CONSERVATION OF MIGRATORY SPECIES IN A CHANGING CLIMATE: STRATEGIC BEHAVIOR AND POLICY DESIGN

BY

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The protection of migratory animals requires cooperation among multiple decision-making entities. These may include individual resource users or property owners, different government agencies within a single national or state jurisdiction, or the governments of different sovereign nations. The fate of the migratory animals, the values accruing to the various human actors, and the costs they bear, will depend on a suite of actions taken by several independent entities at different points in space and time. No single decision maker has full control over the set of human actions that will determine the overall status of the migratory species—or even the outcomes valued by that single decision maker. Recognizing this interdependence, human decision makers will tend to behave strategically. In other words, their decisions regarding the best way to achieve their individually-valued objectives will depend on the expected actions and reactions of the other relevant actors. This interplay can take a variety of forms—ranging from individual decisions on compliance, or not, with hunting regulations as a function of the likelihood of getting caught and the severity of the resulting punishment, to the strategic positions of individual nations in negotiating treaties on habitat conservation or fishery management. The policy problem thus entails designing an appropriate set of incentives for each of the decision-making entities to channel their actions towards mutually satisfactory and environmentally-responsible outcomes. A changing climate can complicate this task by altering the migratory behavior or reproductive success of the animals that a policy or agreement is attempting to manage. This Article will survey a range of policy situations in which the efficacy of a policy, treaty or other agreement could be undermined by strategic behavior—in particular strategic reactions to the effects of changing environmental conditions.

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I. INTRODUCTION

In an increasingly human-dominated world, it may become ever more challenging to maintain the viability of migratory species and even more difficult to restore their populations to sufficient levels to support robust migrations "as phenomena of abundance."[1] As the Earth's human population continues to grow,[2] and as individuals strive to improve their living standards, there are likely to be new pressures to intensify agricultural exploitation or other human uses of the land and water on which migratory species rely. Such pressures could impair the ability of these systems to support animal migrations.[3] Climate change will create additional challenges, as warming temperatures and changing hydrologic regimes alter habitat characteristics, while potentially decoupling phenological relationships that play key roles in the dynamics of migratory populations.[4] Those same climatic changes will also affect the intensity of human demands on land and

1 *See generally* Robert L. Fischman & Jeffery B. Hyman, The Legal Challenge of Protecting Animal Migrations as Phenomena of Abundance, 28 VA. ENVTL. L.J. 173 (2010) (discussing the value of refocusing migratory animal conservation policy to foster abundance, and a describing the threats that must be addressed in order to maintain animal migrations as a phenomenon of abundance).

2 Population Div., U.N. Dep't of Econ. & Soc. Affairs, World Population Prospects: The 2008 Revision, Highlights, Working Paper No. ESA/P/WP.210, ax vii (2009), *available at* http://esa.un.org/unpd/wpp2008/pdf/WPP2008_Highlights.pdf.

3 *See generally* DAVID S. WILCOVE, NO WAY HOME: THE DECLINE OF THE WORLD'S GREAT ANIMAL MIGRATIONS 5–6 (2008) (outlining four threats to migration from human activity); David Molden et al., *Trends in Water and Agricultural Development*, *in* WATER FOR FOOD WATER FOR LIFE: A COMPREHENSIVE ASSESSMENT OF WATER MANAGEMENT IN AGRICULTURE 57, 58–60 (David Molden ed., 2007).

4 J. Michael Scott et al., *National Wildlife Refuges*, *in* U.S. CLIMATE CHANGE SCI. PROGRAM, PRELIMINARY REVIEW OF ADAPTATION OPTIONS FOR CLIMATE-SENSITIVE ECOSYSTEMS AND RESOURCES, at 5-1, 5-15 (Susan Herrod Julius & Jordan M. West eds., 2008), *available at* http://downloads.climatescience.gov/sap/sap4-4/sap4-4-final-report-all.pdf; *see* Markus Ahola et al., *Variation in Climate Warming Along the Migration Route Uncouples Arrival and Breeding Dates*, 10 GLOBAL CHANGE BIOLOGY 1610, 1610–15 (2004); Camille Parmesan, *Ecological and Evolutionary Responses to Recent Climate Change*, 37 ANN. REV. ECOLOGY EVOLUTION SYSTEMATICS 637, 642–44 (2006) (describing climate change impacts on species' phenologies).

water resources by altering the potential productivity of agricultural lands and increasing demands for irrigation water to augment yields.[5]

Following Professor Wilcove's explanation of the major anthropogenic threats to migrations,[6] Professors Fischman and Hyman describe four broad categories of threats to animal migrations.[7] These are habitat destruction, overexploitation, human-created obstacles to migration, and climate change.[8] Each of these threats exists because humans have found it advantageous to engage in activities that cause the harm, whether harm was intended or not.[9] Habitat destruction, human-caused obstacles to migration, and anthropogenic climate change all result from a long sequence of private and public decisions taken in response to economic opportunities. Examples include the efforts of public entities to provide transportation improvements,[10] and water and energy services to support economic development.[11] Overexploitation, on the other hand, is more typically the direct outcome of a competitive race to exploit common property resources in the absence of effective institutional arrangements to constrain that race. Addressing these threats will require finding both the will and the way to alter the choices that imperil the vitality of animal migrations. Two types of human choices are relevant: 1) those that are directly focused on migratory animal conservation, including the development of conservation reserves, hunting laws, and land use regulations specifically tailored to protect animals and their migratory corridors; and 2) decisions made for other purposes that entail incidental or unintentional impacts on animals and their habitats. The focus, here, is primarily on the first category of decisions, but the outcome of any given conservation policy clearly depends on a whole suite of choices in both categories, made at different points in time by different parties. This Article focuses not on the behavior and ecology of migratory animals, but rather on the behavior and interactions of humans whose individual and collective actions could either assist or impair the survival and abundance of migratory animals in a changing climate.

A central feature of the challenge of maintaining animal migrations is that effective conservation typically requires coordinated actions on the part of a variety of public and private entities.[12] These may include individual

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[5] FOOD & AGRIC. ORG., WORLD AGRICULTURE: TOWARDS 2015/2030 AN FAO PERSPECTIVE 357–74 (Jelle Bruinsma ed., 2003); Zbigniew W. Kundzewicz et al., *Freshwater Resources and Their Management*, *in* CLIMATE CHANGE 2007: IMPACTS, ADAPTATION AND VULNERABILITY 173, 191–92 (Martin Perry et al. eds., 2007), *available at* http://www.ipcc-wg2.gov/AR4/website/03.pdf.

[6] WILCOVE, *supra* note 3, at 5.

[7] Fischman & Hyman, *supra* note 1, at 183.

[8] *Id.*

[9] *See id.* at 184 (giving examples of threats such as dams, buildings, roads, and fences that were not necessarily put in place to harm migration routes).

[10] *See* WILCOVE, *supra* note 3, at 6 (explaining how a single road can eliminate a salamander population).

[11] *See, e.g.*, Fischman & Hyman, *supra* note 1, at 184 (describing how hydroelectric dams are a common obstacle to salmon migration).

[12] *See id.* at 179 ("Protecting migrations typically involves some sort of inter-jurisdictional challenge."); *see also* SCOTT BARRETT, ENVIRONMENT AND STATECRAFT: THE STRATEGY OF ENVIRONMENTAL TREATY-MAKING xi (2003) (describing the difficulties associated with

resource users or property owners, different government agencies within a single national or state jurisdiction, or the governments of different sovereign nations. No single entity has full control over the set of human actions that determine the fate of migrating animals and long-term protection of their migratory corridors. This creates an inherent interdependence among their conservation decisions—in other words, the success of actions taken by one entity depend very much on what other entities decide to do.[13]

While altruism and dedication to environmental stewardship may motivate a certain level of willingness to engage in collective efforts of preserve animal migrations, each decision-making entity also is likely to care about the particular balance of benefits and costs it expects to incur as a result of the cooperative conservation project. The theory of games—or strategic optimization—can provide useful insights regarding the effects of such interdependence on individual decisions as well as on the conditions needed to induce successful coordination of conservation actions.

Game theoretic concepts thus provide the backdrop for the following discussion of the human side of animal migration conservation. The questions to be faced include not only how to secure agreement on a desirable set of coordinated conservation actions, but also how to ensure that parties will actually carry out their obligations. A further challenge is how to ensure the continued workability of a coordinated conservation program in the face of changing conditions, including climate-driven environmental changes that might dramatically alter the effectiveness of a planned management strategy. Also relevant are socioeconomic changes that could alter the perceived net benefits of complying with an existing agreement.

II. CONCEPTS AND INSIGHTS FROM THE THEORY OF GAMES

The theory of games describes the strategizing behavior of two or more decisionmakers when their options are characterized by mutual interdependence.[14] The decision makers are called "players" and they are assumed to be self interested—in other words, each is attempting to achieve the best outcome from that player's individual perspective.[15] Game theory has been argued to be

negotiating and enforcing transnational environmental treaties); David N. Cherney, *Securing the Free Movement of Wildlife: Lessons from the American West's Longest Land Mammal Migration*, 41 ENVTL. L. 599, 612–15 (2011); David S. Wilcove & Martin Wikelski, *Going, Going, Gone: Is Animal Migration Disappearing?*, 6 PLOS BIOLOGY 1361, 1363 (2008) ("It seems reasonable to assume that the more jurisdictions a species crosses, the more difficult it is to protect.").

13 BARRETT, *supra* note 12, at 49–50.

14 *See generally* DREW FUDENBERG & JEAN TIROLE, *Introduction* to GAME THEORY xviii (1991) (exploring the aspects of game theory most useful for economic problems); Don Ross, *Game Theory*, *in* STANFORD ENCYCLOPEDIA OF PHILOSOPHY (2010) *available at* http://plato.stanford.edu/entries/game-theory/ (summarizing the philosophical and historical context of game theory).

15 FUDENBERG & TIROLE, *supra* note 14, at xviii.

> the most important and useful tool in the analyst's kit whenever she confronts situations in which what counts as one agent's best action (for her) depends on expectations about what one or more other agents will do, and what counts as their best actions (for them) similarly depend on expectations about her.[16]

In particular, mathematical models of game-playing behavior provide useful insights on how the structure of incentives inherent in a particular situation may affect the likelihood of achieving mutually satisfactory solutions to social problems.[17] By explicitly articulating the incentives facing each agent and analyzing the likely outcome of the sequence of actions and reactions available to them within the particular game setting, it becomes easier to identify how outcomes depend on the rules of play and the payoffs that a player expects to achieve from different courses of action. When the parties to a negotiation understand that dependence, they then may be able to conceive of ways to alter the structure of games in which they find themselves to achieve a superior outcome.[18]

Indeed, in the context of international environmental agreements, Professor Barrett argues that "if they are to succeed, treaties must strategically manipulate the incentives states have to exploit the environment."[19] Specifically, Barrett notes that state sovereignty means that there is no external authority that can force a nation to enter into a treaty or abide by its terms, and as a result, international agreements must be "self-enforcing."[20] In practical terms, that means that it typically will be necessary to craft the terms of an agreement to make compliance the preferred strategy for each participant.[21] He thus describes "statecraft" as the art and science of changing the rules of the game to "improve on unilateralism and make every party better off."[22]

The problem of assuring compliance with a mutually beneficial program of action is not unique to international environmental agreements. In the often-cited single-period "prisoner's dilemma" game the participants know that they will be better off if they cooperate with one another, but the rules of the game and the structure of the expected payoffs lead them inexorably to the outcome that nobody desires, with each choosing not to cooperate and thus each achieving a much lower payoff than could have been achieved if all participants had cooperated.[23] The inevitability of this outcome arises because the game is only played once. There is thus no opportunity for the players to develop mechanisms to reward one another for cooperation or to punish failures to cooperate. Even if the players in a one-shot prisoner's dilemma can communicate—and agree beforehand on what they will do—when the moment comes they are likely to break their word because none

16 Ross, *supra* note 14, pt. 1.
17 *Id.* pt. 1.
18 *Id.* pt. 2.2.
19 BARRETT, *supra* note 12, at xi.
20 *Id.* at 62–64.
21 *Id.* at 33.
22 *Id.*
23 Ross, *supra* note 14, pt. 2.4.

will trust the others to carry through, and each fears being played for a chump.[24] The only way to avoid that universally-undesired outcome is to introduce an enforcement mechanism that changes the structure of payoffs to make cooperation the best strategy for each player—in essence changing the prisoner's dilemma game into something else.[25]

Fortunately, most of the policy coordination problems relevant to protecting animal migrations are not very much like a single-period prisoner's dilemma game. In particular, they do not involve one-shot interactions with strangers who one never expects to encounter again. Rather, the decision makers whose choices will determine the sustainability of robust animal migrations may be involved in long-term ongoing relationships with one another, perhaps encompassing a variety of interactions revolving around different functions and issues.

Another difference between the policy setting for animal migration conservation and the prisoner's dilemma is that even unilateral conservation actions may, in some circumstances, yield considerable benefits to the parties undertaking those actions. Such unilateral conservation actions also could confer benefits to one's neighbors—a beneficial externality. In the absence of a coordination mechanism, such externalities wouldn't matter to a purely self-interested decision maker, and thus the level of conservation action that would be undertaken unilaterally is likely to be smaller than the level that would be jointly optimal. There would be gains to be achieved by entering into a bargain to reach the jointly optimal level of action, and game theory has a lot to say about what it takes to make such an agreement work.

The theory of games provides some useful insights relevant for animal migration conservation policymaking. The most basic insight is that if cooperation is to succeed, it must yield some aggregate net benefit—a larger pie to be shared. Another necessary condition is that a cooperative agreement must leave each player at least as well off as that player would have been in the original situation. This requirement is called the "individual rationality" constraint.[26]

There may be many possible combinations of actions (feasible solutions) that would satisfy both of those conditions, but it is important to understand that in some cases, a game may have no feasible solutions. For example, that would be the case if the potential gains from cooperation are smaller than the transaction costs that would have to be incurred to negotiate, monitor and enforce the agreement. For games that have a feasible set of mutually beneficial outcomes, some solutions will yield a larger total social gain than others. In addition, the division of the gains

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24 *Id.*

25 *See id.* pt. 2.7 (explaining that the altruistic intentions of the players may alter the payoff structure and turn what otherwise would have been a prisoner-dilemma game into a non-prisoner-dilemma game); BARRETT, *supra* note 12, at 57 (noting that a 1911 treaty "restructured the game" of seal hunting such that overharvesting was no longer an equilibrium).

26 *See* FUNDENBERG & TIROLE, *supra* note 14, at 245, 247 (explaining that the scholarly literature presumes the individual rationality constraint to be applicable except in certain situations, especially where the government can coerce individuals to participate in game theoretic situations).

among the players may vary from being equally shared to being skewed heavily in favor of one or another player. A game solution is said to be an "equilibrium" if no player would prefer to deviate from that outcome, given the choices made by the other players.[27] In some games, there may be several possible equilibrium solutions. Which solution is selected will depend on such factors as the bargaining prowess of each player and the information that each has about the structure of payoffs that all players can achieve as a result of cooperation.

Figure 1 illustrates a simple two-party game, relevant to a wide variety of cases. Payoffs are expressed in units of cardinal utility,[28] and payoffs to player 1 increase rightward along the horizontal axis, while payoffs to player 2 increase in the vertical direction. In this illustration, the "threat point" payoffs that the players could achieve in the absence of cooperation are denoted by the pairing $[U_1^o, U_2^o]$. Neither player will agree to accept less from a cooperative arrangement than it could achieve unilaterally—the principle of individual rationality. Thus, only the points within the shaded space in this figure fall within the feasible set of solutions. These are the possible pairings of the utility levels of players 1 and 2 as a function of the costs they incur to enhance the production or quality of the shared resource and the benefits they derive from that effort. Points outside of the shaded region violate one or the other player's individual rationality constraint, and some of them would yield a net social loss. The curved line represents the "Pareto boundary" of possible equilibrium solutions to the game.[29] Along the Pareto boundary it is not possible to further increase the utility of one player without harming the other.[30] In the absence of side-payments, the efficient "bargaining set" would be confined to that darkened segment of the Pareto boundary which lies between the horizontal and vertical lines passing through the threat point.

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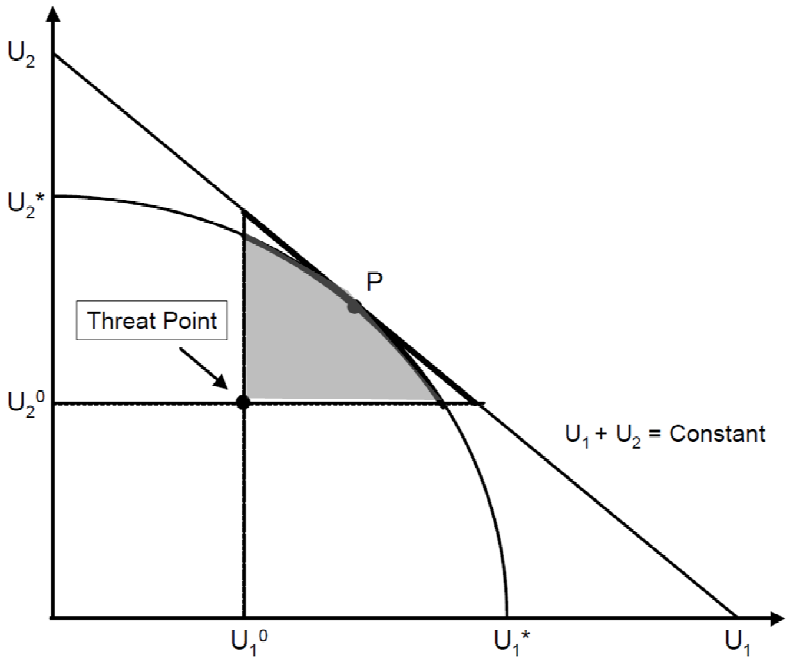
27 Ross, *supra* note 14, pt. 2.5 (explaining, for example, that the solution to the prisoner's dilemma is called the Nash Equilibrium, in which no player can improve his or her payoff given the strategies of the other players). Barrett observes that it may take several iterations of repeated play for a set of players to discover and converge on an equilibrium game solution. *See* BARRETT, *supra* note 12, at 57.

28 Economists use the concept of "utility" as a measure of individual satisfaction or psychic well-being. *See* Ross, *supra* note 14, pt. 2.1 (explaining that ordinal utility functions rank an individual's preferences without regard to differences in magnitude between those preferences, while cardinal utility functions do take magnitudes into account).

29 ORRIS C. HERFINDAHL & ALLEN V. KNEESE, ECONOMIC THEORY OF NATURAL RESOURCES 40–47 (1974) (discussing the similarity between the production and distribution pareto boundaries); *cf.* JOSEPH E. STIGLITZ, ECONOMICS 321–22 (2d ed. 1997) (providing a discussion of pareto curves in the context of economic production).

30 *See* TODD SANDLER, COLLECTIVE ACTION: THEORY AND APPLICATIONS 13 (1992).

Figure 1: Two Party Game



There is a large amount of literature on game theory describing a wide variety of game situations and applications to different policy problems.[31] Many game theoretic treatments rely on highly simplified representations of the structure of payoffs and availability of information to the players, but analyses that explore the implications of more realistic assumptions provide useful insights on conditions that can promote or inhibit cooperation.[32] Relevant factors include exactly how the payoffs to one party depend on actions taken by others; the level of uncertainty regarding the structure of payoffs and the intentions of other players; the size of the cooperative gain relative to the transaction costs of negotiating the agreement and monitoring

[31] AVINASH K. DIXIT & BARRY J. NALEBUFF, THE ART OF STRATEGY: A GAME THEORIST'S GUIDE TO SUCCESS IN BUSINESS & LIFE 64–66 (2008) (describing game theory in the context of price wars, elections, and fisheries); FUDENBERG & TIROLE, *supra* note 14, at 416–21 (describing game theory in the context of short- and long-term rental contracts); *see, e.g.*, Fanny Missfeldt, *Nuclear Power Games*, *in* GAME THEORY AND THE ENVIRONMENT 98, 98 (Nick Hanley & Henk Folmer eds., 1998) (describing game theory in the context of transboundary pollution from nuclear accidents); Andrew Schotter & Gerhard Schwödiauer, *Economics and the Theory of Games: A Survey*, 18 J. ECON. LITERATURE 479, 488–93 (1980) (describing game theory in the context of public utility pricing).

[32] *See* Ross, *supra* note 14, pt. 7.3 (noting that it is advisable for contemporary researchers using game theory to model social situations among human beings to discover the actual utility functions of the members of the community that they are studying).

compliance; and the impacts of exogenous changes (e.g., climatic variability) on the shared resource.[33]

When considering the requirements for effective international agreements, it is useful to consider in more detail the implications of state sovereignty;[34] the existence of many nations with different relationships to the animal resources in question; and the multiple fronts on which these nations interact with one another. The number of cooperating parties needed to secure meaningful cooperative gains is an especially important factor, because it is generally more difficult to achieve and maintain cooperation when many independent players are involved.[35]

In addition, Barrett further clarifies the individual rationality concept in the context of international environmental treaties, as follows:

> First, a treaty must be *individually rational.* This means that no party to the treaty can gain by withdrawing, given the choices made by every other country, and that no non-party (if any) can gain by acceding—again, given the decisions made by every other country. It also means that no party can gain by failing to comply, given the treaty's design. And it means that no non-party (again, if any) can gain by changing its behavior (by polluting more or less, say), given every other country's behavior.[36]

Uncertainty is a salient aspect of many natural resource management problems, and it can have significant impacts on both the character and outcome of play among parties who are attempting to manage their use or stewardship of the shared resource. For mathematical tractability, game theoretic models often assume that players either possess complete information, or where they don't, they at least know who knows what, and how other players form expectations when they possess incomplete information.[37] More realistic representations of real-world environmental problems recognize that players have limited ability to predict the payoffs

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[33] *See, e.g.*, Ross, *supra* note 14, pt. 5 (explaining that the models of cold war dynamics were overly simplified and ignored factors relating to the global context of the standoff between the United States and Russia).

[34] Elizabeth A. Baldwin, *Twenty-Five Years Under the Convention on Migratory Species: Migration Conservation Lessons from Europe*, 41 ENVTL. L. 535, 544 (2011) (explaining that although an international memorandum of understanding is not legally binding, it may still encourage a party with national sovereignty concerns to participate considering that it can be politically binding).

[35] Todd Sandler & Keith Sargent, *Management of Transnational Commons: Coordination, Publicness, and Treaty Formation*, 71 LAND ECON. 145, 145 (1995) ("An increase in the number of ratifiers creates a trade-off between the efficiency gains from increased participation and the opportunity to free ride by the nonparticipants. Transaction costs may also rise as the size of the ratification group increases.").

[36] BARRETT, *supra* note 12, at xiii.

[37] MICHAEL FINUS, GAME THEORY AND INTERNATIONAL ENVIRONMENTAL COOPERATION 15–16 (2001).

that would be generated by specific management actions,[38] and limited ability to predict the actions of other players.[39]

In addition, the true location of the threat point may be only hazily understood. Given such uncertainty, players may come to differing conclusions about achievable gains and the locus of the bargaining set. If their understandings don't overlap, they are unlikely to come to a satisfactory agreement. One function of the bargaining process is to reveal information about the players' valuations, allowing them to converge on a mutually beneficial solution. Information is power in that process. Thus, parties are likely to strategically conceal information on their own true valuations, or send misleading signals intended to bolster their own bargaining positions in order to secure a more favorable distribution of the ultimate gains.[40]

When negotiations on a resource management problem fail, it is sometimes possible to make progress by broadening the scope for bargaining. For example, if one party expects to benefit handsomely from a specific joint management program while a needed partner expects to incur a net cost, the former could induce cooperation by offering a side payment—either in explicit monetary form or implicitly in the form of other concessions.[41] A related tactic would be to link multiple issues together in a comprehensive balancing of concessions and gains. As noted by Professor Folmer et al.:

> An interconnected approach to an international environmental problem becomes relevant if the countries in question are also involved in other problems in which the net-benefits of cooperation are (in some sense) reversed. For instance, a country who suffers from transboundary pollution may be an important trade partner of the polluting country and could thereby offer trade concessions to induce the latter to cooperate on environmental issues.[42]

Returning to the subject of animal migration conservation, two types of cases can be distinguished. In the first type, the migratory animals are harvested and each player is interested in how many of those animals it will

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[38] Robert McKelvey et al., *Fish-Wars Revisited: A Stochastic Incomplete-Information Harvesting Game*, *in* RISK AND UNCERTAINTY IN ENVIRONMENTAL AND NATURAL RESOURCES ECONOMICS 93, 94, 98 (Justus Wesseler et al. eds., 2003).

[39] Carlisle Ford Runge, *Institutions and the Free Rider: The Assurance Problem in Collective Action*, 46 J. POL. 154, 162, 164 (1984).

[40] *See* DIXIT & NALEBUFF, *supra* note 31, at 181–83 (discussing the use of threats in bargaining); David Ettinger & Philippe Jehiel, *A Theory of Deception*, 2 AM. ECON. J.: MICROECONOMICS 1 (2010) (discussing asymmetric information in games).

[41] GORDON MUNRO ET AL., FOOD & AGRIC. ORG., FISHERIES TECHNICAL PAPER NO. 465, THE CONSERVATION AND MANAGEMENT OF SHARED FISH STOCKS: LEGAL AND ECONOMIC ASPECTS 17 (2004) (discussing the value of side payments, also called "negotiation facilitators").

[42] Henk Folmer et al., *Interconnected Games and International Environmental Problems*, 3 ENVTL. & RESOURCE ECON. 313, 315 (arguing that the practice of tying multiple issues together in a set of negotiations may be more palatable than explicit side payments, which may signify application of a "victim pays" principle).

be able to harvest—both now and in the future. Typically, it is not just the number of harvested animals that matters, but their net value after adjusting for the full cost of harvesting, including the lost future growth and reproductive potential of the harvested animals.[43] When two or more players are harvesting from the same population, the ability of each to take those future values into account is constrained by the fact that an animal that one player leaves unharvested may very well be taken by another. Each player's harvesting subtracts animal units from the common population, making them unavailable to the other players. Thus, in the absence of a mechanism to control incentives to engage in a harvesting race, the outcome is likely to be a classic "tragedy of the commons" that will tend to dissipate the potential economic value of the shared resource and may greatly reduce the size of the animal population and its resilience to other stresses.[44]

In the second type of case, the value that each player attaches to the migratory animals is derived not from harvesting, but rather from enjoyment of the aesthetic values and ecosystem services provided by the animal population. The enjoyment of such values by one party need not subtract from the enjoyment of others, and to the extent that others cannot be excluded from partaking in the benefits supplied by the resource, it would be characterized as a "public good."[45]

A. Harvesting Games

Let us start with the first type of case. One might naively assume harvesting games to be "zero-sum" with any gain to one party necessarily coming at the expense of the other. If that were the case, there would be nothing to be gained by cooperating. Obviously, if I catch a fish, it is no longer there for you to catch, but unless we are exactly identical including the detail of how many fish we have already caught, we are likely to feel differently about the value of catching that particular fish. If there is such a difference in the marginal utility (satisfaction) that two parties would derive from catching that fish, there is already a gain to be achieved by assuring that player with the higher marginal valuation actually gets the fish and then compensates the other player by an amount sufficient to make up for that party's loss of the fish.[46]

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43 COLIN W. CLARK, MATHEMATICAL BIOECONOMICS: THE OPTIMAL MANAGEMENT OF RENEWABLE RESOURCES 4–5, 26 (1976).

44 Colin W. Clark, *Restricted Access to Common-Property Fishery Resources: A Game-Theoretic Analysis*, *in* DYNAMIC OPTIMIZATION AND MATHEMATICAL ECONOMICS 117, 117–18 (Pan-Tai Liu ed., 1980); *see* Gordon R. Munro, *The Optimal Management of Transboundary Fisheries: Game Theoretic Considerations*, 4 NAT. RESOURCES MODELING 403 (1990) (discussing transboundary fish management works to create cooperation among competing interests).

45 SANDLER, *supra* note 30, at 5–6.

46 KATHLEEN A. MILLER ET AL., *The 1999 Pacific Salmon Agreement: A Sustainable Solution?*, Canadian-Am. Pub. Pol'y, Oct. 1, 2001, 2001 WLNR 12684965. This example assumes that harvesting costs do not differ across the individuals. It also can be demonstrated that differences in the technical efficiency of harvesting across different parties would affect the solution to a cooperative game. *See, e.g.*, CLARK, *supra* note 43, at 158–65.

Further gains can be achieved by retreating from destructive competitive over-harvesting of a shared resource. Cooperation can thus increase the size of the pie to be shared, and promote a higher level of satisfaction from the sharing. As previously noted, the potential for gain is a necessary first condition for a cooperative solution to a harvesting game.[47]

Looking again at Figure 1, in this case the levels of utility enjoyed by each party would be interpreted as depending on the allocation of harvests between them. The Pareto boundary has a convex shape (i.e., bulging upward at its center). Near the upper-left-hand corner of the Pareto boundary, the value to player 1 of an increment in its share of the harvest is very high, but that marginal value would tend to decline as one moves downward and to the right along the boundary. Simultaneously, the marginal value to player 2 grows, more than offsetting the former's decline. The darkened segment of the frontier satisfies the Pareto-optimal condition for a stable game solution.

Again, the threat point [U_1^o, U_2^o], represents the payoffs available to the players when they make independent and competitive harvesting decisions. The fact that it falls well below the boundary reflects the destructive effects of such competitive harvesting.

This very simple model demonstrates the existence of many joint harvesting arrangements that are preferable to the non-cooperative threat point. Which solution is achieved will depend on how the gains to each party are effectively weighted in the negotiation process. For example, if the parties' levels of well-being [U_1^o, U_2^o] are given equal weight, then there is one coordinated management arrangement which maximizes total community utility (well-being). This corresponds to the point P—the point of tangency of the Pareto boundary of the feasible solution set with a 45-degree line.[48]

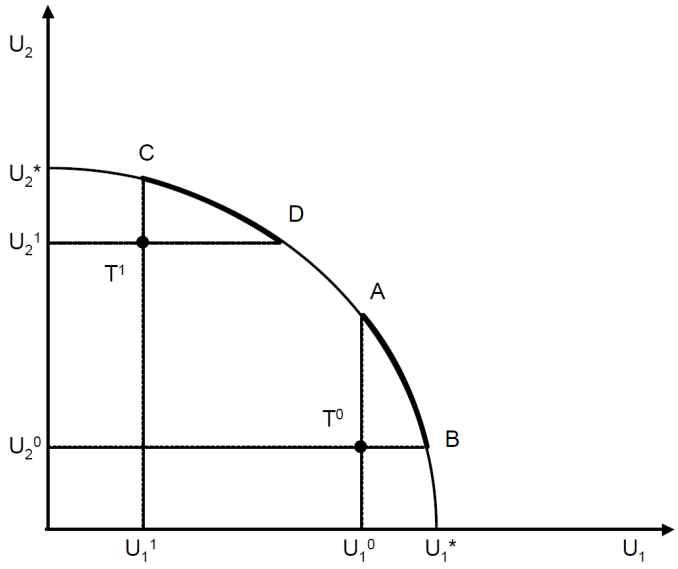
One also can use this simple model to examine the possible effects of climate change on a binational harvest sharing agreement. By altering the spatial distribution of the exploited populations, climate change could disrupt cooperation by shifting the position of the threat point. Such a situation is depicted in Figure 2. Suppose that the threat point is initially at T^o and the players have struck an agreement within the bargaining set A–B. A climatic shift then occurs that favors player 2. For example, the population's migratory pattern may have changed to increase the period of residence in player 2's territory. If this changes the position of the threat point to T^1, there is still plenty of room for mutually advantageous cooperation within the new bargaining set C–D. However player 1 might fail to recognize the shift, while player 2, believing that the new migratory pattern represents a long-term change, would no longer find the original cooperative agreement to be acceptable. That player now would expect to do better by refusing to cooperate than by adhering to the original agreement. In such a situation, renegotiation of the terms of cooperation will

47 BARRETT, *supra* note 12, at 33.

48 *See* McKelvey et al., *supra* note 38, at 96–98.

be necessary to avoid a retreat to mutually destructive competition (i.e., to the new threat point), and the likelihood of successful renegotiation will depend on whether or not the two parties come to a shared understanding of the true position of the threat point.

Figure 2: Game with Climate-Induced Shift in Threat Point



B. Issues Related to Non-Harvested Migratory Species

The issues surrounding the conservation of unharvested migratory animals are somewhat different in that the focus is not on allocation of shares of a harvested stock, but rather on allocation of responsibility for taking actions that will contribute to a public good. In broad terms, the analytics of the two types of games would be similar, but the nature of the payoffs would be different. It also is likely to be the case that the specific actions over which the players will be negotiating are somewhat more complex and multifaceted than choices about allowable harvest rates, techniques, and locations. For example, a wide range of options might be available for selection of sites to be preserved and for the design of a network of interlinked reserves along a migration corridor, which may open up numerous opportunities for making trade-offs across multiple elements of a package of conservation options. This could help to ensure that each player's individual rationality constraint is met, but it also could lead to rather protracted and complex negotiations that could eat into the aggregate gains achievable under a coordinated conservation agreement.

The prospective impacts of climate change will also create moving targets for the negotiation process. Preserving the viability and resilience of migratory species in the face of global environmental change will require

maintaining the animals' ability to move freely between favorable breeding sites and areas offering "abundant but ephemeral resources"[49] for feeding. This is difficult even in the absence of the effects of climate change, and the task is likely to become considerably more complex as climate change leads to changes in habitat characteristics and shifting migratory patterns.[50]

Professor Todd Sandler provides an informative discussion of the role of uncertainty and alternative payoff configurations in the context of games involving provision of public goods.[51] In the paper abstract he summarizes: "Factors promoting collective action at the transnational level include the removal of uncertainty, a high share of nation-specific benefits, a limited number of essential participants and the presence of an influential leader nation."[52] Each of these factors is relevant for analysis of options for promoting international cooperation on the protection of animal migrations. For example, the significance of uncertainty suggests that joint scientific research and monitoring can play important roles in maintaining cooperation. As climate change creates new uncertainties about the responses of migratory animals to evolving stresses and about the likely efficacy of specific management actions, it seems likely that transparent exchange of scientific data and collaborative research will become increasingly important.[53]

Regarding "nation-specific benefits," Sandler argues that it is important to understand whether the international coordination problem revolves around provision of "pure" public goods that "provide non-rival and non-excludable benefits to the world at large" or "impurely-public" goods having a mixture of public and private attributes.[54] Specifically, some international environmental policy problems, such as controlling greenhouse gas emissions, involve pure public goods. In those cases, the level of benefit enjoyed by each nation depends only on the aggregate contributions of all nations to its provision. Games about provision of pure public goods face significant challenges in inducing participation and rewarding performance in that it is difficult if not impossible to exclude non-participants from enjoying the fruits of others' labors. Such free-riding inhibits—and may even prevent—cooperative action, and it is thus a potentially significant hurdle to be addressed.

In other cases, the benefits enjoyed by an individual nation may have some public good attributes, but may also depend importantly on that

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49 Fischman & Hyman, *supra* note 1, at 182–83 (quoting WILCOVE, *supra* note 3, at 4).

50 *See* Parmesan, *supra* note 4, at 644–45, 648, 657 (documenting shifts in species ranges in response to warmer conditions, and giving evidence of growing temporal and spatial mismatches between blooms in prey species and the ability of migratory animals to relocate to take advantage of those blooms).

51 Todd Sandler, *Global and Regional Public Goods: A Prognosis for Collective Action*, 19 FISCAL STUD. 221, 223 (1998).

52 *Id.* at 221.

53 For a related argument, see Kathleen Miller et al., *Climate Change, Uncertainty, and Resilient Fisheries: Institutional Responses Through Integrative Science*, 87 PROGRESS OCEANOGRAPHY 338, 341–44 (2010).

54 Sandler, *supra* note 51, at 222.

nation's own investments in the shared resource. In addition, the benefits accruing to one nation may depend significantly on the actions of a specific other nation. These cases can be described by expressing benefits to each nation as a weighted function of its own and other nations' contributions to provision of the impurely-public good. For example, suppose that the benefits from protecting an animal migration could be described as follows:

$$B^i = \sum_{j=1}^{n} a_{ij} b^j$$

Where B^i denotes the benefits enjoyed by nation i; b^j is the production of benefits by nation j; and a_{ij} is the share of country j's provision received by country i.[55] If the a_{ii} term is close to one, while the a_{ij} terms are small, the benefits enjoyed by nation i would depend mostly on its own conservation investments and only slightly on the actions of other nations. Such would be the case if the most critical breeding and feeding sites are located in nation i, but a portion of the population makes short forays into the territory of a neighboring country, where losses could result from hunting or habitat destruction. If that is the case, nation i would have a relatively strong incentive to undertake conservation actions regardless of action by the other country, but also might find it advantageous to provide a side payment to the other country to encourage habitat preservation or regulation of hunting activity.

In an alternative case, the benefits accruing to nation i might depend heavily on actions taken in one or more other countries. For example, a population of migratory birds might spend part of the year in the first country, where it is highly prized by bird watchers, or where it performs important insect-control services. Its critical breeding sites, however, might be located elsewhere where the citizens may or may not especially care about the status of the population. In such a case, the likelihood of achieving a satisfactory transnational management agreement and the structure of that agreement would depend on how many countries control portions of the critical habitat, as well as their relative contributions to, and valuations of the status of the migrating population. As noted above, cooperative action is more likely if a small number of parties are involved; they are all well informed both about the dynamics of the population and about one another's perspectives; and leadership is exercised by one of the nations involved.

[55] *Id.* at 226. Notation has been slightly modified for this presentation.

III. INSIGHTS FROM CASE ANALYSES

A. North Pacific Fur Seals and Statecraft

Scott Barrett points to the 1911 North Pacific Fur Seal Treaty[56] as a stellar example of a successful international agreement to manage harvesting of a migratory species, and he uses his analysis of that case to illustrate the conditions that must be met for an international environmental agreement to succeed.[57] He identifies five key tasks that a treaty must perform if it is to improve on the consequences of unilateral action. These are:

> (1) create an aggregate gain, a reason for all countries to come to the bargaining table; (2) distribute this gain such that all countries would prefer that the agreement succeed; (3) ensure that each country would lose by not participating, given that all the other agreed to participate; (4) provide incentives for all the parties to comply with the treaty; and (5) deter entry by third parties.[58]

We begin with a brief history of the case. Industrial harvesting of Pacific fur seal (*Callorhinus ursinus*) pelts began in the late eighteenth century.[59] The pelts were a highly valuable commodity, but only a handful of nations were engaged in the harvest.[60] By the late nineteenth century the market was narrower still, with virtually all sales going to London furriers, who were able to maintain a monopoly position by closely guarding the secrets of their processing techniques.[61]

Initially, virtually all harvesting took place on land at the breeding rookeries.[62] The major breeding sites were within the national jurisdictions of Russia and the United States, but there were shifts in ownership of the rookeries as territorial boundaries changed as a consequence of the Alaska Treaty of 1867,[63] and the transfer of Robben Island to Japan in 1906 at the end of the Russo–Japanese War.[64] After short periods of destructive overexploitation, each national authority quickly developed a relatively effective set of regulations to control land-based harvesting within its jurisdiction.[65]

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56 International Convention for Protection of Fur Seals, July 7, 1911, 37 Stat. 1542.

57 BARRETT, *supra* note 12, at 19–48.

58 *Id.* at 33.

59 *Id.* at 20, 23–25.

60 *See id.* at 19, 22–23.

61 *Id.* at 38.

62 *See id.* at 19–22.

63 Treaty Concerning the Cession of the Russian Possessions in North America by His Majesty the Emperor of All the Russias to the United States of America, U.S.-Russ., Mar. 30, 1867, 15 Stat. 539; *see also* Barrett, *supra* note 12, at 22–25.

64 Barrett, *supra* note 12, at 31.

65 *See id.* at 22–25.

Fur seals, however, spend much of their time at sea, beyond the three-mile territorial waters of these nations,[66] where they were vulnerable to uncontrolled capture by other nations.[67] In particular, Canadian and Japanese harvesters engaged in highly-inefficient harvesting at sea, which resulted in sharp declines in the seal populations.[68] A number of ineffective bilateral agreements were tried[69] before the United States, Russia, Canada, Japan, and Great Britain finally signed the 1911 Pacific Fur Seal Treaty, which succeeded in performing all five of the tasks enumerated above.

It was the very inefficiency of at-sea harvesting that provided the major impetus for the cooperative solution. Harvesting on land was both cheaper and biologically more sustainable than pelagic harvesting.[70] Large aggregations of easily-herded animals at the rookeries made harvesting there trivially easy.[71] Breeding females could be protected on land, but could not be readily distinguished and protected by vessels hunting the seals at sea.[72] This differential harvesting efficiency created the potential for large aggregate gains from a cooperative agreement.

The 1911 Pacific Fur Seal Treaty banned all pelagic harvesting, and compensated the nations that had formerly engaged in that harvest with both pelts and cash.[73] Under the agreement, a set of multilateral transfers satisfied the individual rationality of each participant, distributed the benefits of the harvest in a way that all could perceive as fair, and gave them incentives to remain true to the agreement. Specifically, the United States made up-front cash payments and supplied fifteen percent of its harvested skins each to Great Britain and Japan.[74] Russia shared fifteen percent of its skins each with Canada and Japan, while Japan transferred ten percent of its skins each to the United States, Canada, and Russia.[75] "Each country was thus required by the treaty to forfeit thirty percent of its annual harvest of sealskins, provided it had a population to exploit: a bargain that was symmetric, and for that reason, fair."[76] In addition, the parties were induced to join the agreement and to honor their commitments by provisions specifying that the treaty would come into effect only when ratified by all four nations, and that the agreement would be dissolved if any country should withdraw.[77] Finally, because Great Britain represented the only market for those unprocessed furs, the treaty participants were able to deter the entry of non-participating nations by stipulating that only authenticated

66 *Id.* at 25.
67 *See id.*
68 *Id.* at 25–27, 30–31.
69 *See id.* at 28–29, 31.
70 *See id.* at 33.
71 *Id.* at 21.
72 *Id.* at 25–27.
73 *Id.* at 31–32, 34.
74 *Id.* at 34.
75 *Id.* at 34.
76 *Id.*
77 *Id.* at 35–36.

furs—harvested by one of the member nations—could be imported into the British market.[78]

B. Atlantic Bluefin Tuna

Not all efforts to cooperate on harvesting of migratory species come to such a happy conclusion. The story of Atlantic Bluefin Tuna (*Thunnus thynnus*) management stands in stark contrast to the successful Pacific fur seal case. The Atlantic Bluefin Tuna engages in long-distance migrations across the Atlantic Basin.[79] There are considered to be two stocks that intermingle on the high seas, but breed separately in the Mediterranean Sea and the Gulf of Mexico.[80] Both stocks have been heavily overharvested and have experienced sharp declines in population levels.[81] Their declining status prompted a 2009 proposal by the government of Monaco to list them as an Appendix I species under Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES).[82] Had the proposal succeeded—it did not—it would have banned international trade in the species[83]—a rather draconian step that would have eliminated the major market for these fish. Uncertainty about the impact of climate variability in driving fluctuations in the abundance of the eastern stock of Atlantic Bluefin played a role in the debate over the CITES listing proposal. Opponents of the listing cited evidence of large historical swings in abundance that could have had little to do with fishing pressure in arguing that the current downturn could be at least partly attributed to climatic factors and that "[i]t is extremely difficult to estimate the initial (unfished) stock biomass of such resources."[84]

The International Commission for the Conservation of Atlantic Tuna (ICCAT) was established in 1969 to promote conservation of tunas and tuna-

78 *Id.* at 38.

79 *See* Michael J. W. Stokesbury et al., *Results of Satellite Tagging of Atlantic Bluefin Tuna,* Thunnus thynnus*, Off the Coast of Ireland*, 582 HYDROBIOLOGIA 91, 96–97 (2007) (discussing the migratory routes of Atlantic bluefin tuna).

80 STANDING COMM. ON RESEARCH & STATISTICS, INT'L COMM'N FOR THE CONSERVATION OF ATLANTIC TUNAS, REPORT FOR THE BIENNIAL PERIOD, 2010-11: PART I (2010), at 75 (2011), *available at* http://www.iccat.int/Documents/BienRep/REP_EN_10-11_I_2.pdf.

81 Principality of Monaco, Proposal to Include Atlantic Bluefin Tuna (*Thunnus thynnus* (Linnaeus, 1758)) on Appendix I of CITES in Accordance with Article II of the Convention, at 12–13 (2009), *available at* http://www.publicintegrity.org/assets/pdf/CitesProposal.pdf (stating that the Atlantic West population was overfished during the 1970s and 1980s and that the Atlantic East population has suffered a high rate of fishing mortality).

82 *Id.* at 7; Convention on International Trade in Endangered Species of Wild Fauna and Flora, Mar. 3, 1973, 27 U.S.T. 1087, 993 U.N.T.S. 243.

83 Makato Miyake, *Why Ban of Trade in Atlantic Bluefin Tuna Now? Questions About Scientific Basis of the CITES Appendix Listing Proposal*, NEWSL. INT'L FOR CONSERVATION & SUSTAINABLE USE OF TUNAS (Org. for the Promotion of Responsible Tuna Fisheries, Tokyo, Japan), Mar. 2010, *available at* theabta.com/OP27.pdf; *cf.* Sarah M. Kutil, *Scientific Certainty Thresholds in Fisheries Management: A Response to a Changing Climate*, 40 ENVTL L. 233, 235 (2011) (stating that the Chukchi and Beaufort Seas have been proactively closed to commercial fishing to protect the ecosystem).

84 Miyake, *supra* note 83.

like species in the Atlantic Ocean and its adjacent seas.[85] However, throughout its history ICCAT has largely failed to implement and enforce effective management measures, especially for bluefin tuna—the most valuable of the approximately thirty species within its purview.[86] In the eastern Atlantic and Mediterranean, long-term overfishing has diminished the population of East Atlantic bluefin tuna to a fraction of the biomass that is considered consistent with maximum sustainable yield and stock collapse is a real possibility.[87] In addition, expanding pen-fattening and farming operations to serve the sashimi market[88] have both intensified harvesting pressure and have contributed to massive under-reporting of catches.[89] The harvesting race has been fueled by very high market prices for sashimi-grade bluefin tuna, with especially high prices for large specimens with a high fat content.[90]

A recent high-level review of ICCAT's performance chastised the commission's membership (called Contracting Parties, Cooperating non-Contracting Parties, Entities and Fishing Entities, or CPC), finding that

> ICCAT CPCs' performance in managing fisheries on bluefin tuna particularly in the eastern Atlantic and Mediterranean Sea is widely regarded as an international disgrace and the international community which has entrusted the

85 Int'l Comm'n for the Conservation of Atlantic Tuna, Introduction, http://www.iccat.int/en/introduction.htm (last visited Apr. 9, 2010).

86 INT'L COMM'N FOR THE CONSERVATION OF ATLANTIC TUNAS, REPORT OF THE INDEPENDENT PERFORMANCE REVIEW OF ICCAT 39–52 (2009) (noting that ICCAT has developed specific management recommendations for only 13 of the species within its purview); *see also* ROBIN ALLEN, FOOD & AGRIC. ORG., FISHERIES AND AQUACULTURE TECHNICAL PAPER 536, INTERNATIONAL MANAGEMENT OF TUNA FISHERIES: ARRANGEMENTS, CHALLENGES AND A WAY FORWARD 17–22 (2010) (discussing stocks managed by ICCAT).

87 ALLEN, *supra* note 86, at 20–21.

88 MAKOTO PETER MIYAKE ET AL., FOOD & AGRIC. ORG., FISHERIES AND AQUACULTURE TECHNICAL PAPER 543, RECENT DEVELOPMENTS IN THE TUNA INDUSTRY: STOCKS, FISHERIES, MANAGEMENT, PROCESSING, TRADE AND MARKETS, at 35 box 3 (2010). These operations have grown explosively in the Mediterranean since their introduction in 1997. The total capacity of the floating pens now greatly exceeds ICCAT's agreed total allowable catch (TAC) for eastern Atlantic and Mediterranean bluefin tuna. *Id.* at 35–37. The function of these operations is to increase the fat content of captured fish to augment their market value. "Juvenile or adult bluefins, which are lean in fat content, are generally captured by purse seines and kept in floating cages, fed excessively for a few months and then exported for the *sashimi* market." *Id.* at 35 box 3.

89 *See* INT'L COMM'N FOR THE CONSERVATION OF ATLANTIC TUNAS, *supra* note 86, at 44–45; ALLEN, *supra* note 86, at 20–21.

90 For price information, see MIYAKE ET AL., *supra* note 88, at 67 fig.38, which shows an upward trend in wholesale prices for frozen bluefin tuna in Japan's main fish market, with average prices since 2008 in the range of $35–$40 (US) per kilogram. A National Geographic website reports that: "In January 2001, a prime, 444-lb (201-kg) bluefin tuna sold in a Japanese fish market for $173,600 (¥20.2 million), a world record." Nat'l Geographic, Atlantic Bluefin Tuna: *Thunnus thynnus*, http://animals.nationalgeographic.com/animals/fish/bluefin-tuna.html (last visited Apr. 9, 2011).

> management of this iconic species to ICCAT deserve better performance from ICCAT than it has received to date.[91]

The large number of fishing nations included in ICCAT's membership is one of the significant factors behind the organization's inability to achieve cooperation.[92] As is the case for other international Regional Fishery Management Organizations (RFMOs), ICCAT does not have direct authority to control harvesting activities, but rather provides a forum for member nations to develop recommended management measures that they each agree to implement.[93] In ICCAT's experience, even when management measures have been agreed, widespread failure to comply with the rules has allowed competitive overharvesting to continue almost unabated.[94] In laying blame at the doorstep of the CPCs, the Independent Review concludes that

> the Panel is of the view that rather than ICCAT failing in its mandate it is ICCAT that has been failed by its members (CPCs). Most of the evidence available to the Panel is that ICCAT has with a few exceptions, adopted in its basic texts and recommendations generally sound approaches to fisheries management. However this has been undermined by systemic failures by CPCs to implement such rules and recommendations.[95]

This conclusion is supported by a recent report by the International Consortium of Investigative Journalists, which argues that "behind the plummeting stocks is a decade-long history of rampant fraud and lack of official oversight. Each year, thousands of tons of fish have been illegally caught and traded. At its peak—between 1998 and 2007—this black market included more than one out of every three bluefin caught."[96] The Independent Review Panel made a number of recommendations to

91 INT'L COMM'N FOR THE CONSERVATION OF ATLANTIC TUNAS, *supra* note 86, at 2. ICCAT has a total of 46 contracting parties and 3 cooperating non-contracting parties. *Id.* at 6.

92 *Id.* at 7 (noting that the logistics of coordinating communication with such a large number of CPCs is a significant challenge).

93 *See* MUNRO ET AL., *supra* note 43, at 37–42 (discussing the role and powers of Regional Fishery Organizations).

94 The high market value of bluefin tuna also creates powerful incentives to cheat on agreements. *See, e.g.*, Marina Walker Guevara et al., *The Black Market in Bluefin: How a Runaway Fishing Industry Looted the Seas of Tuna*, *in* INT'L CONSORTIUM OF INVESTIGATIVE JOURNALISTS, LOOTING THE SEAS: A GLOBAL INVESTIGATION 2, 4, 7 (2010), *available at* http://www.publicintegrity.org/treesaver/tuna/# (last visited Apr. 9, 2011).

95 INT'L COMM'N FOR THE CONSERVATION OF ATLANTIC TUNAS, *supra* note 86, at 2.

96 Guevara et al., *supra* note 94, at 2. Other estimates of the extent of illegal, unregulated and unreported (IUU) harvesting of eastern Atlantic and Mediterranean bluefin tuna are similar. ALLEN, *supra* note 86, at 21 ("In 2008, the SCRS estimated total catches of 50,000 tonnes for 2006 and 61,000 tonnes for 2007 compared with reported catches of 30,647 tonnes for 2006 and 32,398 tonnes for 2007. In its comment on the effect of management regulations, the SCRS concluded its advice with 'Based on the Committee's analysis, it is apparent that the TAC is not respected and is largely ineffective in controlling overall catch . . . .'"). SCRS refers to ICCAT's Standing Committee for Research and Statistics, and TAC refers to the total allowable catch as agreed by ICCAT's member nations. CONSERVATION OF ATLANTIC TUNAS, GLOSSARY OF FISHERY TERMS, INT'L COMM'N FOR THE 15, 18 (2000) *available at* http://www.iccat.int/en/iccatmanual.asp?mid=5 (click on download link for "A7. Glossary of ICCAT Terms").

strengthen ICCAT's ability to enforce management measures, including providing for stringent penalties for failure to enforce quotas and accurately report harvests, [97] but is unclear if such measures stand much chance of being adopted in the absence of a dramatic stock collapse or concerted citizen pressure on member governments. ICCAT introduced a Bluefin Catch Document Scheme in 2008 which requires that a tag be attached to each harvested fish.[98] The tag is intended to provide a fully traceable record from point of capture to point of sale.[99] While the system could theoretically short-circuit the black market, numerous holes in documentation have been uncovered.[100] A hopeful sign is that non-governmental organizations—including the above-mentioned investigative journalists and international environmental groups—have entered the fray and are applying pressure on the governments of fishing nations, including the government of Japan—the major market for Atlantic bluefin tuna—to implement more effective control measures.[101] In game-theoretic terms, such third-party "naming and shaming" activity can act to alter players' perceived payoffs in ways that would make cooperative conservation more likely.[102]

C. Eastern African Wildebeest Migration

An interesting asymmetric game concerning conservation of largely-unharvested migratory animals is currently playing out in eastern Africa where the nations of Tanzania and Kenya are facing off over the proposed construction of a road that could imperil a phenomenon regarded as the world's last "Great Migration."[103] This annual spectacle involves the mass movement of over 1 million wildebeest (*Connochaetes taurinus*), 200,000 zebra (*Equus burchelli*), 18,000 eland (*Taurotragus oryx*), and 500,000 Thompson's gazelle (*Gazella thomsoni*), as well as associated predators that prey on the hoofed migrants through a grand circuit in northern Tanzania and the southwest corner of Kenya.[104] The annual journey begins in Tanzania, where the wildebeest and other grazers follow seasonal moisture and nutrient gradients, moving through several protected areas in the Serengeti

97 INT'L COMM'N FOR THE CONSERVATION OF ATLANTIC TUNAS, *supra* note 86, at 4.

98 *See id.* at 26.

99 *See id.*

100 *See id.* at 27; Guevara et al., *supra* note 94, at 2.

101 *See* Guevara et al., *supra* note 94, at 6; *see also* PEW ENV'T GROUP, CITES PROPOSAL 19: ATLANTIC BLUEFIN TUNA (2010), *available at* http://www.pewtrusts.org/uploadedFiles/wwwpewtrustsorg/Fact_Sheets/Protecting_ocean_life/English_CITES_tuna_prop19.pdf?n=5396 (explaining that listing the Atlantic bluefin tuna on Appendix 1 of CITES would prohibit international trading of the fish).

102 DAVID HUNTER ET AL., INTERNATIONAL ENVIRONMENTAL LAW AND POLICY 137 (3d ed. 2007).

103 Jeffrey Gettleman, *Proposed Serengeti Highway Is Lined with Prospects and Fears*, N.Y. TIMES, October 31, 2010, at A6; Paul Wafula, *Controversy over Serengeti Road Plan Deepens*, BUS. DAILY, October 7, 2010, http://www.businessdailyafrica.com/Corporate+News/Controversy+over+Serengeti+road+plan+deepens/-/539550/1027510/-/item/1/-/t4nj/-/index.html (last visited Apr. 9, 2011).

104 Mara Conservancy, The Greatest Show on Earth, http://www.maratriangle.org/wildebeest-migration/ (last visited Apr. 9, 2011).

ecosystem.[105] At the start of the dry season, the animals move north into Kenya's water-rich Maasai Mara.[106] Three months later, the wildebeest assemblage journeys southward back into Tanzania.[107]

The wildebeest migration attracts several hundred thousand tourists to East Africa each year, providing an important source of income for both Tanzania and Kenya. It is estimated that tourism accounted for approximately fifteen percent of both countries' GDPs in 2007, providing revenues of nearly $4 and $2.7 billion annually to Kenya and Tanzania, respectively.[108] While this ecotourism income is important to both countries, there are differences in what it costs each country to preserve this migration. Specifically, Kenya's Maasai Mara covers only five percent of the wildebeest's range area and occupies a small corner of Kenya, while Tanzania hosts the remainder of the habitat.[109] In addition to management expenses that Tanzania incurs for its Serengeti National Park and the adjacent protected areas traversed by the migrating herds, Tanzania argues that the absence of roads in the area imposes significant costs on its citizens in the form of limited access to convenient transportation routes.[110]

To remedy that problem, Tanzania's government recently announced plans to build a road to connect a remote area near Lake Victoria with the rest of the country, bisecting thirty miles of a key migratory corridor (Figure 3).[111] Similar plans had been proposed in the past and rejected due to expected environmental impacts including increased poacher access, introduction of invasive species, and direct interference with the migration.[112] A key concern is that the danger posed by the migrating animals to human travelers would require fencing, which could isolate the wildebeest from food and water sources and lead to massive die-offs.[113] Scientists estimate that the road could reduce the wildebeest population from its current level to fewer than 300,000 animals.[114]

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105 *See generally* Ricardo M. Holdo et al., *Opposing Rainfall and Plant Nutritional Gradients Best Explain the Wildebeest Migration in the Serengeti*, 173 AM. NATURALIST 431 (2009) (discussing wildebeest migration and its possible drivers, including seasonal rainfall and fertility gradients).

106 A. R. E. Sinclair et al., *Historical and Future Changes to the Serengeti Ecosystem*, *in* SERENGETI III: HUMAN IMPACTS ON ECOSYSTEM DYNAMICS 7, 23–24 (A. R. E. Sinclair et al. eds., 2008).

107 *Id.*

108 World Travel & Tourism Council, Economic Data Search Tool, http://www.wttc.org/eng/Tourism_Research/Economic_Data_Search_Tool/ (for Step 1 select "Countries" then "Sub-Saharan Africa" then "Kenya" and "Tanzania"; for Step 2 select "Travel & Tourism Total Contribution to GDP"; for Step 3 select "US$ bn" and "% share"; for Step 4 select "From 2000 to 2007") (last visited Apr. 9, 2011).

109 *See* Sinclair et al., *supra* note 106, at 9, 11.

110 Simon Thirgood et al., *Who Pays for Conservation? Current and Future Financing Scenarios for the Serengeti Ecosystem*, *in* SERENGETI III: HUMAN IMPACTS ON ECOSYSTEM DYNAMICS, *supra* note 106, at 443, 448–51; Gettleman, *supra* note 103, at 6.

111 Gettleman, *supra* note 103, at 6.

112 Olivia Judson, Op-Ed., *Road Kill in the Serengeti?*, N.Y. TIMES OPINIONATOR, Jun. 15, 2010, http://opinionator.blogs.nytimes.com/2010/06/15/road-kill-in-the-serengeti/ (last visited Apr. 9, 2011).

113 *Id.*

114 Andrew P. Dobson et al., *Road Will Ruin Serengeti*, 467 NATURE 272, 272 (2010).

The road was a campaign promise from President Kikwete to rural communities, and if built, it would connect these communities with new economic development opportunities.[115] Another possible motivation for the road is a recent discovery of a gold deposit near the Serengeti, expected to produce 4000 ounces of gold annually for twenty years.[116] The road is expected to cost about $500 million.[117]

Several environmental organizations have proposed an alternate route that would bypass the Serengeti ecosystem to the south of the park, adding about 250 miles to the proposed route, but linking the same regional centers and serving about five times the rural populations.[118] This alternative would effectively address Kenya's concerns about ecotourism, but would add additional construction costs, and would lengthen travel-times for many of the proposed beneficiaries of the road project. Other possible alternatives include building overpasses and underpasses, which have been used to help animals cross roads in other migratory corridors.[119] These technical solutions would add significant expenses to a road construction project, and it is not clear that they would be feasible for the wildebeest migration, given the sheer number of wildebeests and other animals that would need to cross the road. These solutions also do not address all of the significant conservation concerns with the road, such as the increased risk of poaching, development in the park, and the introduction of invasive species.

Both countries stand to lose ecotourism income if the currently proposed road is built, but this contest is marked by asymmetries in expected payoffs, access to information, and power to affect the outcome. Kenya would likely experience substantial losses if Tanzania presses forward with the current plan, while it appears that Tanzania expects the economic development benefits of the road to more than offset its loss of tourism dollars. Tanzania possesses the overriding power in this conflict—it has the unilateral ability to choose whether or not to build the road and where to put it. Kenya's ability to influence that decision is relatively limited, but includes the option of offering a monetary payment to its neighbor for selecting the less damaging route.

The size of the side payment that Kenya would need to make is not entirely clear. At a minimum Tanzania could demand compensation for additional construction costs and for the additional inconvenience to its citizens from the longer alternative route—minus adjustment for the fact that the longer route would likely avoid loss of its own tourism income. One

115 Gettleman, *supra* note 103, at 6.

116 Kipchumba Kemei, *Gold Mining in the Mara, a Threat to Tourism-Experts*, STANDARD (KENYA), Sept. 14, 2010, http://www.standardmedia.co.ke/InsidePage.php?id=2000018358&cid=4 (last visited Mar. 8, 2011).

117 Gettleman, *supra* note 103, at 6.

118 *E.g.*, Zoologische Gesellschaft Frankfurt (Frankfurt Zoological Soc'y), The Proposed Serengeti Commercial Road (Jun. 15, 2010), http://www.zgf.de/?id=61&language=en &reportId=137 (last visited Apr. 9, 2011).

119 *See* Rodney van der Ree et al., *Overcoming the Barrier Effect of Roads–How Effective are Mitigation Strategies?*, 2007 PROC. INT'L CONF. ECOLOGY & TRANSP. 423, 424, 427 (C. Leroy Irwin et al. eds., 2007).

would call this hypothetical minimum payment Tanzania's willingness to accept (WTA). But uncertainty prevails—Kenya does not know Tanzania's WTA and Tanzania is not likely to reveal the minimum payment that it would accept for choosing the road option preferred by Kenya. Rather, as the power-holder in the negotiations, it would be to Tanzania's advantage to play up its threat to proceed as planned, because by making the threat credible, it will likely capture a larger share of the gains from an eventual cooperative solution.[120] Given the size of Kenya's potential losses, Tanzania could potentially extract a side-payment for accepting the alternate route well in excess of its minimum WTA. Of course, Kenya's maximum willingness to pay (WTP) to avoid damage to the migration and the resulting loss of ecotourism income is also unknown to its neighbor, so the negotiation process is likely to entail some jockeying back forth—each side probing the other to discover just where a bargain might be struck.

Another twist in this story is that Kenya is not the only potential loser. There is a large international community that values the existence and vitality of the wildebeest migration. This community cares about the outcome of the road dispute and may be willing to use both sticks and carrots to convince Tanzania to accept the alternative, less environmentally-damaging proposed route. For example, ecotourism interests could potentially mount a travel boycott against Tanzania, or alternatively, foreign governments and NGOs might offer to cover part or all of the additional costs of the preferred road option. Such actions would change Tanzania's expected payoffs from its alternative courses of actions. In addition, it would be to Kenya's advantage to convince these potential foreign donors to step up and shoulder a major share of any side-payment to Tanzania.

Given the fact that there is considerable uncertainty about what each country stands to gain or lose from the alternative road development proposals, it may be advantageous for both countries to delay a resolution and advertise the threat to the global community in order to muster substantial external contributions for the environmentally-preferable alternative. At present, it is not clear how Tanzania and Kenya will resolve their differences and what the solution will mean to the future of the wildebeest migration. It is likely, however, that the international community's involvement will play a role.

One issue that has not yet received much attention is the extent to which climate change might alter the environmental conditions that drive the wildebeest migration. If so, would that appreciably alter the migration route, the size of the herds involved in the migration, and the potential impacts of either of the road placement alternatives? Those are the types of questions that a functional cooperative process would need to consider.

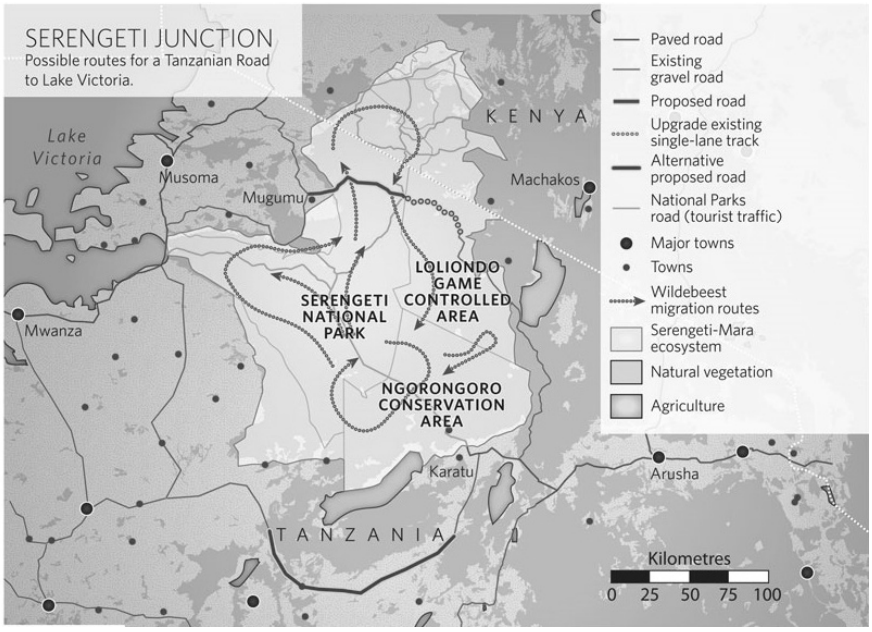
120 *See* DIXIT & NALEBUFF, *supra* note 31, at 192–93 (discussing the advantages that threats offer in negotiations).

IV. CONCLUDING THOUGHTS

These cases demonstrate the complexity of policymaking for animal migration conservation, especially when multiple sovereign nations would need to take action to ensure protection of the animals and their habitats. Even in the absence of the complications posed by the impacts of climate variability and climate change, environmental statecraft is difficult—requiring both art and science. Insights from the theory of games can help negotiators to understand the challenges that need to be addressed and potential avenues for their resolution. As Barrett notes, the ingredients for a successful environmental agreement include focusing on provisions designed to yield net gains to the participants; distributing those gains in a way that all perceive as fair; providing incentives to make participation in the agreement and compliance with its terms the best strategy for all relevant parties; and ensuring that the gains from cooperative action cannot be undermined by the actions of non-participants.[121] This is a tall order even under stable environmental conditions. When considering the further challenges posed by environmental variability and the prospective effects of climate change, we can add one more element to this order—specifically, that there must be a fair and flexible mechanism for modifying agreed management plans in response to changing conditions and new information. This will require transparency about both the process and the information upon which management revisions will be based. In providing that transparency, collaborative multinational scientific research programs will need to play an increasing role.

121 *See* BARRETT, *supra* note 12, at 33.

Figure 3: Map of the wildebeest migration, proposed road, and alternate route.



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