CATCH SHARES, THE THEORY OF COOPERATIVE GAMES AND THE SPIRIT OF ELINOR OSTROM: A RESEARCH AGENDA

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Abstract

This paper puts forth the proposition that all catch share schemes should be analysed primarily through the lens of cooperative game theory, which has now been developed to an advanced degree in the analysis of international fisheries management. If the fishers in a catch share scheme are playing cooperatively, the resource managers are at the same time to be seen as playing a leader-follower game with the fishers. While the proposition obviously applies to all catch share schemes, the focus of the paper will be on ITQ schemes. The basic rudiments of the required theory are to be found in a 2006 article by Lone Krønbak and Marko Lindroos, and carry with it the spirit of Elinor Ostrom. We will argue that much more needs to be done.

We shall maintain that, if a given ITQ scheme constitutes a stable cooperative game, the various residual inefficiencies of ITQ schemes discussed in many articles should vanish. Needless to say, if a given ITQ scheme constitutes a stable cooperative game the distinction between it and other catch right schemes will blur. We shall also argue that, if ITQ schemes succeed as stable cooperative games, this will enable the fishers to bargain constructively with other stakeholders. Examples will be drawn, inter alia, from the evolving harvesting rights schemes off Canada's Pacific coast.

Introduction

Harvesting rights based management programs (catch share programs), broadly defined, are now being used increasingly in the management of intra-EEZ fishery resources, in both developed and developing fishing states. It is our contention that these programs should, to a far greater degree than they have been in the past, be analyzed by economists through the lens of game theory. In particular, we would argue for the greater use of the theory of cooperative games, which has been developed to a high degree in the analysis of the management on international fisheries (see for example, Pintassilgo et al. [1]). It is our perception that this branch of game theory has been applied but little in the analysis of the economics of the management of intra-EEZ fishery resources.[2] This is in spite of the fact that the application of even elementary cooperative game theory to the question can yield substantial insights.

The basic rudiments of what we deem to be the appropriate game theoretic approach to the economics of harvesting rights based management programs was set forth a few years ago by Kronbak and Lindroos [4] both of whom have done extensive game theoretic analyses of international fisheries management issues.[3] We shall explore the relevant part of this article at a later point. We shall then go on to emphasize that, while the Kronbak and Lindroos article is a very useful starting point, it is just that. Much more needs to be done.

Our primary motivation for emphasizing a game theoretic approach to the management of intra-EEZ fisheries management, and to the implementation of harvesting rights based schemes in particular, has come from a study that the authors (along with Colin Clark and Megan Bailey) were commissioned to undertake by the Canadian Department of Fisheries and Oceans on harvesting rights based programs employed in the management of select groundfish fisheries off Canada's Pacific coast [5]. What was envisaged by the authors of the study, very much in the spirit of Elinor Ostrom [6,7], was that of fishers playing competitive or cooperative games among themselves, but unlike Ostrom [7], of there being at the same time game between the fishers and the resource managers. The theoretical foundation was provided by the Kronbak- Lindroos model [4].

We will draw extensively upon these fisheries for examples. While the particular harvesting rights employed in the fisheries did and do consist of individual transferable harvest quotas (ITQs), we must emphasize that our concern is with harvesting rights programs in general. Having said this, the focus in our examples on ITQ schemes is useful, because the relevance of cooperative game theory to the analysis of the economics of harvesting rights schemes is least obvious in the case of ITQs.

What we shall not present in this paper is anything remotely approaching a fully developed model. Rather, what the paper offers is more in the nature of a sketch, an outline of research, that we propose should be undertaken. Nonetheless, one author (Munro) has already found the approach to be very useful as a broad framework for the discussion of harvesting rights based fisheries management programs in a textbook setting, specifically: *The Economics and Management of World Fisheries* [8].

We turn first to the Kronbak and Lindroos (K and L from hereon in) model.

The Kronbak-Lindroos Model

K and L focus on the Baltic Sea and the management of shared fish stocks, grouping the relevant national bodies into three. They are concerned with the game played among these national bodies, the game played by each of the three national bodies with their respective fishers, and finally the games played by these respective fishers among themselves. We have no interest in the games played internationally, and so focus upon the part of their article in which the national bodies form a Grand Coalition, namely Part 3, "A Centralized Authority" ([4], p.175 ff.] What is then of key interest is the games played by the authorities, or resource manager, with the fishers, and the games being played among the fishers.

K and L set up a multi-stage game. The resource managers are seen as playing a von Stackelberg leader-follower game with the fishers.[4] The fishers, in turn are seen as playing a competitive, or partially cooperative, or fully cooperative game among themselves [4].

In any event, the resource manager is to be seen as a national government body, representing the public, which has the ultimate authority to grant access to the fishery resource within national waters. The resource manager has but two instruments of control, namely the establishment of a TAC and control over fishing effort, where the objective of controlling fishing effort is to keep the actual seasonal catch from exceeding the TAC.

The TAC is established before the games commence, so that leaves the control over fishing effort as the resource manager's key, and indeed only, decision variable. Denote this key variable by Z. The control of fishing effort is, however, a costly undertaking, with the consequence, à la Sutinen and Andersen [10], that the complete prevention of TAC "overages" is seldom economically feasible.

The model is static, so that dynamic issues are basically ignored. The TAC is in some sense optimal, for reasons not given. Distributional issues are also assumed away. The objective of the resource manager is to maximize the profits of the fishers, net of control costs.[5] Finally, with regards to the fishers, each is assumed to attempt to maximize its profits. In so doing, each will assess the probability of incurring a fine for taking harvests in excess of the TAC.

Consider now Figure 1, adopted from K and L [4]. In Stage 1, with the TAC established, the resource manager determines the level of effort control, Z. In Stage 2, the fishers determine their coalition structure – fully competitive (i.e., every fisher playing as a singleton), partially cooperative, Grand Coalition – given the level of fishing effort control being applied by the resource manager. In Stage 3, the fishers determine their fishing effort level, given the chosen coalition structure.

In Stage 1, the resource manager selects Z, in full knowledge of the impact of that decision upon Stages 2 and 3. The resource manager's objective function can be expressed in the following manner. Choose Z, such that:

$$\max \pi = \sum_{i=1}^{n} P(\psi) - \frac{\gamma}{1-Z} \quad \text{s.t. to } 0 \le Z \le 1 \qquad \text{(Eq. 1)}$$

where π denotes global net economic returns from the fishery, as perceived by the resource manager; i denotes the individual fishers from 1 to n; Pi, expected profits of fisher i; ψ the probability of detection; and γ, a constant, which is the cost of management , given that $Z = 0$. There is assumed to be a one to one relationship between Z and ψ, such that, if $Z = 1$, detection is an absolute certainty, i.e. $\psi = 1$ ([4]).

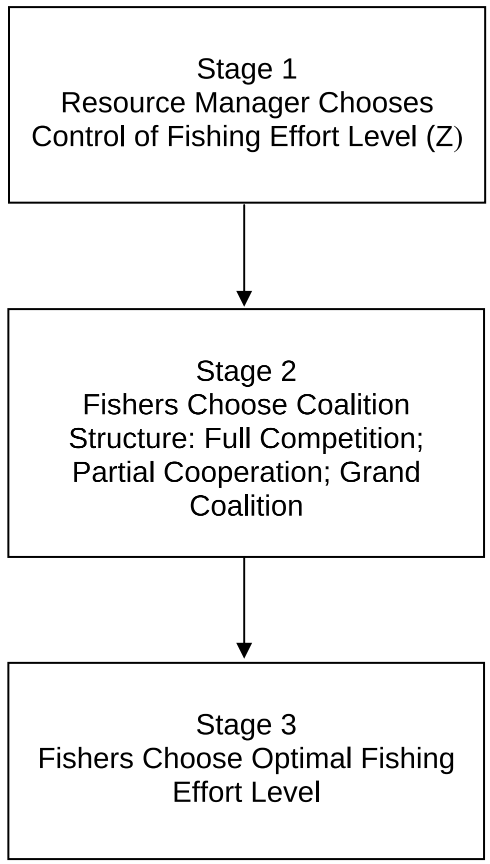

Figure 1. The Kronbak and Lindroos Three Stage Game
Source: [4]

The fishers' profits will depend, in part, upon their harvests in excess of the TAC. Such excess harvests give the resource manager negative satisfaction, which we can think of as being reflected in the term: $\frac{\gamma}{1-Z}$. We can also see this term as reflecting the trade off being faced by the resource manager. Complete elimination of TAC "overages", by ensuring complete certainty of detection, will result in: $\frac{\gamma}{1-Z} = \infty$, given that $\gamma > 0$.[6] If it were the case that $\gamma = 0$, then, of course, we would have: $Z = \psi = 1$, and perfection would reign from the perspective of the resource manager Kronbak and Lindroos [4, ibid.] The resource manager's perception of intra-TAC profits are identical to those of the fishers.

K and L next, through numerical analysis, investigate the consequences for the resource manager of the different coalition structures among the fishers. Not surprisingly, the greater the degree of cooperation among the fishers, the better it is for the resource manager. Given the assumptions of the K and L model, if the fishers form a Grand Coalition, the optimal Z is: $Z = 0$. The objectives of the Grand Coalition are seen to be the same as those of the resource manager and the fisher Grand Coalition will prove to be self enforcing.

The next question, of course, is the conditions that must be met, if the Grand Coalition, upon being formed, is to prove to be stable. If the Grand Coalition is not stable, then there will be at best partial cooperation, if not full scale competition, with all that this implies. It is at this point that the theory of cooperative games, at a really quite elementary level, can be usefully brought to bear.

Why then would the fishers in a K and L type of circumstances even consider cooperation? Elementary cooperative game theory, once again, supported by experience from international fisheries,[7] tells us that cooperation is feasible, if two pre-conditions are met, with these being that the players must be able to communicate effectively with one another, and that the players are persuaded that a potential cooperative surplus exists.

There next follows the fundamental conditions for stability of a solution to a cooperative game, coming yet again from elementary cooperative game theory. The first condition is that the solution to the game be Collectively Rational, which means simply that the solution must be Pareto Optimal. The second is that of Individual Rationality, namely that each and every player must be expect, now and all times in the future, that its payoff from the cooperative game will be at least as great as the payoff that it would expect to obtain from a competitive game.[8]

One can easily find that the Individual Rationality condition, in its original, or extended (see: n 8), form, is being violated by virtue of extensive free riding. We shall here use a broad definition of free riding to include both non-cooperative behaviour by players in the game (cheating), and enjoyment of the fruits of cooperation by non-players in the game (poaching). The difficulty of curbing free riding rises almost exponentially with the number of players in the game. K and L assume this aspect of the problem away by supposing that the number of fishers is small [4, ibid.].

In addressing the free riding issue, K and L bring to bear a decidedly non-elementary class of games that is being used with increasing frequency by both fisheries and environmental economists dealing with the management of internationally shared resources. This is a class of coalitional games referred to as partition function games. In partition function games, the payoff to a coalition (cooperating fishers) depends, not only upon the players within the coalition, but also upon the way the other players are partitioned [12]. In the case at hand, players outside the coalition are seen as playing as singletons, and thus playing against the coalition, i.e. playing as free riders [4, ibid.].

This leads to the concept of "stand alone stability" of the Grand Coalition. Whether the Grand Coalition has, or has not, achieved stand alone stability is determined as follows. First, determine the sum of the payoffs in the Grand Coalition. Then for each player calculate the payoff from free riding, given that the remaining players continue to cooperate. This free rider payoff would include, of course, the negative returns associated with punishments meted out to free riders. The Grand Coalition is then deemed to have achieved stand alone stability, if and only if, the sum of the payoffs in the Grand Coalition is at least as great as the sum of the free rider payoffs. If the sum of the Grand Coalition payoffs is less than the sum of the free riders payoffs, then there is no means of bribing would be free riders into good behaviour, regardless of the distribution scheme of the Grand Coalition payoff [4,13,1].

The K and L model provides us with a very useful starting point. It points to a way to modeling the linkage between the fishers and the resource manager, which has ultimate control over access to the resource. In addition, very much in the spirit of Elinor Ostrom [6], it stresses the critical importance of fostering and maintaining cooperation among the fishers.

Having said this, if the K and L provides us with a very useful starting point, the K and L model is just that, a starting point. Much more remains to be done. We can list some of the extensions and modifications that will have to be considered by future researchers as follows:

I. Rather than limiting the resource manager to a few instruments, think of the resource managers having a choice among management schemes, as will be illustrated in the case study to follow.

II. Obviously the multi-stage game will have to be made dynamic. One immediate consequence that follows from this is that there is another condition for the solution to any cooperative game to be stable, namely time consistency. The cooperative arrangement, or agreement, must have the resiliency to withstand unpredictable shocks [12].

III. The K and L assumption about the number of fishers has to be relaxed. One obvious question, which arises, is the number of players beyond which cooperation becomes infeasible.

IV. One has to relax the assumption that, if the fishers establish a Grand Coalition, the objectives of the fisher Grand Coalition will coincide with those of the resource manager. To take one small example, in a dynamic context there is no justification for assuming that the fishers' rate of discount will necessarily be identical to that of the resource manager.

V. Leader-follower games are normally thought of as being inherently competitive. Indeed, K and L do not even consider the possibility of leader-follower cooperation (Marko Lindroos, personal communication). As the case study to follow indicates, in the evolution of the multi- stage game over time, cooperation between leader and follower may emerge, i.e. co-management. Moreover, as in the spirit of Elinor Ostrom, the "followers" can take the initiative in developing improvements to resource management [6]. In other words the leader-follower roles can become reversed.[9]

British Columbia Groundfish Fisheries: A Case Study

We turn now to our primary example, or case study, the one that gave us the motivation to look towards a game theoretic approach towards the intra-EEZ management of fishery resources. To repeat, the authors (along with Colin Clark and Megan Bailey) were called upon to give an assessment of harvesting rights based management of fishery resources within the Pacific EEZ of Canada. Due to time constraints, the assessment was confined to three groundfish fisheries: a Pacific halibut fishery, a sablefish fishery and a very complex multi-species fishery, involving some 67 different stocks, known as the groundfish trawl fishery.

Over the period of the mid-1970s to the early 1980s, the Canadian Department of Fisheries and Oceans (DFO, from hereon in) introduced a scheme of limited entry, combined with what the authors of the report to DFO referred to as Olympics style TACs – he/she who wins the race gets the fish [5]. The limited number of fishers are expected to compete for shares of the TAC.

Return to the K and L three stage game. We can think of the resource manager (DFO) making a decision, not simply on effort control, but more importantly on the type of fisheries management scheme.

The goals of DFO were and are to ensure the sustainability of the fishery resources and to enhance the economic viability of the fisheries [5, p.1]. This meant that DFO had as its objective ensuring that the actual harvests did not exceed the TACs, but also of ensuring that the economic returns from the fisheries were not dissipated through, for example, the build up of excess capacity so typical of Regulated Open Access fisheries [15].

Within each fishery, the fishing firms were sufficiently limited that there was clear strategic interaction among them. Hence, one could talk meaningfully about fisher games in each of the fisheries.

Taking a K and L view, it could be said that in Stage 2, the coalition structure adopted by the fishers was that of full competition, i.e. what evidence that there is suggested that all of the fishers acted as singletons. The resultant competitive fisher games – Stage 3 – were, the authors of the report to DFO argue, almost text book examples of the Prisoner's Dilemma [5]. By the end of the 1980s all three fisheries found themselves in serious economic difficulties, largely through the emergence of excess capacity [5].

Return to Eq. (1), the resource manager's objective function from K and L ; namely:

$$\max \pi = \sum_{i=1}^{n} P(\psi) - \frac{\gamma}{1-Z} \quad \text{s.t. to } 0 \leq Z \leq 1$$

Munro et al. conjecture that by the late 1980s, the actual π, period after period, was negative for each of the fisheries [5, ibid.].

One can argue that, in a K and L sense, where the Z is to be seen as a measure of control over fishing capacity, as well as fishing effort, the costs of suppressing capacity growth became prohibitive at Zeds well below 1. There is, of course, nothing new, or exceptional, about this. It has been recognized by many authors, over many decades, that limited entry schemes, in which the capacity is ineffectively controlled, are to be seen as resulting in competitive fisher games, with destructive economic consequences (e.g. [15]).

A second phase to the three stage game commenced, as both the resource manager and the fishers reacted to the severe economic consequences of the limited entry combined with Olympics style TACs management scheme. In a new Stage 1, DFO retained limited entry and TACs, but abandoned the Olympics style nature of the TACs , by introducing IQs, to become ITQs, into the Pacific halibut fishery (1990) and sablefish fishery (1991), and full fledged ITQs into the groundfish trawl fishery in 1997 [5, ibid.].

The question now becomes whether the strategic interaction among the fishers is eliminated by the introduction of ITQs. In the case of the three British Columbia groundfish fisheries, Munro et al. conclude that the strategic interactions remained very much in place [5].

A commonly held view of ITQ schemes is that they involve decentralized decision making among the fishers, since, after all, the quotas are issued to individual fishers/vessel owners/companies, rather than to a collective group, as in the case of fisher cooperatives, or TURFs (see, for example: [3]). The implication is that, where strategic interaction is ongoing, the quota holders will play competitively against one another. The competition maybe more muted and constrained than it is under limited entry with Olympics style TACs, but it is competition, nonetheless. Thus, for example, if the relevant fishery resource is characterized by spatial heterogeneity, the quota holders will competitively target the most profitable patches of the resources, leading to these patches being overexploited in relative terms. Similarly habitat protection that might be economically beneficial to the ITQ holders as a group will be ignored [3, pp. 398-400].

Can, in fact, competitive ITQ holders transform their competitive game into a cooperative one, and, if they can, why should they? The answers are provided by cooperative game theory, once again at an elementary level. They can endeavour to cooperate, if they are able to communicate effectively with one another, and if free riding can be effectively constrained.

What incentive would they have to cooperate, given that cooperation is within the realm of feasibility? Once again, we turn to elementary cooperative game theory. To repeat what we said earlier, the fishers would have an incentive to attempt to cooperate, if they perceive the existence a potential cooperative surplus. Indeed, one can argue that in these circumstances, a refusal to explore the possibility of cooperation would be collectively irrational. Of course, the attempt might not succeed over time. The stability conditions must be remembered.

Munro et al. [5] looked for what evidence they could, concerning cooperation, or non-cooperation, among the three groups of ITQ holders. The evidence was, admittedly, fragmentary.[10] To begin, all three groups had established fisher associations[11] which at least indicated that communication among the different groups of fishers was occurring.

If the ITQ holders start playing a cooperative game, one would expect to see the elimination of various inefficiencies present under competition, such as the consequences of excess capacity. The reason is, quite simply, collective rationality.

One of the most important consequences, in two out of the three fisheries, of excess capacity, under the previous management regime was the rapidly declining season length. The British Columbia Pacific halibut fishery provides an example. The fishery has a maximum season length of about 250 days per year. By 1990, the season length was down to 6 days per year. After the introduction of IQs, the season length increased swiftly to the maximum [5]. This does not "prove" that cooperation among the fishers was occurring after the introduction of IQs in 1990, but the results are certainly consistent with what one would expect under cooperation.

Since the Munro et al. report was released, striking evidence of cooperation among fishers in one of the three fisheries has emerged, that being the groundfish trawl fishery. As indicated at an earlier point, this is a very complex fishery involving over 60 stocks that are harvested by a mix of mid-water and bottom trawls [5]. The bottom trawling had aroused the vigorous opposition of various environmental groups, which claimed that the bottom trawling was damaging to the habitat. Of particular concern was the impact of such trawling upon eleven coral species and three sponge species [16]. There was, in effect, a competitive game between the environmental groups and the groundfish fishers.

The cost to the industry of this competition was the bad publicity directed towards the industry by the environmental groups charging that the industry was engaging in destructive fishing practices. One member of the industry is quoted as saying: "… we know that in order to maintain and expand market opportunities, we need to provide assurances to environmental organizations, retailers and consumers that we are serious about managing and reducing our impact on ocean ecosystems" (cited in [16, p.2]). Here is a case in point in which habitat protection (or the lack thereof) has an economic impact upon ITQ holders as a group.

The groundfish trawl fishers have established an organization, the Canadian Groundfish Research and Conservation Society (CGRCS) [17] (see: n.11). The CGRCS includes in its membership relevant processors, as well as fishers.

In 2009-2010, the CGRCS entered into negotiations with a consortium of environmental groups, referred to as the Pacific Marine Conservation Caucus,[12] to resolve the habitat issue. Let the obvious be stated. Unless the members of the CGRCS were playing a stable cooperative game among themselves, meaningful negotiations with the environmental groups would have been inconceivable.

Negotiations proceeded over a two year period.[13] The official resource manager, DFO, was, of course, involved. DFO had to give its approval before negotiations could proceed, and in so doing it had to determine whether the proposed Collaboration Agreement was consistent with its own management plans. Upon giving its approval, the Department was then called upon to provide the negotiators with extensive data.

The negotiations came to a successful conclusion with the signing of the British Columbia Groundfish Trawl Habitat Conservation Collaboration Agreement (Collaboration Agreement from herein on), which was formally released in March 2012 [16].

The key objectives of the Collaboration Agreement are:

A. to reduce and manage the catch of eleven species of coral and three species of sponge.

B. to ensure that the annual fleet wide combined catch of coral and sponges does not exceed 4500 kgs, with the objective of reducing over time the combined annual catch of the eleven coral species to not more than 562 kg. and the combined annual catch of the three sponge species to not more than 322 kg. .

C. to reduce the impact of the British Columbia groundfish bottom trawl fishery on low energy and low productivity environments in deep waters off British Columbia.

D. to improve the performance of the British Columbia groundfish bottom trawl fishery against habitat criteria used to evaluate the sustainability of fisheries [19, p.2]

The allowed catches of the coral and sponge species are referred to as Habitat Bycatch Conservation Limits (HBCLs). These are to be allocated among vessels in the fishery essentially as ITQs. Vessels catching any of the designated coral or sponge species will not be allowed to retain and land their catches unless authorized by DFO to collect samples for scientific purposes [19, p. 4].

These very small HBCLs are to be allocated among some 60 active vessels. The Agreement states that: "… vessels unable to cover their coral and sponge catch with individual HBCL *will have to cease groundfish bottom trawling* [ital. ours]" [19, p. 5]. The relevant coral and sponge species can be seen as the ultimate "choke" species.

There are numerous implications and ramifications that follow from the Collaboration Agreement. First, one can regard the Collaboration Agreement as the outcome of an environmental- fisheries cooperative game, involving two sub-coalitions, the CGRCS, the Pacific Marine Conservation Caucus, and a singleton the Department of Fisheries and Oceans (DFO). To repeat our comment about the CGRCS, if one desires hard evidence of ITQ holders engaging in a cooperative game, this is it.[14]

Finally, when listing areas of future research following upon our discussion of the K and L model, we referred to the possibility of cooperation between leader and follower, and of the possibility of the leader-follower role being reversed. Here is a case in point. Clearly there was cooperation between the "leader" – DFO – and the "followers" – CGRCS. Importantly, the initiative in moving towards improved resource management – habitat protection came not from the "leader" – DFO, but rather from the "followers" – CGRCS – the spirit of Elinor Ostrom, once again.[15] At this stage, there is no game theory model, of which the authors are aware, that allows for this leader-follower cooperation and role reversal. Hopefully, future research will correct the situation.[16]

Other Harvesting Rights Programs

Up to this point, our focus has been on ITQs alone. The relevance of the K and L type of model and the theory of cooperative games to other harvesting rights schemes, such as fisher cooperatives or TURFs, is even more obvious than is the relevance of the two to ITQ schemes. Since the harvesting rights, in the case of fisher cooperatives or TURFs, are extended on a collective basis, it is self-evident that such schemes will not succeed, unless the relevant fishers are engaging in a cooperative game, and unless the solution to the fisher cooperative game is stable through time.

We should now note and stress the following. If the K and L model, with the theory of cooperative games developed for the analysis of the economic management of international fisheries, are of equal relevance to ITQ schemes and to all other harvesting rights schemes, then it follows that distinction between ITQ schemes on the one hand, and other harvesting rights based schemes on the other, blurs, indeed at times to the point of imperceptibility. If we accept what should be self-evident, namely that, under harvesting rights schemes, society is better off, if the resultant fisher game is cooperative, rather than competitive, then the question becomes which harvesting rights scheme is likely to lead to a cooperative fisher arrangement that is stable over time. The answer to the question can be expected to vary from fishery to fishery, and from time to time [8].

Conclusions

The purpose of this paper has been to put forward a suggested sketch for future research into harvesting rights schemes in both developed and developing fishing states. We have argued for a greater application of game theory than has been used in the past. We see the model of Lone Kronbak and Marko Lindroos [4] as providing a useful starting point. The authors set forth a three stage game, in which the resource manager plays a leader – follower game with the fishers, in which the fishers decide whether to play competitively, or cooperatively among themselves, and in which the fishers develop their operational plans depending upon their decision in the second stage. The only decision variable available to the resource manager, leader, is control over fishing effort. Not surprisingly, the best outcome for the resource manager is one in which there is a fisher Grand Coalition.

For future research, we envisage a model in which the choice available to the resource manager involves, not simply a few control instruments, but rather a set of management schemes, including harvesting rights schemes, which can, we contend, lead to the desired fisher Grand Coalition. Importantly, this includes ITQ schemes, even though the harvesting rights are issued on an individual, rather than on a collective, basis.

To answer the questions of what conditions must prevail to make cooperation among fishers feasible, and what conditions must prevail to ensure the stability of the fisher Grand Coalition through time, one should, we contend, bring to bear the theory of cooperative games, which has been developed and applied extensively in the analysis of the economics of the management of international fisheries. We find little evidence of the application, to date, of this branch of game theory to intra-EEZ fisheries management.

Our motivation comes from research, which the authors were called upon to undertake on ITQ fisheries, off Canada's Pacific coast. We point to evidence from these fisheries of ITQ holders establishing cooperative arrangements. In particular, we point to evidence of a group of ITQ holders, in the spirit of Elinor Ostrom, promoting on their own initiative improved resource management by negotiating a habitat protection agreement with a consortium of environmental groups, with the support and acquiescence of the resource manager. The "followers" have become "leaders". How such developments are to be modeled awaits future research.[17]

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References

[1] Pintassilgo, R., M. Finus, M. Lindroos and G. Munro 2010. Stability and Success of Regional Fisheries Management Organizations, *Environmental and Resource Economics*, vol. 46:377-402.

[2] Arnason. R. 2007. Fisheries Self-Management under ITQs, *Marine Resource Economics*, vol. 22: 373-390.

[3] Cancino, J. P., Uchida, H. and Wilen, J. E 2007. TURFs and ITQs: Collective vs. Individual Decision Making, *Marine Resource Economics*, vol. 22: 391-406.

[4] Kronbak, L. and M. Lindroos 2006. An Enforcement-Coalition Model: Fishermen and Authorities Forming Coalitions, *Environmental and Resource Economics*, vol. 35: 169-194.

[5] Munro, G.R., B. Turris, C. Clark, U.R. Sumaila and M. Bailey 2009. *Impacts of Harvesting Rights in Canadian Pacific Fisheries*, Ottawa, Fisheries and Oceans Canada, Statistical and Economic Analysis Series Publication No. 1-3.

[6] Ostrom, E., J. Burger, C. Field, R. Norgaard and D. Policansky 1999. Revisiting the Commons: Local Lessons, Global Challenges, *Science*, vol. 284: 278-282.

[7] Ostrom, E., R. Gardiner and J. Walker 1994. *Rules, Games and Common-Pool Resources*. Ann Arbor, University of Michigan Press.

[8] Bjørndal, T. and G. Munro forthcoming. *The Economics and Management of World Fisheries*,. Oxford, Oxford University Press.

[9] Mesterton-Gibbons, M. 1993. Game-Theoretic Resource Modeling, *Natural Resource Modeling*, vol. 7: 93-147.

[10] Sutinen, J. and P Andersen,. 1985. The Economics of Fisheries Law Enforcement. *Land Economics*, 61: 387–97.

[11] Munro, G., A. Van Houtte and R. Willmann 2004. *The Conservation and Management of Shared Fish Stocks: Legal and Economic Aspects*, FAO Fisheries Technical Paper 465, Rome.

[12] Bailey, M., U.R. Sumaila and M. Lindroos 2010. Application of Game Theory to Fisheries Over Three Decades, *Fisheries Research*, vol. 102: 1-8.

[13] Pintassilgo, R. 2003. A Coalition Approach to the Management of High Seas Fisheries in the Presence of Externalities, *Natural Resource Modeling*, Vol. 16: 175-197.

[14] Townsend, R., R. Shotton and H. Uchida (eds.) 2008. *Case Studies in Fisheries Self-Governance*, FAO Fisheries Technical Paper 504, Rome.

[15] Wilen, J. E. 1985. Towards a Theory of the Regulated Fishery, *Marine Resource Economics*, 1: 69-388.
[16] David Suzuki Foundation 2012. Environmentalists and Industry Develop Innovative Measures to Improve Fishery, http://www.davidsuzuki.org/media/news
[17] Canadian Groundfish Research and Conservation Society 2012. http://www.cgrcs.com
[18] Pacific Marine Conservation Caucus 2012. http://www.mccpacific.org
[19] British Columbia Groundfish Trawl Habitat Conservation Collaboration Agreement 2012. http://www.livingoceans.org.
[20] Sumaila, U.R., W. Cheung, M. Lam. D. Pauly, S. Herrick 2011. Climate Change Impacts on the Biophysics and Economics of World Fisheries, *Nature Climate Change* 1: 449-456.

Notes

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2 We can find examples of articles on harvesting rights schemes in which the theory of cooperative games is at least hinted at, e.g. Arnason, [1]; Cancino, Uchida and Wilen [2]. The operative word, however, is “hint”.
3 As is made clear in Kronbak and Lindroos [4].
4 Munro et al. [5] and Bjørndal and Munro [8] prefer to talk in terms of a Principal - Agent framework, where the resource manager, representing the public, is seen as the Principal and the fishers are seen as the Agents. There is no conflict. As Mesterton-Gibbons [9] points out, a Principal-Agent relationship can be seen as a type of leader – follower game.
5 Given, of course, that the harvest is kept within the TAC. See the comments to follow.
6 K and L do not state this interpretation explicitly in their 2006 article. Assurance has been received, however, that the interpretation is, in fact, correct (Marko Lindroos, personal communication).
7 See: Munro et al. [11].
8 If sub-coalitions are possible, then meeting the Individual Rationality condition is not sufficient. We must add that the Grand Coalition will not be stable, unless each sub-coalition is convinced that it will be at least as well off in a Grand Coalition as it would be, if it were to play competitively against the remaining players ([4], *ibid*.).
9 Towsend, Shotton and Uchida [14] present several case studies on harvesting rights schemes, in which the fishers take on significant management roles and in which , virtually be necessity, there is cooperation between followers and leaders.
10 But not trivial. See; Munro et al. [5].
11 Pacific Halibut Management Association; Canadian Sablefish Association; Canadian Groundfish Research and Conservation Society
12 Members of the Pacific Marine Conservation Caucus, [18] signatory to the British Columbia Groundfish Trawl Habitat Conservation Collaboration Agreement, are: the David Suzuki Foundation, the Living Oceans Society, the Watershed Watch Salmon Society and the World Wildlife Fund.
13 One author, Turris, works closely with the CGRCS, and was heavily involved in the negotiations leading to the signing of the Collaboration Agreement.
14 Turris (see n. 13), estimates that the body has upwards of 80 members, which raises the interesting question of how a cooperative game with such a large number of players has managed to achieve stability. Turris argues that cooperation has strengthened over time, with success leading to success. In game theoretic terms, we could say that the players collectively have perceived the cooperative surplus to be steadily increasing in size over time.
15 Turris maintains that to be fair to DFO, DFO was developing a habitat protection scheme, but that this scheme could have taken several years to put into place. Turris continues that the industry was motivated to take the lead, because it wanted to address the bad publicity issue, referred at an earlier point, as quickly as possible, and because by taking the lead, the industry would have a greater say in the protective measures put into place.

As well as the spirit of Elinor Ostrom, the perceptive reader will also detect a hint of the Coase Theorem.
16 One of the authors, Munro, has been in correspondence with Lone Kronbak and Marko Lindroos about the possibility of future collaborative work in this area.
17 One important complicating factor that could influence such developments is ongoing climate change [20].