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GAME THEORY, INTERNATIONAL LAW, AND FUTURE ENVIRONMENTAL COOPERATION IN THE MIDDLE EAST

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I. INTRODUCTION

Interdependence is an underlying factor within numerous transnational environmental systems. This interdependence generates an interactive decision-making setting in which a state's choice of action is contingent upon the expected behavior of other actors in the international arena. National decision-makers are aware that the quality and quantity of essential environmental resources available in their territories is determined not only by natural factors and their own behavior, but by the actions of other states.

Attaining optimal results in an interactive situation frequently requires "collective action." Collective action occurs when the efforts of two or more individuals are needed to achieve a certain outcome, one which will typically further the interests or well-being of the group.[1] In terms of *Pareto Optimality*,[2] the course of action which leads to the best outcome for the group is cooperative behavior. The main problem with collective action occurs when a rational individual's behavior leads to *Pareto inferior* outcomes. This phenomenon often happens in large groups and in situations in which all individuals agree about the common good and the desirable means of achieving it.[3]

In his seminal book, "*The Logic of Collective Action*", Mancur Olson rigorously presents the basic proposition that rational self-interested individuals frequently will not act in concert to achieve common interests.[4] The negative repercussions of Olson's proposition for international environmental cooperation increases together with the ratio of inter-state environmental independence. While environmental interdependence has long been apparent in the international arena, it has become increasingly prevalent in recent decades. In light of this rapidly growing trend, as well as the deterioration of essential environmental resources in most parts of the world, Olson's theory is particularly relevant to the international community today.

The Middle East environmental system exemplifies both the need for and the impediments to successful regional collective action. Several diverse parties share the Middle East's primary environmental resources. Thus, when a party takes action in one jurisdiction it fre-

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1. TODD SANDLER, COLLECTIVE ACTION: THEORY AND APPLICATIONS 1 (1992). *See also* Jon Elster, *Rationality, Morality and Collective Action*, 96 ETHICS 136, 139 (1985).

2. "An allocation . . . of resources is *Pareto optimal* when it is not possible to improve the well-being of one individual without harming at least one other." SANDLER, *supra* note 1, at 13-14.

3. MANCUR OLSON, THE LOGIC OF COLLECTIVE ACTION: PUBLIC GOODS AND THE THEORY OF GROUPS 2 (1965);MICHAEL TAYLOR, THE POSSIBILITY OF COOPERATION 19 (1987).

4. OLSON, *supra* note 3, at 2.

quently affects environmental resources in neighboring areas.[5] Such interactive features characterize the Middle East's crucial water resources, marine environment and air basin. Some of the region's environmental resources are at significant risk and future developments may further imperil their sustainable utilization. The peace process, if successful, is expected to generate accelerated economic development and industrialization in the region, particularly in the West Bank and Gaza Strip. Increased economic development will place more pressure on the region's fragile resources.

Efficient utilization of the Middle East's environmental resources requires the parties to establish and implement cooperative arrangements. In the past, armed conflicts in the Middle East precluded almost any environmental cooperation among the parties. Indeed, the first elaborated cooperative arrangements only emerged in 1994. The environmental provisions in the recently concluded agreements between Israel and its neighbors[6] have a clear bilateral character. However, optimal protection and utilization of the region's environmental resources frequently necessitates the establishment of cooperative arrangements on a regional level. Furthermore, the termination of hostilities does not ensure that an optimal framework for cooperation will emerge in the future. Recall Olson's proposition regarding collective action failure: rational self-interested actors frequently will not act to achieve their common interests, even when optimal results and the appropriate means of attaining them are agreed upon.

Avoiding collective action failure in the Middle Eastern environmental system requires an examination of the factors motivating or hindering international cooperation.[7] Identification of these critical factors helps predict which environmental domains are more susceptible to collective action failure. Armed with an understanding of the impact of these factors, the challenge facing scholars of international law is to devise appropriate legal mechanisms to modify the structure of problem-

5. This article focuses on environmental resources available to Egypt, Israel, Jordan, and the Palestinians in the West Bank and Gaza Strip. The inputs of other states, like Syria and Lebanon, are also taken into account.

6. *See* Articles 12, 25, 27, and 40 of the Protocol Concerning Civil Affairs to the 1995 Israeli-Palestinian Interim Agreement on the West Bank and the Gaza Strip 36 I.L.M. 551 (1997). See Moshe Hirsch, *Environmental Aspects of the Cairo Agreement on the Gaza Strip and the Jericho Area*, 28 ISR. L. REV. 374 (1994), for a discussion on the environmental provisions of the 1994 Cairo Agreement. *See also* Articles 6, 18, Annex II, and Annex V of the 1994 Treaty of Peace between The State of Israel and the Hashemite Kingdom of Jordan, 34 I.L.M. 46 (1995).

7. On the significance of this question, Elster states: "I believe there is no more important problem in the social sciences, and none that is more difficult. Understanding why people cooperate and trust one another may be the first step toward bringing about more cooperation and trust." Elster, *supra* note 1, at 141.

atic settings to improve the prospects of cooperation.[8]

Through the use of game theory, this article explores some of the principal factors influencing the emergence and maintenance of international cooperation in order to develop legal guidelines for establishing an effective environmental mechanism in the Middle East. As this article will show, game theory concepts and models provide a valuable tool for analyzing the phenomenon of cooperation, enabling international lawyers to shape legal norms which will enhance the prospects for environmental cooperation in the Middle East. Part II of this article sets forth the basic concepts and models of game theory and its relationship to modern international relations theory. Part III presents a game theoretical analysis of two major environmental settings in the Middle East: marine pollution in the Gulf of Aqaba and water contamination of the Mountain Aquifer. It then suggests some legal mechanisms to enhance the likelihood of cooperation in these settings. Part IV concludes the article by exploring the options and limits of combining game theory and international law as an instrument to improve the prospects of cooperation. The article ultimately states that this combination offers scholars and policy-makers important insights into better legal mechanisms for long-term international cooperation.

II. GAME THEORY AND COOPERATION

A. *Basic Elements of Game Theory*[9]

Mathematicians were the first to develop game theory, primarily for use in economics. Later, other disciplines, such as political science, international relations, law, sociology and biology also employed game theory concepts. Game theory is a strand of rational choice theory,[10] "designed to treat rigorously the question of [the] optimal behavior"[11] of

8. Legal rules do not always aim to support cooperation. In some cases, the major aim of a legal mechanism is to avoid cooperation. For example, anti-trust laws or legal rules prohibiting criminal collaboration exist for this purpose.

9. For a general introduction to game theory, see DREW FUDENBERG & JEAN TIROLE, GAME THEORY (1991); ROBERT GIBBONS, GAME THEORY FOR APPLIED ECONOMISTS (1992); SHAUN P. HARGREAVES HEAP & YANIS VAROUFAKIS, GAME THEORY: A CRITICAL INTRODUCTION (1995); R. DUNCAN LUCE & HOWARD RAIFFA, GAMES AND DECISIONS: INTRODUCTION AND CRITICAL SURVEY (1957); JAMES D. MORROW, GAME THEORY FOR POLITICAL SCIENTISTS (1994); ERIC RASMUSEN, GAMES AND INFORMATION (2d ed. 1994); JOHN VON NEUMANN & OSKAR MORGENSTERN, THEORY OF GAMES AND ECONOMIC BEHAVIOR (3d ed. 1953).

10. See SHAUN HARGREAVES HEAP ET AL., THE THEORY OF CHOICE: A CRITICAL GUIDE at vii-x, 3-25 (1992); MORROW, *supra* note 9, at 7-8, for a discussion on rational choice theory and its basic assumptions,.

11. Oskar Morgenstern, *Game Theory: Theoretical Aspects*, *in* 6 INTERNATIONAL ENCYCLOPEDIA OF THE SOCIAL SCIENCES 62 (David L. Sills ed., 1968).

decision-makers in "strategic" situations. The term "strategic" refers to situations in which the outcome does not depend solely on the decision-maker's behavior or nature, but also on the behavior of other participants. An important factor shaping an individual's choice is the social setting or "structure" of a particular situation. Game theory enables social scientists to formalize social structures and then examine the implications of the structure on individual decisions.[12]

A *"game"* is any interaction between players governed by a set of rules specifying the possible moves for each participant and a set of outcomes for each possible combination of moves. The decision-makers are assumed to be *rational* in the sense that they have certain goals, which they strive to attain through their actions. They have a consistent preference ordering of goals, know the rules of the game, and know that the other players are also rational.[13]

Game theory represents interactions between participants in two principal forms: the normal (or strategic) form game and the extensive (or tree) form game. A matrix showing each player's payoff for each combination of strategies often represents a normal game. The normal representation is more appropriate for simultaneous decision-making while the extensive form is more suitable to sequential-move games. The latter form also displays the information each player knows when making his decisions.[14] The basic elements of the normal form game include: (1) *the players* - the actors who make the decisions (either individuals or collective decision-making units like firms or states); (2) *the strategy* space - the range of moves available to a player in a given situation (i.e., to cooperate or to defect); and (3) *the payoffs* ('utilities') - the outcome generated for the players from a chosen move or strategy.[15]

A game theoretical analysis of social phenomena often does not allow for the allocation of accurate payoffs to expected outcomes. In some cases, it is possible to assign *ordinal payoffs* to expected outcomes (i.e., to organize the various outcomes in accordance with the order of priorities for the relevant player) and then to allocate a respective ordinal number to each outcome. This method leads to interesting inferences in numerous situations.[16] However, without knowing the "distance" be-

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12. *Id. See also* Robert. J. Aumann, *Game Theory, in* THE NEW PALGRAVE: GAME THEORY 1, 2 (John Eatwell et al. eds., 1987); MORROW, *supra* note 9, at 1.

13. FUDENBERG & TIROLE, *supra* note 9, at 4; HEAP & VAROUFAKIS, *supra* note 9, at 1, 4-31; MORROW, *supra* note 9, at 7-8, 16-20.

14. D.G. BAIRD ET AL., GAME THEORY AND THE LAW 50 (1994); FUDENBERG & TIROLE, *supra* note 9, at 67; GIBBONS, *supra* note 9, at 4, 115-16; HEAP & VAROUFAKIS, *supra* note 9, at 42-43 MORROW, *supra* note 9, at 58-69.

15. BAIRD ET AL., *supra* note 14, at 7-9; FUDENBERG & TIROLE, *supra* note 9, at 4-5; GIBBONS, *supra* note 9, at 2-4.

16. For a discussion of this method of assigning payoffs, see HEAP & VAROUFAKIS, *supra* note 9, at 5-12; Duncan Snidal, *The Game Theory of International Politics*, 38 WORLD POL. 25, 46-48 (1985); *see also* STEVEN J. BRAMS, GAME THEORY AND POLITICS 13-

tween the payoffs on an interval scale, one cannot accurately calculate the probabilities with which each party would choose each outcome.[17]

After reducing sets of interactions to a normal or extensive game, the next step is to determine the game's solution. Finding the "solution" of a game serves a normative goal, as it may reveal the best strategy for a rational player. It also serves a predictive aim, as it may indicate how rational players are likely to behave in such situations. A simple example is the notion of *dominant strategy*. A strategy is strictly dominant if it is a best strategy (i.e., it maximizes a player's payoff), regardless of the other player's actions. When it is possible to identify a single dominant strategy, one can safely assume that a rational player will adopt the dominant strategy. Conversely, by identifying dominated strategies, one can assume that rational players will not adopt them.[18]

While a strict dominant strategy will not solve many games, the Nash-equilibrium solution applies to a much broader spectrum of cases. A *Nash-equilibrium* is the combination of strategies, representing the best response of each player to the predicted strategies of the other players. Such a prediction may be called "strategically stable" or "self-enforcing" because no single player is interested in deviating from the predicted strategy.[19]

Game theory is divided into cooperative and non-cooperative game theory, based on the enforceability of agreements and communication. *Cooperative game theory* assumes the existence of an institution capable of enforcing the agreements concluded between the players; whereas *non-cooperative game theory* assumes no such institution exists. In cooperative games, communication between the players is allowed while in non-cooperative games, communication may or may not be allowed.[20] Due to the lack of a central enforcement mechanism within the current international system, this study is concerned with non-cooperative games.

16 (1975) (using the ordinal method to analyze a specific case).

17. BRAMS, *supra* note 16, at 20.

18. GIBBONS, *supra* note 9, at 5; BAIRD ET AL., *supra* note 14, at 11-14; HEAP & VAROUFAKIS, *supra* note 9, at 44-45; FUDENBERG & TIROLE, *supra* note 9, at 6-8. A dominated strategy can sometimes be found by a process of iterated elimination of strictly dominated strategies. *See* GIBBONS, *supra* note 9, at 4-8.

19. BAIRD ET AL., *supra* note 14, at 11-22; FUDENBERG & TIROLE, *supra* note 9, at 11-12; GIBBONS, *supra* note 9, at 8-9; HEAP & VAROUFAKIS, *supra* note 9, at 52-53.

20. Joseph E. Harrington, Jr., *Noncooperative Games*, *in* THE NEW PALGRAVE, *supra* note 12, at 178; MORROW, *supra* note 9, at 75-76; HEAP & VAROUFAKIS, *supra* note 9, at 38.

B. Game Theory and Modern International Relations Theory

The basic assumptions of game theory are compatible with the basic assumptions of modern international relations theory. Prevailing international relations theory assumes that: (1) States are the central actors in the international system; (2) States are not subordinated to a central international authority to enforce cooperation; (3) States are egoists - they constantly try to maximize their interests; and (4) States are rational - they have consistent, ordered preferences, which derive from calculating the costs and benefits of alternative courses of action.[21] Clearly, assumptions (2), (3) and (4) are consistent with those of non-cooperative game theory. Meanwhile, assumption (1) in no way contradicts any of the underlying premises of game theory.[22]

The concepts fundamental to international regimes, game theory and cooperation, are interrelated.[23] Game theory explains the conditions under which international regimes arise as an instance of cooperation, suggesting conditions conducive to stable compliance with them. Generally, international cooperation is a prerequisite to the establishment of international regimes.[24] However, cooperation, particularly short-term cooperation, can take place without the existence of international regimes.[25] Nonetheless in most cases, the creation of international regimes facilitates the establishment of long-term cooperative patterns between States.

While game theory provides a valuable tool for analysis of international cooperation, game theoretical models do not take into account various factors which frequently affect international cooperation. Such missing factors include the personal characteristics of decision-makers, as well as the social and moral values prevailing in their respective environments. On the other hand, game theoretical models do not at-

21. ROBERT O. KEOHANE, AFTER HEGEMONY: COOPERATION AND DISCORD IN THE WORLD POLITICAL ECONOMY 18, 27 (1984); Kenneth W. Abbott, *Modern International Relations Theory: A Prospectus for International Lawyers*, 14 YALE J. INT'L L. 335, 346-50 (1989).

22. While the above assumptions largely reflect the neo-realist school in international relations (the prevailing school today), both realists and liberals presume self-interested, purposive and calculated behavior by states. *See* ARTHUR A. STEIN, WHY NATIONS COOPERATE: CIRCUMSTANCE AND CHOICE IN INTERNATIONAL RELATIONS 10 (1990).

23. The prevailing definition of international regimes is "implicit or explicit principles, norms, rules and decision-making procedures around which the actors' expectations converge in a given area of international relations." Stephen D. Krasner, *Structural Causes and Regime Consequences: Regimes as Intervening Variables, in* INTERNATIONAL REGIMES 1, 2 (Stephen D. Krasver ed., 1983). *See also* KEOHANE, *supra* note 22, at 57. For other definitions, see Stephan Haggard & Beth A. Simmons, *Theories of International Regimes*, 40 INT'L ORG. 491, 493-94 (1987).

24. *See* Kenneth A. Oye, *Explaining Cooperation Under Anarchy: Hypotheses and Strategies*, 38 WORLD POL. 1, 20-21 (1985).

25. Haggard & Simmons, *supra* note 23, at 504.

tempt to address all factors relevant to collective action. Rather, they aim to simplify and abstract reality by focusing on certain factors of collective action while exploring the interplay among them. Such an analysis seems simplistic, but the simplification proves useful in clarifying complex interactions.[26]

Despite the imperfections which come from focusing on one set of variables, and the difficulties associated with assigning numerical payoffs to expected outcomes, game theoretical analysis sets forth the expected trends of decision-makers as well as the decisions likely to be adopted in particular settings. Furthermore, game theoretical analysis frequently provides scholars and policy-makers with insights regarding mechanisms designed to elicit and support stable cooperation.

C. *Models of Collective Action*

Each of the many collective action models presents a different payoff structure. This section presents the widely discussed models in game theoretical and international relations literature. After clarifying the basic features of each model, this section focuses on the prospects for cooperation in each setting. It should be noted that the Middle Eastern environmental settings do not accurately reflect the game theoretical models presented here. Frequently, however, it is possible to identify a particular environmental setting which presents strong features of a certain game theoretical model. As such, the insights drawn from the models presented below provide important indications regarding the expected trends of the decision-makers in these environmental settings.

1. Zero-Sum Games

Zero-sum game is one of game theory's most famous models. Particularly during the early stages of the theory's development, zero-sum game served as a polar case and historical point of departure. The key feature of zero-sum game is that the sum generated for the players for each possible combination of moves is zero. A game in which the sum of the payoffs is always constant (not necessarily zero) is called "constant-sum game" and its strategic analysis is equivalent to zero-sum game. In zero-sum games, whatever one player wins the other loses.[27] Since the payoffs to Player 2 are equal to the negative payoffs to Player 1, it is possible to simplify the strategic form and only write the payoffs of

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26. MORROW, *supra* note 9, at 8. For a discussion on the application of rational choice models to international relations, *see* KEOHANE, *supra* note 21, at 65-74; Robert Jervis, *Realism, Game Theory and Cooperation*, 40 WORLD POL. 317 (1988).

27. FUDENBERG & TIROLE, *supra* note 9, at 4; MORROW, *supra* note 9, at 74-75; VON NEUMANN & MORGENSTERN, *supra* note 9, at 46-47.

Player 1. Figure 1 illustrates the payoff matrix for a two-person zero-sum game:[28]

Player 2

Player 1		S1	S2
	S1	2	2
	S2	1	3

Figure 1: A Two-Player Zero-Sum Game

The solution to a zero-sum game, as suggested by Von Neumann and Morgenstern, involves the *Maximin Principle*, which directs players to maximize their security levels. The security level is the least amount that a player can receive from his move. The result of this game is an equilibrium pair in cell S1S1 generating 2 payoffs to Player 1, and -2 to Player 2.[29] This cell is called the "saddle-point." However, not all zero-sum games have a saddle-point.[30] The *Maximin Principle* is not only valid for a one-shot game, but applies to iterated games as well.[31]

Two-player zero-sum games represent strictly competitive situations. The players maintain opposing preferences and are considered rivals. As such, the players are in conflict and not inclined to cooperate.[32] Zero-sum games may have more than two players (*N-players games*) and some players may have an interest in cooperating against the rest of the players (i.e., in forming a *coalition*).[33] As one might imagine, a two player zero-sum game represents one of the worst models for international cooperation.

Similar levels of competitiveness also exist in non-zero-sum. These are games in which the players seek relative rather than absolute gains

28. This figure illustrates the famous Battle of Bismarck Sea in World War II; *see* LUCE & RAIFFA, *supra* note 9, at 64-65; BRAMS, *supra* note 16, at 3-4.

29. In the case represented in Figure 1, Player 1 (the maximizing player) should choose S1, the strategy that assures him/ her at least 2 payoffs. Player 2 (the minimizing player) should select S1, which would assure him no more than -2 (in comparison to -3 which may arise from S2). BRAMS, *supra* note 16, at 4; LUCE & RAIFFA, *supra* note 9, at 64-65; Michael Bacharach, *Zero-sum Games, in* THE NEW PALGRAVE, *supra* note 12, at 253. For some criticism of the Minimax principle, see Bacharach, *id.*, at 255-56.

30. Every zero-sum game with mixed strategies, however, has a saddle point; *see* Bacharach, *supra* note 29, at 255. In a *pure strategy*, a player adopts a particular strategy throughout the game. In a *mixed strategy*, a player adopts a strategy that distributes probability among several pure strategies; GIBBONS, *supra* note 9, at 30.

31. LUCE & RAIFFA, *supra* note 9, at 103. 'One shot games' and 'iterated games' will be explained in Part II.C(2).

32. LUCE & RAIFFA, *supra* note 9, at 59-61; Bacharach, *supra* note 29, at 253.

33. MORROW, *supra* note 9, at 75; VON NEUMANN & MORGENSTERN, *supra* note 9, at 220-22.

(i.e., in military contexts where the aim is to achieve superiority). When the game has only two players who are exclusively interested in relative gains, the situation can be modeled as a zero-sum game with no room for cooperation. The conflict diminishes significantly when there are more than two players, or if the concern for relative gains is less than total.[34]

Pure zero-sum situations rarely arise in the international arena, if at all. Strong features of zero-sum games are present in some international settings such as wars or sovereignty disputes over a particular territory.[35] Fortunately, the utilization of common environmental resources almost never represents a zero-sum game. Most international environmental resources are renewable. Thus, the sum of quantities available to the parties is not constant, rather it depends significantly upon the players' strategies. However, use of a shared, non-renewable environmental resource, like fossil water reservoirs,[36] may lead the parties to adopt strategies commonly employed in zero-sum games.

2. The Prisoner's Dilemma

The models discussed in the remainder of this section represent non-zero-sum games, the most famous of which is the Prisoner's Dilemma ("PD").[37] The PD model attracted considerable attention from both game theorists and scientists in various disciplines because the game's implications apply to a wide range of social phenomena. The normal form of PD is presented in Figure 2: let C (Cooperate) equal

34. Duncan Snidal, *Relative Gains and the Pattern of International Cooperation*, 85 AM. POL. SCI. REV. 703 (1991). See Robert Powell, *Absolute and Relative Gains in International Relations Theory*, 85 AM. POL. SCI. REV. 1303 (1991), for a further discussion on relative gains.

35. *See, e.g.*, with respect to the dispute between Israel and the Palestinians over East Jerusalem, Moshe Hirsch, *The Future Negotiations Over Jerusalem, Strategical Factors and Game Theory*, 45 CATH. U. L. REV. 699, 711-12 (1996).

36. On nonrenewable groundwater in the Middle East, *see* MASAHIRO MURAKAMI, MANAGING WATER FOR PEACE IN THE MIDDLE EAST: ALTERNATIVE STRATEGIES 90-103, 182-83 (1995).

37. The game nicknamed Prisoner's Dilemma, attributed to A. W. Tucker, is typically presented with the following story. Two persons, apprehended by the police with stolen goods, are suspected of burglary and taken into custody and separated. The district attorney is certain that they are guilty of burglary, but he/she does not have adequate evidence to convict them at a trial. The district attorney explains to each prisoner (separately) that he/she has two alternatives: (1) to confess to the crime of burglary, or (2) not to confess. If both of them confess, both will be convicted of burglary and sentenced to two years in prison. If neither confesses, both will be convicted of possession of stolen goods and given a six-month prison sentence. If only one confesses, the confessor will go free, while the other will get the maximum sentence of five years. *See* ANATOL RAPOPORT & ALBERT M. CHAMMAH, PRISONER'S DILEMMA: A STUDY IN CONFLICT AND COOPERATION 24-25 (1965); LUCE & RAIFFA, *supra* note 9, at 94-95; Anatol Rapoport, *Prisoner's Dilemma*, *in* THE NEW PALGRAVE, *supra* note 12, at 198.

"not confess;" and D (Defect) equal "confess." By convention, the first payoff in each cell is to the row player, and the second payoff is to the column player.

Player 2

Player 1		C	D
	C	0.5, 0.5	5, 0
	D	0, 5	2, 2

Figure 2 : Prisoner's Dilemma

From Player 1's perspective; if Player 2 chooses strategy C or D, then Player 1 prefers D to C. Thus, strategy D strictly dominates strategy C. The same analysis holds true for Player 2, as C is strictly dominated by D. The result is that D is the *dominant strategy* for both players and cell DD represents the only *Nash equilibrium* for PD. As explained above, in *Nash equilibrium*, no player is interested in deviating from his predicted strategy.[38] The result generated in DD (2,2) is sub-optimal for both players who strongly prefer the result of CC (0.5, 0.5). PD represents a collective action failure. Since each rational player is not expected to deviate from his strategy of confession, the outcome of the combined strategies (mutual confession) constitutes a *Pareto inferior* equilibrium.

A situation is defined as PD and generates the undesirable results noted above if the following inequalities among payoffs exist:

$DC > CC > DD > CD$

and $2CC > CD + DC$.[39]

PD is by definition a *non-cooperative game* and communication is not allowed between the players. Yet even allowing the players to communicate would not significantly change the expected outcomes of the game. If the players could communicate, they would be expected to agree to adopt strategy CC to generate better payoffs. Even after they agreed, the structure of the game would not change. Without an authority to enforce the agreement, each party would have a strong interest in breaching it because the payoff structure remains the same: $2CC > CD + DC$.[40]

Increasing the number of players (*N-players games*) does not alter the sub-optimal outcome of the game. In fact, the problem may even

38. *See also*, DAVID KREPS, GAME THEORY AND ECONOMIC MODELLING 28 (1990).

39. *See* RAPOPORT & CHAMMAH, *supra* note 37, at 34-35.

40. *See* RAPOPORT & CHAMMAH, *supra* note 37, at 25-26; LUCE & RAIFFA, *supra* note 9, at 96.

worsen because each additional player obtains a higher payoff if he or she adopts strategy D in comparison to strategy C, and D dominates C.[41]

The sub-optimal outcomes generated by *Nash equilibrium* in one-stage games ("one-shot games") do not necessarily occur in iterated games. The main point in iterated games is that credible threats or promises regarding future rounds can influence the players' behavior in the present round. *Finite iterated PD games* involve situations in which the players know when the game ends. Employing *backward induction* logic, one can anticipate that players in these games will adopt their dominant strategy of defection. When the game is iterated a finite number of times, the players in the last stage will not concern themselves with how their action will affect future payoffs. Thus, rational players will adopt their dominant strategy and "defect" in the last round (as they are expected to do in one-shot games). On the next-to-last move, given the solid expectation of defection in the last round, there is no incentive for players to deviate from the dominant strategy. The same pattern of behavior is expected until the players reach the first round.[42]

Mutual cooperative behavior is expected in infinite iterated games, or in finite games in which the players are not certain when the last play will occur. Without a specific date for the last stage, there is no starting point for backward induction logic, thus inducing cooperation in the next stages by current behavior remains a viable option. The key factor is that choices made in the present round not only determine the outcome of this stage, but can affect payoffs generated in future rounds. Future payoffs are, however, probably less important than present payoffs. This phenomenon is referred to as the *discount factor*. The *discount factor* represents the current value of a dollar to be generated at some later stage. The discount factor (usually written as 'δ') falls between 0 and 1, and its relation to the interest rate (r) is $\delta = 1/(1+r)$.[43]

There is more than one strategy that can elicit cooperation in infinite iterated PD. The most famous is *Tit-for-Tat,* which achieved the highest score in Axelrod's well-known experiments.[44] *Tit-for-Tat* is a

41. Rapoport, *in* THE NEW PALGRAVE, *supra* note 12, at 199-200; LUCE & RAIFFA, *supra* note 9, at 97; TAYLOR, *supra* note 3, at 15.

42. *Compare* HEAP & VAROUFAKIS, *supra* note 9, at 168-69, *and* FUDENBERG & TIROLE, *supra* note 9, at 111, *and* LUCE & RAIFFA, *supra* note 9, at 98-99, *with* RAPOPORT & CHAMMAH, *supra* note 37, at 28-29, *and* GIBBONS, *supra* note 9, at 224 (presenting experimental evidence).

43. *See* GIBBONS, *supra* note 9, at 68, 88; MORROW, *supra* note 9, at 38.

44. In Axelrod's experiments, professional game theorists were invited to send programs to a computer tournament playing iterated PD 200 times. Each participant wrote a program which included a rule for selecting the cooperative or non-cooperative choice on each move. The program had access to the history of the game and could use this history in making a choice. Each program was paired with another program, including its own

strategy of cooperating on the first move and then copying the other player's previous move. In order to motivate cooperation by *Tit-for-Tat* in infinite PD games, the players must not significantly underestimate future gains. In other words, the discount rate should be close to one. Generally, the likelihood of cooperation in such circumstances is increased together with the increase in three variables: (1) the discount rate; (2) the payoffs associated with cooperation; and (3) the reduction in the payoffs generated by defection. There is interplay between these variables. For instance, when the discount factor is not high enough to elicit cooperation through simple *Tit-for-Tat* strategy, using a more severe contingent strategy to decrease the payoffs for defection (like the *Grim Trigger*)[45] may remedy this shortage and increase the likelihood of cooperation.

When the discount factor or the number of payoffs generated by cooperation is decreased, cooperation can be attained by decreasing the payoffs associated with defection, particularly by harsher acts of retaliation. The possibilities of motivating cooperation by threats are, however, limited. A player is not expected to take into account a *noncredible threat*; that is, a threat that costs more to carry out than not to carry out.[46] A strategy involving threats is considered *credible* if it yields the threatening player, and other participants, the best outcomes in the remaining stages of the game (i.e., constitutes a subgame-perfect *Nash equilibrium*).[47]

These results regarding cooperation in two-player infinite PD games also apply to N-player games.[48] The difference is that in N-player infinite games, cooperation may emerge among some players

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program. The program with the largest cumulated payoff won the tournament. *Tit-for-Tat*, which was submitted by Rapoport, won the tournament over the other fourteen programs submitted. The results of the tournament were published and a second round was conducted. Out of the 63 programs submitted, *Tit-for-Tat*, which Rapoport resubmitted, achieved the best score. *See* ROBERT AXELROD, THE EVOLUTION OF COOPERATION 27-54 (1984); Robert Axelrod, *The Emergence of Cooperation Among Egoists*, 75 AM. POL. SCI. REV. 306 (1981); Rapoport, *in* THE NEW PALGRAVE, *supra* note 12, at 200-202.

45. The *Grim Trigger* answers any move of defection with defection for all future rounds of the game; MORROW, *supra* note 9, at 266. *See also* GIBBONS, *supra* note 9, at 91-99. On other contingent strategies, see Martin Patchen, *Strategies for Eliciting Cooperation from an Adversary*, 31 J. CONFLICT RESOL. 164, 171-81 (1987).

46. HEAP & VAROUFAKIS, *supra* note 9, at 115-16; KREPS, *supra* note 38, at 49-53.

47. GIBBONS, *supra* note 9, at 57, 94-99. A subgame is a part of a game, or the part that remains to be played beginning at any point at which the complete history of the game is common knowledge among the players. For a precise definition of a subgame see GIBBONS, *supra* note 9, at 94, and HEAP & VAROUFAKIS, *supra* note 9, at 82. A Nash equilibrium is subgame-perfect if the players' strategies constitute a Nash equilibrium in every subgame. *See* GIBBONS, *supra* note 9, at 95; *see also* HEAP & VAROUFAKIS, *supra*, note 9, at 84.

48. HEAP & VAROUFAKIS, *supra* note 9, at 175-76.

even if the rest consistently adopt a non-cooperative strategy. Such partial cooperation is possible if the cooperative players cooperate on the condition that the other cooperative players cooperate, and if each of their discount rates is high enough.[49]

The Prisoner's Dilemma attracted enormous attention from game theorists and social scientists, especially after the publication of Axelrod's work. Many scholars believed that PD captured the problem of collective action. PD became the paradigmatic example, as stated by Rasmusen: "[w]henever you observe individuals in a conflict that hurts them all, your first thought should be of The Prisoner's Dilemma."[50]

Axelrod's optimistic message was that cooperation may emerge and be sustained even among egoists operating in a system without a central enforcement authority. As previously stated, PD has been applied to numerous disciplines, including biology,[51] economics,[52] international trade,[53] political science,[54] international relations[55] (especially arms control)[56] and law.[57] In addition, the model effectively represents the problem of externalities and thus has been applied to several environmental collective action problems.[58] Some scholars[59] even characterized the celebrated "Tragedy of the Commons"[60] as a PD. At some point, it seemed that the model represented all forms of collective action prob-

49. TAYLOR, *supra* note 3, at 82-105. In some groups, there is an inherent tendency for exploitation of the great members (in terms of the size and extent of their interest in the product to be generated by cooperation) by the smaller ones. *See* OLSON, *supra* note 3, at 34-36; SANDLER, *supra* note 1, at 54-58.

50. RASMUSEN, *supra* note 9, at 18.

51. *See, e.g.*, Robert Axelrod & William D. Hamilton, *The Evolution of Cooperation*, 211 SCI. 1390 (1981).

52. *See, e.g.*, KREPS, *supra* note 38, at 39.

53. *See* J. David Richardson, *The New Political Economy of Trade Policy, in* STRATEGIC TRADE POLICY AND THE NEW INTERNATIONAL ECONOMICS 267, 270-75 (1986).

54. TAYLOR, *supra* note 3, at 129; *see also* STEIN, *supra* note 22, and the references therein.

55. *See, e.g.*, Glenn H. Snyder, *Prisoner's Dilemma and Chicken Models in International Politics*, 15 INT'L STUD. Q. 66 (1971); BRAMS, *supra* note 16, at 26-38; STEIN, *supra* note 22, at 31-35. *See* Abbott, *supra* note 21, at 360-62 (for additional references on the subject).

56. *See, e.g.*, STEVE WEBER, COOPERATION AND DISCORD IN U.S.-SOVIET ARMS CONTROL 17 (1991).

57. *See* BAIRD ET AL., *supra* note 14, at 167, 201.

58. *See, e.g.*, Eyal Benvenisti, *Collective Action in the Utilization of Shared Freshwater: The Challenges of International Water Resource Law*, 90 AM. J. INT'L L. 384, 389 (1996); CRISTINA BICCHIERI, RATIONALITY AND COORDINATION 224 (1993); William H. Rodgers, Jr., *The Evolution of Cooperation in Natural Resources Law: The Drifter/Habitue Distinction*, 38 U. FLA. L. REV. 195, 199-200 (1986).

59. THOMAS C. SCHELLING, MICROMOTIVES AND MACROBEHAVIOR 110-15 (1978); Duncan Snidal, *Coordination versus Prisoner's Dilemma: Implications for International Cooperation and Regimes*, 79 AM. POL. SCI. REV. 923, 929 (1985) [hereinafter *Coordination*].

60. Garret Hardin, *The Tragedy of the Commons*, 162 SCI. 1243 (1968).

lems, and several authors expressed the view that the logic underlying the problem of collective action is the logic of the PD.[61] This was a sweeping generalization. Today, it is clear that the structure of some collective action problems is different from the structure of the PD.

3. The Assurance Game

Scholars approaching collective action problems with the tools of game theory devoted disproportional attention to PD. Nevertheless, all that attention should not detract from the relevance of other game structures commonly applied in the international system. While the Assurance game[62] presents less conflict-driven features than PD, successful collective action remains uncertain. As shown in Figure 3, attaining the optimal outcome in the Assurance game requires cooperation by all players.

		Player 2	
		C	D
Player 1	C	4, 4	1, 3
	D	3, 1	2, 2

Figure 3: The Assurance Game

The preference ordering of the players in the Assurance game is: CC>DC>DD>CD.

Examination of the above matrix shows that the game has two *Nash equilibriums* (CC and DD) and neither dominates the other. While CC is *Pareto superior* to the other possibilities, rational players may reach the equilibrium of DD. A player may play D if he or she is not certain whether the other will play C or D, and if he or she is determined to avoid the worst outcomes of CD. In such cases, "all hare risk-dominates all stag."[63] Pre-play communication between the players may alleviate the problem in Assurance situations. A rational

61. *See, e.g.*, Russell Hardin, *Collective Action as an Agreeable N-Prisoners' Dilemma*, 16 BEHAV. SCI. 472 (1971).

62. Rousseau's story of the stag hunt commonly illustrates the Assurance game structure in which two hunters must cooperate in order to catch a stag. If they catch a stag, it will be shared between the hunters, thus generating the best outcome (CC). If both hunt for hare, each of them will catch one hare and attain inferior payoffs (DD). The worst result for a hunter arises if he/she attempts to catch the stag while the other hunts for hare (CD). Here, the second will catch a hare and the first will catch nothing. *See* FUDENBERG & TIROLE, *supra* note 9, at 3; RUSSELL HARDIN, COLLECTIVE ACTION 167-68 (1982).

63. FUDENBERG & TIROLE, *supra* note 9, at 20.

player is expected to pledge to play C, thus improving the chances that the other player also will adopt a cooperative strategy. Such communication does not, however, completely eliminate the likelihood of defection.[64]

In two-player sequential Assurance situations, a player may drive the other to cooperate in the next move by playing C in the first stage. A player may also accomplish this by committing to a cooperative strategy in an early stage. The same is true for N-player settings regarding all the players but the last one. If all players except the last one have already played C , or committed themselves to cooperate, a last rational player will cooperate to gain the optimal results of CC.

Attaining optimal results in N-player games is less likely than in two-player sequential situations. A rational player in N-player games is aware that the desirable result emerges only if all players cooperate. Increasing the number of players increases the likelihood that one player will defect. Subsequently, this decreases a rational player's incentive to cooperate and to take the risk of suffering the worst outcome.

In the iterated game scenario, the prospects for cooperation are fostered. In iterated Assurance games, the gap between the optimal outcomes (CC) and those generated by cautious strategies (DD) grows, increasing the losses from long-term mutual defection. As the gap increases, the likelihood that a player will take the risk of a cooperative strategy, thereby encouraging the other player to cooperate, is increased. Contingent strategies, like *Tit-for-Tat,* generally lead to more cooperative results.[65]

The above analysis demonstrates that a player in Assurance situations will cooperate if assured that the other players will also cooperate. Therefore, gaining reliable information regarding the players' intentions is crucial to cooperation in Assurance situations. Some scholars argue that the Assurance game does not constitute a genuine collective action problem, but rather presents only an "information problem."[66] Lack of information occurs frequently in the international arena. Players are expected to gather information regarding the expected behavior and expectations of the other players. This task may be realized, wherever possible, through pre-play communication and examination of the other players' records in similar situations. In iterated situations, the players also learn about others' intentions through the moves of the game itself. In sequential cases, the most efficient information-

64. As observed by Aumann, regardless of his/her own play, player 2 gains more if player 1 plays C. Thus, no matter what action is intended by player 2, he/she will tell player 1 that that he/she intends to play C. Player 1, of course, should not be assumed to believe Player 2. *See* FUDENBERG & TIROLE, *supra* note 9, at 21.

65. *See, e.g.*, SANDLER, *supra* note 1, at 83.

66. Elster, *supra* note 1, at 140; *see also* TAYLOR, *supra* note 3, at 19, 39; STEIN, *supra* note 22, at 30.

gathering strategy for a player is to start with cooperation.[67]

Without reliable information, the variables used to determine the probability of a player adopting a cooperative or noncooperative strategy include: (1) the extent of the gap between CC and DD; (2) the number of remaining stages of the game; (3) the discount rate (in iterated games); (4) the number of players; and (5) the magnitude of the risk generated by CD. Increasing the value of the first three variables increases the prospects for cooperative moves, while increasing the number of players and the magnitude associated with CD, decreases the prospects for cooperative moves.

Scholars have applied the Assurance game to various international situations in which attaining optimal results required cooperative moves by all participants.[68] Surprisingly, the model rarely has been applied to international environmental collective action problems.[69]

4. The Coordination Game

As in the Assurance game, all players in the Coordination game[70] have to cooperate in order to attain the optimal outcome. The central difference between these two game models is that while the Assurance game presents only one Pareto-equilibrium position, the Coordination game presents multiple Pareto-equilibria over which the players have divergent preferences. The normal form of this problem is presented in Figure 4.

67. Hugh Ward, *Testing the Waters: Taking Risks to Gain Reassurance in Public Goods Games*, 33 J. CONFLICT RES. 274 (1988). In this article, Ward analyzes an Assurance model in which a player is not certain whether the other players have Assurance or PD preferences.

68. *See, e.g.*, Kenneth W. Abbott, *Collective Goods, Mobile Resources, and Extraterritorial Trade Controls*, 50 LAW & CONTEMP. PROBS. 117 (1987); Robert Jervis, *From Balanced to Concert: A Study of International Security Cooperation*, 38 WORLD POL. 58, 67-68 (1985); Carlise Ford Rounge, *Institutions and the Free Rider: The Assurance Problem in Collective Action*, 46 J. POL. 154 (1984); STEIN, *supra* note 22, at 31; Ward, *supra* note 67, at 279.

69. *See, e.g.*, SANDLER, *supra* note 1, at 168.

70. The story of the Coordination game, also known as "The Battle of the Sexes," involves two players who wish to go to an event together but who disagree about whether to go to a football game or to the ballet. Each player gets a payoff of 2 if both go to his or her preferred event, a payoff of 1 if both go to the other's preferred event, and 0 payoffs if they are unable to agree. FUDENBERG & TIROLE, *supra* note 9, at 18; *see also* the original story in LUCE & RAIFFA, *supra* note 9, at 91.

Player 2

Player 1

	S1	S2
S1	2, 1	0, 0
S2	0, 0	1, 2

Figure 4: Coordination Game

The preference ordering for player 1 is:

S1, S1 > S2, S2 > S1, S2 = S2, S1

And for player 2:

S2, S2 > S1, S1 > S1, S2 = S2, S1

The Coordination game has two *Nash equilibria* in pure strategy: (S1, S1) and (S2, S2). Both strategies are efficient. Each one, however, generates different payoffs to the players. The players are interested in coordinating on one of the equilibria positions. The collective action problem arises since they have conflicting preferences regarding the chosen equilibrium.[71]

This game represents a clear distributional problem,[72] which impedes cooperation. However, once the players agree on a cooperative solution, there are no significant incentives to depart from the coordination point, making the solution self-enforcing.[73] If pre-play communication exists, each rational player may announce that he or she would follow his or her preferred equilibrium point (e.g., S1 for Player 1), while the other player, seeking to avoid the worst results (S1, S2), is driven to the first preferred strategy.[74] Assuming that both players are rational and adopt this strategy, the above proposition does not aid in solving the game. On the other hand, in sequential games the first player to move may have a significant advantage since he or she is able to commit himself or herself in an earlier stage to the preferred equilibrium position. Meanwhile, the second player has no choice but to join the first player.

The prospects for cooperation are not necessarily decreased in N-player games (as in PD). Indeed, in some cases, the prospects are enhanced. Increasing the number of players impedes communication and

71. For a discussion of situations in which players converge on some "focal point" (a prominent position in terms of uniqueness, simplicity, or precedency), *see* THOMAS C. SHELLING, THE STRATEGY OF CONFLICT 69-72, 89, 92 (1960); RASMUSEN, *supra* note 9, at 28-29.

72. *See Coordination*, *supra* note 59, at 931-32; James D. Morrow, *Modelling the Forms of International Cooperation: Distribution versus Information*, 48 INT'L ORG. 387, 388 (1994) [hereinafter *Modelling*].

73. *Coordination*, *supra* note 59, at 932; STEIN, *supra* note 22, at 42.

74. LUCE & RAIFFA, *supra* note 9, at 91.

complicates bargaining, but does not increase the players' incentives to defect from the equilibrium point. While each player in games with a small number of players may have an incentive to depart (or threaten to depart) from the coordination point in an attempt to compel the others to accept his/her preferred point, the strategy's impact decreases as the number of players increases.[75]

In contrast to PD situations, the iteration of the Coordination game does not lead to better cooperative results. On the contrary, playing through time may become one of the destabilizing factors in Coordination situations. The magnitude of the distributional problem corresponds to the extent of the gap between the payoffs generated to the players in the different equilibria positions. This gap is relatively small in a one-shot game (i.e., 1 in Figure 4), but it increases together with the iteration of the game. Thus, a player willing to give up the relatively small additional benefit of his or her preferred equilibrium, in order to avoid the worst results, would find it more difficult as the gap grows with each iteration of the game.[76] The discount factor's impact upon the prospects for cooperation is very different from that in the PD. Decreasing the discount rate to zero in the Coordination game brings the players closer to the one-shot games. The decrease in the discount rate reduces future losses arising from compromise on the unfavorable equilibrium point. Therefore, decreasing the discount rate encourages the players to cooperate.

Players in Coordination situations are expected to misrepresent their private information. They are likely to attempt to convince the others that adopting their preferred equilibrium position will also further their own interests (i.e., that the situation is similar to the Assurance game). Players in Coordination situations have incentive to dissemble information; conceal or underrate unfavorable information, and exaggerate favorable data. Increasing the gap between the different equilibria positions enhances the distributional problem and intensifies the information problem. When the players do not trust messages conveyed by the other players, the likelihood of successful coordination is reduced.[77]

The Coordination game captures the essence of numerous collective action situations, in which several ways of attaining optimal results exist. The Coordination game is applied to various international contexts where the actors are interested in "meeting" each other in some coordinated position but have conflicting preferences over the particular meeting point. The prominent examples in the international arena include setting common standards for international communication,

75. *Coordination, supra* note 59, at 935-36.

76. *Coordination, supra* note 59, at 936. *See also Modelling, supra* note 72, at 411.

77. *Modelling, supra* note 72, at 400-06.

agreeing on radio-emergency frequency for civil aviation, and formulating an international system for the classification of goods for customs purposes.[78]

III. GAME THEORY AND ENVIRONMENTAL COOPERATION IN THE MIDDLE EAST

A. *The Prospects for Environmental Cooperation: Game Theoretical Analysis*

Having clarified the central notions and models of game theory, this article now turns to an examination of the major environmental problems in the Middle East. This Part analyzes two of the region's principal environmental problems: marine pollution in the Gulf of Aqaba and water contamination of the Mountain Aquifer. This section will also briefly discuss other regional environmental problems.

1. Marine Pollution in the Gulf of Aqaba

a. Background

The Gulf of Aqaba ("Gulf") is one of two northern extensions of the Red Sea, the other being the Gulf of Suez. The Gulf extends about 180 km from the Israeli and Jordanian shores in the north to the Strait of Tiran in the South, bordering the coastlines of Egypt and Saudi Arabia. It is both narrow, with an average width of only 18 km, and deep, with an average depth of 800 meters. The water in the Gulf is calm and the winds generally come from the north. The water is exceptionally clear, due to a very low concentration of nutrients and plankton. The Gulf's natural features create ideal conditions for an abundant and diverse aquatic system. At the heart of the ecosystem are the Gulf's world-renowned and exquisite coral reefs, which are home to myriad aquatic life forms.[79]

The four littoral states of the Gulf of Aqaba are Egypt, Israel, Jordan and Saudi Arabia. Aside from the intrinsic environmental value of

78. For more situations presenting the features of the Coordination game, *see* STEIN, *supra* note 22, at 42-43; Abbott, *supra* note 21, at 371-72, 374; *Coordination*, *supra* note 59, at 932; *Modelling*, *supra* note 72, at 390-93, 409-13.

79. Khalil Hosny Mancy, *Gulf of Aqaba Ecological Overview and Call to Action*, *in* PROTECTING THE GULF OF AQABA 19 (Deborah Sandler et al. eds., 1993) [hereinafter PROTECTING THE GULF OF AQABA]; A REGIONAL PROJECT BETWEEN EGYPT, ISRAEL, AND JORDAN: UPPER GULF OF AQABA OIL SPILL CONTINGENCY PROJECT 4, 6 (Eur. Comm'n, DG I B, External Relations, Brussels, 1995) [hereinafter UPPER GULF OF AQABA]; Grant James Hewison & Boaz Oren, *Protecting Sensitive Aquatic Habitats in the Gulf of Aqaba*, *in* PROTECTING THE GULF OF AQABA , *supra*, at 119.

its unique ecosystem, there are two principal reasons why the Gulf is of considerable importance to Egypt, Israel, and Jordan:[80]

The first is that the Gulf is an important transportation route for Jordan and Israel, and to a lesser degree, for Egypt. The Port of Aqaba is Jordan's only outlet to the sea, and the Port of Eilat is Israel's only gateway to the East. The regular ferry traffic inside the Gulf, between Nuweiba in Egypt and Aqaba, serves tourists and Egyptian workers in neighboring countries. Cargo traffic to Aqaba, as well as cargo and crude oil traffic to Eilat, dominates the maritime traffic in the Gulf. In 1993, the Port of Aqaba received 1,430 of the 1,615 vessels entering the Gulf through the Strait of Tiran. Oil tankers carrying crude oil from Egypt make up approximately one-third of the ship's calls to Eilat.[81]

The second reason is that the Gulf harbors several very popular tourist destinations, including unique coral reefs. The reefs attract a significant number of tourists from around the world. Israel and Jordan maintain large tourist resorts, mainly in Eilat and Aqaba. However, some facilities are found along the Egyptian coast (mainly in Taba, Nueiba, and Dahab). All three States continue to expand their existing resorts, rapidly making tourism the major source of employment and income in the area.[82]

The Gulf's precious environmental resources, maritime transportation and tourist industry are interrelated. While environmental pollution rarely affects maritime transportation, maritime transportation, and activities associated with it do affect the waters. For instance, accidents during cargo loading and unloading or crude oil terminal operations can have a significant impact on the Gulf's extremely fragile environmental resources. Furthermore, the success of the area's tourist industry largely depends upon the quality of the coast's environmental resources since most tourists engage in water activities like swimming, diving, and snorkeling. Ironically, however, the tourist industry remains one of the principal sources of marine pollution in the Gulf.[83]

80. The Gulf is of lesser importance to Saudi Arabia. There are only a few small towns on the Saudi Arabian coast, and it seems that the government is not interested in developing tourist resorts in the area.

81. UPPER GULF OF AQABA, *supra* note 79, at 8.

82. *See* Roy B. Mann, *Tourism and Related Development Compatible with Aesthetic Resource Protection in the Gulf of Aqaba, in* PROTECTING THE GULF OF AQABA, *supra* note 79, at 143; Fouad Sultan, *Tourism Development Along the Gulf of Aqaba Coast: An Egyptian Perspective, in* PROTECTING THE GULF OF AQABA, *supra* note 79, at 177; UPPER GULF OF AQABA, *supra* note 79, at 8-9.

83. On the sources of pollution in the Gulf, see Zihad Jaber Alawneh, *Jordanian Environmental Laws, Institutions, and Treaties Affecting the Gulf of Aqaba, in* PROTECTING THE GULF OF AQABA, *supra* note 79, at 97, 98-102; Deborah Sandler, *Environmental Law and Policy for the Gulf of Aqaba: An Israeli Perspective, in* PROTECING THE GULF OF AQABA, *supra* note 79, at 69, 85-89; Mohammed I. Wahbeh, *An Agenda for Scientific Research in the Gulf of Aqaba, in* PROTECTING THE GULF OF AQABA, *supra* note 79, at 25, 28-

The Gulf of Aqaba area is undergoing a wave of economic development, a fact which poses significant risk to its fragile environmental resources. This is particularly true because the current utilization of the region's resources borders its carrying capacity. Given this state of affairs, any significant pollution is expected to generate harmful results to the Gulf ecosystem and, consequently, to the tourist industry.

b. Analysis: Israel and Jordan

Significant pollution originating from either Israel or Jordan generates similar negative payoffs for both parties. This is due to the geographic proximity of the two States' coasts and the marine pollution frequently generated in the Gulf by events close to shore, like mooring operations in the harbors, oil unloading, or sewage disposal.[84] Large amounts of pollutants originating from either State will first harm the coastal ecosystem of the originating State, and several hours later, the environmental resources of the neighboring State. An oil spill can drift from Jordan to Israel or from Israel to Jordan within six hours.[85] This type of pollution, especially if repeated, would significantly harm both parties' vital tourist industry.

To simplify the game theory analysis, assume that each party has two principal strategies, C and D. C refers to a cooperative strategy in which a party takes the appropriate preventive measures to avoid marine pollution, while D refers to a non-cooperative strategy in which a party does not take the required preventive measures. Significant pollution occurs if one of the parties defects (CD or DC). Pollution is avoided if both parties cooperate (CC), while serious pollution occurs if both parties adopt non-cooperative strategies (DD). Several assumptions enable the presentation of the parties' ordinal payoffs in a normal form (Figure 6). First, preventive costs are lower than the benefits generated by utilizing non-polluted environmental resources. Second, the preventive costs and the positive payoffs in the absence of pollution are similar for both parties. Finally, the worst possibility for each party is to take precautionary measures while still suffering the negative payoffs resulting from pollution.

31.

84. The likelihood of ship collision leading to major spills in the Gulf is remote. *See* UPPER GULF OF AQABA, *supra* note 79, at 10-11.

85. UPPER GULF OF AQABA, *supra* note 79, at 21.

		Jordan	
		C	D
Israel	C	4, 4	1, 3
	D	3, 1	2, 2

Figure 6: Ordinal payoff matrix for Jordan and Israel in the Gulf of Aqaba

Thus, the preference ordering for Israel and Jordan in this setting is:

CC > DC > DD > CD[86]

The structure of the interactive sub-setting between Jordan and Israel is that of the Assurance game and the attainment of the optimal outcome (CC) requires both parties to adopt cooperative strategies. This situation presents two Nash equilibria (CC and DD), but neither dominates the other. While CC equilibrium is clearly *Pareto superior* to DD, a rational actor cooperates only if inclined to believe that the other party will cooperate. Since the Gulf of Aqaba system presents an infinite iterated situation, the gap between the optimal and worst results grows, thereby fostering the prospects for mutual cooperation. The discount rates of Israel and Jordan are relatively high. The fact that both parties currently invest considerable resources in developing their regional tourist industries testifies to that effect. This factor increases the likelihood that both parties' strategies will converge on the mutual cooperative equilibrium.

The Assurance game's characteristics explain why Israel and Jordan have adopted the current cooperative strategies in the Gulf, leading to stable cooperation. In this sub-setting, a party generally departs from its cooperative strategy only if it expects that the other party will adopt a non-cooperative strategy. Thus, for instance, Jordan is expected to forgo its preventive measures if convinced that Israel is likely to refrain from adopting the required precautionary measures. Here, Jordan avoids the worst outcome of incurring both the preventive costs and the expected harmful results from significant pollution by "defecting" in advance. Information regarding the other party's expected behavior plays a vital role in such situations.

86. In CC, a party bears the preventive costs and benefits from utilizing Gulf resources in the absence of pollution. In DC, a party does not incur the preventive costs but sustains the damages arising from significant marine pollution. In DD, a party does not bear the preventive costs but suffers the harmful results generated by serious pollution. In CD, a party incurs the preventive costs and sustains the damages arising from significant pollution.

c. Egypt, Israel, and Jordan

The structure of the environmental setting between Egypt, Jordan, and Israel differs from that of only Israel and Jordan. Egypt, like Israel and Jordan, maintains a significant interest in sustaining and developing its tourist industry along the Gulf coast. The basic difference between the two settings derives from the geographic location of the parties and the circulation patterns within the Gulf. The prevailing winds are from north to south and the currents run from Jordan and Israel southward to the Egyptian coast. Thus, while pollutants from Jordan or Israel can travel to Egypt within 12 hours,[87] most pollutants from Egypt are not expected to even reach either Jordan or Israel.

Though significant pollution originating from the Egyptian coast is unlikely to pollute Israeli or Jordanian coasts, it may well cause some harm to other southern Egyptian coasts. The negative effects on other Egyptian coasts change in accordance with the location of the pollution's source. Pollutants originating in the *northern* Egyptian coasts (e.g., Taba) are likely to harm the originating coast, and then travel southward, inflicting environmental damage on the Egyptian coastal resorts in the south (e.g., Dahab). Pollutants originating in the *southern* coasts (e.g., Ras Nasrani), will travel southwards to the Red Sea and are not likely to harm other Egyptian coastal resorts. Thus, the further south the pollution's source, the greater is Egypt's externalization rate.

Externalization changes according to the geographic location of the pollution's source, generating different payoff structures for various Egyptian coasts. To simplify, the payoff structures of two representative cases are examined below: (a) the source of pollution is on Egypt's northern coast; and (b) the source of pollution is on Egypt's southern coast. The similar interests of Israel and Jordan *vis-a-vis* Egypt enable the insertion of either one as a player in the following matrices. The assumption is that Israel and Jordan converge on the same position, either CC or DD, *supra*. Employing the same assumptions and notations as in Figure 6, the normal form of the parties' ordinal payoffs for pollution originating in the *northern* Egyptian coast is presented in Figure 7.

87. UPPER GULF OF AQABA, *supra* note 79, at 21.

Egypt

Israel/Jordan

	C	D
C	4, 4	4, 3
D	2, 1	2, 2

Figure 7: Ordinal payoff matrix for pollution originating from Egypt's northern coasts.

Two prominent features arise from this matrix. First, from Israel or Jordan's point of view, Egypt's strategy will not affect their behavior. Israel or Jordan will cooperate as long as the other cooperates, regardless of whether Egypt cooperates. Under the present circumstances, CC > DD is true for both Israel and Jordan. Thus, C is the dominant strategy for each of them. Second, since Egypt is aware that C is the dominant strategy for Israel and Jordan, and since CC > DC for Egypt, C is also the dominant strategy for Egypt.[88] Egypt's preference ordering in this case reflects the Assurance game. If Jordan or Israel changes its current strategy and adopts a non-cooperative approach, D becomes the dominant strategy for Egypt (DD > CD for Egypt).

As one moves southward down the Egyptian coast, Egypt can externalize more of its pollutants to the Red Sea, thus changing the relationship between CC and DC. While it is clear that CC > DC remains true for pollution originating from northern coasts, the gap decreases as one moves southward. At some "critical point," CC will be equal to DD. When crossing the "critical point" on Egypt's southern coasts, DC becomes greater than CC. Figure 8 sets forth the normal form of the parties' ordinal payoffs for marine pollution originating from Egypt's *southern* coasts:

Egypt

Israel/Jordan

	C	D
C	4, 3	4, 4
D	2, 1	2, 2

Figure 8: Ordinal payoff matrix for pollution originating in Egypt's southern coasts

88. In CC, Egypt bears the preventive costs and benefits from utilizing the Gulf in the absence of pollution. In DC, Egypt does not incur the preventive costs but sustains the damage arising from significant marine pollution on the southern coasts. In DD, Egypt does not bear the preventive costs but suffers the harmful results generated by serious pollution. In CD, Egypt incurs the preventive costs and sustains the damage arising from significant pollution.

Egypt's ordering preference in this case is as follows:

DC > CC > DD > CD

In contrast to pollution originating from Egypt's northern coasts, Egypt's optimal combination in the present case is CD. Egypt's ordering preferences reflect the Prisoner's Dilemma structure. Jordan and Israel's positions, however, remain the same as for pollution originating in Egypt's northern coasts (Assurance preferences between themselves). In this case, C is still the dominant strategy for Israel and Jordan. Egypt, knowing their preference ordering, is expected to adopt its optimal strategy (DC), choosing not to invest significant resources to prevent pollution originating from its southern coasts.[89] Israel and Jordan will not be affected by Egypt's non-cooperative strategy and are not expected to press the latter to take preventive measures. Furthermore, even if Israel and Jordan threaten to employ retaliatory measures against Egypt for pollution originating from Egypt's southern coasts, such threats will be considered "*noncredible*"[90] and are unlikely to persuade Egypt to divert from its expected strategy. Clearly, the equilibrium resulting from the above matrix does not favor the protection of the environmental resources in the southern part of the Gulf.[91]

d. Future Development and the Need for Common Standards

Current utilization of the Gulf's resources stretches the limits of its environmental carrying capacity. As the three coastal States launch various projects to expand their tourist industries, the risk of overloading the region's natural resources remains acute, while the need for greater coordination increases. The seeds of cooperation already exist in the recent "Upper Gulf of Aqaba Oil Spill Contingency Project,"[92] but much more is needed to counter the expected environmental degradation.

Further measures should set common and more stringent standards for sewage discharge, (particularly industrial), prevention of leaks and spills from port facilities, and reduction of emissions of airborne chemicals like phosphates, potash, and bromide. There should be common rules to prevent dumping of wastes from private boats and for

89. Egypt externalizes its pollution from the southern coasts. It is possible that Egypt's relationships with the other coastal states outside the Gulf of Aqaba (in the Red Sea) will be similar to those in the Prisoner's Dilemma. That subject, however, exceeds the limits of this study.

90. As explained above, a player is not expected to take into account non-credible threats, i.e., threats that if carried out, cost more to the player who issues them than if they are not carried out. *See* discussion *supra* Part II.C(2).

91. Some methods to modify the current structure of settings susceptible to collective action failure will be dealt with, *infra*, in Part III.B.

92. *See* UPPER GULF OF AQABA, *supra* note 79, at 18-23; Ministry of the Environment, *Upper Gulf of Aqaba Oil Spill Contingency Project*, 18 ISR. ENVTL. BULL. 10 (1995).

the establishment of adequate port facilities to collect these wastes.[93] Establishing common standards is expected to generate an interactive situation characterized by the Coordination game's features, a subject dealt with later in Part III(C).

2. Water Contamination of the Mountain Aquifer

a. Background

Water is essential for survival and economic development in the semi-arid climate of the Middle East, and this is one of the scarcest resources in the region. According to water experts, Jordan, Israel, and the Palestinians are much below the "Water Stress Level" of 500 cubic meters per person per year.[94] Not surprisingly, the parties in the region have struggled fiercely over control and allocation of this precious and scarce resource.[95]

The Mountain Aquifer represents the largest water resource in the region, supplying 600 million cubic meters of water per year ("MCMY"). The Aquifer supplies approximately a third of Israel's annual water consumption and 90% of the Palestinians' consumption. The underground reservoir lies beneath the West Bank's mountains in the central part of the mountain ridge. The Aquifer consists of three major basins: the Yarkon Taninim basin (360 MCMY), the Nablus-Gilboa basin (140 MCMY), and the Eastern basin (100 MCMY). Of the 600 MCMY from the entire Aquifer, Israel and its Jewish settlements in the area use about 495 MCMY, while the Palestinians use about 105 MCMY.[96]

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93. In addition, a reduction in the number of active ports and marinas will save resources and enable better supervision over the port facilities which constitute a source of frequent pollution in the Gulf. Thus, the proposal to close Eilat Port and the proposal that the Aqaba Port will serve both Jordan and Israel may well lead to desirable results. *See* Dany Morgenstern, *Implementing Jordanian Option*, GREEN-BLUE-WHITE J. ENVTL. PROTECTION IN ISR. 8, 10-11 (Jan-Feb. 1995) (in Hebrew).

94. Hillel I. Shuval, *Approaches to Resolving the Water Conflicts between Israel and her Neighbors: A Regional Water-for-Peace Plan*, 17 WATER INT'L 133 (1992).

95. For a discussion on the history of the struggle over the allocation of water among the Middle Eastern States, *see* KATHRYN B. DOHERTY, JORDAN WATERS CONFLICT 3 (1965); MIRIAM R. LOWI, WATER AND POWER: THE POLITICS OF A SCARCE RESOURCE IN THE JORDAN RIVER BASIN 79-203 (1993); J. W. Eaton & D. J. Eaton, *Water Utilization in the Yarmuk-Jordan, 1192-1992, in* WATER AND PEACE IN THE MIDDLE EAST 93 (J. Isaac & H. Shuval eds., 1994) [hereinafter WATER AND PEACE]; Aaron Wolf & John Ross, *The Impact of Scarce Water Resources on the Arab-Israeli Conflict*, 32 NAT. RESOURCES J. 919, 926-48 (1992); Aaron Wolf, *Water for Peace in the Jordan River Watershed*, 33 NAT. RESOURCES J. 797, 799-806 (1993).

96. Eyal Benvenisti & Haim Gvirtzman, *Harnessing International Law to Determine Israeli-Palestinian Water Rights: The Mountain Aquifer*, 33 NAT. RESOURCES J. 543, 550-59 (1993); Haim Gvirtzman, *Groundwater Allocation in Judea and Samaria, in* WATER AND PEACE, *supra* note 95, at 205, 208-14. A slightly different assessment of the issue

Two central terms need definition before continuing the article. First, the *feeding area* is the surface area composed of permeable rock outcrops through which both rainwater and pollutants can penetrate the aquifer. Second, the *storage area* is that part of the aquifer where surface rocks are impermeable, serving as a "roof" covering the groundwater reservoir. Pumping water from the storage area is stable and cheap, and most of the wells pumping water from the Aquifer are in this area. The majority of the Mountain Aquifer's feeding area is outside Israel's pre-1967 borders, and is predominantly inhabited by Palestinians. However, a greater amount of the Aquifer's water volume is contained within Israel's 1967 borders.[97]

The physical properties of the particular aquifer determine its groundwater vulnerability to pollution.[98] The "DRASTIC" model, developed by the U.S. Environmental Protection Agency, assesses an aquifer's sensitivity to contamination using seven factors.[99] In light of the Mountain Aquifer's importance to the region, it is surprising that no one, using either DRASTIC or any other model, has completed a comprehensive assessment of the Mountain Aquifer's vulnerability to contamination. The available information regarding some of the DRASTIC central factors indicates, however, that most of the Aquifer remains highly vulnerable to anthropogenic pollution. For one, the Aquifer's hydraulic conductivity is relatively high.[100] The aquifer media includes

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appears in Hillel I. Shuval, *Geopolitical Aspects of Shared Aquifers: A Case Study of a Conflict, in* GROUNDWATER CONTAMINATION AND CONTROL 661 (Uri Zoller ed., 1994). *See also* Hillel I. Shuval, *Proposed Principles and Methodology for the Equitable Allocation of the Water Resources Shared by the Israelis, Palestinians, Jordanians, Lebanese and Syrians, in* WATER AND PEACE, *supra* note 95, at 481-86 (discussing the same issue); Wolf & Ross, *supra* note 95, at 924-25. For a more meticulous analysis of the structure of the Aquifer's sub-basins, see Dror Avisar, *The Impact of Pollutants from Anthropogenic Sources within a Hydrologically Sensitive Area; the Wadi Rabba* 44 (1996) (in Hebrew).

97. Gvirtzman, *supra* note 96, at 208, 212-13; Benvenisti & Gvirtzman, *supra* note 96, at 552-57.

98. Yehuda Bachmat and Martin Collin define groundwater vulnerability to pollution as "the sensitivity of its quality to anthropogenic activities which may prove detrimental to the present and/or intended usage-value of the resource." Yehuda Bachmat & Martin Collin, *Mapping to Assess Groundwater Vulnerability to Pollution, in* VULNERABILITY OF SOIL AND GROUNDWATER TO POLLUTANTS 3, 297 (W. van Duijvenbooden & H. G. van Waegeningh eds., 1987).

99. D.R.A.S.T.I.C. refers to the initial of each factor: Depth to water table, Recharge amount, Aquifer media, Soil media, Topography, Impact of the vadose zone, and Conductivity of the aquifer. *See* LINDA ALLER, DRASTIC: A STANDARDIZED SYSTEM FOR EVALUATING GROUND WATER POLLUTION POTENTIAL USING HYDROGEOLOGIC SETTINGS 14-22 (1985); *see also* Sara Secunda, et al., *Composite DRASTIC Land-Use Vulnerability Assessment of Groundwater in Israel's Sharon Region Utilizing GIS Technology* 4, *in* HYDROLOGICAL REPORT 1996 (Water Comm'n Hydrological Serv. & Ministry of the Env't, 1996).

100. BOYKO ET AL., UNDERGROUND WATER CONTAMINATION POTENTIAL IN WESTERN

many cracks and fractions, which create "short-cuts" through the geologic system,[101] while the soil media consists of primarily limestone and dolomite rock formations, allowing rapid infiltration of the soil by various pollutants.[102]

The three principal sources of water pollution within the Mountain Aquifer include, in order of their polluting impact: domestic, industrial, and agricultural pollution.[103] An inadequate infrastructure for treating wastewater in the inhabited parts above the aquifer is responsible for most of the domestic wastewater.[104] The population in this area includes approximately 1,121,900 Palestinians and 133, 200 Israeli settlers.[105] Most Palestinian cities and rural areas do not have adequate wastewater collection or treatment systems.[106] On the other hand, most

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SAMARIA 33 (1993) (in Hebrew, summary in English); Haim Gvirtzman, *The Hydrology of Judea and Samaria, in* JUDEA AND SAMARIA RESEARCH STUDIES-PROCEEDINGS OF THE FIFTH ANNUAL MEETING 269, 278 (1995) (in Hebrew, summary in English) [hereinafter *Hydrology*]; Haim Gvirtzman et al., *Water Reservoirs on the Western Slopes of Samaria for Preventing Floods in the Dan Region, in* JUDEA AND SAMARIA RESEARCH STUDIES-PROCEEDINGS OF THE FOURTH ANNUAL MEETING 315, 325 (1994) (in Hebrew, summary in English) [hereinafter *Water Reservoirs*].

101. V. RUDESKY ET AL., GROUNDWATER POLLUTION HAZARDS FROM THE BARKAN INDUSTRIAL ZONE 11 (The Geological Survey of Israel, 1993) (in Hebrew).

102. V. Rudesky, *The Impact of Barkan Industrial Zone Wastewater on Groundwater Quality, in* JUDEA AND SAMARIA RESEARCH STUDIES-PROCEEDINGS OF THE FOURTH ANNUAL MEETING, *supra* note 100, at 328; Gvirtzman, *Hydrology*, *supra* note 100, at 269-70.

103. *See generally* JEAN J. FRIED, GROUNDWATER POLLUTION 1 (1975) and UNITED STATES ENVIRONMENTAL PROTECTION AGENCY, GROUNDWATER HANDBOOK 97 (2d ed., 1992) (discussing sources of groundwater pollution in general).

104. Feitelson and Abdul-Jaber state in their joint study that "[m]ost of the sewage generated in the West Bank and Gaza Strip, by Jews and Arabs alike, is not treated. Moreover, much of it flows over aquifer recharge areas." ERAN FEITELSON & QASEM HASSAN ABDUL-JABER, PROSPECTS FOR ISRAELI-PALESTINIAN COOPERATION IN WASTEWATER TREATMENT AND RE-USE IN THE JERUSALEM REGION 1 (1997).

105. Central Bureau of Statistics, Pub. No. 573, Statistical Abstract of Israel-1996, at 55 (1996).

106. *See* Jad Isaac et al., *The Palestinian Environmental Dilemma* 14 (International Conference on Ecological Development in the Middle East Paper, Feb. 7-14, 1995)[hereinafter *Dilemma*]; ISRAEL-PALESTINE CENTER FOR RESEARCH AND INFORMATION, *Workshop Session: Water Quality in Israel's Central District and the West Bank, in* OUR SHARED ENVIRONMENT: THE 1995 CONFERENCE 67, at 72-73 (Robin Twite & Robin Menczel eds., 1996). *See* THE APPLIED RESEARCH INSTITUTE OF JERUSALEM (ARIJ), ENVIRONMENTAL PROFILE FOR THE WEST BANK: HEBRON DISTRICT 55 (1995) [hereinafter ARIJ, HEBRON DISTRICT]; ARIJ, ENVIRONMENTAL PROFILE FOR THE WEST BANK: BETHLEHEM DISTRICT 46-49 (1995) [hereinafter ARIJ, BETHLEHEM DISTRICT] and 24 THE BIOSPHERE 26 (No. 3-4, Dec.-Jan. 1994-95) (in Hebrew), for a discussion on the situation in the Palestinian cities of Hebron and Bethlehem. Most of the Palestinian rural population and the inhabitants in the refugee camps dispose their wastewater into cesspits, septic tanks, absorption pits and open sewage channels. When these installations fill up, the raw wastes are disposed into the open wadis and fields. This wastewater directly infil-

Israeli settlements in this area have some collection systems, but in many the wastewater is dumped into the surrounding wadis and open fields.[107]

Agricultural activities above the Mountain Aquifer also harm its water quality, largely due to extensive utilization of agrochemicals, pesticides, fertilizers, and fluents for irrigation.[108] A significant part of the resident Palestinian population (about 50%) benefits directly from the intense agricultural activities undertaken in the area.[109] Farmers cultivating lands above the Aquifer regularly use agrochemicals. As a result, some underground contamination has already been traced.[110] In addition, the rural population above the Aquifer uses untreated sewage for irrigation, threatening the reservoir's water quality.[111]

Information on industrial pollution is scarce. Water experts consider factories owned by the Israeli population (especially in the Barkan industrial zone) the principal sources of industrial pollution.[112] The Israeli factories generate wastewater, some of which includes heavy metals and other dangerous substances. Many of the Israeli factories dump the wastewater into the wadis.[113] There are some Palestinian factories

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trates the aquifer or is carried into the water reservoir by the rain; ARIJ, BETHLEHEM DISTRICT, *id.* at 46-49. *See also* Mohammed Said Al-Hamaidi, *Palestinian Policy and Regional Environmental Cooperation*, PALESTINE-ISRAEL J. 15, 16-17 (1998).

107. BOYKO ET AL., *supra* note 100, at 3. *See, e.g.*, on Barkan settlement, Avisar, *supra* note 96, at 13-15. Some settlements have established purification installations but many of them are poorly maintained, *see, e.g.*, Avisar, *supra* note 96, at 13-15; THE BIOSPHERE, *supra* note 106, at 29; *Workshop Session: Water Quality in Israel's Central District and the West Bank*, *id.* at 72-73 (regarding the El-Kana settlement).

108. *See, e.g.*, Lea Muszkat, *Groundwater Quality: Problems and Solutions*, *in* OUR SHARED-ENVIRONMENT: THE 1994 CONFERENCE 70 (Robin Twite & Robin Menczel eds., 1995) [hereinafter THE 1994 CONFERENCE].

109. Agriculture accounts for 20 to 30% of the Palestinian GDP and the population's employment, *see* THE WORLD BANK, DEVELOPING THE OCCUPIED TERRITORIES: AN INVESTMENT IN PEACE 1 (1993) [hereinafter DEVELOPING THE OCCUPIED TERRITORIES]; Issac et al., *Dilemma*, *supra* note 106, at 5, 7-8; Jad Issac, *Sustainable Development and the Palestinians*, *in* THE 1994 CONFERENCE, *id* at 33, 36 and Jad Issac, *Environmental Protection and Sustainable Development in Palestine*, *in* OUR COMMON ENVIRONMENT 7,15 (Robin Twite & Jad Issac eds., 1994).

110. Karen Assaf, *Palestinian Water Resources-Water Quality*, *in* OUR COMMON ENVIRONMENT, *supra* note 109, at 279, 291-92; Issac et al., *Dilemma*, *supra* note 106, at 7-10; Said Assaf, *Overview of Some Traditional Agricultural Practices Used by Palestinians in the Protection of the Environment*, *in* THE 1994 CONFERENCE, *supra* note 108, at 17.

111. *See* ARIJ, BETHLEHEM DISTRICT, *supra* note 106, at 49 and ARIJ, HEBRON DISTRICT, *supra* note 106, at 57.

112. *See* BOYKO ET AL., *supra* note 100, at 25; Interview with Professor Hillel Shouval, Department of Environmental Studies, at the Hebrew University of Jerusalem (July 3, 1997) [hereinafter Shouval interview]; Interview with Dr. Stuart Wollman, Department of Environmental Studies, at the Hebrew University of Jerusalem (July 4, 1997) [hereinafter Wollman interview].

113. *See* Avisar, *supra* note 96, at 15; BOYKO ET AL., *supra* note 100, at 21-25 and

that generate industrial wastewater, particularly in the tanning and stonecutting industries, which is not pre-treated and is disposed of in a central network of cesspits.[114]

b. Analysis

The Palestinian Authority ("PA") currently controls only a small portion of the lands located over the Mountain Aquifer, though its jurisdiction is expected to expand significantly. Here, the central question concerns the prospects for Israeli-Palestinian cooperation once the PA gains control over a substantial part of the West Bank. Analyzing the prospects for cooperation in order to avoid water contamination requires an examination of two principal factors: (1) each party's positive payoffs from the use of uncontaminated water and (2) the negative payoffs associated with the implementation of the required preventive measures.

In terms of the latter, it is plain that the Palestinians hold the brunt of the burden. For the most part, avoiding contamination of the Aquifer involves an investment designed to prevent the infiltration of domestic wastewater into the underground reservoir. This requires the establishment of an adequate infrastructure for collecting and treating sewage. The financial resources needed to establish the system depends upon the number of people residing in the area. As noted above, almost 90% of the population in the area is Palestinian. According to experts, the required investment in an adequate sewage system in the West Bank is approximately $500 per person, which amounts to more than $600 million for the entire project.[115] With Palestinians making up almost 90% of the population, they would incur the greater share of the costs.

The Palestinians would also incur the greater share of costs associated with preventive measures against water contamination resulting from agricultural activities. Palestinian farmers perform most of the agricultural activities in this area. Agriculture plays a greater role in the Palestinian economy than in the Israeli economy.[116] Consequently,

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Rudesky, *supra* note 102, at 25.

114. *See* ARIJ, HEBRON DISTRICT, *supra* note 106, at 54-55 and ARIJ, BETHLEHEM DISTRICT, *supra* note 106, at 46.

115. Shouval interview, *supra* note 112.

116. 2.9% of the employed population in Israel works in the agricultural sector, which contributes about 4% to the Israeli GDP. *See* ISRAEL INSTITUTE OF PRODUCTIVITY, PRODUCTIVITY IN ISRAEL: INTERNATIONAL PERSPECTIVE 62 (1997) [hereinafter PRODUCTIVITY IN ISRAEL]; DEVELOPING THE OCCUPIED TERRITORIES, *supra* note 109, at 57. Agriculture accounts for 20 to 30% of the Palestinian GDP and employment. *See supra* text accompanying note 109. It is expected that the share of the agricultural sector in

the Palestinians' investment in the required preventive measures related to agricultural activities would be higher than the Israelis' investment.

Currently, industrial operations constitute the smallest source of water pollution in the Mountain Aquifer. Yet the detrimental effects of industrial operations may grow over the next decade. At present, most of the polluting factories in the area are Israeli owned. Under the current analysis, Israel would bear the greater share of preventive costs associated with industrial discharges. However, care should be taken not to overestimate these numbers, as industrial operations in this area constitute only a small share of Israel's overall industry. In addition, anticipated industrialization in the territories under the PA's jurisdiction suggests that the present allocation of preventive costs in the industrial sphere may increase, thus increasing the Palestinian's share of those costs.

An overall assessment of the parties' negative payoffs resulting from the implementation of the required preventive measures shows that the Palestinians would incur substantially more expenses than the Israelis. The gap is considerable with respect to the vast resources needed for the establishment of an adequate sewage system to avoid domestic pollution, and less substantial (but still significant) regarding agricultural pollution. At the moment, the Israelis would bear more preventive costs for industrial pollution.

One can estimate the positive payoffs generated to the parties from using uncontaminated water by examining the expected damage to each party from pollution of the Aquifer. Significant discharge of pollutants into the reservoir by either party will generate negative payoffs for both, since both parties share the same pool. The pollutants in the underground reservoir know no political boundaries. This does not mean that the positive payoffs generated to the parties from using uncontaminated water are the same.

Comparison of the quantities of water used by the parties does not lead to a clear answer. Indeed, two important factors lead to different conclusions. On the one hand, the fact that Israel's share in the Aquifer's waters is much greater than the Palestinians (currently 5:1) suggests that significant water pollution in the Aquifer will entail greater negative payoffs to the Israelis than to Palestinians. On the other hand, the Aquifer supplies 90% of the Palestinian annual consumption and only about a third of Israel's consumption. This indicates that the

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the Palestinian economy will decrease in the future, together with the processes of agricultural industrialization. In light of the current major role of agriculture in the Palestinian economic life, however, we may well anticipate that its share in the GDP will be much greater than the Israeli's share over the next decades.

loss sustained by Palestinians following a significant contamination will be larger than the loss sustained by Israel. Analysis of the timeframe in which the harmful results are anticipated and the parties' discount rates regarding such future losses, reveals asymmetric preferences.

It is precisely known how long it will take from the pollution's discharge until the Aquifer's extracted waters exhibit significant detrimental effects. Water experts claim this period will vary from several years to several decades in most cases of pollution.[117] The time interval introduces an important variable of the parties' discount rate regarding future losses. The discount factor has a major influence upon a party's willingness to cooperate in infinite iterated games.[118] The utilization of the Mountain Aquifer constitutes an infinite iterated situation,[119] and the economic resources available to the parties affect their respective discount rates. As Brown-Weiss observes in her book, "In Fairness to Future Generations: International Law, Common Patrimony and Intergenerational Equity," poor communities are not inclined to cooperate to secure future environmental gains and "desperate actors" are more predisposed to adopt short-term strategies.[120]

Recent economic data shows that Israel is considered a developed State, while the Palestinians are considered a developing nation.[121] In light of the considerable and pressing problems of unemployment and poverty faced by the Palestinian Authority,[122] it is clear that the Palestinians' discount rate regarding water contamination, expected to occur within several years to decades, is quite low. The situation in the Gaza Strip exemplifies the Palestinians' low discount rate regarding future water sources. Over-exploitation of the aquifer in the Gaza Strip, where one of the poorest communities in the Middle East lives, has led

117. Wollman interview, *supra* note 112; Interviews with Dr. Yehuda Bachmat, Israel Hydrological Service (Sept. 25, 1996) and Dr. Dror Gilad, Israel Hydrological Service (Jul. 3, 1997). *See also* Karen Assaf, *supra* note 110, at 291.

118. On the role of the discount rate in infinite games, *see supra* Part II.C(2-4).

119. The Aquifer is replenishable and allows infinite utilization. A persistent extraction beyond the replenishment rate, however, will terminate its existence. In the latter case, the structure of the setting will be similar to a zero-sum game.

120. EDITH BROWN-WEISS, IN FAIRNESS TO FUTURE GENERATIONS: INTERNATIONAL LAW, COMMON PATRIMONY. AND INTERGENERATIONAL EQUITY 162-63 (2d ed. 1989). *See generally* ELINOR OSTROM, GOVERNING THE COMMONS: THE EVOLUTION OF INSTITUTIONS FOR COLLECTIVE ACTION (1990) (discussing common-pool resources and ways that they can be organized to avoid excessive consumption and administrative costs).

121. In 1992, the Israeli's annual GDP per capita was estimated at $16,600 while the Palestinian's annual GDP per capita was approximately $1700. *See* SHARIF S. ELMUSA, INSTITUTE FOR PALESTINE STUDIES, NEGOTIATING WATER: ISRAEL AND THE PALESTINIANS 22-23 (1996); *The Palestinian Economy*, PALESTINE-ISRAEL J. 106-07 (1998); and PRODUCTIVITY IN ISRAEL: AN INTERNATIONAL PERSPECTIVE, *supra* note 116, at 82.

122. *See, e.g.*, THE WORLD BANK, BACKGROUND NOTE ON THE ECONOMY 1-5 (Fourth Meeting of the Consultative Group for the West Bank and Gaza, 1996).

to saltwater intrusion into the reservoir and increased salinity.[123] Generally speaking, a low discount rate decreases the value of future gains or losses for a party.

Three main conclusions can be drawn from the above analysis. First, the Palestinians' expected preventive costs are substantially greater than those of Israel. Second, the Palestinians' discount rate is significantly lower than that of Israel. Finally, as a result of the second conclusion Israel's future positive payoffs are greater than the Palestinians.

Assuming that both Israel and the Palestinians have two principal strategies, C (cooperate) and D (defect), significant pollution results if one party cooperates and the other does not cooperate (CD or DC). Pollution is avoided if both parties adopt cooperative strategies (CC). Serious contamination takes place if both adopt non-cooperative strategies (DD). Figure 9 sets forth the normal form of the parties' ordinal payoffs for water contamination of the Mountain Aquifer.

		The Palestinians	
		C	D
Israel	C	4, 2	1, 4
	D	3, 1	2, 3

Figure 9: Ordinal payoff matrix for Israel and the Palestinians re-garding water contamination of the Mountain Aquifer.

The matrix reveals asymmetric preferences. The Palestinians' order of priorities is:

DC> DD > CC > CD[124]

123. *See* Karen Assaf, *supra* note 110, at 286-89; Reitse Koopmans, *Environmental Problems in the Gaza Strip, in* THE 1994 CONFERENCE, *supra* note 108, at 126, 128-29; Gaza Isam R. Shawwa, *Water Situation in the Gaza Strip, in* WATER AND PEACE, *supra* note 95, at 251; Ephraim Ahiram & Hanna Siniora, *The Gaza Strip Water Problem: An Emergency Solution for the Palestinian Population, id.* at 261.

124. In DC, the Palestinians do not bear the expensive costs of preventive measures but will suffer from significant pollution in the future. As explained above, future negative payoffs are significantly discounted by the Palestinians. In DD, the Palestinians do not incur the expensive preventive costs but will sustain serious water pollution in the future; the latter negative payoffs are significantly discounted. In CC, the Palestinians bear the expensive costs of preventive measures but will benefit from clean water for the long range; future gains, however, are significantly discounted. In CD, the Palestinians incur the expensive costs of preventive measures and will suffer significant pollution in the future; future losses are discounted but the considerable expenses incurred at present are not.

Note that the Palestinians' order of priorities is quite similar to a player in a PD game.[125]

Israel's order of priorities is:

CC > DC > DD > CD[126]

Israel's order of priorities is the same as in the Assurance game.[127]

An analysis of the above matrix reveals that strategy D is the *dominant strategy* for the Palestinians (DC>CC and DD>CD). In other words, the Palestinians are likely to prefer D regardless of Israel's action. Israel, aware that D is the Palestinians' dominant strategy, is likely to prefer strategy D as well (DD>CD). Thus, the resulting equilibrium is DD in which both parties prefer not take preventive measures. This equilibrium point represents the Palestinians' second-best alternative and Israel's third-best alternative. Needless to say, the DD equilibrium represents the worst environmental alternative.

Characterizing the Palestinians' ordering preferences as similar to a player's in an infinite iterated PD game may suggest that Israel should employ contingent strategies (like *Tit-for-Tat*), which normally motivate cooperation in such settings.[128] An analysis of the above matrix and the parties' particular properties reveals that Israel's exercise of a contingent strategy (polluting the aquifer if the Palestinians do so) is not likely to stimulate the Palestinians into cooperation. The Palestinians will feel the harmful consequences only after several years or decades. Motivating cooperation by contingent strategies in infinite iterated PD requires the players to have high discount rates.[129] As discussed above, the Palestinians' discount rate regarding future water contamination is quite low. More importantly, even if Israel attempts to remedy the problem of the Palestinians' low discount rate by threatening to employ harsh contingent strategies, such as the *Grim Trigger*,[130] the Palestinians' choice is not expected to change. Regardless of whether Israel cooperates, since D is the Palestinians' dominant strat-

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125. The difference is that in the PD game CC>DD, and in our case DD>CC. *See supra* Part II.C(2) for a discussion of the PD game and its special properties.

126. In CC, Israel bears the preventive costs but will benefit from future uncontaminated water; Israel's future payoffs are not significantly discounted. In DC, Israel does not incur the preventive costs but will sustain the harmful results of significant water pollution in the future. In DD, Israel does not bear the costs of the preventive measures but will suffer a serious water contamination. In CD, Israel incurs the preventive costs and will sustain significant water pollution.

127. *See supra* Part II.C(3) for a discussion of the Assurance Game and its special properties.

128. *See supra* Part II.C(2) for a discussion on the role of contingent strategies, including *Tit-for-Tat*, in PD situations.

129. *See supra* Part II.C(2).

130. *See supra* Part II.C(2) for a discussion on the Grim Trigger strategy.

egy, they are unlikely to be motivated to cooperate in response to a harsh contingent strategy.[131]

In summary, the structure of the setting between Israel and the Palestinians is clearly asymmetric. The above analysis suggests that the prospects for cooperation regarding the aquifer setting are unlikely. Moreover, employment of contingent strategies is not likely to change the parties' preferences. Unfortunately, the lack of cooperation could result in long-term damage to the environment.

B. Employing Legal Mechanisms to Avoid Collective Action Failure

The above game theoretical analysis indicates that cooperation is not expected to be easily elicited regarding the use and maintenance of the southern part of the Gulf of Aqaba and the Mountain Aquifer. Having employed game theory's tools, it may be possible to suggest some international legal mechanisms to modify the structure of settings susceptible to collective action failure. The challenge revolves around creating international settings that are more favorable to international cooperation and exploring legal techniques available to international lawyers to further this end.

The most frequent tool employed by international law to change payoff structures is the formulation of substantive norms, which create new rights and obligations for States. Establishing a legal obligation to follow a particular course of action modifies the payoff structure to a party, who then must contemplate whether or not to pursue the legally required course of action. Although States usually react unfavorably to another State's harmful activities, their reaction is compounded when the detrimental act violates rights prescribed under international law.[132] Thus, a new legal norm binding parties to a cooperative strategy in a given sphere increases the negative payoffs generated to a player who breaches an obligation. For this reason, establishing a legal obligation to cooperate, for instance in a treaty, improves the likelihood of cooperation.

The importance of contingent strategies in eliciting cooperation[133] highlights the role of international rules regarding "countermeasures" designed to enhance cooperation. International treaty law and customary international law set particular limitations on the use of retaliatory measures.[134] As illustrated below, widening or narrowing the possibil-

131. This conclusion applies *a fortiori* to a milder contingent strategy, like *Tit-for-Tat*.

132. *See, e.g*, LOUIS HENKIN, HOW NATIONS BEHAVE (2d ed., 1979).

133. *See supra* Part III.C(2-4) for a discussion of the role of contingent strategies to support cooperation.

134. *See, e.g.*, Article 60 of the 1969 Vienna Convention on the Law of Treaties, 8 I.L.M. 679 (1969); Article 30 of the International Law Commissions' Draft Articles on State Responsibility; (1979) Y.B. INT'L L. COMM'N 115-22 (Vol. II, Part 2); (1992) Y.B.

ity of retaliation in a given area is likely to affect the prospects for cooperation in that sphere.

International law also supports the prospects for cooperation by iteration of interaction among the parties.[135] The establishment of joint institutions may be realized by enlarging the "shadow of the future".[136] Information is crucial to cooperation in some settings, such as Assurance situations. Indeed, as described below, legal mechanisms facilitating collection and dissemination of information have significantly contributed to the emergence and maintenance of international cooperation.

The mechanism of *linkage* may be of great importance to the future environmental regime in the Middle East. When a particular international setting is susceptible to collective action failure (for instance when it presents strong features of zero-sum or Chicken game),[137] international law can alter the structure of the game by establishing a *linkage* between several issue-areas. The structural features of the new setting, composed of the formerly separated domains, may provide the parties with adequate incentives to cooperate. As noted above, the environmental settings of the Mountain Aquifer and the southern part of the Gulf of Aqaba are significantly asymmetric, and the parties are not likely to adopt cooperative strategies.

Similar asymmetric features are prevalent in other environmental spheres in the Middle East, such as air pollution. Scientific evidence gathered in the recent decade, along with well-known data regarding the general air flow patterns in the Middle East, show that Israel "exports" significant amounts of particulate sulfate and ground-level ozone (O3) to the West Bank, and probably to Jordan.[138] The wind regime in

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INT'L L. COMM'N 31-55 (Vol. II, Part 2).

135. *See supra* Part II.C(2-3) for a discussion on the role of iteration to elicit cooperation. *See generally* John K. Setear, *An Iterative Perspective on Treaties: A Synthesis of International Relations Theory and International Law*, 37 HARV. INT'L L. J. 139 (1996) (discussing iteration in the international law of treaties).

136. Duncan Snidal, *The Politics of Scope: Endogenous Actors, Heterogeneity and Institutions*, *in* LOCAL COMMONS AND GLOBAL INTERDEPENDENCE: HETEROGENEITY AND COOPERATION IN TWO DOMAINS 47 (Robert O. Keohane & Elinor Ostrom eds., 1995) [hereinafter LOCAL COMMONS AND GLOBAL INTERDEPENDENCE]. *See* Benvenisti, *supra* note 58, at 410-13 (discussing the role of institutions and how they can cooperate to intensify interactions, especially regarding the utilization of shared freshwater resources).

137. On the Chicken Game, *see generally* Hugh Ward, *Three Men in a Boat, Two Must Row: An Analysis of a Three-Person Chicken Pregame*, 34 J. CONFLICT RESOL. 371 (1990); Barton L. Lipman, *Cooperation Among Egoists in Prisoners' Dilemma and Chicken Games*, 51 PUBLIC CHOICE 315, 316 (1986); Ward, *supra* note 67, at 354, 367-69.

138. *See* Menachem Luria et al., TRANSPORTATION OF AIR POLLUTANTS FROM ISRAEL TO THE JORDAN VALLEY 56 (1996) (in Hebrew); Yossi Sachi et al., *Airborne Measurements of Ozone Levels over Central Israel*, *in* JUDEA AND SAMARIA RESEARCH STUDIES-

the region, mostly from northwest or northeast to the east,[139] and Israel's eastern neighbors' modest level of industrial activity results in a situation in which transboundary air pollution in the opposite direction is negligible (from the Palestinian territories and Jordan to Israel).

Asymmetric environmental settings occur regularly in the international arena, frequently inhibiting the emergence of cooperation.[140] Asymmetric preferences often lead the less-interested parties to reject a legal regime binding them to significant costs.[141] If they do join, they often tend not to comply with the agreement's main obligations. When any of the major polluting parties adopt this strategy, the overall effectiveness of the environmental regime is significantly undermined. International law may enhance the prospects for cooperation in such asymmetric settings by creating a link between the legal regimes to be established for each particular environmental sphere. For instance, a regime aiming to reduce transboundary air pollution in the Middle East may be linked to a regime designed to avoid water contamination of the Mountain Aquifer.

The technique of legal linkage addresses two basic problems arising in asymmetric environmental settings. First, a legal regime that combines several environmental spheres can provide the less-interested party in each domain with an incentive to join the comprehensive regime. Second, the establishment of a combined regime widens the opportunities for contingent strategies, which are capable of eliciting co-

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PROCEEDINGS OF THE FIFTH ANNUAL MEETING 339, 340-341 (1995) (in Hebrew; summary in English); 2 Mordechai Peleg et al., *Airborne Measurements of Ozone Levels over Central Israel, in* PROCEEDINGS OF THE 10TH WORLD CLEAN AIR CONGRESS 292, 294 (1995); Menachem Luria et al., *The Formation of O3 over Israel: A Growing Concern and a Potential International Issue, in* PRESERVATION OF OUR WORLD IN THE WAKE OF CHANGE 13-16 (1996).

139. Uri Dayan, *Climatology of Back Trajectories from Israel Based on Synoptic Analysis*, 25 J. CLIMATE & APPLIED METEOROLOGY 591 (1986).

140. Asymmetric preferences, however, may support cooperation in some settings. For articles discussing conflicting views on whether heterogeneity impedes or supports the emergence of environmental cooperation, *see* Lisa L. Martin, *Heterogeneity, Linkage and Commons Problems, in* LOCAL COMMONS AND GLOBAL INTERDEPENDENCE, *supra* note 136, at 73; Duncan Snidal, *The Politics of Scope: Endogenous Actoers, Heterogeneity and Institutions, id.* at 47 and Ronald B. Mitchell, *Heterogeneities at Two Levels: States, Non-State Actors and International Oil Pollution, id.* at 239-40.

141. For example see the position of the United Kingdom, one of the main exporters of sulfur in Europe, regarding the agreement concluded under the auspices of UNECE to reduce sulfur emissions. Armin Rosencranz, *The Acid Rain Controversy in Europe and North America: A Political Analysis, in* INTERNATIONAL ENVIRONMENTAL DIPLOMACY 173-85 (1988); Johaan G. Lammers, *The European Approach to Acid Rain, in* INTERNATIONAL LAW AND POLLUTION 265, 273 (1991); Amy A. Fraenkel, *The Convention on Long-Range Transboundary Air Pollution: Meeting the Challenge of International Cooperation*, 30 HARV. INT'L L. REV. 447, 463, 473-74 (1989).

operation in competitive settings. A party who cannot adopt retaliatory measures within a particular sphere[142] may find new opportunities in an expanded regime. These factors suggest that, generally, the broader the scope of the regional environmental regime in the Middle East (in terms of the amount and diversification of interests involved), the more the parties are likely to undertake and comply with its provisions.

Establishing a legal link between the Middle East's various environmental issues enhances the probability that more parties will implement the provisions of the regional regime. Still, such legal linkages cannot always remedy the problem of asymmetric preferences. One particular party may be relatively disinterested in all environmental issues covered by the regional regime. Transboundary air pollution from Israel, for instance, is not expected to significantly affect Syria and Lebanon. They represent the "upstream parties" in the Jordan River basin and the Mediterranean Sea, and they have no significant interest in the Gulf of Aqaba. Pulling such "persistently" disinterested parties into the regional effort may require a legal linkage between the regional environmental regime and a non-environmental regime.[143]

While legal linkages may significantly enhance the effectiveness of any future environmental regime in the Middle East, they also raise numerous questions. For instance, which legal field is most appropriately to be linked with the environmental sphere? Clearly, the linked field should be of significant interest to all parties who are likely to affect the quality of the region's principal environmental resources. It must also represent a relatively stable domain, in that it acknowledges the parties' long-standing interests.

The field of commercial relations among the Middle Eastern parties generally meets the above criteria.[144] The legal linkage between issues of trade and the environment is well established in international environmental treaties, such as the Ozone Layer agreements.[145] While much attention has recently been devoted to the legal problems accom-

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142. For example, Israel, with regard to water contamination of the Mountain Aquifer (*see* Part III.A(2)), or the Palestinians, with regard to air pollution (*see* Part III.B).

143. *See*, *infra*, for a discussion on the possible issue-areas to be linked with the future environmental regime.

144. On the current and prospective commercial relations between the parties in the Middle East, *see* Hisham Awartani, *Palestinian-Israeli Economic Relations: Is Cooperation Possible?*, *in* THE ECONOMICS OF MIDDLE EAST PEACE: VIEWS FROM THE REGION 281 (1993) [hereinafter THE ECONOMICS OF MIDDLE EAST PEACE]; Natan Zusman, *Trade Agreements as a Part of Peace Agreements-An Historical View*, 4 ECON. Q. 630 (1994); Ephraim Kleiman, *Some Basic Problems of the Economic Relationships between Israel, the West Bank and Gaza*, *in* THE ECONOMICS OF MIDDLE EAST PEACE, *id.* at 305; Tal Sadeh, THE ECONOMIC DESIRABILITY OF MIDDLE EAST EASTERN MONETARY COOPERATION 15-18 (The Helmut Kohl Institute for European Studies Working Paper 1/97, 1997).

145. *See, e.g.*, Article 4 of the Montreal Protocol on Substances that Deplete the Ozone Layer, 26 I.L.M. 1550 (1987).

panying the linkage between environment and trade,[146] the option remains a viable one for the Middle Eastern environmental regime. The commercial sphere offers relatively significant and stable benefits to all parties in the region. Moreover, its importance is expected to grow, thereby enlarging the range of contingent measures to support effective cooperation.

Yet establishing a linkage between the environmental and commercial spheres may expose environmental resources to adverse effects triggered by cross-sector retaliations. A party within the regional framework may invoke another party's alleged violation of an agreement's commercial provisions in order to justify noncompliance with its environmental obligations. If frequent enough, such cross-sector retaliatory measures could significantly harm the region's environmental resources. The problem, however, has a legal solution.

Legal norms may allow cross-sector retaliation in one direction. With respect to the environment, this means admission of retaliatory measures for protecting the environment, with a prohibition to operate such measures against environmental resources. For example, the technique of "one-way retaliation" frequently occurs under international human rights law. While various countermeasures, including trade sanctions, are admissible to protect human rights, reprisals involving human rights violations are strictly forbidden.[147]

C. Information and Environmental Cooperation in the Middle East

Information plays a major role in game theoretical analysis. The collection and dissemination of reliable information often[148] fosters the prospects for cooperation. This part of the article examines the role of information in the Middle East's environmental settings and suggests some legal means for improving the flow of information between the parties.

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146. Among the endless list of publications on this subject, see DANIEL ESTY, GREENING THE GATT: TRADE, ENVIRONMENT AND THE FUTURE 3 (1994); C. FORD RUNGE, FREER TRADE, PROTECTED ENVIRONMENT 5 (1994); Thomas J. Schoenbaum, *Free International Trade and Protection of the Environment: Irreconcilable Conflict?* 86 AM. J. INT'L L. 700 (1992); Edith Brown-Weiss, *Environment and Trade as Partners in Sustainable Development*, 86 AM. J. INT'L L. 728 (1992).

147. *See* Article 60(5) of the 1969 Vienna Convention on the Law of Treaties, *supra* note 134; (1979) Y.B. INT'L L. COMM'N, *supra* note 134, at 116; (1992) Y.B. INT'L L. COMM'N, *supra* note 134, at 32-33; OMER YOUSIF ELAGAB, THE LEGALITY OF NON-FORCIBLE COUNTER-MEASURES IN INTERNATIONAL LAW 99-104 (1988).

148. It should be noted that complete information may hinder cooperation in some settings. This is clearly the case in PD situations in which cooperation may arise where the parties lack information regarding the number of the remaining rounds to be played; on infinite PD games, *see* Part II.C(2).

1. Environmental Standards and Coordination Games

Current use of the Gulf of Aqaba and the Mountain Aquifer is stretching their respective environmental capacities. Moreover, the expected wave of economic development in the region poses significant perils to their sustainable use. The need for regional environmental standards in the Gulf of Aqaba[149] applies *a fortiori* to the crucial water reservoir of the Mountain Aquifer. Ensuring future sustainable use of the Aquifer's water requires standards for establishing and maintaining adequate sewage infrastructure, as well as for the content of irrigation fluents in the areas above the aquifer.[150]

The formulation of common standards for Middle Eastern parties in the environmental field should generate an interactive setting, characterized by the features of the Coordination game. Such a setting creates multiple *Pareto equilibria* positions over which the players have divergent preferences. Different equilibiria positions generate a distribution problem since each player wants the other to converge on his or her preferred position. In the Gulf of Aqaba, for instance, Israel is expected to require strict emission standards regarding pollution emitted from phosphates (transmitted from Jordan),[151] while Jordan is likely to insist on more stringent standards for port facilities dealing with loading and unloading crude oil (located in Eilat's Port). The fact that the Gulf of Aqaba represents an infinite iterated situation, and that the parties have relatively high discount rates, intensifies the distribution problem.[152]

Parties in Coordination settings are expected to misrepresent their private information.[153] This leads to a situation in which a party does not trust the information provided by the other players, thus decreasing the prospects for successful coordination. The tense and suspicious relationships in the Middle East, particularly between the Israelis and the Palestinians, exacerbate this problem. Entrusting the task of collection and analysis of relevant information to a professional third party may mitigate the informational problem (e.g., a private consultant or research institute specializing in the particular environmental field). These specialists must be authorized to travel freely within the territories of the relevant parties, in order to accomplish their objectives. Needless to say, the parties should be bound to facilitate these operations by, among other things, providing the specialists with all

149. *See supra* Part III.A(1).

150. For more detail on this problem, *see supra* Part III.A(2).

151. *See* Maher F. Abu-Taleb, *Environmental Management in Jordan: Problems and Recommendations*, 21 ENVTL. CONSERVATION 35, 36 (1994).

152. On the impact of the discount factor and iteration on the prospects for cooperation in the Coordination game, *see supra* Part II.C(4).

153. *See supra* Part II.C(4).

necessary data. Finally, in order to foster trust in the specialists, the parties' representatives should be present in both information gathering and analysis.

The process of agreeing upon environmental standards features elements found in the Coordination game, but their *implementation* is another matter. In a classic Coordination game, once the players agree on a cooperative solution, their incentive to depart from the coordination point diminishes, and the solution becomes self-enforcing.[154] This is not necessarily the case when implementing environmental standards in different environmental settings. For instance, the implementation of standards to set up a sewage infrastructure in the Palestinian cities above the Mountain Aquifer represents the features of the Prisoner's Dilemma. In such cases, the standards are not "self-enforcing" and their implementation requires relatively strong monitoring and enforcement mechanisms.[155]

2. Conveying Assurances and Information

The above analysis of the structure of the Middle Eastern environmental settings reveals that the Assurance game reflects the relationships between Israel and Jordan in the Gulf of Aqaba. The Assurance game also reflects the relationship between Egypt and Israel or Jordan in the northern part of the Gulf; and Israel's preferences regarding the Mountain Aquifer. Information regarding the other party plays a crucial role in Assurance situations. A player in such a setting is likely to cooperate if he or she expects the other players to cooperate as well. A cooperating party is likely to depart from his or her cooperative course if he or she expects the others to adopt a non-cooperative strategy.[156] A lack of information and the resulting atmosphere of uncertainty might lead a player to adopt a non-cooperative strategy.[157]

The importance of information in Assurance situations demonstrates the need for an adequate mechanism to ensure transparency. For example, an effective legal mechanism should prescribe explicit and detailed provisions binding the parties to prepare a comprehensive Environmental Impact Assessment (EIA) regarding any planned measure with a potentially transborder environmental impact. Parties should transmit copies of the EIAs to the other parties in each environmental setting. Establishing a forum for the exchange of information and consultations on planned projects is also highly desirable.

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154. For detail, *see supra* Part II.C(4).
155. *See* Snidal, *Coordination*, *supra* note 59, at 938.
156. *See supra* Part III.C(3).
157. That may be the case, for instance, where the negative payoffs generated to the cooperative party in CD are substantial and the expected damage is irreversible.

3. Contingent Strategies and Information

As in Assurance situations, information plays an essential role in the operation of contingent strategies to support cooperation, like infinite PD situations. As noted above, the possibility of effective retaliatory measures is crucial for attaining environmental cooperation in the comprehensive Middle Eastern regime.[158] Countermeasures are triggered when there is information indicating that the other player has adopted a non-cooperative strategy. In the absence of reliable information regarding measures taken by the other parties, the effectiveness of contingent strategies decreases. Similarly, unreliable information may generate unjustified "retaliatory" measures against a cooperative party. This may result in the collapse of an otherwise successful cooperation.

These observations lead to the conclusion that a reliable monitoring mechanism is imperative to ensure environmental cooperation in the Middle East. The first step is to set out detailed provisions requiring the parties to provide data on the state of environmental resources under their jurisdiction, as well as the relevant measures to protect the environment they have already undertaken. Farming out some of the central functions to a panel of specialists (e.g., for inspections and data analysis) would enhance the reliability of the information gathered. In turn, this would promote the prospects for cooperation.

IV. CONCLUSION

This article demonstrates that combining game theory and international law enhances the prospects of international environmental cooperation. The concepts and models of game theory often assist scholars and policy-makers in identifying why cooperation failed in a given international setting. It may also aid them in predicting settings that are more susceptible to collective action failure. More importantly, game theoretical tools can be used to alter the current competitive settings, while serving as a planning tool for the construction of international regimes more suitable to stable cooperation. Legal mechanisms that draw on game theory's insights can increase the likelihood of future cooperation in the Middle East. These mechanisms include legal linkage between particular issue-areas, adequate rules regarding retaliation, and norms regarding dissemination of information. If the respective parties adopt these legal mechanisms it will unquestionably promote environmental cooperation in the Mountain Aquifer and the Gulf of Aqaba.

As with any handy tool, users should be aware of game theory's limitations. The advantages of combining game theory and interna-

158. *See supra* Part III(B).

tional law should not disguise its inherent imperfections.[159] Game theoretical analysis does not always lead to a unique equilibrium. Indeed, in many cases, multiple equilibria exist. When this occurs, as in the Coordination game, game theory does not help direct one to the particular outcome of the game.[160] Nonetheless, game theoretical analysis frequently narrows the number of possible solutions and provides a limited range of possible outcomes.

Game theory assumes, *inter alia*, that the players have predetermined goals and that they strive to attain these goals through their actions.[161] The theory does not explain which factors motivate a player to adopt a certain preference and how this preference is modified over time. The process of emerging and changing preferences is exogenous to game theory. Additionally, some collective action failure situations are not amenable to structural alteration designed to support cooperation. In others, the cost of structural change is prohibitive.[162] Where this is the case it would be more realistic to explore methods of modifying the players' preferences, rather than changing the payoffs aimed at satisfying these preferences.

Game theory does not aim to explain how preferences are formed. As noted above, game theory focuses on one set of variables (payoffs, strategies, information, iteration, discount factors, etc.) influencing decision-makers, but it does not represent a comprehensive theory exhausting all factors involved in international cooperation. Factors such as the personal characteristics of the decision-makers or social values prevailing in their community, which may affect the decision-makers' choices, are exogenous to game theoretical analysis. The absence of these factors is a central shortcoming of game theory. Yet it also underscores the theory's essential goal of simplifying and abstracting complex social phenomena into formal models. Focusing on one set of variables facilitates rigorous analysis and the exploration of interplay between the variables involved in collective action, such as discount factors and cooperative behavior.

Legal mechanisms, such as retaliatory rules and linkage arrangements, are valuable tools in encouraging international environmental cooperation. However, the law's capacity to modify existing structures

159. For detail regarding the limitations of game theory, *see* KEN BINMORE, ESSAYS ON THE FOUNDATIONS OF GAME THEORY 5-21 (1990); KREPS, *supra* note 38, at 91-132, 177-83; HEAP & VAROUFAKIS, *supra* note 9, at 12-18.

160. *See* MARTIN HOLLIS, THE PHILOSOPHY OF SOCIAL SCIENCE 137 (1994); KREPS, *supra* note 38, at 95-102.

161. *See supra* Part II.A. This assumption reflects the instrumental sense of rationality. *See* SHAUN H. HEAP, RATIONALITY, IN THE THEORY OF CHOICE: A CRITICAL GUIDE, 4-5 (1992); HEAP & VAROUFAKIS, *supra* note 9, at 5.

162. Interactive settings, which are hardly amenable to structural change will be dealt further below.

depends upon numerous factors. These include the scope of the particular setting and the gap between the payoffs generated to the players from cooperative and non-cooperative strategies. Generally, the smaller the setting's dimensions in terms of the extent and the value of the involved resources, the actors' strength, etc., the easier it is to change its structure. Similarly, legal intervention to support cooperation in competitive settings is more viable when there is a minimal payoff gap (in favor of non-cooperation). Establishing a legal linkage between several issue-areas, however, can remedy the problems associated with large-scale settings and substantial payoff gaps. Linkage makes it possible to mobilize adequate resources from different domains to support cooperation in problematic settings.

In conclusion, both game theory and international law have inherent limitations. These limitations occasionally limit their ability to modify the structure of international settings susceptible to collective action failure. Nevertheless, the combination of game theoretical analysis and international law offers scholars and policy-makers important insights in devising suitable legal mechanisms that support international environmental cooperation.