Full citation: Dodds, Walter K. "The Commons, Game Theory, and Aspects of Human Nature that May Allow Conservation of Global Resources." *Environmental Values* 14, no. 4, (2005): 411-425. http://www.environmentandsociety.org/node/5945

The Commons, Game Theory and Aspects of Human Nature that May Allow Conservation of Global Resources

WALTER K. DODDS

Division of Biology
Kansas State University
Manhattan KS 66506, USA
Email: wkdodds@ksu.edu

ABSTRACT

Fundamental aspects of human use of the environment can be explained by game theory. Game theory explains aggregate behaviour of the human species driven by perceived costs and benefits. In the 'game' of global environmental protection and conservation, the stakes are the living conditions of all species including the human race, and the playing field is our planet. The question is can we control humanity's hitherto endless appetite for resources before we irreparably harm the global ecosystem and cause extinction of even more species? The central problem is that some proportion of the individuals or groups will behave selfishly. The inducement for using more than a fair share, or 'cheating', increases as that resource becomes rarer, thus the benefits of cheating increase. In addition, the total number of people is increasing, so the proportion of cheaters must decrease to even keep total resource use constant. Cost benefit analysis of the effect of regulation and incentives on potential cheaters may provide a rational approach to controlling environmental problems. While it is debatable that environmental values are constant across cultures, communal use of resources seems to follow global rules. Cooperative use and punishment of those who use more than their share appear to be ubiquitous in human societies. Schemes for controlling human impact on the global environment must take into consideration basic behaviours including development of social norms and the positive feedback created because resources become more valuable with increasing rarity leading to more incentive for consumption.

KEYWORDS

Commons, game theory, global environment, human behaviour

Environmental Values **14** (2005): 411–25

Game theory offers a way to characterise the behaviour of groups of animals, including people. Protection of the global environment will certainly require understanding the human dimension, and game theory offers a potentially useful avenue for understanding innate aggregate behaviours of many people as related to strategies of resource use. The strength of game theory is that it can characterise general human strategies for cooperation and decisions related to resource use. A number of the ideas generated from game theory have been verified across many human cultures, making it an attractive way to approach global environmental problems. This is important because environmental values vary widely across and even within cultures (Gardner and Stern 1996).

In this paper I describe how selfish players use an unregulated resource (the well known tragedy of the commons), and the various strategies that humans use to decide when to cooperate. Resources are defined here as anything humans use from the environment (e.g. water, energy, species, forests). The application of game theory to resource usage rates is a potential avenue for bridging social science and environmental science to address environmental problems.

Garrett Hardin's 'Tragedy of the Commons' (1968) is a simple application of game theory to environmental resource use. For the tragedy of the commons to be in effect, selfish individuals are exploiting a finite unregulated resource base. The example Hardin used was an unregulated village communal pasture where each individual gains the most benefit if they put more animals on the pasture (they feed more cows). Overgrazing occurs in spite of the fact that it will ultimately destroy the pasture for everyone because each individual has the most to gain in the short term by grazing more cows. An external market for cattle exacerbates the problem.

Overexploiting the commons is the story of essentially all unregulated resources at the global scale (in spite of claims of technology obviating limits of resource availability, Sharma 2001) because most global resources are unregulated and the human population is large enough to make global resource bases functionally finite. Thus, we have experienced the collapse of every major unregulated fishery that has been exploited by humans (Jackson et al. 2001); global deforestation rates remain unabated; we continue to pollute the atmosphere with carbon dioxide and other chemicals, and numerous species have been driven to extinction. The concept behind the tragedy of the commons has been around at least since the Middle Ages, and it has been claimed that there is no direct evolutionary way for humans to escape it with regard to their resource use on earth (Sigmund 1993). However, humans do have a way out of the tragedy of the commons, namely control and punishment of cheaters (those that take more than their communal share). Hardin specifically claimed that regulations, laws and incentives were necessary to avert the tragedy.

The tragedy of the commons has been averted in certain historical contexts (Gardner and Stern 1996) without the specific remedies thought necessary by Hardin. For example, grazing commons were widespread and sustainable across much of post-medieval Europe. Sustainable use was ensured by limiting the number of people who could use the commons, and the intensity at which users could graze livestock. In contrast to arguments by Hardin, such limitation was achieved without formal regulations, laws, or incentives. Rather, informal social mechanisms evolved that led to sustainable grazing practices within small communities (Gardner and Sterner 1996). The key point is that each member of the small community clearly understood the limits of the resource base, and formally or informally enforced controlled grazing rates. The question remains if such controls can be exerted over global resource bases by a world community.

Given that human populations have expanded across the globe, society must regulate resources to avoid over-exploitation of a finite resource pool. The successful regulation of resource use requires the cooperation of most individuals that exploit the finite resource pool. This is true because in all cases where a significant number of people are involved, there are some cheaters in spite of the regulations, social norms, or incentives, because some individuals perceive the benefits of cheating to outweigh the costs. In the case of the pasture, a cheater may sneak more cows on at night, or pay the authorities to ignore his extra cows. In the case of sustainable English pastures, the system eventually fell apart because of increased control by a few wealthy landowners and large scale farming (Gardner and Sterner 1996). The political changes that accompanied the industrial revolution favoured those who used more than their individual share (cheaters in the terminology used here).

Some additional examples of cheaters who avoid regulations or go against social norms include poachers who hunt off season, polluters who dump in spite of regulations, people who water their lawns during times of restricted usage, people who take welfare payments they do not need, and people who kill endangered species for personal profit. Game theory allows us to explore why some choose to be cheaters and others choose to cooperate, and ultimately guide control over global resource use rates.

GAME THEORY: 'LET'S SHARE YOUR RESOURCES AND I'LL USE MINE'

Since John von Neumann discovered that game theory can describe why people make economic choices, games have been used frequently as a model for human behaviour that occurs under real situations. The theory has applications ranging from military and economic strategy to describing evolution of animal behaviour (Sigmund 1993), including human-environment interactions (Grant and Thompson 1997). Game theory can be used to provide indications of how human behaviour will be related to resource use rates in a finite world because it offers a powerful tool to predict the way selfish behaviours dictate the portion of any population that will take advantage of others. Game theory predicts that people will cooperate to conserve resources when it is in their own best interests.

Selfishness is the basic assumption behind game theory. Assuming that individuals act in their own best interest allows prediction of the optimal strategy for solving problems. In general, an individual will not cooperate when potential net benefits of cheating outweigh those of cooperating. Research on cooperation in humans and other animals reinforces this point.

Animals behave selfishly because of their evolved propensity to survive and propagate. All non-human animal behaviours that seem altruistic (unselfish) can be explained as successful strategies of selfish individuals driven by their genetic program (Hamilton 1964a, 1964b, Trivers 1971). Dawkins' '*The Selfish Gene*' (1976) explained eloquently how evolution selects for strategies that benefit the survival of genes, leading to a ubiquitous strategy of 'you scratch my back, I'll ride on yours'. Humans are unique in that we, as a species, are able to realise that it is in our best interests to avoid destructive short-term behaviour of selfish individuals. We are also unique in having cultural evolution in addition to biological evolution. The question is under what conditions is cooperation expected?

Human behaviour can be more complex than simple evolutionary selfishness or altruism. It may be useful to distinguish between selfishness as a characteristic of evolutionary fitness and psychological egoism (the idea that human behavioural choices are always driven by selfish motives). Likewise, evolutionary and psychological altruism can be thought of separately (Sober 1994). In this paper, I make the assumption that a majority of the players operate selfishly, but do not distinguish between evolutionary selfishness and psychological egoism. Thus my terminology may be somewhat fuzzy, but this does not matter to my final result. The end result of the games is the same, regardless of the mechanism of self-promotion in game play. The end result is not changed because psychological altruism may lead some proportion of players to play more altruistically than others, but the remaining selfish players behave as predicted (in the current case take more than their share of environmental resources). Perhaps one of the solutions to global environmental problems lies in enough people behaving as extreme psychological altruists. I think this is not a likely outcome and can think of no mechanism that would bring it about. If psychological altruism mitigates human global environmental impacts, I would be happy to have the fundamental assumption of this analysis proven wrong.

Humans can cooperate when it is not in their best interests to do so. There are clear examples of people behaving completely selflessly (and examples of people behaving completely destructively). However, psychological studies do not support the idea that uncritical altruism is common. Schwartz (1977) theorised that human altruistic behaviour is influenced by 1) the personal obligation felt to take specific helping actions, 2) the occurrence of situations that activate an individual's norms and values, and 3) critical evaluation of whether altruistic behaviour is truly warranted in any specific situation. These ideas are supported by research that verifies that altruism is conditional upon an individual's value system. Schwartz (1977) considered these findings supplementary to genetic explanations. Further research has verified that human cooperative behaviour can be explained on many levels, from genetic to cultural (Richerson et al. 2002), consistent with the view of Schwartz.

Regardless of the fact that some individuals may not behave selfishly, game theory with selfish players is applicable to global resource use rates because if a sizable portion of the 'players' behave selfishly, resource consumption dynamics stay the same. The unconditional altruists may remove themselves from the game, but the remaining selfish players still have the ability to use resources in a non-sustainable fashion. Thus, I will proceed with the concept of using game theory to characterise humans' approaches to resource management.

WHEN DO HUMANS COOPERATE TO CONSERVE RESOURCES?

Cooperation among most humans (also sometimes referred to as reciprocal altruism) will be necessary to reach the point of sustainable use of the environment. It is well documented that individual gain is most often the prime reason for cooperation among animals (Clutton-Brock 2002). Applying the assumption of selfishness to human behaviour allows cost-benefit analysis to determine a balance between cheaters and cooperators (i.e. when altruistic behaviour will occur and at what level). Consider a case where the cheaters always steal resources and the cooperators always share and cooperate in acquiring resources. The cooperators continue to cooperate as long as others do, but refuse to cooperate with known cheaters. Assume that the resource base is a fishery; the cooperators establish how many fish can be caught and still protect an area from over-harvesting. In this example, a group working cooperatively can harvest fish with the least amount of effort, but limit their take to sustain the fishery. The cheaters take as many fish as they can in any way that they can.

If there are more cheater fishers than cooperators, most individuals spend their time distrusting others, protecting acquired resources from cheaters, and thus fishing less successfully. If there are a few cooperative strategists, they will tend to find the other cooperators (because they only will interact with cheaters once) and the cooperative strategy should become more successful because they will spend less time fighting over resources. However, there will be some balance between cooperators and cheaters depending upon the costs of each strategy.

The North Atlantic cod fishery provides one of many cases where the 'cheaters' won before the cooperators could control resource use rates. While the fishery was unregulated, the cod were relentlessly harvested. More efficient equipment allowed fisherman to take an ever-greater number of smaller fish, but fishermen needed to cooperate to purchase bigger boats. When Iceland tried to control takes from their coastal fishery, English fishermen were willing to risk armed conflict to take fish. Ultimately, the 'cheaters' prevailed because too many people harvested too many fish and the commercial cod fishery has for the most part collapsed (Kurlansky 1997).

If there is a high cost of cheating relative to the benefit derived from cooperating (e.g. cheaters are shot by cooperators), the cooperative strategy will be more successful, and cooperators will dominate (but not completely, because a cheater strategy will be more and more successful the higher the proportion of cooperators is). Conversely, if the cost of cheating is low, and the rewards high, a higher proportion of cheaters will be established.

The idea that cooperation is the preferred behaviour when the cost is low and the payoff is high has been documented for a variety or organisms, including humans (Trivers 1971). Examples include coral reef fish where some small fish clean parasites from large fish. The large fish go to cleaning stations and allow the small fish to pick away their parasites. The cleaner fish are fearless and swim inside the mouths and under the gill covers of the large fish to clean them. The small fish receive food, and the large fish are freed of harmful parasites. Both participants gain substantially from the interaction, with little cost. Of course some species cheat; there are small fish that look and act like cleaners but actually bite chunks out of the larger fish and some large fish eat cleaner fish under certain conditions.

In flocks of birds and other groups of animals, warning calls may fall under the category of cooperation with small cost and large benefit. The alarm crier incurs little or no cost, but the benefit to the group is huge. As long as most individuals in the group are willing to make alarm calls, this cooperative behaviour can be very beneficial to each individual.

There are many examples of cooperative behaviours in humans where there is little cost to provide help, but immense benefit to the individual who receives help. Such behaviours include 1) helping endangered, hurt, or sick individuals; 2) sharing food or other resources; and 3) sharing implements or knowledge. Consider food sharing in a village of hunters; an individual that kills a large animal may share meat at very little cost because the successful hunter and their family are unable to consume the entire kill before it rots. This same hunter may not be successful the next time, but receive meat from another cooperative hunter who is. Such examples illustrate how humans may assess costs and benefits and how this drives behaviour.

A key aspect of game theory is that players respond proportionally relative to costs. Individual players calculate costs based upon the proportion of other players with each strategy. Thus, if the proportion of cheaters is high, the perceived benefits of cooperating increase. As a result, some proportion of humans will usually play cooperatively, and others will usually not, because the success of each strategy is defined relative to the proportion of each strategy in the total population.

These arguments hold even if a cheater sometimes cooperates and vice versa (i.e., strategy is context dependent). Each individual assesses the costs and benefits of cooperating in each case and a larger proportion of the population will cheat if the benefits to cheating increase relative to the costs. Most people would never rob a bank, but if a bag of money falls off of a bank truck and blows around, many people will keep the money they pick up, even though it is functionally the same as robbing the bank.

There are almost always some individuals that perceive the benefits of cheating to be high enough that they will attempt to take more than their share. That a variety of strategies always occurs in populations is a function of natural genotypic, phenotypic, and cultural variability. Chance can also play a part in that particular strategies may be successful depending upon the subset of the other players that is being interacted with (Deadman 1999). The proportion of cheaters overall however, depends on how much is to be gained by cheating relative to the benefits of cooperating. In the case of the global environment, cooperators strive to use resources at sustainable rates, and cheaters use more than their share. While the fact that there will always be a proportion of cheaters seems to doom humanity to the fate of a few destroying the environment for the rest of us, there is reason for hope. Social scientists have demonstrated that humans have a deeply entrenched propensity to punish cheaters.

REASON FOR HOPE: THE DESIRE TO PUNISH CHEATERS

Punishing behaviour is so ingrained that individuals will punish cheaters at substantial cost to themselves. This is true across all known human cultures. Even monkeys perceive social inequity as unfair (Brosnan and de Waal 2003). Human punishment enforces cooperative behaviour among non-related individuals (Fehr and Gätcher 2002). Several simple games illustrate that short-term cost-benefit analyses do not completely describe this human punishment behaviour (Sigmund et al. 2002). In the Ultimatum Game, two players share $100, but they do not know each other and cannot exchange information. The money is randomly given to one player, and this player offers a portion of it to the second player. If the second player says yes to the first player's offer, both players receive the proportion determined by the first player. If the second player says no, then neither player receives any of the money. Since the game is only played once, the most rational response for the second player is to accept any amount, because even one dollar is better than none, and punishment does not cause a stingy player to share more freely in this particular game.

The surprising result of the Ultimatum Game is that the majority of people offer roughly half the money they receive, and that more than half of the people that are offered less than 20% ($20) reject the offer. If people are truly objective about simply taking money in a game played only one time, they should take an offer of less than 20%. When the experiment is conducted with people of different cultures, ages, and socioeconomic classes, the exact results vary, but the gist is the same. People will punish those who they perceive to be cheating them, even if it costs them to do so. Apparently, players that make the initial decision on how to split the money understand that people have the tendency to punish selfishness, and tend to make fair offers.

The Public Goods game further explores the tendency of humans to cooperate and punish cheaters. In this game, four players each receive $20. Each player may donate to a common pool (pot, in gambling parlance), but does not know what the other players are donating. After each player donates or not, the pot is doubled by the experimenter and then all the money in the pot is evenly divided between all the players. The best group strategy would be to all invest the full amount every time, and then all players double their money every time. The best individual strategy would be to invest nothing, but share investments of others.

Three scenarios of the Public Goods game can be illustrated using the first round of game play (Figure 1). If all players initially put $20 into the pot, they all end up with $40. If Ralph puts in $10, Emily and Fred $5 each, and George nothing, then Ralph will end up with $20, Emily and Fred $25, and George $30. If Ralph, Emily, and Fred each put in $20, but George puts in nothing, after it is doubled and divided, Ralph, Emily, and Fred each have $30, but George ends up with $30 plus his original $20 that he held back. Thus, in the third scenario, George ends up with more money than if he had cooperated.

When people really play the Public Goods game, most initially invest about half of their money, thus they play somewhat selfishly. However, if the game is played for 10 rounds, by the last round, most players invest little or nothing.

In a simple twist to the Public Goods game, a player can impose fines on other players at a cost. So, for example, Emily can fine George $1 at a cost to her of 30 cents, and both the fine and the penalty are removed from the game. If this is the case, players fine others who they perceive as cheating, even though nothing directly comes back to them. Players are willing to seek revenge on cheaters even at personal cost. When the game is played this way, all players tend to be more cooperative through the entire game as compared to the game played with no punishment. The results of studies based on this game have reinforced the idea that human behaviour does include some ingrained long-term assessment of maintaining an even playing field for future contests (Tyler and Blader 2000).

The Ultimatum and Public Goods games illustrate that people do behave selfishly to some degree. They also demonstrate that costs and benefits of cooperating are weighed, and most players are somewhat cooperative. The final point of the results of these two games is that people are willing to punish cheaters

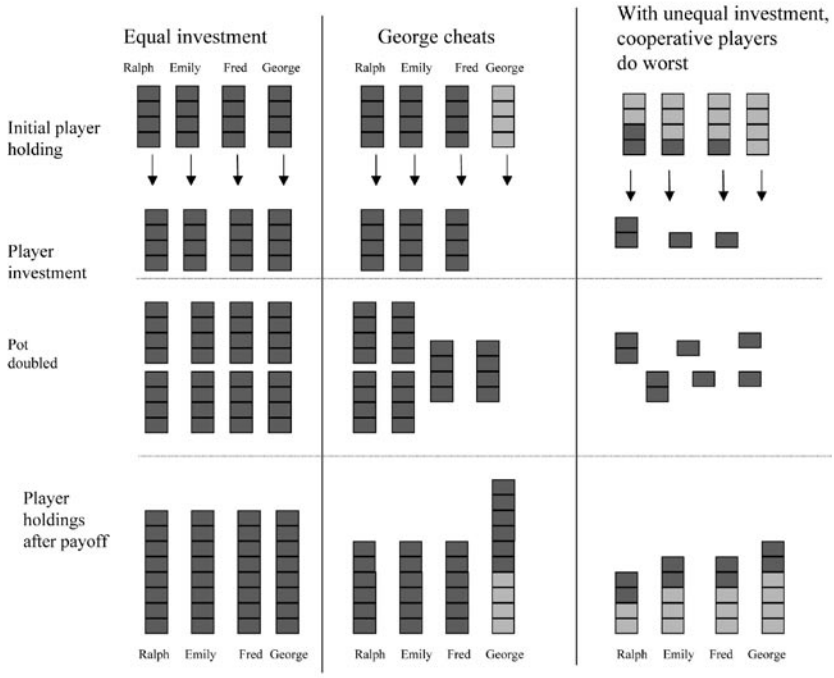

Figure 1. The Public Goods Game where all players start with the same amount, invest as much as they want, the pot is doubled and divided equally among players. A lone cheater does the best, and cooperation is punished when all players invest unequally, with nobody doing as well as if they all cooperated. Lightly shaded blocks represent those held back from initial investment by players.

and potential cheaters behave accordingly. Thus, it appears to be a fundamental human characteristic that people will police cooperative behaviour at some personal cost. Punishing behaviour probably arose in small social groups of humans, where it was advantageous over a period of time to insure that other members of the group did not habitually cheat and use more than their fair share of the resources. Over much of human history, it has been easy to ascertain who is a cheater, and behaviours have evolved culturally or genetically to punish such cheaters.

One way that people assess the potential for punishment by other members in the group is through development of a social norm (Uphoff and Langholz 1998). For example, people are more likely to throw trash into the ocean if they see other boaters throwing trash into the ocean. This may explain why littering is less prevalent in the United States than it was 40 years ago; there are laws against littering, but more importantly, most people don't openly litter. Similarly, willingness to conserve water by Mexican citizens is substantially greater if they perceive that others in the community conserve water, further evidence of the importance of a social norm (Corral-Verdugo et al. 2002).

The concept of development of infrastructure to facilitate implementation of social norms is called social capital (Pretty 2003). There are several modes of formation of social capital, most likely when there is relatively high social and economic well being. Thus, there is a social mechanism for enforcing group cooperation, but it depends in part upon quality of life. It probably also depends on the idea that there is some moral obligation to future generations (Johnson 2003). Thus, such mechanisms are not likely to work well if humans destroy the environmental capital that supports their quality of life, as well as any prospect of future generations obtaining a decent quality of life.

WHAT DO ALL THESE GAMES HAVE TO DO WITH THE REAL WORLD?

When rates of cheating are viewed as unacceptable, the response of the regulators is to increase the cost to cheaters if they are caught. Since most people weigh behaviour on a cost-benefit basis, increased cost of cheating should effectively decrease the proportion of cheaters. It is fairly certain that the proportion of jaywalkers would decrease substantially if the offence carried a death penalty.

The global resource base is finite, and can only sustainably support a set rate of use. Only a set number of cheaters can be tolerated, and it becomes ever more difficult to control this number of cheaters as the total human population increases. Unfortunately, this means that human society is caught in an escalating problem because there are increasingly more people, so the proportion of cheaters must be decreased simply to control the absolute number of cheaters. If the absolute number of cheaters increases, the absolute environmental impact increases as well. Stated another way, if the total population doubles, there are twice as many cheaters even though the proportion of cheaters remains the same. So for example if $^1/_4$ of the population cheats, but the population doubles, the fraction of cheaters would need to be lowered to $^1/_8$ of the population simply to keep the absolute number of cheaters the same. With a finite resource base, the increase in the number of people using the resource base will cause problems unless the proportion of cheaters can be brought way down.

Game theory predicts some proportion of the population will decide that the payoff for not cooperating exceeds the possible costs for getting caught cheating. The more valuable the resource, the greater the penalties must be to stop cheaters. Unfortunately, as a resource becomes more and more limited, its value goes up accordingly giving even greater incentive to cheat. Even with high costs imposed by regulations, there still is the likelihood that somebody will perceive the probability of being caught low enough to cheat.

People commit crimes even when there is the chance they will be killed if caught. Rhinoceros horns have a high monetary value that increases with rarity. Even though poachers know they may be killed if caught slaughtering a rhinoceros for its horn, poaching continues. If these poachers have starving families and a single animal can provide 10 years of income, even the threat of death may not be enough to keep them from cheating (Wilson 2002).

Governments behave in a similar fashion with regard to resource use and game theory. Thus, we have nations cooperating to control the price and availability of oil, and nations willing to go to war to ensure a continued supply of oil. As a resource, whaling has no significant benefits for most nations so they readily agree not to exploit whales as a resource. Some nations are 'cheaters' because the perceived value of the whaling is greater than the costs of international censure.

The leaders of each nation strive to expand the amount of resources controlled and utilised by their nation. All the behaviours described for individuals above apply to nations; governments cooperate when they think it benefits them, but some governments cheat. The more important a resource is to a variety of nations, the less likely there will be global cooperation. Penalties and punishments for cheating are much more poorly defined at the international level than within countries because there are less well-defined mechanisms for punishing cheaters than in most small societal groups, and the existence of an international, global social norm is less clearly defined. Thus, the ability to regulate global resource use rates is compromised.

WHY EDUCATION AND RESEARCH ARE CENTRAL TO SOLVING GLOBAL ENVIRONMENTAL PROBLEMS

Keeping people or nations from cheating and using more than their share of these limiting resources requires general public acknowledgement of the limited nature of the resource base before sustainable resource use is attained. That is, both the knowledge about the resource (research) and transmission of that knowledge (education) must occur. The sustainably managed grazing commons in post-medieval Europe were managed successfully because the members of the community were aware (educated) of the problems that would occur if people were allowed to have more livestock and to graze more than their share or if more people were allowed to graze their livestock. Presumably the research in this case was the hard lesson the community learned when the pasture was overgrazed at some time in the past.

In our modern world, the people, governments, or corporations that use resources at greater than sustainable rates will never be controlled if the majority of people do not perceive them as cheaters. Thus, education and research are key components in efforts to conserve resources. Research is needed to convince a sceptical sector of the population that questions the urgency of protecting the global environment. Education is required to transmit that information. It was easy to detect cheaters in primitive human societies or even small communities where resources needed for survival were clearly defined and accounted for. Accounting for global environmental damage and who is responsible is more complex.

The earth's atmosphere and its ability to sustain life on the planet is a resource. One way atmosphere sustains life is by regulating climate. Increased levels of greenhouse gasses such as carbon dioxide from burning fossil fuels degrade the ability of the atmosphere to control temperatures at levels that are optimal for human inhabitation of the planet. The effects of more greenhouse gasses are not necessarily immediately catastrophic for the entire human race, so the perceived costs of using the atmosphere to dump carbon dioxide are not extremely high.

The atmosphere is currently an unregulated resource. Nations are unwilling to control their rate of burning fossil fuels, and the United States does not classify carbon dioxide as a pollutant. It has been impossible for most nations to agree to limit their rates of fossil fuel burning even to current levels. Some nations completely refuse to enter the negotiations, or perhaps worse, the United States, the largest single source of carbon dioxide pollution, is backing out of agreements that were previously made.

The atmosphere, being an unregulated resource with no restraints on use, is subject to the Tragedy of the Commons. As long as the perceived benefits of overuse of the resource exceed the costs, the resource will be used. Thus, the United States continues increasing the already massive rates of fossil fuel burning to sustain the lifestyle of its inhabitants, while claiming to be concerned about greenhouse gas emissions. China claims that raising its standard of living to that of developed nations is more important than any damage caused by the greenhouse effect, and emissions from China will grow given the increasing population and the rising standard of living (per capita resource use rates). Even if the larger producers (e.g. China, United States, Europe) control carbon dioxide emissions, there will be nations with ever greater populations and increasing demand for energy. These nations are likely to refuse to control their emissions without substantial penalties for excessive carbon dioxide emissions.

Those unwilling to control greenhouse emissions seize on any uncertainty in research on global warming. It is not until the overwhelming weight of evidence for global warming related to emission of greenhouse gases is understood by the public that governments will be forced to act on the problem. Thus, education and research are key components of regulation. Nothing in our prior cultural or genetic evolutionary history has prepared us to deal with global environmental problems. Research and education will be required to fill this void.

In contrast to the public uncertainty surrounding the environmental effects of greenhouse gas emissions, it was immediately clear that destruction of the ozone layer could ultimately destroy much of the life on earth. The potential damage from increased ultraviolet is obvious to educated people in every nation in the world. Thus, the immediate perceived costs were high to all the major countries that produce CFCs. Yet there was still a time lag of decades between describing the problem and agreeing on a solution. Regulations to protect the ozone have finally been enacted and emissions have slowed. Even though some countries or individuals may cheat and release ozone-destroying CFC compounds, it is possible that the ozone layer will recover.

Species extinctions continue at an alarming rate because many countries do not view the costs of maintaining species (habitat protection, reducing pollution, halting alien species invasions, and controlling species harvesting) as equal to the benefits to be gained by activities that ultimately lead to extinction (such as logging, slash and burn agriculture, and other types of habitat destruction). In spite of the fact that many nations have agreed in principal that humans should not cause species extinctions, extinctions continue in both developed and less developed countries. Many perceive the benefits of activities leading to the extinction of species to outweigh the costs of protecting them.

When regulations to control resource use are developed, the costs of excessive resource use to the society as a whole, as well as the potential benefits to cheaters, need to be assessed when setting the regulatory framework. Thus, conservation biologists and other environmental scientists need to clearly identify the value of species and environmental attributes to be preserved, and the potential social cost for doing so. Perhaps even more important, people with the knowledge of the importance and uniqueness of particular resources need to transmit that information to the public, to allow them to assess why complying with regulations and taking steps to stop cheaters is in their best interests.

Environmental education seems particularly important considering that a social norm makes compliance with regulations much more likely (Haab and McConnell 2002). If most people agree with a regulation, a potential cheater will perceive a greater cost for cheating related to punishment from cooperators.

Educated people will understand who is cheating and using more than their share of resources and be more likely to punish them. The earth's resources belong to all of humanity, present and future. Squandering this capital for the benefit of a few individuals, corporations, or nations does not make sense for the long-range survival of the human (and many other) species. The longer we wait to control the global explosion in resource use, the harder it will be to control. Efforts to control resource exploitation are bound to fail if they do not consider human nature. If they do, we can win the game and our descendants will inherit a habitable earth.

ACKNOWLEDGMENTS

I thank Dolly Gudder for her editorial assistance and the Aquatic Journal Club and two anonymous referees for their input. This research is supported in part by funding from the Konza US NSF LTER program.

REFERENCES

Brosnan, S. F., and B. M. de Waal 2003. 'Monkeys Reject Unequal Pay', *Nature*, **425**: 297–9.

Clutton-Brock, T. 2002. 'Breeding Together: Kin Selection and Mutualism in Cooperative Vertebrates', *Science*, **296**: 69–72.

Corral-Verdugo, V., M. Frías-Armenta, F. Pérez-Urias, V. Orduña-Cabrera, and N. Espinoza-Gallego 2002. 'Residential Water Consumption, Motivation for Conserving Water and the Continuing Tragedy of the Commons', *Environmental Management*, **30**: 527–35.

Dawkins, R. 1976. *The Selfish Gene*. Oxford: Oxford University Press.

Deadman, P.J. 1999. 'Modelling Individual Behaviour and Group Performance in an Intelligent Agent-Based Simulation of the Tragedy of the Commons', J*ournal of Environmental Management*, **56**: 159–72.

Fehr, E., and S. Gätcher 2002. 'Altruistic Punishment in Humans', *Nature*, **415**: 137–40.

Gardner, G. T., and P. C. Stern. 1996. *Environmental Problems and Human Behaviour*. Boston: Allyn and Bacon.

Grant, W. E., and P. B. Thompson 1997. 'Integrated Ecological Models: Simulation of Socio-Cultural Constraints on Ecological Dynamics', *Ecological Modelling*, **100**: 43–59.

Haab, T. C., and K. E. McConnell 2002. 'Social Norms and Illicit Behaviour: An Evolutionary Model of Compliance', *Journal of Environmental Management*, **66**: 67–76.

Hamilton, W. D. 1964a. 'The Genetical Evolution of Social Behaviour I', *Journal of Theoretical Biology,* **7**: 1–16.

Hamilton, W. D. 1964b. 'The Genetical Evolution of Social Behaviour II', *Journal of Theoretical Biology,* **7**: 17–52.

Hardin, G. 1968. 'The Tragedy of the Commons', *Science,* **162**: 1243–8.

Johnson, L. E. 2003. 'Future Generations and Contemporary Ethics', *Environmental Values* **12**: 471–97.

Jackson, J. G. C. et al. 2001. 'Historical Overfishing and the Recent Collapse of Coastal Ecosystems', *Science,* **293**: 629–38.

Kurlansky, M. 1997. *Cod: The Biography of the Fish that Changed the World*. New York: Penguin Books.

Pretty, J. 2003. 'Social Capital and the Collective Management of Resources', *Science* **302**: 1912–14.

Richerson, P. J., R. T. Boyd, and J. Henrich. 2003. 'Cultural Evolution of Human Co-operation', pp. 357–88 in Hammerstein, P. (ed.), *Genetic and Cultural Evolution of Cooperation*. Cambridge: The MIT Press.

Schwartz, S. H. 1977. 'Normative Influences on Altruism', pp. 221–79 in Berkowitz, L. (ed.) *Experimental Social Psychology.* New York: Academic Press.

Sharma, S. 2001. 'Managing Environment: A Critique of 'The Tragedy of Commons', *Journal of Human Ecology,* **12**: 1–9.

Sigmund, K. 1993. *Games of Life*. Oxford: Oxford University Press.

Sigmund, K., E. Gehr, and A. Nowak 2002. 'The Economics of Fair Play', *Scientific American*, January, 83-7.

Sober, E. 1994. *From a Biological Point of View, Essays in Evolutionary Philosophy.* Cambridge: Cambridge University Press

Trivers, R. L. 1971. 'The Evolution of Reciprocal Altruism', *The Quarterly Review of Biology,* **46**: 35–57.

Tyler, T. R., and S. L. Blader 2000. *Cooperation in Groups: Procedural Justice, Social Identity, and Behavioural Engagement*. Philadelphia: Taylor and Francis.

Uphoff, N., and J. Langholz 1998. 'Incentives for Avoiding the Tragedy of the Commons', *Environmental Conservation*, **25**: 251–61.

Wilson, E. O. 2002. *The Future of Life*. New York: Alfred A. Knopff.