose from the fact that most, if not all, of the new fishery resources over which Canada would be given jurisdiction by implementing its Pacific EEZ would be shared with the United States. Given my interest in international issues in general, I seized upon the issue as my topic for the paper.

In undertaking my research for the paper, I found a few then recent articles by fisheries economists on the management of internationally shared fishery resources. All were incomprehensible, and all seemed devoid of policy value. I earnestly hoped that a better way existed.

By a stroke of good fortune, my department was visited by Robert Pindyck, from MIT, who gave a seminar on a recent article, which he had co-authored on optimal pricing policies for OPEC. The Grand Coalition, that was then OPEC, divided into two sub-coalitions, with one sub-coalition effectively employing a high discount rate, and the other effectively employing a low discount rate. Thus, there was a clash in pricing, and resource management goals.

Pindyck and his co-author addressed the issue by applying Nash's theory of a two player cooperative game (Hnyilicza and Pindyck, 1976). The light broke through. I had found my better way. I might add, I knew from the outset that the probability of any two coastal states having differing resource management goals was high indeed.

In any event, the aforementioned articles on internationally shared fishery resources had employed no game theory whatsoever. Since strategic interaction between and among those sharing the fishery resources lies at the heart of the management issue, it is no wonder that the articles were (and are) incomprehensible.

This leads to my first conclusion, with respect to value, if any, of game theory to policy makers involved in the management of internationally shared fishery resources. Economists cannot analyse the economics of the management of such fisheries, with the hope of providing useful insights to policy makers, other than through the lens of game theory. I stand by this conclusion, because I know what the alternative is.

Be that as it may, after the revealing Pindyck seminar, I quickly became a student of game theory. In so doing, I was greatly assisted by my mathematician colleague, Colin Clark, whose Department of Mathematics happened to have a visiting scholar who was a bona fide game theorist.

Since the focus was on transboundary fish stocks alone, it was not unreasonable to set the problem up as a simple two player Nash cooperative game, following Hnyilicza and Pindyck. This had to be blended with the standard dynamic economic model of the fishery. The conference paper was completed (Munro, 1977). A much more developed and extended version appeared in the *Canadian Journal of Economics*, two years later (Munro, 1979).

In both the 1977 conference paper and 1979 article, I simply asserted that non-cooperative management of the resource would produce inferior results. My assertion was dealt with in 1980 in articles by Clark (1980), and Levhari and Mirman (1980). Both articles essentially reach the same conclusions, namely that non-cooperative management can, with few exceptions, be expected to lead to a Prisoner's Dilemma type of outcome, in which all players deem the resource to be overexploited.

We deal first with the fisheries non-cooperative game, in order to have a more precise understanding of the Threat Point payoffs in the simple cooperative fisheries game. We shall turn to Clark's treatment of the non–cooperative fisheries game, because his economic model of the fisheries is (no surprise) identical to the one employed in my 1979 article.

Prior to reviewing Clark's model, let us first note that, if neighbouring coastal states sharing a transboundary fish stock attempt to manage the resource non-cooperatively, they are not necessarily in violation of the 1982 UN Convention. Under the 1982 Convention states are indeed admonished to enter into negotiations with a view to managing the resource cooperatively (UN, 1982, Article 63(1)). Importantly, however, the coastal states are not required to reach an agreement. If the states negotiate in good faith, but are unable to reach an agreement, then each coastal state is to manage its segment of the resource independently in accordance with the other provisions of the 1982 UN Convention (UN, 1982; Munro, Van Houtte and Willmann, 2004). Hence, non-cooperative management of the transboundary fish stock is countenanced under the 1982 UN Convention.

We turn now to the Clark (1980) article. In the real world of shared fish stock management, asymmetry of players in the fisheries game is the rule, not the exception. Appropriately, Clark sets up a two player Nash non-cooperative fisheries game in which the players are asymmetric in that their fishing effort costs are different. In all other respects, the players are identical.

As before, let b, a constant, denote unit fishing effort costs. Denote the players by α and β. By assumption, $b_\alpha < b_\beta$. It can be easily shown that the difference in fishing effort costs leads to the following: $x_\alpha^* < x_\beta^*$; $x_\alpha^\infty < x_\beta^\infty$.

In the Clark model, the non-cooperative feedback strategies (denoted by N) of the two players are defined as:

$$E_\alpha^N(x) = \begin{cases} E_\alpha^{max} & \text{for} \quad x > \min(x_\alpha^*, x_\beta^\infty) \\ F(x)/x & \text{for} \quad x = \min(x_\alpha^*, x_\beta^\infty)) \\ 0 & \text{for} \quad x < \min(x_\alpha^*, x_\beta^\infty) \end{cases} \tag{8a}$$

$$E_\beta^N(x) = \begin{cases} E_\beta^{max} & \text{for} \quad x > x_\beta^\infty \\ 0 & \text{for} \quad x < x_\beta^\infty \end{cases} \tag{8b}$$

If $x_\alpha^* < x_\beta^\infty$, the high cost player is driven out, and an optimal result is forthcoming. On the other hand, if $x_\alpha^* > x_\beta^\infty$, then we get unambiguous overexploitation of the resource. Clark also demonstrates that, if $b_\alpha = b_\beta$, the two players are symmetrical, the resource will be driven down to the common Bionomic Equilibrium, $x_\alpha^\infty = x_\beta^\infty$ (Clark, 1980). Thus, in the Clark model, while a Prisoner's Dilemma type of outcome is not guaranteed, the outcome is definitely likely. Thus a failure, on the part of neighbouring coastal states to cooperate can have severe consequences. To those versed in game theory, the conclusion is obvious. I shall, however, argue that, in the world of policy makers, while all acknowledge that cooperation is a *Good Thing*, there is not full recognition of the possible consequences of non-cooperation.

With respect to the two-player cooperative fisheries game, in the 1979 article I assume that the two players are asymmetric for several reasons, and thus have clashing resource management goals. A major conclusion is that compromise cooperative management programs are achievable, although some of the compromises are awkward and of questionable policy value (Munro, 1979).

Hnyilicza and Pindyck (1976), whose lead I followed, did not allow for the possibility of side payments. In attempting to educate myself on the elementary theory of cooperative games, I soon discovered side payments. In writing the 1977 article, I quickly realized that the introduction of side payments led to a massive simplification of the analysis. Side payments, as I shall argue at a later point, do matter for policy purposes. To begin, the introduction of side payments shifts the focus away from the sharing of agreed upon harvests between and among fleets of relevant states and entities, to the sharing of the global net economic returns from the fishery. In many instances, the two are not the same.

In passing, I am well aware that the introduction of side payments is a matter of controversy in the literature on environmental cooperative games. The argument is made that side payments can have negative effects (Folmer and de Zeeuw, 2000). While it is certainly possible to think of fishery cooperative games, in which side payments have no value, this author would be hard pressed to point to any example of a cooperative fisheries game in which the introduction of side payments can be expected to have negative consequences.

With side payments (and binding cooperative agreements), the solution to the two player Nash cooperative game becomes particularly simple. Let the global net economic return from the cooperatively managed fishery (expressed in PV terms), commencing at x = x(0), be denoted as $\omega(x(0))$. We have:

$$\omega(x(0)) = \omega_\alpha(x(0)) + \omega_\beta(x(0)) \tag{9}$$

where the two players are α and β, and where the RHS of Eq .(9) denotes their respective shares.

Now denote the returns to the two players from a Nash non-cooperative game as: $J_\alpha(x(0),E^N_\alpha,E^N_\beta)$, and $J_\beta(x(0),E^N_\alpha,E^N_\beta)$, and denote the cooperative surplus as: e(x(0)), where:

$$e(x(0)) = \omega(x(0)) - [J_\alpha(x(0),E^N_\alpha,E^N_\beta) + J_\beta(x(0),E^N_\alpha,E^N_\beta)] \tag{10}$$

We then have:

$$\omega_i(x(0)) = e(x(0))/2 + J_i(x(0)),E^N_\alpha,E^N_\beta), i = \alpha,\beta \tag{11}$$

Thus we have the well known result in which the players divide the cooperative surplus equally, and in which each player’s cooperative solution payoff is the sum of its Threat Point payoff and its equal share of the cooperative surplus (Bjørndal, Kaitala, Lindroos and Munro, 2000).

In my 1979 article, several heroic assumptions are made. One of these assumptions attracted a host of critics, namely the assumption that cooperative management agreements, upon being achieved, are binding through time. These critics were then faced with the task of attempting to show how one establishes stable cooperative fishery management agreements, when they are not binding through time. By far the most successful attempts, in this author's view, came from what I have chosen to call the Helsinki School, the prominent members of which are Veijo Kaitala and his protégé Marke Lindroos (see, for example: Kaitala, 1985; Lindroos, forthcoming).

The obvious threat to stability in a non-binding cooperative resource management agreement is that of cheating. Kaitala demonstrates that the problem can be addressed with credible mutual threat schemes (Kaitala, *ibid*.).

The Helsinki School did much more than address the problem of possible cheating, however. It brought to light a problem which has a high degree of relevance in the real world of policy making. The problem arises from the fact that shifting underlying conditions through time can have an impact on the relative bargaining power of the players.

The consequences of shifting underlying conditions were set forth in a 1988 article by Veijo Kaitala and Matti Pohjola. Kaitala and Pohjola (1988) take a Clark-like two player fisheries game, in which the players, α and β, differ only in terms of fishing effort costs. In the game, $x_\alpha^* > x_\beta^\infty$. Initially, a non-cooperative game ensues, and a Nash equilibrium is achieved at $x = x_\beta^\infty$. With the damaging consequences of non-cooperation now evident to both countries, the two enter into a cooperative management agreement. Side payments are allowed, with the result that α effectively buys out β. Player α will plan to re-build the resource up to $x = x_\alpha^*$.

At the commencement of the cooperative game, β's bargaining power is very low. If an ironclad binding agreement could be entered into, β would receive a very modest return and that would be that. If the agreement is non-binding, however, α must take into account that β's bargaining strength will steadily increase as the resource rebuilds. If, when $x = x_\alpha^*$ is achieved, β is receiving very little, it will have an incentive to cheat, to break the agreement, even if punishment from α is immediately forthcoming. Hence, the side payments offered by α to β must be such that β has no incentive to defect, once $x = x_\alpha^*$ is achieved.

The Kaitala/Pohjola model is deterministic. The future course of events is entirely predictable, with the result that α can plan accordingly. As we shall point out, experience from the real world shows that shifts affecting relative bargaining power can often be no more than anticipated, not predicted with any accuracy in terms of timing, or direction of effect. Real world experience also demonstrates that such shifts can readily de-stabilize cooperative resource management agreements that are ostensibly binding in nature.

III. A Review of the Management of Internationally Shared Fishery Resources: Stage Two – High Seas Shared Stocks – the New Problem

The anticipation, throughout the UN Third Conference on the Law of the Sea, that fishery resources in the remaining high seas beyond the EEZs would be of minor importance proved, as we have noted, to be dramatically wrong. While discrete high seas stocks have yet to achieve great importance, there was extensive exploitation of the high seas segments of straddling stocks, which undermined coastal state attempts to manage the intra-EEZ segments of the stocks.[13]

The high seas segments of straddling fish stocks, which are subject to exploitation by both coastal states and DWFSs, and discrete high seas stocks are covered in the 1982 UN Convention by Part VII High Seas. Article 87, in Part VII, accords all states the freedom to fish in the high seas, subject to the conditions laid down by Articles 116-120. States engaging in high seas fishing are to cooperate for the purposes of conserving the resources, and in the case of straddling stocks, DWFSs are to recognize the rights, duties and interests of relevant coastal states.[14] Having said all of this, the fisheries articles of Part VII of the 1982 Convention have been described as constituting a model of opaqueness (Munro, 2000). The rights, duties and obligations of coastal states on the one hand, and those of DWFSs on the other, with respect to the high seas segments of straddling fish stocks, are made very unclear. This reflects the fact that the drafters of the Convention had a difficult balancing act to perform, namely the freedom to fish of DWFSs on the high seas against the interests of the coastal state to manage the intra-EEZ segments of the straddling stocks (Munro et al., 2004).

The lack of clarity of the fisheries article of Part VII of the 1982 UN Convention made it exceedingly difficult to effect cooperative management of the resources. The

[13] The reason for this surprising development lies mainly in the fact that DWFS fleets were being eliminated from the newly formed EEZs. This is discussed in detail in Munro (2000).
[14] UN, 1995, Article 116.

history of the 1980s, following the conclusion of the UN Third Conference on the Law of the Sea, and the early 1990s, demonstrated that the economist's model of non-cooperative management of transboundary stocks applied, without modification, to straddling stocks. Case after case of overexploitation of such resources emerged.

An example is provided by the Alaska pollock, the species, which historically has yielded the largest harvest in the North Pacific. Large concentrations are to be found in the Bering Sea. A significant part of the resource straddles the American zone and a high seas enclave, between the American and Russian zones, referred to as the "Doughnut Hole." The management of the straddling stock was non-cooperative. The pollock resources in the "Doughnut Hole" were not just overexploited they were, in the words of the FAO, plundered (FAO, 1994). As Munro et al. (2004) remark, "… the overexploitation of straddling/highly migratory fish stocks worldwide … bears powerful testimony to the predictive powers of the economic analysis of the non-cooperative management of such resources" (Munro, et al., 2004, p. 45).

It was this growing crisis that gave rise to the UN Fish Stocks Conference, 1993-1995. The Conference, let it be observed, focussed solely on straddling fish stocks (broadly defined). Discrete high seas stocks were ignored.

Let us recall that, under the terms of the 1995 UN Fish Stocks Agreement (1995 UNFSA, from hereon in), straddling stocks (broadly defined) are to be managed on a region by region basis through Regional Fisheries Management Organizations (RFMOs). The RFMOs are to have as members both coastal states and DWFSs. An RFMO cannot be a club reserved for the sole use of coastal states. Let us also recall that the purpose of the 1995 UNFSA was that not of replacing any part of the 1982 UN Convention. Rather the purpose was and is, to buttress the Convention (Part VII, in particular).

The question then becomes to what extent do the economic game theory models developed for transboundary fish stocks have to be modified, first when dealing with straddling fish stocks. One part of this question has already been answered. The model of non-cooperative management of transboundary stocks applied without modification to straddling stocks.[15]

When we turn to the cooperative management of the resources, the answer is quite different. The economic game theory model of cooperative management of

.[15] Discrete high seas stocks will be discussed at a later point transboundary stocks requires substantial modification when one confront the issue of cooperative management of straddling stocks. To begin, one can anticipate that the number of players in the typical straddling stock game will be large. In the analysis of transboundary fish stock management, considerable progress can be made using two player models. Two player models are simply inadequate for straddling stocks. We are compelled to employ n > 2 models, which in turn means that a coalitional bargaining approach becomes mandatory.

Secondly, in contrast to transboundary stock management, the number and nature of the players cannot be expected to be constant through time. Some members of the RFMO are DWFSs, the fleets of which are nothing if not mobile. An original, or "charter," member of a RFMO may withdraw. More importantly, a DWFS, hitherto not a member of the RFMO, may apply for membership. The 1995 UN Agreement makes it clear that the "charter" members of a RFMO cannot bar prospective new entrants, members outright (UN, 1995, Articles 8, 10 and 11; Munro et al., 2004). This gives rise to the so called "New Member Problem" (Kaitala and Munro, 1997).[16]

The third difference falls under the heading of the prevalence of "free riding," the common affliction of environmental cooperative arrangements. For the purposes of this paper, I shall define "free riding" as enjoyment of the fruits of cooperation by non-participants in the cooperative management arrangement. I will concede that the boundary between free riding and non-compliance may lack clarity.

Be that as it may, Munro et al. (2004) maintain that, while free riding is theoretically possible in the management of transboundary fish stocks, they are hard pressed to come up with any real world examples. Free riding, by way of contrast, historically is a very serious problem in the management of straddling stocks.

The difference arises largely because of the distinction between illegal and unregulated fishing. According to the FAO, illegal fishing involves fishing by one state, or entity, in the EEZ of another state without the latter's permission, or wilful non-compliance with the management provisions of a RFMO by a member of the RFMO (FAO, 2001). Vigorous action can be taken to deal with such fishing. On the other hand, if vessels, flying the flags of non-members of a RFMO, fish in the high seas portion of the area governed by the RFMO in a manner inconsistent with the

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[16] Some of the pre-1995 RFMOs, particularly those concerned with tuna had coastal states as non-charter members. This is seen as an aberration. In the discussion to follow, every prospective New Member wil be presumed to be a DWFS. See: Lodge,et. al., 2007.

management provisions of the RFMO, such vessels are deemed to be engaging in *unregulated fishing* (FAO, *ibid*.). Unregulated fishing is a much vaguer concept than illegal fishing and does, I would suggest, reflect the influence of the lingering Freedom of the Seas principle. While unregulated fishing is deemed to be morally undesirable, it has, in the past, been unclear what RFMO members can to do curb such activities. As we shall relate, the UN, through the FAO, and the OECD are actively addressing the problem (see, for example: FAO, 2001).

One factor exacerbating the unregulated fishing problem rests in international law. A fundamental principle in international law is that an international treaty is binding, only upon those that are parties to the treaty,[17] i.e., those states that have ratified the treaty, unless the provisions of the treaty are deemed to be a part of customary international law. If the provisions are deemed to be a part of customary international law, the provisions are binding upon non-party states to the treaty, unless such a non-party state states explicitly that it will not be so bound. Thus, for example, Part V of the 1982 UN Convention – The Exclusive Economic Zone – has been declared to be customary international law. The United States, which has not ratified the 1982 Convention, deems itself to be bound by the provisions of Part V of the Convention.

Article 8(4) of the 1995 UNFSA states explicitly that only those states which are members of a given RFMO, or which agree to abide by the conservation and management measures of the RFMO (a cooperating non-member), shall have access to the fisheries resources under the governance of the RFMO. The 1995 UNFSA became international treaty law in 2001 (Munro, et. al., 2004). There is no consensus within the legal community as to whether or not the 1995 UNFSA can be deemed to be customary international law. Thus, fishing states, which have yet to ratify the 1995 UNFSA – of which there are many – can claim that they are not bound by Article 8(4) of the 1995 UNFSA.

In any event, the consequences of the uncertainty regarding the nature of unregulated fishing and of means of curbing it are clear enough. The uncertainty acts as an open invitation to free riding.

The level of game theory required in the analysis of the economics of cooperative management of shared stocks is, needless to say, substantially higher than that required for analysis of cooperative transboundary stock management. Since the level lies well

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[17] *pact tertiis nec nocent nec prosunt*

above my limited capabilities, I made a conscious effort to join forces with the members of the Helsinki School, Veijo Kaitala in particular, but also his protegé Marko Lindroos.

There now exists as well what I choose to call the Lisbon School. I have learned a great deal from the papers and articles produced by the School, by such authors as Clara Costa Duarte, Ana Brasão, M.A. Cunha-e-Sá, and Pedro Pintassilgo (who has shifted the base of his operations to Faro) (Brasão, Duarte, Cunha-e-Sá, 2000; Pintassilgo and Duarte, 2000).

I am pleased to say that I am currently co-authoring a paper with Pedro Pintassilgo and Marko Lindroos, a first version of which was presented at The 7th Meeting on Game Theory and Practice. We have now been joined by Michael Finus (Pintassilgo, Lindroos, Munro, and Finus, 2007). I am pleased, both because I have the opportunity to work with leaders in the application of game theory to fisheries economics, and because the Helsinki and Lisbon schools are joining forces. I should also add, in passing, that I have benefited greatly, as well, by working with an American applied mathematician and game theorist, Robert McKelvey.

With respect to a coalition bargaining approach to the issue at hand, this has essentially proceeded in two stages (Bjørndal and Munro, forthcoming). The first stage consists of taking a characteristic function game approach, which focusses on the fairness of the cooperative outcome, with emphasis being given to the Shapley value. It is demonstrated that, in terms of fairness, the Nash rule of dividing the cooperative surplus equally among the players is not adequate when $n > 2$ (Kaitala and Lindroos, 1998).

The limitation of the characteristic function game (c-game) approach is that it does not allow one to address the issue of free riding directly. An alternative approach, the partition function approach, does just this. It is concerned primarily with the stability of the Grand Coalition, in the face of free riding (Pintassilgo, et. al., 2007). Central to the partition function game is the concept of "externality," a concept that can readily be translated into a form that can be understood by policy makers. To quote Pintassilgo et al. (2007):

> … externalities are present, in a game in coalition form if and only if, there is at least a merger of coalitions that changes the payoff of a player belonging to a coalition not involved in the merger. If the merger increases (decreases) the

payoff of the player, the externality is considered to be positive (negative) (Pintassilgo, et al., p, 10).

Suppose that a group of states establish a RFMO. Are those states, having an interest in the relevant resources, that are left outside of the "club" made worse off (negative externality) or better off (positive externality), by the establishment of the RFMO? If the establishment of the RFMO leads to improved management of the relevant fishery resources, and if those left outside can engage in unregulated fishing, "free riding", at will, then clearly the externality is positive.

What then can the "charter" members do? They could attempt to "bribe" the outsiders to become new Members by granting allocations of the total allowable catches (TACs). This, however, can give rise to implicit "free riding," which Veijo Kaitala and I explored a decade ago (Kaitala and Munro, 1997).

Consider, for example, the case of a group of "charter" members of a RFMO undertaking to rebuild a hitherto overexploited straddling stock. They engage in a resource investment program over time. As they are about to enjoy the fruits of their investment, they are approached by a prospective New Member, which agrees to abide by the management regime of the RFMO, but which demands a pro rata share of the TAC, and thus net economic returns from the fishery free of charge. If the New Member's demands are acceded to, the New Member will be effectively free riding by enjoying a share of the return on the resource, while having borne none of the cost of the investment (Kaitala and Munro, 1997; Munro et al., 2004).

Veijo Kaitala demonstrates that anticipation of such New Member free riding could lead to "charter" RFMO members calculating that their expected cooperative payoffs would fall below their Threat Point payoffs. The RFMO would be stillborn (Kaitala and Munro, *ibid.*).

With all of this in mind, the partition function approach now allows us to analyze the internal stability, or lack thereof, of a RFMO type of coalition. Assume that the non-participants in the RFMO play as singletons. The basic condition for internal stability is then that there exists a sharing rule, such that the payoff of the coalition is not less than the sum of the singleton payoffs resulting from unilateral deviations from it (Pintassilgo, et al., 2007, p. 13). If this basic condition is not met, then effective "bribing" of those engaged in explicit "free riding" is impossible. If the "bribes" are large enough to attract prospective New Members, implicit "free riding" will undermine the RFMO.

Pintassilgo et al. investigate the internal stability of RFMO type of coalitions in the face of untrammeled unregulated fishing, assuming that the players are heterogeneous, differing in terms of fishing effort costs. If n = 2 , internal stability is ensured. If n = 3, internal stability is possible, given the right set of circumstances. If n > 3, the prospects of internal stability becomes increasingly dim, the larger is n. The typical RFMO is characterized by n >> 3.

This author and Veijo Kaitala suggested that one possible way out, to be discussed further, may be in allowing prospective “New Members” to buy their way in. The implication would be that the “charter” members of the RFMO would be granted de facto collective property rights to the fishery resources under RFMO governance. The purchase of quota scheme would obviously have to be accompanied by a punishment regime for unregulated fishing (Kaitala and Munro, *ibid*.).

Finally, a comment about discrete high seas stocks is in order. The stocks were, as noted earlier, ignored by the 1993-1995 UN Fish Stocks Conference. Munro, Van Houtte and Willmann (2004) describe them as the “orphans of the sea.” The only legal protection that they were hitherto given was through Part VII (High Seas) of the 1982 UN Convention, the same part of the Convention that proved to be so lamentably inadequate for the protection of straddling stocks.

Many of these resources have been protected by virtue of the fact that it has been uneconomic to explolit them. The history of world fisheries assures us that this protection will prove to be no more than temporary. Munro, Van Houtte and Willmann (2004) argue that, if nothing further is done, one can look forward to the fisheries based on these resources being played out as destructive competitive games. The only solution they argue is to incorporate these resources under RFMO governance. There are now signs that exactly this is beginning to take place. The South Pacific Regional Fisheries Management Organization (2007), which is now being established and which will focus on non-tuna resources, will have discrete high seas stocks under its governance.

The review is now complete. We now turn to the question of the relevance of this game theoretic analysis to the real world of policy making in internationally shared fishery resources. In the review, I have already implied that the game theoretic analysis is highly relevant. We now discuss the question more fully.

IV. The Relevance of Game Theory Analysis to Real World Policy Making in Internationally Shared Fishery Resources

I would commence by repeating the assertion that I made in an earlier part of the paper, namely that is all but impossible to analyse effectively the economics of the management of internationally shared fish stocks – be those stocks transboundary, straddling or discrete high seas – other than through the lens of game theory. I would also add that game theory analysis and concepts, applied to the management of such shared stocks, has long since moved beyond the realm of academia and appears in publications forthcoming from international bodies, such as the World Bank, the OECD and the FAO.[18]

Having said this, I want to discuss three interrelated concepts from elementary game theory, which have a high degree of relevance to real world fisheries management, but which I find to be imperfectly understood by policy makers. These are (a) the individual/sub-coalition rationality condition, (b) the Prisoner's Dilemma, and (c) side-payments. I then want to discuss two non-elementary issues, namely, (d) the relevance of the partition function game approach to the emerging RFMO regime, and (e) the question of the dynamic "resilience" of cooperative fisheries management arrangements. I will argue that the dynamic resilience question has yet to be fully explored by game theorists.

A. Individual (sub-coalition) Rationality Conditions

The Norway–FAO Expert Consultation on the Management of Shared Fish Stocks established several working groups, one which was Working Group A on Resolving Allocation Issues. In its report to the Expert Consultation plenary, Working Group A stated that it intended to list general features of the allocation issue, which it felt are not sufficiently understood in the realm of policy. One of these was:

> the basic requirement for stable long term cooperation: it has to be recognized that each and every participant in a cooperative arrangement must anticipate receiving long term benefits from the cooperative arrangement that are at least equal to the long term benefits, which it

[18] For examples see: Agüero and Gonzalez, 1996; Munro, Van Houtte and Willmann, 2004; OECD, 1997.

would receive, if it refused to cooperate. This fact, which should be obvious, is often ignored in practice (FAO, 2002, p. 8).

A particularly clear example of this obvious fact being ignored comes from the management of transboundary fish stocks – a much less formidable resource management problem than that of straddling stocks or discrete high seas stocks. The example is provided by the Canada-United States Pacific Salmon Treaty, 1985, governing the management of Pacific salmon from northern California to the Gulf of Alaska (Treaty, 1985). The Canada–US Pacific salmon fisheries game is reasonably complex. While Canada can be regarded as a single player, the United States is really a

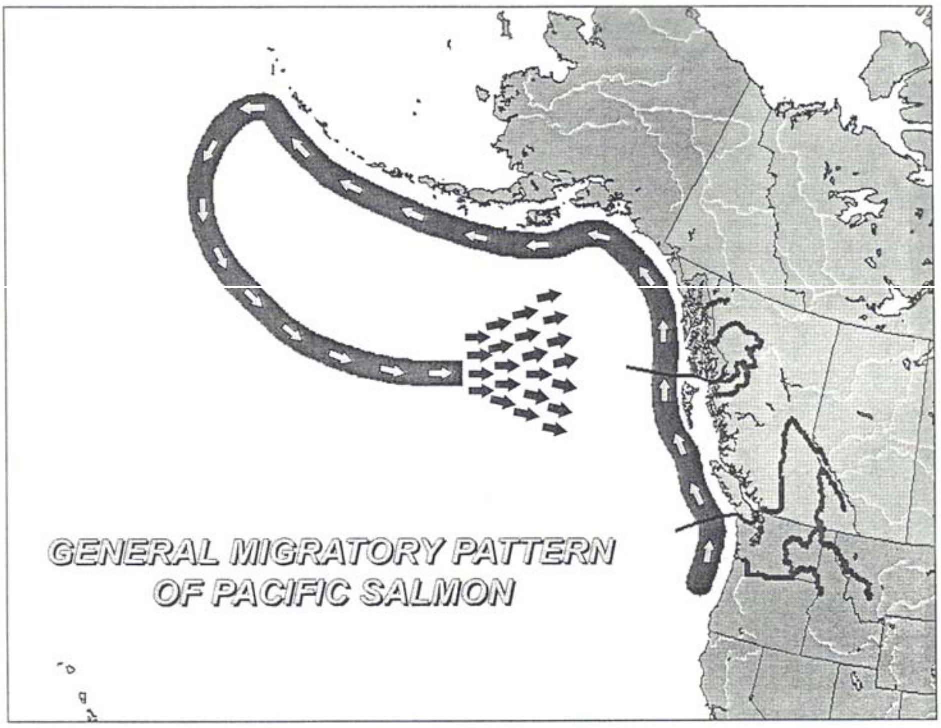

Figure 1. Source: Miller and Munro, 2004.

coalition consisting of Alaska, the combined states of Washington and Oregon, the so called Treaty Indian Tribes of Washington/Oregon and the US federal government. Bargaining, historically, has proceeded in two stages. There is a sub-game played among the players in the US coalition, followed by game between the American coalition and Canada.

Having said this, both the United States and Canada are wealthy, developed, states. Both take pride in the quality of their fisheries research and management. Finally, at the time that the Treaty was being negotiated, Pacific salmon was the most important resource for the fishing industries of the states of Oregon, Washington and Alaska, and the province of British Columbia.

After many years of painful negotiations, a treaty was concluded between the governments of Canada and the US in 1983. The treaty was blocked in the US Senate by the senior Senator from Alaska. A review of the history reveals that Alaska was quite literally worse off under the 1983 version of the treaty than it would have been in the absence of a treaty (Munro and Stokes, 1989).

Expressing outrage at the blocking of the treaty, Canada reverted to competitive behavior through deliberate overfishing, as the theory would predict. The states of Washington and Oregon, not Alaska, suffered from Canada's reversion to competitive behavior.[19] The strategy was effective. Washington/Oregon and the Treaty Tribes were compelled to re-negotiate with Alaska and "buy it off." Treaty negotiations recommenced and the treaty was ratified in 1985. The solution to the cooperative game was only temporary, however. By the early 1990s, environmental shifts had brought about a situation in which Alaska once again found itself having nothing to gain from the Treaty (Huppert, 1995).

In the early 1990s, the sub-coalitions reconfigured, with Canada entering into a de facto sub-coalition with Washington/Oregon and the Treaty Tribes. Alaska played competitively against this sub-coalition. The cooperative game crumbled. While the Treaty, in a strictly legal sense, remained in place, it entered into a state of paralysis which lasted for six years. The Prisoner's Dilemma played itself out, with damaging consequences for the resources (Miller, Munro, McDorman, McKelvey and Tydemers, 2001).

With the consequences of non-cooperation becoming increasingly evident, a series of negotiations took place, that resulted in a Canada–US Agreement being signed in 1999 to "patch up" the Treaty, which appeared to satisfy the Alaskan individual rationality condition. How stable the solution to the new cooperative game will prove to be over time remains to be seen (U.S. Department of State, 1999; Miller et al., 2001).

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[19] Canada was generally on very good terms with the states of Washington and Oregon, and the Treaty Tribes of Washington and Oregon. The Canadian strategy can be described as that of punishing one's friends.

B. The Prisoner's Dilemma

The 1982 UN Convention does, as we have pointed out, allow for the possibility that states/entities sharing a fishery resource will not be able to achieve an agreement and will, as a result, manage their segments of the resource independently, without the benefit of cooperation. While I can point to instances in which states sharing a resource have at least some degree of awareness of the consequences of non-cooperation, I have encountered other cases in which the relevant states appear to be only dimly aware of the potentially damaging consequences of non-cooperation. One gains the impression that there is comforting belief that honorable states will at least engage in tacit cooperation, if no formal cooperative mechanism is established.

An example of states being caught by surprise by the consequences of ineffective cooperation is provided by the case of the South Tasmanian Rise Trawl Fishery, the details are to be found in Munro et al., 2004. The resource is an orange roughy stock, which straddles the boundary of the Australian EEZ and the adjacent high seas. While the stock is straddling by definition, the resource was initially managed as if it were a de facto transboundary stock (Australia and New Zealand). The resource was then to show its true straddling stock nature.

Orange roughy is usually exploited during its spawning phase, when it is concentrated. It is highly valued, and is extremely slow growing. Orange roughy stocks are thus highly vulnerable to overfishing.

The Australians became aware of the resource in 1997, and saw New Zealand as the only other state likely to attempt to harvest the resource. The Australians approached their New Zealand counterparts, with the objective of establishing a cooperative management arrangement. Australia and New Zealand are both developed, and have a common cultural background, having both been former British colonies. Each country has an exemplary record of domestic fisheries management. Establishing an effective cooperative management arrangement should have been straightforward.

An agreement was put into place in late December, 1997. The implementation was, however, faulty. The first fishing season under the agreement was to commence on March 1, 1998. Allowable activities of the two fleets during the first two months were ill defined, thus creating an unplanned for window of non-cooperation. Given that the two fleets likely regarded one another with suspicion during this period and that the resource was high valued and highly vulnerable, any competent game theorist could predict what could have happened, and what in fact did.

The Australians struck first. The Australian fleet reputedly took the entire TAC agreed to under the December 1997 agreement before the March start date. The New Zealand fleet fished after the start date regardless. The next year the Australian fleet promised to behave, but the New Zealand fleet greatly exceeded its assigned share of the TAC – no surprise, given that it had been stung the previous year. The situation was further

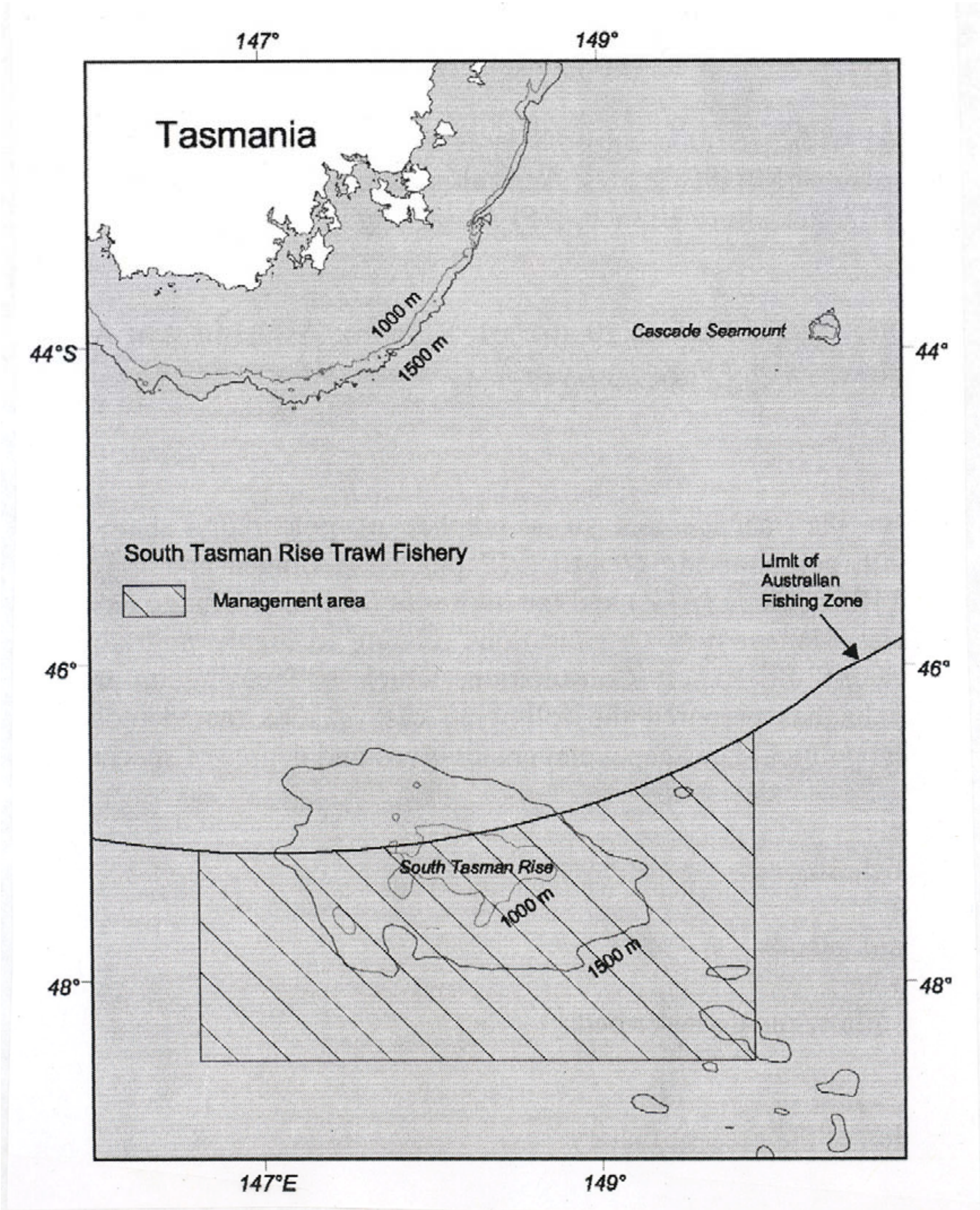

Figure 2. Source: Munro, Van Houtte and Willmann, 2994.

aggravated by unexpected free riding by a third party, in the form of South African vessels (Munro, et al., *ibid*.)

In 2000, Australia and New Zealand signed a well thought out, air tight, cooperative management agreement, which, *inter alia*, dealt with third party free riding.

Effectively, there had been a set of repeated PD games, leading ultimately to cooperation. The cooperation had, however, come too late. The resource had been heavily overfished between 1998 and 2000. Given the extremely slow growing nature of the resource, it will be a very long time before the resource recovers, if in fact it ever does (Munro et al., 2004).

C. Side Payments

Let me commence with a definition. At this stage, I define a cooperative fisheries game *without* side payments to be one in which a player's payoff from the cooperative game is determined entirely by the harvests of the player's fleet or fleets.

My perception is that that the value of side payments is gradually, but only gradually, coming to be understood by policy makers. One difficulty is with the terminology. My experience on the RFMO Panel impressed upon me the fact that to many policy makers the term "side payments" connotes bribery and corruption. A good deal of circumlocution is often required. As an example, the RFMO Panel Report reads as follows on the subject of broadening the scope for bargaining among RFMO members through the use of side payments:

> One conclusion arising from cooperative game theory with immediate appeal to common sense is that if one wishes to ensure the stability of the bargaining outcome, it is very important to keep the scope for bargaining as broad as possible. The *Report of the Norway-FAO Expert Consultation on the Management of Shared Fish Stocks* [2002] talks in terms of employing 'negotiation facilitators,' and goes on to state that, in a fisheries context, negotiations over allocations among cooperating states should not be confined to shares of total allowable catch (TAAC) alone. Cooperation can be facilitated, the *Report* argues, by supplementing such allocations with, *inter alia*, access arrangements and quota trading. (Lodge, Anderson, Løbach, Munro, Sainsbury and Willock, 2007, p. 14)

Nonetheless, there is some encouraging evidence that the message is getting through. Let two examples suffice. The first involves the Canada–U.S. Pacific Salmon

Treaty, to which reference has already been made. The fish are produced in rivers, streams and lakes. After birth, the fish go down river to the ocean, where they may live for several years. The fish are harvested as they are about to return to the fresh water habitat where the survivors spawn and die. The resource is shared by virtue of the fact that Canadian fishermen inevitably "intercept," i.e. catch, some American produced salmon, and that American fishermen inevitably "intercept" Canadian produced salmon.

The original Treaty made no provision whatsoever for side payments between Canada and the American coalition. American "interceptions" were to be strictly balanced by Canadian "interceptions." Over time, it became obvious to the naked eye that this "fish for fish" rule seriously narrowed the scope for bargaining. The 1999 Agreement, designed to repair the Treaty, to which we referred earlier, does contain provisions for side payments, although they are certainly not labelled as such. The side payments are modest, but what is important is that the precedent has been set (Miller, et al., 2001).

Another example is provided by the Pacific Island States of the Western and Central Pacific. This region has the largest stock of tropical tuna resources in the real world. The resource is both transboundary and straddling in nature.

The Pacific Island States undertook to manage their resources cooperatively in 1979, using the emerging UN Law of the Sea Convention as a framework. The tuna resources are not spread evenly throughout the region, tending to concentrate around the Equator. Two sub-coalitions emerged: the "haves," i.e. states close to the Equator, such as Papua New Guinea, and the "have nots," states more distant from the Equator, such as Fiji. There is clear evidence that there have been side-payments from the "haves" to the "have nots," with the objective of enhancing cooperation, although the term transfers, let alone side payments, has never been used (Munro, 1990; Munro et al., 2004).[20]

The Pacific Island States, along with neighbouring Indonesia and the Philippines and DWFSs operating in the region, e.g. United States and Japan, have recently

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[20] One example is provided by a treaty that the Pacific Islands signed with the United States in 1987. Under the treaty the US fleet has multilateral harvesting rights. American licence fees were to be paid into a single fund, which the Pacific Islands were to allocate among themselves. The Pacific Islands agreed that 75 per cent should be paid out on the basis of American harvests within their respective EEZs. The remaining 25 per cent was to be divided equally, without reference to American harvests. Effectively, this meant that the "have nots" would receive more than could be justified by American harvests in their EEZs. Hence, the "have nots" received implicit side payments from the "haves" (Munro, 1990).

established what is to date the largest RFMO in the world, the Western and Central Pacific Fisheries Commission (WCPFC) (see Figure 4). The WCPFC will govern the management of four tuna species : skipjack, albacore, bigeye and yellowfin. Concern

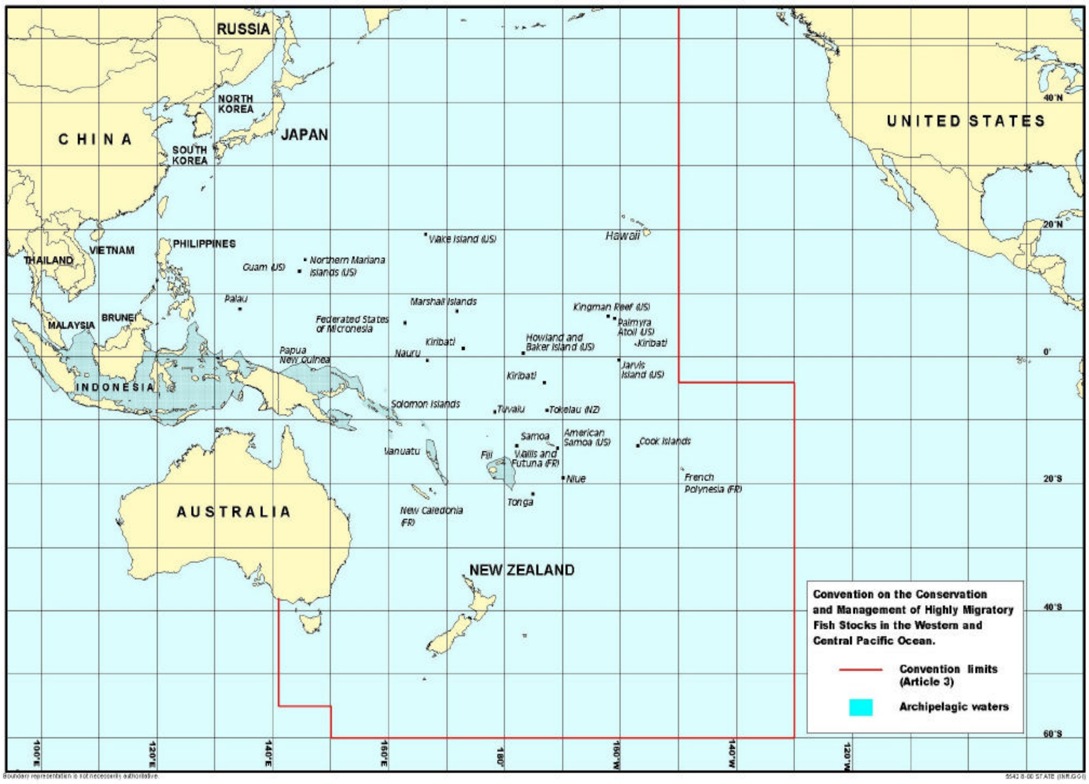

Figure 4. Source: Munro, Van Houtte and Willmann, 2004.

has been expressed about the impending state of two of these species, yellowfin and bigeye (Reid, 2006).

The Scientific Committee of the WCPFC has recommended, as one possible solution, a 15 per cent reduction in fishing effort across the board for *all* tuna species. The extensive intermingling of the tuna species (FAO, 2005) underlies this across the board recommendation.

The Pacific Island States coordinate their fisheries planning through the Pacific Islands Forum Fishing Agency (FFA). A senior economist employed by the FFA (Christopher Reid) has undertaken an assessment of the economic consequences of the Scientific Committee's proposal (Reid, *ibid*.).

The targeting of the four species is not uniform throughout the region. Reid concludes in his assessment that those vessels operating on the high seas portion of the WCPFC, DWFSs, would benefit substantially from the proposed resource investment.

The Pacific Island States, as a group, would actually suffer an economic loss. Needless to say, the Pacific Island States, if rational, would block the proposal (sub-coalition rationality). What then, asks Reid, is to be done? He responds by turning to the Report of the Norway– FAO Expert Consultation on the Management of Shared Fish Stocks, and quotes the Report verbatim on the importance of side payments ("negotiation facilitators"), Reid concludes:

> To overcome the difficulties inherent in obtaining agreement on management measures, members of the WCPFC will need to give serious consideration to the possibility of the use of "negotiation facilitators," or "side payments," in order to ensure that the costs and benefits of any such management measures are borne equitably between members (Reid, *ibid*., p. 7).

This particular case is relatively easy, in that it is one of obvious winners compensating obvious losers. Nonetheless, if the advice were to be followed, an important precedent would have been set.

A further comment is in order. Those of us who originally wrote about the value of side payments (e.g. Munro, 1979; 1987) probably wrote better than we knew. We discussed this in the context of two player games involving the management of a single species. In the RFMO regime, we have to deal with n >> 2 players. Furthermore, many cooperative fisheries arrangements are concerned, not with just one species, but several, e.g. WCPFC. If we think of a fishery resource as a "natural" capital asset, these arrangements are thus called upon to manage cooperatively a portfolio of such assets. My FAO co-author, Rolf Willmann, has asserted that, as the number of players increases, and the resource portfolio broadens, the scope for the use of side payments can be expected to increase exponentially (Rolf Willman, personal communication). I support the assertion.[21]

D. Unregulated Fishing

[21] Rolf notes that no game theorist has yet to confirm or repudiate the assertion. He is confident that some game theorist will rise to the challenge (Rolf Willmann, personal communication).

The New International Law of the Sea, as it pertains to fisheries, is not rigid and static. Rather it is in a process of evolution through state practice. Game theory analysis can contribute by helping to direct the evolution along appropriate lines. The analysis forthcoming from the application of partition function games is helping to do just this. The analysis makes it very clear that uncontrolled unregulated fishing is a severe threat to the stability of the RFMO regime. One can add that unregulated fishing and the closely related New Member problem constituted the most difficult set of problems that the RFMO Panel was called upon to address (Lodge, et al., 2007).

Action is now being taken. The FAO has put forward a Plan of Action, which is being supplemented by the OECD, to curb what it refers to as illegal, *unregulated* and unreported fishing (FAO, 2001;OECD, 2006). RFMOs are introducing punishment regimes to be applied to those engaging in unregulated fishing. One such device is the blacklisting of vessels, with the objective of denying such vessels port facilities and making it difficult for them to market their catches. This is being done without undue sensitivity towards those who have yet to ratify the 1995 UNFSA.

Two RFMOs, the Northwest Atlantic Fisheries Organization (NAFO) and the Northeast Atlantic Fisheries Commission (NEAFC) have joint black lists. A vessel that is blacklisted by NAFO is automatically blacklisted by NEAFC, and vice versa (Lodge, et al., 2007). What is wanted, of course, is a blacklisting scheme involving the cooperation of RFMOs worldwide.[22]

Another step towards the elimination of the unregulated fishing problem would be that of having the 1995 UNFSA achieve the status of customary international law. Such an achievement would work towards transforming unregulated fishing into illegal fishing.

There still remains the closely related issue of the New Member problem. RFMOs to date have, either effectively closed the door on New Members, the 1995 UNFSA notwithstanding, or have granted TAC allocations to New Members at the expense of "charter" members. Often this is done by granting allocations to New Members that are to be added to the agreed upon TAC to mask the pain to "charter" members. The masking is, of course, futile (Lodge, et al. 2005). The first approach exacerbates the unregulated fishing problem, and does so for obvious reasons. The second approach leads to the implicit free riding problem discussed earlier.

[22] See: Lodge, 2007, Ch. 5 for a full discussinof blacklisting and the measures to curb unregulated fishing.

Another approach, to which we referred at an earlier point, is the Kaitala and Munro game theory inspired proposal of enabling prospective New Members to buy or lease quota from "charter" RFMO members (Kaitala and Munro, 1997). The proposed scheme is similar to what commonly occurs in domestic fisheries with individual harvest quota schemes, in which new entrants gain access by buying quota from existing participants. The Kaitala/Munro scheme would eliminate the implicit free riding problem, without closing the door on prospective New Members.

This proposed scheme is of academic interest only, if it runs contrary to international law. Andrew Serdy, a specialist in international Law of the Seas issues, argues, in a recent article, that the proposal is fully compatible with international law. He goes further by arguing that the proposed scheme would speed the 1995 UNFSA on its way towards achieving the status of customary international law.[23]

The proposed scheme is not, however, without its complications. Kaitala and Munro demonstrate that the proposed scheme, if implemented, would throw up a host of game theoretic problems. They did not explore the problems in detail, in part because the proposal seemed slightly outlandish, a decade ago (Kaitala and Munro, *ibid*.).

E. Resilience

The final issue pertains to the dynamic resilience of cooperative fisheries management regimes through time. As we have discussed, the importance of shifting threat points over time was raised by Kaitala and Pohjola (1988), almost two decades ago. We also pointed out that their model is limited by the fact that it is deterministic.

For an example of the problem of resilience, we turn yet again to the Canada– US Pacific Salmon Treaty. When the Treaty was ratified in 1985, there was more or less balance between Canadian and American "interceptions," and the Alaskans had been placated. If environmental and economic conditions had remained unchanged through time, the Treaty would have remained stable.

Environmental conditions did not remain unchanged. What was not realized, at the time that the Treaty was ratified, was that a climate regime shift was under way. The

[23] Put the punishment of unregulated fishing and the buying of a quota together. An increase in membership of the RFMO could now be hoped to impose a negative externality upon outsiders. Balanced against the improvement of resource management would be the increased effectiveness of the punishment regime that the growth in membership would lead to combined with the possibility that those late to join would face less attractive quota prices than those early to join. This is speculation, of course Further analytical (game theoretic) work is required.

regime shift was to have a strongly negative impact on Pacific salmon stocks off southern British Columbia and the states of Washington and Oregon. The regime shift was also to have a very positive impact upon the Pacific salmon stocks off northern British Columbia and Alaska (Miller, et al., Miller and Munro, 2004).

By the early 1990s, the effects of the climate regime shift had become evident. The “interception” balance was upset, and more importantly, the Alaskan individual rationality condition was no longer satisfied. The Treaty, as we noted before, seized up.

There is no evidence whatsoever that the Alaskans cheated. The Treaty was, and is, effectively legally binding. What the experience revealed is that the disaffected player does not have to resort to cheating to de-stabilize the cooperative game. It can easily “throw sand in the gears” so that the cooperative process becomes unworkable (Miller and Munro, 2004).

The Canada – US Pacific Salmon Treaty has been “patched up” for the time being. As we noted earlier, it remains to be seen whether or not the “patched up” version survives.

Another example, involving a straddling stock, is given by the Norwegian Spring Spawning Herring stock in the North Atlantic. This stock, which historically has been one of the largest fish stocks in the North Atlantic, does, when it is healthy, migrates between Norway and Iceland. The resource crashed in the early 1970s. The remnants of the resource were confined to Norwegian waters, and were subject to a harvest moratorium. By the mid-1990s, the resource had recovered and recommenced its migratory pattern.

The resource is now subject to exploitation by Russia, the Faroe Islands and the EU, as well as Norway and Iceland. In time, a cooperative management arrangement was established under the framework of the 1995 UNFSA. The arrangement came complete with what were close to side payments, and was put forward as a model of cooperative management of a straddling stock (Munro, 2000).

The harvest allocations are based, more or less, on zonal attachments of the resource, determined by the amount, and time spent, in each player’s zone, during the resource’s migration. Norway and Russia can be seen as constituting a sub-coalition (T. Bjørndal, personal communication). The Norway/Russia sub-coalition, due either to unexpected shifts in resource migratory patterns, or faulty earlier biological research, claimed in 2002 that its share fell far short of what it’s zonal attachment dictates. It acted as if its sub-coalition rationality condition is not being satisfied (Bjørndal and Munro, forthcoming). The sub-coalition played competitively against the rest.

The cooperative arrangement remained in place, at least on paper. It was, however, effectively paralysed. There were increasing signs that the PD was beginning to raise its ugly head. The dispute was finally resolved in late 2006 – four dangerous years after the onset of the dispute (Lodge, et al. 2007).

Thus, both the Canada–US Pacific Salmon Treaty and the Norwegian Spring Spawning Herring cooperative arrangements have displayed a lack of dynamic resilience in the face of uncertainty. Working Group A of the Norway–FAO Expert Consultation on the Management of Shared Fish stocks completed its list of general features of the allocations issue that are insufficiently understood by emphasizing the importance of cooperative resource management arrangements having sufficient resilience (FAO, 2002, p. 8).

Miller and Munro (2004) argue that shocks, particularly environmental ones, can be anticipated, but they cannot be predicted. While the need for ensuring flexibility is obvious, they claim that they can obtain no clear guidance on this question from the existing literature on the application of game theory to resource management issues (Miller and Munro, *ibid*.). This author, writing three years later, still lacks such guidance. If articles, or papers, do exist providing such guidance, the author would be grateful, if they were brought to his attention.

V. Conclusions

This paper has been concerned with the relevance, if any, of game theory analysis to a specific resource management issue, namely the management of internationally shared fishery resources, particularly those to be found in the high seas. The immediate response to the question is that it is all but impossible to analyse the economics of the management of these resources other than through the lens of game theory. Strategic interaction between, and among those states sharing the resources lies at the heart of the resource management problem.

It was argued that here are several basic, indeed elementary, game theory concepts, which are of direct and immediate relevance to policy makers. It was also argued that these concepts are, as yet, imperfectly understood by the policy makers. What this requires of us is that we become effective expositors, by taking the results of our game theory analysis and expressing them in a form that can be readily understood and appreciated by the practitioners.

This is an urgent matter. The implementation of the RFMO regime, described in this paper, is an ambitious undertaking. Game theory has a great deal to say about the necessary conditions for stability of the new regime. If the regime proves, in the end, to be unstable and collapses, the consequences for world capture fishery resources, many of which are already threatened, will be severe.

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