Overcoming the "tragedy of the commons" in fishery management

***Sarah B. M. Kraak** considers how to use the "public goods game" to find incentives to preserve the commons.*

In situations of declining or depleted fish stocks, fishers seem to have fallen prey to the "tragedy of the commons". This occurs because fishers face the dilemma that, although they understand that limiting their catches would pay off in the form of sustainable future catches, they can never be sure that the catch which they have just sacrificed will not be immediately snapped up by competing fishers. Standard economic theory predicts that, in such dilemmas, individuals are not willing to cooperate and sacrifice catches in the short term, and that, consequently, the resource is overharvested. However, over past decades, a multitude of research endeavours have shown that humans often achieve outcomes that are "better than rational" by building conditions where reciprocity, reputation, and trust help to overcome the temptations of short-term self-interest (Kraak, 2011).

The biological roots of this cooperative behaviour are gradually being understood (Sigmund, 2010). Studies have provided insight into why and how a natural human tendency to cooperate under certain conditions could have evolved and become hard-wired; the evolutionary roots of human altruism are evident from the fact that chimpanzees display similar behaviour. The hard-wiring itself, namely the physiological basis of trust and cooperation, is being unravelled, giving birth to the discipline of neuroeconomics (Zak, 2008); the hormone oxytocin appears to play a role, and neural correlates in the brain have been uncovered. Moreover, a genetic polymorphism has been found to correlate with individual variation in levels of trust, cooperation, and generosity. Human nature turns out to be self-interested and altruistic! Fishery management could utilize this potential for spontaneous responsible fisher behaviour by setting conditions that enhance natural cooperative tendencies.

Elinor Ostrom, 2009 winner of the Nobel Prize in Economic Sciences, has replaced the grim and gloomy predictions of humans being stuck within the tragedy of the commons with a more optimistic picture. Decades of field research have shown that individuals systematically engage in collective action, for example, to increase the likelihood of sustaining natural resources, without an external authority to offer inducements or impose sanctions. Ostrom (2009) provides an analysis of factors conducive to collective action in real-world examples.

▲ *Nobel Prize laureate Elinor Ostrom has lamented "Many policies based on the assumption that externally imposed sanctions are necessary have exacerbated the very problems they were intended to ameliorate".*

On the negative side, the large resource size of high-sea fisheries, the large uncertainty in knowledge of the state of the resource, and the mobility of fish are all non-conducive to pro-social collective action; unfortunately, these variables are not under our control. On the positive side, when users share a common knowledge of the system and of how their actions affect each other, have full autonomy at the collective-choice level in order to devise and enforce some of their own rules, and depend on the resource for a substantial portion of their livelihoods, pro-social collective action is more likely.

Recently, it has become apparent that central intervention from authorities often directly undermines existing willingness to cooperate and obey the rules, and diminishes any stewardship motives (Bowles, 2008; Richter and van Soest, 2011). Policies based on the assumption that humans can only be lifted out of the economic trap through externally imposed sanctions have been subject to major failure and have exacerbated the very problems they were intended to ameliorate. They remove the possibility of people signalling their good behaviour to their social peers. Economic sanctions may also make people feel that they can "buy the right" to be non-cooperative by paying a fine or fee; in this way, they buy the right to overexploit the common resource. Similarly, the market for carbon-emission permits might be perceived as trading the rights to pollute the world. Also, too much monitoring may produce the counter-intuitive result that individuals feel they are not trusted and thus become less trustworthy. They may assume that formal organizations are charged with the responsibility of taking care of their joint needs and that cooperation is no longer needed. Importantly, whereas economic incentives, such as fines, tend to diminish any existing social capital when they are imposed externally, the opposite seems to be the case when they are imposed from within, by peers. Translated into the fishery-management context, this would imply that, even if managers believe it is desirable to keep institutional sanctioning, it may be important to involve the stakeholders in decision-making, for example, on the level of sanctioning. Alternatively, the stakeholders themselves could institutionalize financial sanctions from within through their producer organizations.

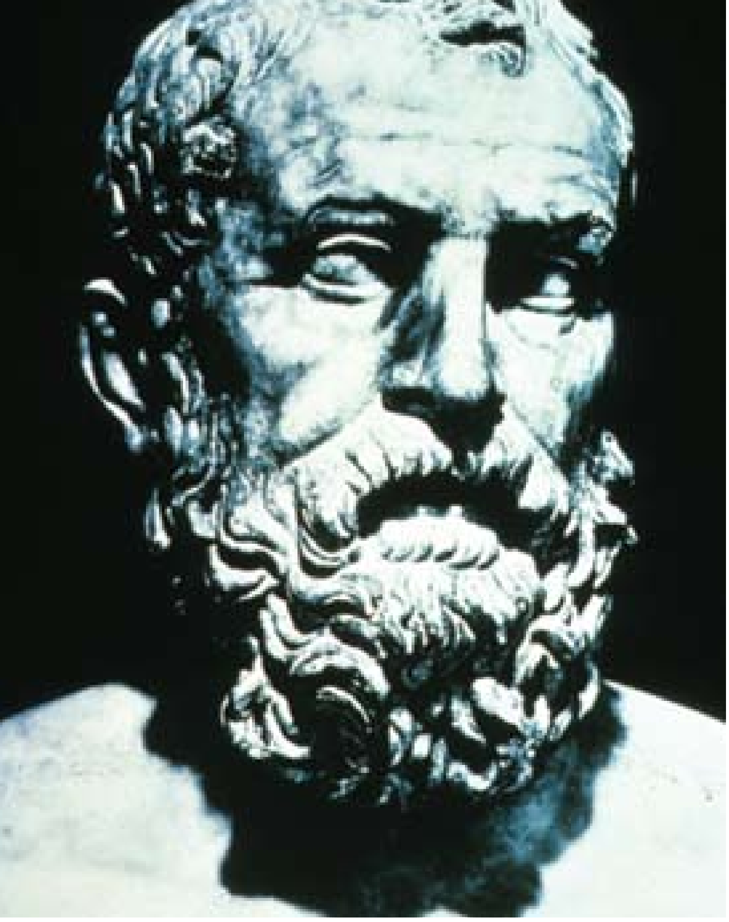
These ideas resonate well with the intentions of the European Union as reflected in the Green Paper on Reform of the Common Fisheries Policy (Commission of the European Communities, 2009). According to this Green Paper, the general framework for fishery policy would be set on the basis of a Commission proposal, but detailed implementation decisions could be taken at a regional level through a process of stakeholder interaction.

This reflects the recognition that a fishing industry cannot be managed effectively without the cooperation and participation of fishers in the formulation of policy and in the implementation and enforcement of laws and regulations.

One dogma that may have to be abolished is that fisheries data at the individual vessel level are often strictly confidential.

The conclusion from Kraak (2011) and Bowles (2008) is that small differences in institutional design may lead to very different outcomes in terms of cooperative fisher behaviour to overcome the tragedy of the commons. Human nature displays both self-interest and altruism, depending on external conditions, which can be manipulated. Thus, self-interested cynical people may become responsible moral agents under the right conditions. Settings that enhance these desirable outcomes include (i) non-anonymity – fishers' individual choices should be publicly known among them and/or within their wider social community; (ii) provision of knowledge to fishers on the state of the resource and on the urgency and impact of their responsible behaviour; (iii) fishers' self-decision on rules and (levels of) economic sanctions; and (iv) face-to-face communication among fishers and between fishers, managers, and other stakeholders.

One dogma that may have to be abolished is that fisheries data at the individual vessel level are often strictly confidential. This suggestion follows from the findings that, in order to maintain high levels of cooperation, it appears to be important to use the opportunity to acquire information on each other's contributions, because this is required for reputation-building and for the (social) rewarding or punishing of each other's behaviour. In the current situation, where individual vessel-based fisheries data are confidential, one such opportunity for monitoring each other's level of pro-social behaviour is absent.



▲ *Athenian statesman and lawmaker Solon (ca. 638–558 BC). In drawing up his laws, Solon was ridiculed for supposing that his countrymen's greed could be kept within bounds by means of laws. He replied that he was framing his laws in such a way as to make it clear that it would be to everybody's advantage to keep the laws rather than to break them.*

Let the games begin!

The public goods game is an experimental model commonly used to study social dilemmas. For example, €5 is given to each of four people, who are given the option of investing some or all of their endowment in a group project by contributing, without discussion, any amount between €0 and €5 into the public pool. The contributions are collected, and the total amount is then doubled and divided equally among the players, irrespective of their contribution. If each of the four players contributed €1, each of them would receive €2 (i.e. a net gain of €1). If only three of the four players contributed €1, each of the three contributors would have a net gain of €0.50, but the defector would have a net gain of €1.50.

The prediction from standard rational economic theory is that no one will ever contribute anything because each €1 contributed yields a return of only €0.50 to its contributor (corresponding to a relative loss of €0.50), no matter what the others do. This is a public goods problem because the group would be best off (i.e. taking home €10 each) if each member contributed €5. However, individual short-term self-interest is at odds with long-term interest. In these experimental settings, people usually cooperate more than is predicted by standard economic theory; nevertheless, observed cooperation is heterogeneous, declines quickly over time, and is often suboptimal.

Translating the public goods game into a fishery-management setting

In a previous article (Kraak, 2011), I used thought experiments to consider how this model could be translated into a fishery-management context. Imagine that four fishers each have a catch quota of five fish. They are told (analogous with the above) that each of them can invest in the rebuilding of the fish stock by refraining from catching between 0 and 5 fish. The total number of spared fish will be doubled and then divided among the group.

In a fishery-management context, it may be more realistic to consider units other than individual fish, such as tonnes of fish, proportion of individual quota share, or allocated effort. In the experimental setting, the experimenter has an apparently unlimited amount of money available with which to artificially double the amount contributed to the common pool. In reality, it would be impossible to double the amount of fish in the common pool. Fortunately, however, fish multiply naturally!

Fish that are left in the pool for any length of time will increase in biomass by the amount of growth minus the natural mortality over that period. Indeed, the dilemma of reducing fishing intensity to the level of maximum sustainable yield demands that fishers forego some yield in the short term while gaining yield in the long term.

For example, the weight of a typical catch of cod from the Irish Sea will increase by a factor of 1.4 if the stock is left alone for one year. Furthermore, because large fish command a better price than small fish, the cod will also have increased in value by a factor of 1.6. Let us call this factor *W* (for "wait") and assign it a value of 1.5.

According to the rules of the game, each of the four fishers makes an individual decision to postpone using a portion of his quota entitlement until, for example, the next year. The next year, the total amount of catch sacrificed by all of the fishers, multiplied by *W*, and divided by the number of fishers in the group will be added to each fisher's basic quota entitlement for that year. Assuming that *W* is 1.5, if each of the four fishers sacrifices catch this year valued at €1000, they would each be allowed to add catch valued at €1500 to their quotas (i.e. a net gain of €500 each) next year. If only one fisher sacrifices this year's catch (value of €1000), each of the four fishers would be allowed to add catch valued at €375 to his/her quota next year; the cooperative fisher would, therefore, suffer a net loss of €625, whereas the defectors would each enjoy a net gain of €375. Note that when the TAC and the quota for the next year are being calculated through standard stock-assessment procedures, an assumption is being made about the current year's total catch; our calculations above are valid providing that any catch sacrificed is not added ("returned") to the modelled stock size.

The calculations above ignore the economic phenomenon of *discounting*, which arises from the rational preference to receive benefits today rather than postponing them until tomorrow: €100 today has a greater value than €100 next year, which is why borrowed money has to be paid back with interest. Great uncertainty about the future results in a high discount rate, and this constitutes one of the fundamental problems in resource management. In our calculations, we could reduce the gain with a factor representing the discount rate – as long as its inverse is (much) smaller than W. With a discounting factor of 0.9 $year^{-1}$ and W equalling 1.5, the perceived gain that drives the cooperation would be +0.35. Another aspect fundamental to making the fishing game more realistic is group size. The experimental setting of four people in a group is very artificial. National quotas are usually distributed to several hundred fishers. Whereas in the example with four players, a player who contributes €1 would lose only €0.50 if the three other players defect; he/she would lose €0.99 (almost all of the €1 contribution) if all of the others in a group of 200 players defected. The gains if all players cooperate do not depend on group size; they are always double the total starting amount. Thus, the rationality of cooperation decreases with group size.

In any case, in the restrictive settings of the model described by the basic public goods game, not a great deal of cooperative behaviour can be expected because the fishers are caught in the tragedy of the commons. Thankfully, humans do not always make decisions based on what is economically rational.

Experimental studies have confirmed that human subjects preferentially help others who have a positive image score.

Exploring the game when reputation matters

Theorists have demonstrated that cooperation can evolve through *indirect reciprocity*. This refers to the phenomenon that individuals who help others are given support, and that supporters as well as helpers accrue a positive reputation or image score. Experimental studies have confirmed that human subjects preferentially help others who have a positive image score.

Milinski *et al.* (2002a) measured the increase in cooperation under indirect reciprocity. In their experiment, participants played a version of the public goods game with an added dimension that they called the "indirect reciprocity game". This game assigns some participants to the role of donor and others to the role of recipient in a public situation where no direct reciprocity is possible. Donors have the option of donating a sum to an assigned recipient who will never be able to reciprocate this gesture. The sum received will be greater than the sum donated by an arbitrary factor; in this experiment, the donors "paid" 2.5 and the recipients "received" 4.

Rounds of both games were played alternately, decisions were made confidentially, and after each round, the outcomes were displayed publicly.

Milinski and his colleagues found that cooperation (and consequently average individual pay-off) in the public goods games increased significantly when they were alternated with the indirect reciprocity games. Over eight rounds, the probability of cooperation in purely public goods games fell from 84 to 45 per cent, but it remained around or above 84 per cent when these games were alternated with indirect reciprocity games, in which case the average individual pay-off was 1.45-fold higher.

Translation of the game when reputation matters into fishery-management settings

The outcome of the above experiment indicates that (i) people are more inclined to contribute to the common pool if their reputation is at stake, and (ii) people reward each other for generosity. If we imagine this game being used as a management tool in a hypothetical fishing community where players are not anonymous, it is expected that generous contributors will receive benefits in their local communities throughout the year, while defectors may become social outcasts. It is precisely this expectation, of receiving favours vs. becoming a social outcast (whether partly or wholly unconscious), that operates as an incentive to contribute more generously. However, if only one round of the public goods game is played per year in this hypothetical fishing community (naturally interspersed by the rest of the year, during which indirect reciprocity takes place), an individual will not be allowed quick adjustment of the level of cooperation in response to feedback about their reputation and generosity. Perhaps multiple rounds per year would have to be played.

Moreover, in a real-world situation, this may only work if a fishery is harvested by fishers in a relatively small local community, where all fishers know each other personally and interact extensively year-round, i.e. where reputation is important. An important prerequisite if this system is to work may be the publication of the outcomes of the public goods game, with participants' full names, for example, in the local newspaper.

In a similar experiment that tested the effect of reputation and indirect reciprocity (Milinski *et al*., 2002b), it was found that, when people donated publicly to a well-known charity, they themselves received increased donations from members of their peer group. Thus, people are rewarded for generosity not only towards fellow players, or towards a common pool of direct interest to the players, but also towards a charity from which only third parties benefit. This has important implications, as explained in the following experiment.

One could envisage establishing a mixture of rewarding fishers with some extra quota for next year combined with the more abstract reward of stock growth.

When the public good game really is for the public good

In another experiment, Milinski *et al*. (2006) demonstrated that if, in contrast to the standard protocol (where the common pool is divided among the participants), it is promised that the pool will be invested to encourage people in the society at large to reduce their fossil fuel use (through an advertisement in a national newspaper), players can behave altruistically. The experimenters found that the basic level of unselfish behaviour was enhanced if the players were provided with expert information describing the state of knowledge in climate research. Analogous to the previous experiment, personal investments in climate-change prevention increased substantially if social reputation was at stake.

Translation of the public good game into fishery-management settings when it really is for the public good

The discovery that individuals are willing to invest in a public good that conveys an uncertain benefit, which is diluted among the whole of society, is an important one for our case. It implies that fishers may be cooperative not only if their sacrificed quota is given back to them multiplied by *W* at a later stage, but also if the only gain to the individual fisher is the possibility of a rebuilt or increased stock. This is important, because, if this were not the case, the stock would not necessarily benefit from such cooperation; after all, fish that were not taken out today would be taken out tomorrow (or rather next year). However, if fishers, under the right conditions, can experience an incentive to invest in the rebuilding of the stock itself – a public good that is shared by all people, not just by their group of players – this can be used in fishery management. In this scenario, fishers would be willing to sacrifice catches for the sake of stock increase, from which they themselves and everybody else may benefit in an undetermined future and by an undetermined and uncertain amount.

As an illustration, the recommended TAC for the Celtic Sea cod stock (ICES Divisions VIIe–k) in 2009 was 2600 tonnes, which was predicted to bring the spawning-stock biomass in 2010 to 8800 tonnes (ICES, 2008). If 10 per cent of that TAC (i.e. 260 tonnes) had been sacrificed, those fish, allowing for growth and natural mortality, would have increased in biomass by a factor $W = 1.4$ to 364 tonnes, resulting in an increase in predicted stock biomass of 4 per cent. Alternatively, if the 10 per cent had not been sacrificed but only postponed for one year, then the 260 tonnes would have been added to the TAC for the next year, and a net gain of only 104 tonnes would have been added to the stock biomass. This would mean that there had only been a 1 per cent increase in the predicted stock biomass.

One could envisage establishing a mixture of rewarding fishers with some extra quota for next year combined with the more abstract reward of stock growth. The fishers' incentive to postpone some of this year's catch would then be partly a "direct" gain (a known increase in quota, albeit postponed to next year) and partly an "indirect" gain through stock growth. The net gain of 104 tonnes could, for example, be split between extra quota and stock growth at a ratio of 1 to 9; in this case, fishers would experience a quota increase of 4 per cent and the predicted stock biomass would still benefit from a 1 per cent increase. Note that even a 1 per cent benefit is probably more than the reduction in society's fossil fuel use that could be expected to result from a newspaper advertisement, as in the experiment by Milinski *et al*. (2006).

Nevertheless, the future states of both fish stocks and catches are notoriously difficult to predict, and such uncertainty results in a high perceived discount rate. One of the (many) reasons fishers do not favour conservation plans, despite their apparent long-term benefits, is that stock–catch predictions are often wrong. Consequently, even if it is predicted that, by taking less today, all fishers will benefit tomorrow, fishers know this will not necessarily happen.

Another interesting result of the experiment by Milinski *et al*. (2006) is that altruistic behaviour was enhanced if the players were provided with expert information describing the state of knowledge in climate research. For our purpose, this suggests that it may be important to inform fishers of their expected gains from projected stock growth.

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