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Measuring the effectiveness of incentives: Can experimental games really give us the answer?

By

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September 11, 2013

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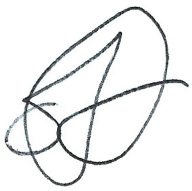
Signature: 

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List of abbreviations

AIC	Akaike information criterion
ANOVA	Analysis of variance
BLUE	Best linear unbiased estimator
BLUP	Best linear unbiased predictor
CC	Conditional Cooperators
CENTDOR	Center for Development Orientated Research into Agriculture and Livelihood Systems
CPR	Common-pool resources
F	Free-rider
GLMM	Generalized linear mixed model
GSS	General Social Survey
ICDP	Integrated Conservation and Development Project
IUCN	International Union for Conservation of Nature
LSD	Least significant difference
MAFF	Ministry of Agriculture, Forestry and Fisheries of the Royal Government of Cambodia
MoE	Ministry of Environment of the Royal Government of Cambodia
PA	Protected Area
PES	Payments for ecosytem services
PG	Public good
PLUP	Participatory land-use plan
SFM	Sustainable forest management
UC	Unconditional cooperator
WCS	Wildlife Conservation Society

Abstract

While the amount of money spent globally on conservation is currently insufficient to sustain environmental services, human overexploitation of common-pool resources is a major threat to conservation. Experimental games have been widely used to gain insight on individual behaviour in common-pool resources problems, including individual response to incentives for conservation, yet few studies have explored the external validity of such games in real life. This study investigates the external validity of a common-pool resources game played in Cambodia, in an area where incentives for conservation have been implemented in recent years. Based on a considerable body of evidence that cooperation and reciprocation are salient determinants of individual behaviour, we develop an innovative method to categorise players according to a dual measure of individual cooperativeness and responsiveness to incentives in the game, and we compare it to individual behaviour in real-life, both observed through involvement in conservation mechanisms and conservation rule compliance, and proxied by preferences stated in a survey. The results provide a weak support to the correlation between game behaviour and observed real-life behaviour. They suggest that experimental games might be a valuable decision-making tool to target conservation interventions or to assess conservation policies, and that further research is required to seek stronger correlations between games and real-life.

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Chapter 1

Introduction

1.1 Context

The amount of money spent globally on conservation is currently insufficient to maintain the Earth's biological diversity (James, Gaston & Balmford, 2001), raising concerns about prioritization of conservation efforts (Wilson *et al.*, 2006). Among threats, overharvesting of open-access natural resources by self-interested humans is predicted to be unavoidable (Hardin, 1968). As a large part of the world's ecosystem services value is unmarketed (Costanza *et al.*, 1997), economic incentives for conservation such as Payments for Ecosystem Services (PES) have been increasingly implemented over the past few years (Jack, Kousky & Sims, 2008).

Yet human behaviour consistently fails to fit into the model of the self-interested man, and rather stems from a complex set of preferences in which social norms and self-interest conflict (Dawes, 1980). Experimental games have been widely used to gain insight on such human behaviour (Gintis, 2000). Among them, Common-Pool Resource (CPR) games let a group of players confront a harveting dilemma in rich and realistic settings (Ostrom, Walker & Gardner, 1992).

Although a salient advantage of experimental games over naturally-occurring observations is that they provide controlled variation of variables (Falk & Heckman, 2009), the question of their external validity is a matter of debate (Levitt & List, 2007). Framed field experiments, which are lab experiments conducted on the targeted population and with realistic rules, allow to overcome two kinds of possible biases that are participants' selection and game structure biases (Harrison & List, 2004). Nevertheless, whether participants behave consistently accross contexts or not remains an open question to which contrasted evidence was brought (Voors *et al.*, 2012). A positive answer would designate experimental games as a valuable decision-making tool for policy targeting; in particular, individual response to incentives in CPR games would allow to identify responsive populations to target conservation incentives in real-life.

This case study focuses on a framed field CPR game. The rules allowed various institutional arrangements, notably economic incentives for conservation. The game was played in Cambodia, in four villages located in two Protected Areas where PES schemes and conservation rules have been implemented in recent years.

1.2 Aims and objectives

The aim is to investigate the external validity of a framed field CPR game.

The stakes are twofold: positive results would indicate that CPR games can be used as a tool to target people receptive to PES opportunities, and to anticipate uneffective implementation of conservation rules. Therefore the objectives of this thesis consist in:

- Developing a method for characterising individual response to incentives from the game data.
- Selecting relevant indicators of individual real-life behaviour, based on observed enrollment in PES schemes, on observed compliance with conservation rules, and stated preferences assessed through surveys.
- Analysing correlation patterns at an individual level between game behaviour and real-life behaviour.

Few studies have tested the external validity of framed field CPR games. To our knowledge, none has examined a wide range of real-life variables, nor has explored responses to conservation incentives. This study aims at bringing evidence to fill this gap.

1.3 Thesis structure

Chapter 2 details the state of the art concerning conservation incentives and human behaviour in common-pool resource dilemmas. It then tackles the use of experimental games for gaining insight on behaviour in such dilemmas, and finally focuses on their external validity, through theoretical considerations as well as empirical results from previous case studies.

Chapter 3 presents the Cambodian case study, including previous research results on individual response to conservation interventions, and on the CPR game.

Chapter 4 formulates objectives and hypotheses in the light of the two introductory chapters.

Chapter 5 describes the method developed to characterise individual behaviour in the game and in real life and to confront them.

Chapter 6 proceeds to an examination of the behavioural indicators defined in the previous chapter, then inspects the correlation patterns between game indicators and real-life indicators.

Chapter 7 discusses the results of Chapter 4, assessing the behavioural indicators and summarising evidence in support of the hypotheses formulated in Chapter 3. It concludes on the external validity of the CPR game, prescribes recommendations for policy-making and suggests tracks for future research.

Chapter 2

Background

2.1 Common-Pool Resources: a behavioural economics problem

2.1.1 Common-Pool Resources and incentives for conservation

Global conservation expenses are currently not efficient enough to sustain environmental services (James, Gaston & Balmford, 1999), so that concerns have emerged about prioritizing conservation efforts in terms of cost-effectiveness (Engel, Pagiola & Wunder, 2008; Ferraro & Kiss, 2002). Common-pool resources (CPR) are subtractable, non-excludable goods (Ostrom, Gardner & Walker, 1994). In his influential paper *"The Tragedy of the Commons"*, Hardin (1968) predicts that self-interested human behaviour necessarily leads to CPR overharvesting under weak property rights, as a result of self-gain maximization. CPR overexploitation therefore endangers a wide range of natural resources, for instance irrigation systems (Fisher *et al.*, 2010; Janssen *et al.*, 2013), forest resources (Ostrom, 1999; Andersson & Agrawal, 2011), or fisheries (Holt, Rutherford & Peterman, 2008; Husain & Bhattacharya, 2004).

A major fraction of environmental services value is unmarketed (Costanza *et al.*, 1997). As a consequence, economic incentives for conservation have been proposed as a means to modify individual utility from CPR extraction and hence trigger conservation of the resource (Sommerville, Jones & Milner-Gulland, 2009). Comparative research has indicated that a programme's cost-effectiveness depends on various factors, including the distribution of payoffs for a single mechanism (Chen *et al.*, 2010) and site targeting (Alix-Garcia, De Janvry & Sadoulet, 2005; Barton *et al.*, 2003; Ferraro, 2004), but also the type of mechanism, as many conservation mechanisms exist, differing mostly in the degree to which they rely on economic incentives and the degree to which they are integrated in broader development policies (Wunder, 2005; Figure 2.1).

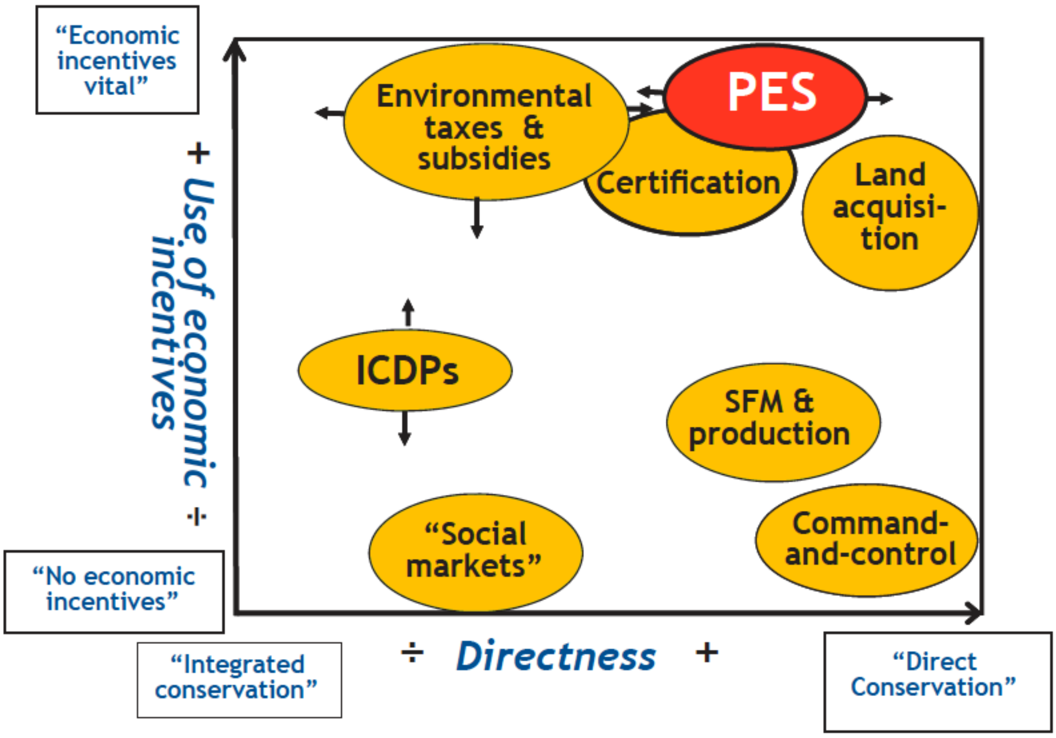

Figure 2.1: Types of conservation approaches. From Wunder (2005).

Integrated approaches, such as Sustainable Forest Management (SFM) or Integrated Conservation and Development Projects (ICDPs) aim at simultaneous progress at the developmental and environmental levels (Wunder, 2005). ICDPs were designed to induce a change in behaviour toward natural resources through enhancement of livelihood conditions (Barrett & Arcese, 1995). However, it appears that ICDPs have not achieved significant progress when conservation goals and the subsidized development activity are not strongly linked (Winkler, 2011), as ICDPs could involve costs higher than the benefits they create (Adams *et al.*, 2004). Consequently, direct approaches have been proposed as more cost-effective than integrated approaches (Ferraro & Simpson, 2002).

Among direct approaches, Payments for Ecosystem Services (PES) are defined as a payment between a 'buyer' and a voluntary 'provider' (*i.e.* economic incentives) under provision that the provider secure an environmental service defined by the two parties (hence direct approach; Wunder, 2007). Examples of PES initiatives include habitat protection (Frost & Bond, 2008), agro-environmental practices (Pagiola *et al.*, 2004) and carbon sequestration schemes (Fisher, 2012), recently comprising Reducing Emissions from Deforestation and Forest Degradation schemes (REDD; Karsenty, Vogel & Castell, in press). As PES schemes are perceived as a more efficient approach (Ferraro, 2001; Wunder, 2005), they have been increasingly implemented over the last decade (Wunder, Engel & Pagiola, 2008).

However, evidence has been found that an agent's participation in PES schemes is not motivated solely by economic incentives, but also by social factors, such as social interaction at the local scale (Chen *et al.*, 2012), and conservation belief system (Villamor & van Noordwijk, 2011). A closer look at individual behaviour is required to understand individual decisions in resource conservation problems.

2.1.2 "Beyond homo economicus"

Collective action dilemmas encompass a range of situations in which a group of agents are to make individual choices between actions that include a self-gain-maximizing action, which once taken by all agents yields a lower individual payoff than another outcome (Goetze, 1994). A rational-choice user would then choose the self-gain-maximizing action, because attaining the more efficient outcome requires an individually costly cooperation between members of the group (Hardin, 1968; Olson, 1971). Collective actions dilemmas include in particular public goods (PG) dilemmas and CPR dilemmas (Dawes, 1980). While both PG and CPR are characterized as non-excludable, or at least non-trivially excludable goods, CPR are subtractable, which means that resource harvesting by an individual reduces the amount of resource available to other users (Ostrom, Gardner & Walker, 1994). As a consequence, a resource-user exerts a negative externality on other users through pressure on the rival resource, which can also affect the quality of other environmental services, *i.e.* exert a negative externality through deterioration of a public good (*e.g.* wood harvesting entailing soil erosion and a decrease in water quality; Cardenas, Stranlund & Willis, 2000).

Hardin's rationale focused on the case of common-pool resources, to demonstrate that homo economicus, as a rational-user, would be trapped by his short-term self-interest, even if it did not coincide with a long-term collective strategy, leading to the overexploitation of the resource. He therefore took the view that solving the commons dilemma would require either the definition of private property rights or the enforcement of rules defined by a central entity, such as a government. However, his theory did not explain why certain local, self-governing communities achieved a sustainable use of their commons (Ostrom, 1990).

Social-psychology has indicated that individual behaviour is not only motivated by outcome-maximization, but also by behavioural satisfaction (Simon, 1976). As such, collective action dilemmas have been termed 'social dilemmas' by Dawes (1980). Since then, a growing body of evidence has highlighted the important role of psychological factors in such problems (Colman, 2003; Dawes & Messick, 2000; Fehr & Fischbacher, 2002; Van Lange *et al.*, 2007) that go “beyond homo economicus” theory (Gintis, 2000).

A considerable amount of research has been conducted to explore the mechanisms that would help solve CPR problems, and more generally social dilemmas. General findings support in particular that cooperation among individuals is higher than expected under the rational-user model, and that it depends on micro-situational factors such as communication and sanctioning among peers (Ostrom, 2000), as well as individual social norms, such as trust, fairness, or reciprocity (Cardenas & Carpenter, 2005, for a review; Ostrom, 1998). To draw these conclusions, research methods mostly involve experimental game studies (*e.g.* Cardenas, 2000; Ostrom, Gardner & Walker, 1994), as well as theoretical modeling (Castillo & Saysel, 2005; Jager *et al.*, 2000). Indeed, though real-life examples of successful and unsuccessful CPR management cases are numerous (Baland & Platteau, 1996; National Reseach Council, 1986; Wade, 1988), natural experiments on CPR problems (that is, based on naturally-occurring observations; List, 2005), are not reported in the literature. Indeed, moving to the field is a difficult process, due to issues such as causality inference from observed behaviour (Durlauf, 2002), and control of variables (Ostrom, 2006).

Experimental games allow for repeated experimental observations, under controlled conditions (Falk & Heckman, 2009). As such, they have yielded a number of consistent observations on behaviour in social dilemmas.

2.2 Behaviour in experimental games

2.2.1 Variables of interest

A general framework to assess which kind of variable affects individual decisions in social dilemmas has been developed by Poteete, Janssen & Ostrom (2010). From the individual level to the broadest level, they propose three categories of variables, *a*) learning and social norms at the individual level, *b*) micro-situational variables and *c*) broader contextual variables (Figure 2.2). In the context of an experiment, social norms are understood to be informal rules, that can be learned and evolve along with micro-situational variables and broader contextual variables. Micro-situational variables, suggested to have a stronger influence on individual-level variables than broader contextual variables, are group-scale variables, which can be related to group composition (*e.g.* group size) or the contextual rules under which the group makes their decisions (*e.g.* allowance of communication, of peer punishment), while broader contextual variables are any relevant macro-situational variables (*e.g.* national rules, geography).
In the light of this framework, experimental games allow researchers to set and to control micro-situational conditions, and to measure individual social preferences accordingly.

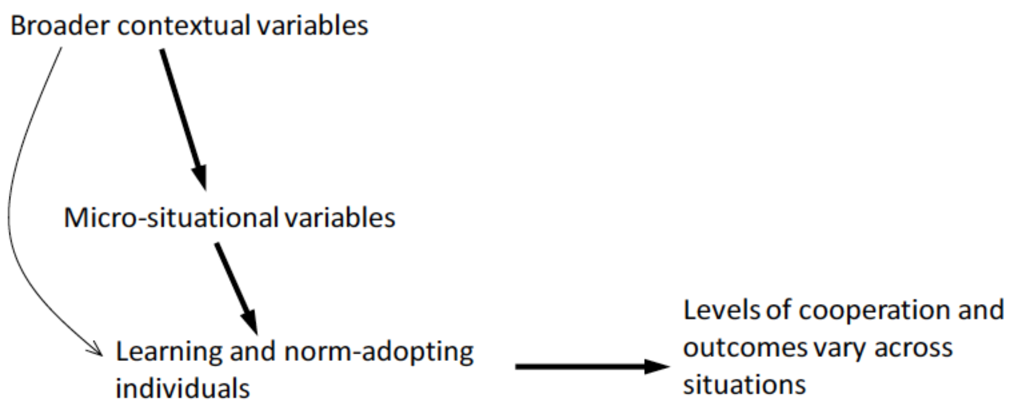

Figure 2.2: Types of variables influencing cooperation and outcomes in social dilemmas. From Poteete, Janssen & Ostrom (2010)

2.2.2 Social preferences in n-person Prisoner's Dilemmas

Different games for different preferences

2-person versus n-person games Games aiming to assess human behaviour in social dilemmas include the Prisoner's Dilemma, as well as Dictator, Ultimatum, Assurance, Trust, Public Goods and Common-Pool Resources Games. These games are commonly used to characterise distinct individual social preferences (Cardenas & Carpenter, 2005). While Dictator and Ultimatum Games measure fairness or inequity aversion (Fehr & Schmidt, 1999), Trust games trust or trustworthiness from players (Glaeser *et al.*, 2000), PG and CPR problems focus on cooperation. Although the Prisoner's Dilemma and Assurance games also focus on cooperation, n-person dilemmas allow for a more refined contextualisation of a group social dilemma, and are believed to deliver more realistic and more subtle outcomes (Ostrom, Walker & Gardner, 1992).

PG versus CPR games PG problems consist of individuals contributing at the expense of private, safe benefits for a collective reward evenly shared among contributors, whereas CPR problems involve individuals extracting or consuming a resource for private, safe benefits at the expense of a collective reward for conserving the resource. However, the question of the difference between PG games and CPR games is nontrivial. Although PG and CPR are two distinct types of *goods*, the *problems* associated are similar n-person Prisoner's Dilemmas (van Dijk & Wilke, 1995). While the common formalization for PG games can be structurally different from CPR games, depending on the expression of rivalry in the CPR game (Apesteguia & Maier-Rigaud, 2006), most researchers agree that they can be formulated with an identical *structure* (Gintis, 2000; Ledyard, 1994; van Dijk & Wilke, 1995). However, research on whether they were associated with distinct *choice behaviours* concluded differently. Consistent results indicate that players are sensitive to the framing difference between PG and CPR games, which makes them *two distinct cooperation games* (Gintis, 2000; Ostrom, 1998; van Dijk & Wilke, 1995).

Response to micro-situational settings

Group interactions Communication has been demonstrated to increase cooperation both in PG games and in CPR games, despite the fact that verbal agreement does not create any externality for a selfish player, who therefore should not be affected by 'cheap talk' (Ostrom & Walker, 1997). Furthermore players engage spontaneously in free-rider punishment when they are allowed to do so, leading to an increase in cooperation (Ostrom, 2000). Punishments increase with the magnitude of free-riders' deviations from average contributions, and punishers readily choose this costly action with no guaranteed prospect of future private reward (Fehr & Gächter, 2000a). Group composition has also been found to be a significant variable: low group size increases cooperation as a possible consequence of easier communication (Poteete & Ostrom, 2004), while group heterogeneity, for instance nationality hererogeneity, was shown to have an impact, albeit an unpredictable one (Cardenas & Carpenter, 2005; Poteete & Ostrom, 2004).

Institutional settings Positive economic incentives aim at creating positive externalities on individual benefits, and economic sanctions at creating negative extrernalities on individual costs, both to stimulate cooperation (Ostrom, Gardner & Walker, 1994). Yet external rules implemented in framed field experiments can meet significant rejection by participants (Cardenas, 2005; Janssen *et al.*, 2013), as regulation might be perceived as illegitimate (Castillo *et al.*, 2011). Acceptance of governmental rules that restrict access to common-pool resources is linked to the paramount role of property rights (Bowles & Gintis, 2002). Indeed, as weak enforcement of property rights acts as an incomplete contract, resource-users might perceive their actual rights over resources are stronger than the law prescribes (Cardenas, 2008). Moreover, external rules can lead to a *crowding-out* effect of norms, that is, economic incentives can reroute moral motivations to economic ones. A pioneering example was provided by Titmuss (1971), who claimed that blood donations might decrease if people were financially rewarded for their donation, instead on relying on civic conscience; which proved true for women (Mellström & Johannesson, 2010). Some experiments suggest that the crowding-out effect might change preferences on the long-term (Bowles, 2008). The occurrence of the effect in CPR games, resulting in a decrease in cooperation, was reported after the introduction of both external penalties (Cardenas, Stranlund & Willis, 2000; Vollan, 2008), and external positive incentives (Narloch, Pascual & Drucker, 2012). Nevetheless, other studies acknowledged the positive effect of external incentives on cooperation (Cardenas, 2005; del Pilar Moreno-Snchez & Maldonado, 2010; Hayo & Vollan, 2012). Rodriguez-Sickert, Guzman and Cardenas (2008) even suggested that low incentives could have an unexpectedly high impact, stemming from both economic reasons and a positive impact on social interactions, by preventing cooperators to engage in retaliation against free-riders.

These observations make clear that individual behaviour in social dilemmas relies not only on individual pre-learnt social norms, but on their complex interaction with micro-situational settings.

Categorisation of players

Three main profiles of players, based on their relation to cooperation in n-person social dilemmas, emerge consistently in the literature:

- Free-riders are uncooperative players, acting out a self-interest. That comprise pure, or strong, free-riders, and weak free-riders (Isaac & Walker, 1988). In the case of PG games, strong free-riders adopt the 'zero-contribution' strategy, whereas weak free-riders merely consistently undercontribute (*e.g.* Isaac and Walker, 1988, use 30% contribution as a threshold). It has been suggested that up to 30% of players adopt the 'zero-contribution' self-interested strategy (Fischbacher, Gächter & Fehr, 2001).

- Altruistic people are unconditional cooperators (Carpenter & Seki, 2011), or sometimes simply called cooperators (Kurzban & Houser, 2005), that is, people bearing a cost for cooperation without any prospect of future net benefits (Fehr & Fischbacher, 2003). That include *pure* altruism, out of which the costs they are ready to bear increase with the others' resulting payoffs, and *warm-glow* altruism, out of which personal costs are not related to others' benefits, as the warm-glow altruistic person enjoys only the act of making an altruistic action (Anderson, Goeree & Holt, 1998).

- The third category of player has received a growing body of attention, as their behaviour is key to group cooperation (Axelrod, 1981; Fehr & Gächter, 2000b; Bowles, 2008). They are conditional cooperators (Fischbacher, Gächter & Fehr, 2001), or reciprocators (Kurzban & Houser, 2007). A lot of research has underlined the importance of reciprocity as a social norm for this kind of player, meaning that they both engage in increased (respectively decreased) cooperation in response to others' signal for (respectively against) cooperation (Fehr & Gächter, 2000b). The response of conditional cooperators to micro-situational changes is therefore paramount. In particular, it is worth noting that it has been suggested conditional cooperation was strengthened by incentives (Gächter & Falk, 2002).

Further research focusing on the link between types of players and other social norms indicates that cooperators (unconditonal plus conditional) are associated with significantly higher measures of trust (Boone, Declerk & Kiyonari, 2010), so that they initiate cooperation by playing as if social dilemmas were a incentive for cooperation (by perceiving for instance Prisoner's Dilemma as an Assurance Game; Simpson, 2004). Although social norms form a social capital that is hard to characterise (Durlauf, 2002), trust is deemed to be a salient indicator of that social capital (Bowles & Gintis, 2002). Reputation is then connected to trust, as players expected to be trustworthy are more easily trusted (English, 2012; Glaeser *et al.*, 2000). On the whole, trust, reciprocity and reputation are interconnected (Berg, Dickhaut & McCabe, 1995), which is particularly relevant in the light of Ostrom's findings that trust, reciprocity and reputation within a group were paramount for solving CPR problems (Ostrom, 1998).

2.3 The external validity of game experiments

Although experimental games deliver valuable insight on mechanisms underlying CPR dilemmas, and especially on the categorisation of individual behaviour in response to a wide range of group-level settings, a major question has not yet been addressed. So far, we have seen evidence that CPR games can be a tool that helps understanding of how CPR dilemmas are dealt with in real life. We have not yet explored whether the very same set of players would behave consistently in these games and in real life.

Does the observation of a set of players in a CPR game predict their actual behaviour in real life?

What is at stake is the ability to identify the individuals most sensitive to conservation policies, what is more at a moderate cost. Establishing external validity could empower games with two purposes: to assess policies efficiency (Attanasio & Phillips, 2008; Coleman & Lopez, 2010), and to target populations particularly responsive to conservation incentives (Voors *et al.*, 2012).

2.3.1 External validity in theory

As the range of experiments and tools available to social and economic sciences has increased only recently (Levitt & List, 2009), increasing attention has been given to the question of external validity over the past few years. Indeed, examples of dual experiments conducted in laboratory and naturally-occurring settings have highlighted stronger anomalies in the lab than in real-life (List, 2005; Lusk, Pruitt & Norwood, 2006). For example, List (2005) reports the results of a card-sale experiment. Sellers provided sport cards to buyers at low and high prices, and the quality of the sport cards sold was unobserved by the buyer. Therefore, card quality was a measure of trustworthiness, and sellers acting out of pure self-interest would sell cards of low quality, no matter what price was offered by the buyer. The experiment showed that pure self-interest was not observed, but that self-interest was significantly higher in the naturally-occurring environment than in the laboratory, where the sellers were scrutinised.

These results lend credence to concerns on the applicability of lab experiment results to real-life conditions (Levitt & List, 2008). Although arguing that experiments provide qualitative insight, Levitt and List (2006) acknowledge that the decisions subjects make in experiments depend on the scrutiny under which they are placed, the context in which the decision is to be made, and the selection process of participants.

Various experimental forms have been developed in order to reduce these biases as much as possible. Harrison and List (2004) defined a taxonomy of experiments according to their contextualisation:

- *Conventional lab experiments* are conducted with a standard pool of participants, typically students, with a standard and imposed set of rules.
- *Artefactual field experiments* differ from conventional lab experiments by using a targeted population instead of students.
- *Framed field experiments* differ from artefactual field experiments by customizing context, using for instance a non-standard commodity (*e.g.* firewood instead of abstract CPR; Cardenas, 2000) or customized rule-making.
- *Natural field Experiments* differ from all others by studying subjects in a naturally-occurring environment without having the participants know they are being observed. Natural field CPR experiments have not yet been reported (Anderies *et al.*, 2011).

Each step closer to the field has been shown to remove or reduce specific biases.

Conventional versus artefactual field experiments

The difference between the two kinds of experiments resides in the profile of participants. Students from western developed countries are commonly employed to take part in experimental games (Henrich *et al.*, 2005). Although cross-cultural analyses show consistent behaviour in social dilemmas (*e.g.* across nationalities; Ahn, Ostrom & Walker, 2010), and although some authors argue that pool homogeneity is the key variable concerning the pool (Harrison & List, 2004), others have found significant behavioural differences between different types of pool. Contributions to a PG game were found to be significantly lower from students than from fishermen of the same country by Carpenter and Seki (2011), and significant variations in social preferences among 15 small-scale societies were reported by Henrich *et al.* (2005). Henrich *et al.* (2010) focused specifically on the difference between western, developped country subjects (WEIRD, for members of Western, Educated, Industrialized, Rich and Democratic countries) and other societies, which revealed significant gaps, notably regarding cooperation in social dilemmas.

Artefactual versus framed field experiments

Framed field experiments allow for a customised context, which can be a major source of bias when not set properly. Crafting realistic rules is important to make participants more sensitive (Voinov & Bousquet, 2010), to reduce behavioural biases (formulation matters, *e.g.* PG and CPR games are structurally identical, but players do not behave the same in the two games) as well as the lack of understanding. Indeed, experimental games are often designed by scientists who assume participants will understand the games as economists do, which they do not (Smith, 2010), and even subjects educated in game theory fail to reach game predictions (Keser & Gardner, 1999). For instance, PG contributions have been reported to be interpreted as opportunities for gambling by some participants in local communities (Hill & Gurven, 2004).

The principal advantages of framed field experiments are twofold: they reduce context biases by confronting participants with close-to-real-life decisions, and participant selection biases by focusing on the very population for which the experiment looks for external validity.

2.3.2 The external validity of social dilemma games: empirical results to date

Only a limited number of empirical studies have aimed at validating game results with real-life data. Among them, few are framed field experiments or are based on n-person social dilemmas, even fewer are actual CPR games (Table 2.1). Real-life individual behaviour can consist either of indicators of observed behaviour, or use preferences stated by participants through surveys and questionnaires as a proxy, which can yield valuable insight on behavioural intentions (Anderies *et al.*, 2011). Table 2.1 presents the characteristics of empirical studies that have analysed the external validity of game experiments.

A very limited number of papers have focused on CPR group dilemmas. Three of them have compared game cooperation with stated preferences, and four of them with indicators of actual behaviour, to contrasted conclusions. Indeed while trust has been mentioned as a key variable for cooperation, all three studies conclude to an absence of correlation between game cooperation and trust as stated in real life. Among the four studies using actual behaviour indicators as measures for real-life cooperation, two find positive results, the other two negative ones. None has investigated individual conservation behaviour in real life. Indeed, Hayo and Vollan (2012), Prediger, Vollan and Frölich (2011), and Ruffle and Sosis (2006) have focused on community work. Gelcich *et al.* (2013) have explored whether the membership of fishermen in unions ranked by cooperativeness levels affected group cooperativeness in the game. However fishermen played with members of their own union, so that their results are valid at a group level only, and what was measured in the game followed its exact match in real-life, so that their results do not inform on the predictive power of CPR games.

Overall, only one study has included both stated preferences and observed behaviour. None has included a wide range of real-life variables, and none has examined game response to incentives, nor real-life conservation actions at an individual level. The aim of this study is to fill that gap.

Table 2.1: Characteristics of studies testing the external validity of experimental games

Paper	Exp. type[2]	Game type[3]	Game variable	Real-life data type[4]	Real-life variable	External validity[1] conclusion
Bouma, Bulte & van Soest (2008)	AF	TG	Trust	Observed	Collective action (money, effort)	Yes
Gurven & Winking (2008)	AF	DG, UG	Fairness	Observed	Prosocial indicators	No
			Trustworthiness			No
Hill & Gurven (2004)	AF	UG	Fairness	Observed	Prosocial indicators	No
Karlan (2005)	AF	TG	Trust	Stated	General Social Survey (trust)	No
			Trustworthiness			Yes
		TG	Trust	Observed	Loan repayment	Yes
			Trustworthiness			Yes
Attanasio & Phillips (2008)	AF	PG	Cooperation	Observed	Programme beneficiary?	Yes (group level)
						No (individual level)
Benz & Meier (2008)	CL	PG	Cooperation	Observed	University funds contribution	Yes
Boone, Declerk & Kiyonari (2010)	CL	PD, AG	Cooperation	Stated	Social Value Orientation	Yes
Carpenter & Seki (2011)	AF	PG	Cooperation	Observed	Fishing productivity	Yes (group level)
Coleman & Lopez (2010)	AF	TG, PG	Cooperation[5]	Observed	Programme beneficiary?	Yes

[1]Main conclusion of the authors on whether external validity was found or not.
[2]Type of game experiment: CL = Conventional laboratory, AF = Artefactual field, FF = Framed field
[3]Type of game: TG = Trust game, DG = Dictator game, UG = Ultimatum game, PG = Public goods game, CPR = Common-pool resource game. "x"-pl. = groups of x players.
[4]Stated: Assessed through the use of surveys/questionnaires on participants' preferences, Observed: Behaviour observed in naturally-occurring environment.
[5]The authors interpreted the results of the Trust Game as a different form of cooperation than commonly reported in the literature.

English (2012)	CL	PG	Cooperation	Stated	General Social Survey (trust)	No
Fehr & Leibbrandt (2011)	AF	PG	Cooperation	Observed	Shrimp traps hole size	Yes
Hill & Gurven (2004)	AF	PG	Cooperation	Observed	Prosocial indicators	No
Karlan (2005)	AF	PG	Cooperation	Stated	General Social Survey (trust)	No
				Observed	Loan repayment	No
Laury & Taylor (2008)	CL	PG	Cooperation	Observed	PG contribution (money)	Yes
Lusk, Pruitt & Norwood (2006)	FF	PG	Cooperation	Observed	Healthy product sales	Yes
Rustagi, Engel & Kosfeld (2010)	AF	PG	Cooperation	Observed	Forest management outcome	Yes
					Costly monitoring	Yes
Voors *et al.* (2011)	AF	PG	Cooperation	Stated	Conservation opinion	No
				Observed	Illegal hunting	No
Voors *et al.* (2012)	AF	PG	Cooperation	Observed	PG contribution (money)	No
Castillo *et al.* (2011)	FF	5-pl CPR	Fishing effort	Stated	Trust	No
Gelcich *et al.* (2013)	FF	5-pl CPR	Fish extraction	Observed	Fisherman's union status	Yes
Hayo & Vollan (2012)	FF	5-pl CPR	Sheep extraction	Observed	Effort in collective action	Yes (group level, homogeneity required)
Janssen *et al.* (2013)	FF	5-pl CPR	Forest harvesting	Stated	Trust	No
Prediger, Vollan & Frölich (2011)	FF	5-pl CPR	Field grazing	Stated	Trust	No
				Observed	Effort in collective action	No
Ruffle & Sosis (2006)	AF	2-pl CPR	Money extraction	Observed	Membership in collectives?	No

Chapter 3

Case Study

3.1 Study site

Cambodia lies within the IndoBurma hotspot (Myers *et al.*, 2000) and contains four of the Global 200 Ecoregions (Olson & Dinerstein, 1998).

The Ministry of Environment (MoE) and Ministry of Agriculture, Forestry and Fisheries (MAFF), with the support of the Wildlife Conservation Society (WCS) launched pilot PES programs as a complementary protected area (PA) management measure (Clements *et al.*, 2010), in the Northern Plains forest landscape, where land and resource rights are contested and governance is weak (Weingart, 2012), and where threats to species populations are considerable (Clements *et al.*, 2013). PA management in the Northern Plains was set as one of eleven top priorities by the MoE in the National Biodiversity Strategy and Action Plan (Ministry of Environment, 2002). Indeed, a significant decline in biodiversity has been recorded over the last decades in Cambodia (Loucks *et al.*, 2009), which shelters now many threatened species, including 17 reptile, 25 bird and 24 mammal species according to IUCN 2000 Red List (Ministry of Environment, 2010). The Northern Plains contain a large area of deciduous dipterocarp forest that include many of them (Clements *et al.*, 2010).

The sampled population lives in four villages within two PAs in the Northern Plains: the Kulen Promtep Wildlife Sanctuary, a 4025 km^2 area managed by the MoE and established in 1993, and Preah Vihear Protected Forest, a 1900 km^2 area

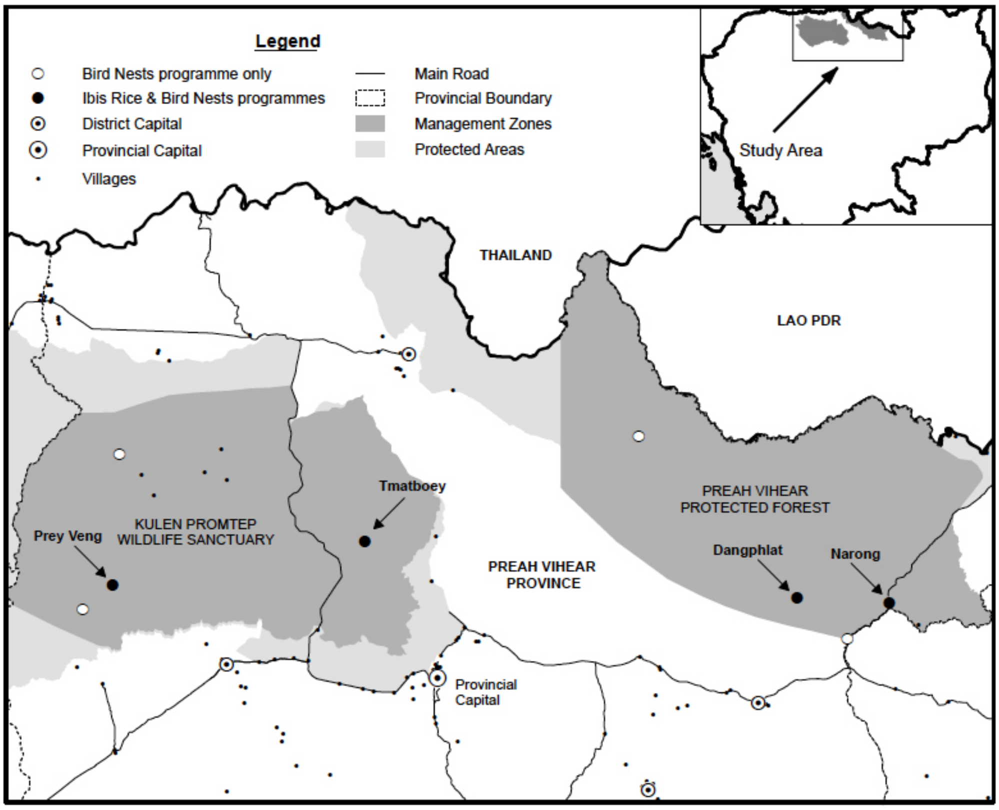

Figure 3.1: Map of the study area. From Clements (2012)

managed by the MAFF, and established in 2002 (Figure 3.1).

Three PES programs were implemented in the four villages. They are characterised by various levels of involvement of local institutions, and differ in the mode of payment. These four villages were selected because they were the first to agree on a participatory land-use plan (PLUP) and to implement PES programs (Clements, 2012).

PES programs.

The Bird Nest protection program delivers individual payments directly from WCS, while the two other schemes are village-managed programs, in which payments were initiated after the two-year PLUP process (Clements *et al.*, 2010).

Bird Nest protection program. Critically endangered bird species, such as giant ibis (Pseudibis gigantea) and white-shouldered ibis (Pseudibis davisoni), live in the area. Payments for bird nest protection are made by WCS to locate, monitor and protect nesting sites that are endangered by collection of eggs and chicks, which can reach prices of US$100 in the national and international wildlife trade. Payments consist of a reward to local people of up to US$5 for reporting nests. Reporters can then be hired as protectors, who receive $1/day for their work and an extra $1/day worked upon completion if the chicks successfully fledge (Clements *et al.*, 2013).

Ibis Rice program. An agri-environmental payment program was launched in 2007 under which farmers that follow a land-use plan and no-hunting rules are allowed to sell their rice through the village committee to a marketing association at preferential prices (Clements *et al.*, 2010).

Eco-tourism program. A community-based ecotourism program began in 2004 in the village of Tmatboey in Kulen Promtep Wildlife Sanctuary. Revenues are both individual, through employment or provision of services to tourists, and communal, as village committees of the villages involved in the program were contracted to stop illegal-hunting and enforce the PLUP (Clements *et al.*, 2008).

Conservation Rules

A PLUP was adopted in 2008 by the village committee of each village, subsequent to which land clearance was forbidden outside the boudaries delimited by the PLUP. Payments for Ibis Rice and Eco-tourism programmes were condtional to PLUP compliance. Participants in the Bird Nest and Eco-tourism schemes were also required to agree not to be involved in illegal hunting.

The PES programs, as well as the conservation rules, targeted a change in behaviour. In particular, the Ibis Rice and Eco-tourism programmes were designed to operate at the individual level and bring a decrease in illegal land clearance cases (Table 3.1). An analysis of their effectiveness in triggering a behavioural change was undertaken by Clements (2012). Individual illegal land clearance was

Table 3.1: PES programmes and targeted behaviour. Adapted from Clements (2012)

	Bird Nest	Ibis Rice	Eco-tourism	Monitoring level
Targeted behaviour				
Illegal bird hunting	Yes	No	Yes	Communal
Illegal land clearance	No	Yes	Yes	Individual
Target level	Individual	Individual	Individual Communal	

found to be correlated with participation in Ibis Rice and Eco-tourism program. However, this result is not sufficient to indicate a long-term link that would persist if partcipants were not involved in PES anymore, as Ibis Rice participants received payments that were conditional on rule compliance, and Eco-tourism participants signed a code of conduct including rule compliance. Therefore, these results do not indicate that any PES scheme affected rule compliance through norm internalization.

Investigation of illegal land clearance behaviour also showed that it was correlated with stated social norms, and stated attitudes toward local actors and local interventions. Indeed, stronger interpersonal trust was associated with lower illegal land clearance for two questions out of three, as well as a higher opinion of local authorities (village committee and PA rangers), and agreement with the PLUP. These findings suggest a set of stated preferences that can be associated with individual behaviour for further analysis. Table 3.2 summarises these correlations and their significance.

Table 3.2: Main figures of previous analyses on real-life behaviour in the study area. Adapted from Clements (2012)

Individual behaviour	Explanatory variable		Impact[1]	Sig.[2]
Illegal land clearance	Social norms	Trust question 1/3	(−)	*
		Trust question 2/3	(−)	(*)
	PES part.[3]	Ibis Rice	(−)	***
		Eco-tourism	(−)	(*)
	Perception	Village committee	(−)	**
		PA rangers	(−)	*
		PLUP disagreement	(+)	**

[1] (+): positive correlation (−): negative correlation
[2] Significance level. (*): $p < 0.1$, *: $p < 0.5$, **: $p < 0.01$, ***: $p < 0.001$
[3] PES program participation

3.2 A framed field CPR game from Travers *et al.* (2011)

A framed field CPR game was played between the 17th of June and the 16th of July, 2009.

3.2.1 Participants' selection

The game was played in the four villages forming the study area, where analyses of PES effectiveness and individual behaviour were performed, as described in the previous section.

80 participants from each village were selected by the village chiefs, who were asked to follow selection guidelines to reduce participants and group composition biases: *(a)* only one member per immediate family (except one village with a low population), *(b)* approximate gender parity each day, *(c)* even age distribution each day and *(d)* sampling covering all parts of the village (Travers, 2009).

The selection of participatns, therefore, allows for a comparison with individual real-life behaviour with a reduced participant selection bias.

3.2.2 Game rules

The CPR game study focused on the effect of institutional arrangements on CPR extraction. The experiment was conducted over four days in each village, 20 subjects playing each day. Subjects played 3 treatments in randomised groups of 10 people, including a control treatment plus two other treatments, randomly selected. Each treatment was a five-round extraction game in which people could extract between 0 and 10 fish from a collective pond. Subjects were told the pond contained 100 fish, and they decided on the number of fish they wanted to extract by circling illustrative fish on a paper sheet to reduce a possible disadvantage for illiterate participants. Hence, participants were confronted with a framed experiment.

The base individual payoff structure was the sum of two terms: a private benefit from individual fish extraction $(80 * x_i)$ proportional to the number of fish extracted x_i by Player i , and a collective benefit from the fish remaining in the pond after the group extraction $12 * (100 - \sum_{k=0}^{10} x_k)$. The game imposed a CPR dilemma as all players extracting zero fish yielded a higher payoff than all of them extracting some fish, but a self-interested player would be predicted to defect if all players agreed on zero-extraction.

Eight treatments were implemented in addition to the control treatment. Communication was not allowed in the control treatment, but was allowed between rounds in all others, giving to groups the possibility to reach an agreement on a collective strategy. The payoff structure of the peer-pressure treatment (treatment 1) was the same as in the control treatment, so that communication was the only difference between the two of them. Other treatments included individual penalty rules for extracting a positive number of fish, individual incentives for being the most cooperative player, and communal incentives for extracting a number of fish below a threshold (Table 3.3).

Table 3.3: CPR game rules, adapted from Travers *et al.* (2011)

Treatment	Incentive type	Effect on payoff
T0: Control	-	Base: $80 * x_i + 12 * (100 - \sum_{k=0}^{10} x_k)$ No communication
T1: Peer-pressure	-	-
T2: Low enforcement	Individual penalty	Low fine, probability 0.1 if $x_i > 0$
T3: High enforcement		High fine, probability 0.1 if $x_i > 0$
T4: External individual $[1]	Individual incentive	External payment if lowest x_i
T5: Internal individual $		Payment if elected by the group
T6: Weak communal $	Communal incentive	Weak conditionality, low payment
T7: Low communal $		Strong conditionality, low payment
T8: High communal $		Strong conditionality, high payment

[1] $: payments

3.2.3 Some results

The impact of socio-demographic factors and micro-situational settings on individual fish extraction was modelled. The fitted model showed the following significant results (summary in Table 3.4):

- Most treatments achieved a reduction in fish extraction. Strongly conditional communal payments had the greatest effects, and individual incentives as well as a strong penalty rules were also effective. Communication alone had an impact, but not significant. The weak penalty rule led to an increase in fish extraction (crowding-out effect), but again this was not significant.

- Some treatments had a lasting effect, with an impact on fish extraction in subsequent treatments, suggesting that they triggered norm internalization.

- Educated people tended to extract more.

- Women tended to extract less.

- When communication was allowed, reaching a group agreement led to significantly lower fish extraction.

- Extraction increased round after round, and the effect was significant as soon as during Round 2.
- Extraction was significantly higher after the first experiment day in the village (*i.e.* during Days 2-3-4), suggesting a leakage effect due to communication between Day 1 participants and Days 2-3-4 participants.
- Individual, group and village effects were found to have an important impact on individual extraction, though the impact significance was not quantified.

Table 3.4: Main figures of previous analyses on individual game behaviour. Adapted from Travers *et al.* (2011)

Individual behaviour	Explanatory variable		Impact[1]	Sig.[2]
Individual Fish Extraction	Treatment	T3	(−)	**
		T4	(−)	*
		T5	(−)	*
		T7	(−)	***
		T8	(−)	**
	Previous	T5	(−)	***
		T8	(−)	**
	Education		(+)	*
	Woman		(−)	*
	Group decision		(−)	***
	Round $\neq 1$		(+)	***
	Day $\neq 1$		(+)	***

[1] (+): positive correlation (−): negative correlation
[2] Significance level. (*): $p < 0.1$, *: $p < 0.5$, **: $p < 0.01$, ***: $p < 0.001$

Chapter 4

Hypotheses

On the one hand, research on the study site on real-life behaviour (response to incentives, rule compliance) has indicated that behaviour was linked to preferences stated by individuals: their social norms, and their perceptions of local authorities and of conservation interventions.

On the other hand, game analysis has underlined a number of factors at individual level and micro-situational level that have a significant impact on CPR extraction behaviour. Moreover, micro-situational settings included conditions suitable for the study of PES opportunities (*i.e.* individual positive incentives) and conservation rules (*i.e.* individual penalty rules).

Given the insightful observations on individual game and real-life behaviour detailed in the Background chapter, and provided the specific circumstances of the Cambodian case study described in the previous chapter, Table 4.1 summarises the hypotheses this study investigated.

Table 4.1: Summary of hypotheses

Hypothesis						#[1]
Real-life behaviour		Expectation	Correlation	Game behaviour	Game conditions	
PES participation		is strongly expected	to be correlated to	cooperativeness under	individual positive incentives	$H1_1$
			and to	responsiveness to		$H1_2$
Rule compliance		is strongly expected	to be correlated to	cooperativeness under	individual penalty rules	$H2_1$
			and to	responsiveness to		$H2_2$
Opinion on	PES schemes	is expected	to be correlated to	cooperativeness under	individual positive incentives	$H3_{a1}$
			and to	responsiveness to		$H3_{a2}$
Opinion on	conservation rules	is expected	to be correlated to	cooperativeness under to	individual penalty rules	$H3_{b1}$
			and to	responsiveness to		$H3_{b2}$
Opinion on	Both[2]	is expected	to be correlated to	cooperativeness under	baseline settings	$H3_c$
Perception of authorities		is expected	to be correlated to	cooperativeness under	individual incentives	$H4_1$
			and to	responsiveness to		$H4_2$
Social norms		are expected	to be correlated to	cooperativeness under	baseline settings	$H5$

Possible interpretation	#[1]
Cooperative players under individual economic incentives are either more conservation-minded or attracted by PES benefits	$H1_1$, $H3_{a1}$
Players more sensitive to individual economic incentives are more likely to be attracted by PES benefits	$H1_2$, $H3_{a2}$
Players cooperative under and sensitive to individual penalty rules are likely to be more compliant with real-life conservation rules	$H2$, $H3_b$
Naturally cooperative players are likely to be more conservation-minded	$H3_c$
Players cooperative under (sensitive to) incentives are more obedient to (easily influenced by) conservation authorities	$H4$
Social norms are more strongly embedded among naturally cooperative players	$H5$

[1] Hypothesis number.

[2] All conservation interventions.

Chapter 5

Methods

5.1 Individual game behaviour

5.1.1 Modeling approach

Instead of defining individual game behaviour indicators directly with empirical fish extraction data, we predicted the number of fish taken by each player through a regression model, as it would allow us to control for micro-situational settings, by modelling the effect of each variable and then taking into account the ones relevant for mimicking real-life conditions. Besides, multiple observations for each individual could then be condensed into one point per player.

As described by Travers *et al.* (2011), a Generalized Linear Mixel Model (GLMM) was used to account for non-normal expectation function for the response variable (Lindstrom & Bates, 1990), and logit as the associated link function was adapted to the response variable type, that is, proportional discrete data (Zuur *et al.*, 2009). Besides, clustered data made the use of a mixed model necessary (Zuur *et al.*, 2009). In addition to that, mixed model random effects are particularly useful when multiple responses are recorded per individual, and individual variation is the focus of interest (Bolker *et al.*, 2009; Lindstrom & Bates, 1990).

All the analysis described in this chapter was performed using R software version 2.14.1 (R Developement Core Team, 2011), unless specified otherwise. We ran

GLMMs with the ‘lme4’ package version 0.99937542 (Bates, Maechler & Bolker, 2010).

Parameter interpretation

Mixed models rely on the distinction between variables, which can be accounted for either as fixed effects with the aim of determining the specific effect of a variable value, and random effects that focus on the variation between levels of a variable (Bolker *et al.*, 2009).

Fixed effects can be interpreted as either the effect of an incremental unit for continuous and bounded proportional variables (*e.g.* one more year spent in education), or the effect of a specific level compared to the baseline level for binary and categorical variables (*e.g.* the effect size of a treatment different from the baseline treatment).

Random effects are normally distributed by the GLMM algorithm (Bates, 2010). Therefore, they can be interpreted as a deviation from the average value.

Model selection

Model selection was undertaken according to the protocol described by Travers *et al.* (2011). Relevant variables for fixed effects were selected through backwards stepwise selection and based on akaike information criterion (AIC; Akaike, 1974), with a threshold equal to 2: if deleting a variable induced a variation in AIC superior to 2, the variable was kept; otherwise, the most parsimonious model (*i.e.* the one without the considered variable) was preferred (Burnham & Anderson, 2004). Relevant variables for random effects were selected through likelihood ratios tests with and without each variable. Since parameters were estimated with Laplace approximation, this method of selection was appropriate (Bolker *et al.*, 2009).

Travers *et al.* (2011) fitted a model for fish extraction consisting of 6 fixed effect variables and 3 random effects. No interaction term between variables was included. Subsequent analysis by Travers *et al.* (2011) revealed that the effect of round played was likely to be correlated with the effect of treatment played, as the evolution of the number of fish taken during a session of five rounds (the shape of the fish versus round curve) was dependent on the treatment played. Similarly, the effect of whether a decision was made and the effect of treatment played were likely to be correlated, as the effects of treatments yielded different conclusions with and without group decision. As a consequence, we tested models adding interaction terms between round, decision made and/or treatment to the model fitted in Travers *et al.* (2011), and selected the best fit based on the protocol described above (model selection table are provided in Appendix A, Table A.1).

5.1.2 Estimators/predictors of individual fish extraction

To predict individual fish extraction under the relevant micro-situational settings, we extracted from the fitted GLMM output the Best Linear Unbiased Estimators (BLUE, for fixed effects) and Predictors (BLUP, for random effects) which quantify variables effects (Henderson, 1975), and built an estimator for the effect of individual attributes and an estimator for the effect of micro-situational settings. The sum of the two estimators enabled us to predict fish extraction for each individual, under the set of relevant micro-situational conditions. In the subsections that follow, C_k is the GLMM output for the effect of variable k.

Individual attributes estimator

The individual attributes estimator P_i for player i was built aggregating the effects of individual socio-demographic variables and the remaining individual effect. These effects included:

- $C_{village_i}$ is the BLUP of the village in which player i lived
- C_{gender} is the BLUE of the gender of player i: $\begin{cases} 0 & \text{if man (baseline)} \\ C_{gender} & \text{if woman} \end{cases}$
- $C_{education}$ is the BLUE of the effect of one year spent in education. The effect of the time $education_i$ player i spent in education is thus:

$$C_{education} * education_i$$

- $C_{individual}$ is the BLUP of the remaining individual effect, that is, a predictor of the remaining propensity to fish more or less than average for player i, having controlled for the socio-demographic variables mentioned above. It can be interpreted as the temperament of Player i, where temperament describes behavioural disposition repeatable over time and accross situations (Réale *et al.*, 2007).

The objective is to categorise players according to their fish extraction behaviour. Temperament is a useful predictor, as it is a direct predictor of the deviation of player i from average. As such, a BLUP for temperament has already been used with fish in Behavioural Ecology to characterize individual propensity to take risks (Magnhagen & Bunnefeld, 2009).
However, the aim is to compare game behaviour with real-life behaviour, which was assessed in conditions in which socio-demographic variables are also attached to players (that is, people were observed behaving in their village environment and they answered village-scale questions, and gender and education are inseparable from the individual). Given the distribution of temperament estimators $(C_{individual_i})_{i \in [1..317]}$, individuals are associated with a individual rank within that distribution. As gender, village and education effects belong to the fitted GLMM, adding each variable results in significant changes in the distribution. However, our focus lies in differences between individuals, so that individual ranks in the distribution are particularly important. We tested whether including socio-demographic variables had a significant impact on the individual ranks in the distribution of individual attributes estimators.
The impact of adding separately each socio-demographic variable to the temperament BLUPs was tested through a Student t-test (for gender effect), an ANOVA coupled with a LSD test (for village effect), and a linear regression (for education effect). The overall effect of adding the three variables to the temperament BLUP was measured with a t-test on the mean absolute individual rank variation before/after adding them. We decided to include the three socio-demographic variables to compute individual attributes estimator for player i as:

$$P_i = C_{village_i} + C_{gender} * gender_i + C_{education} * education_i + C_{individual_i} \ , \ i \in [1..317]$$

Baseline player. To measure an individual's deviance from average, a baseline player was defined as a reference for comparison. The baseline player is therefore a virtual player with neutral characteristics. We set village and individual random effects to zero, *i.e.* average since they both follow normal distributions, gender effect to the mean between men and women effects, and education effect to the effect for the mean level of education of the sample $\overline{education}$. We will denote P_0 the individual attributes estimator for the baseline player.

Micro-situational settings estimator

Micro-situational settings must reflect conditions in which individuals make decisions and take actions in real-life.

- *Communication.* Except the control treatment, all treatments allowed communication in the group between rounds. Analysing the response of players to incentives implies comparing individual behaviour under incentive treatments and under a baseline treatment. We chose to set the peer-pressure treatment as the baseline treatment to compare incentive treatments to, because it allows to control for communication among players and reflect the existence of communication in real-life.

- C_{round} is the BLUE of the round played. On average, fish extraction was found to increase round after round during a game (Travers *et al.*, 2011), which is a common CPR game observation (Ostrom, 2000). A limited time horizon is predicted to reduce cooperation if players apply backward induction (Gintis, 2000), culminating with a peak of free-riding during the final round (Ostrom, 2000). At the same time, it is suggested that experience acquired by players has a positive impact for cooperation (Ostrom, 2000). Given these two observations, we decided to set a neutral setting for round effect. We averaged for the treatment j we are focusing on, the BLUEs for round r effects and the BLUEs for the interactions between round r and treatment j over the five rounds of a game. The mean round effect for Treatment j was thus:

$$\frac{1}{5}\sum_{r=0}^{5}(C_{round_r} + C_{treatment_j * round_r})$$

- $C_{decision}$ is the BLUE of whether a decision was taken. When group communication was allowed, reaching an agreement was found to significantly increase cooperation (Travers *et al.*, 2011). As the proportion of rounds in which a decision was made depended on the treatment implemented and the game round, but as we could not include interaction terms between decision and round or treatment (*cf.* Appendix A, Table A.1, for details), we accounted for the decision effect by weighting $C_{decision}$ with the proportion of rounds where a decision was made under Treatment j:
$$\frac{\#(\text{Decision rounds})_j}{\#\text{Rounds}_j}$$

- $C_{previous}$ and C_{day} are the BLUEs of the respective effects of the treatment played just before the current treatment, and of the day the session was held. The previous treatment effect was found for strong self-regulation treatments to increase subsequent cooperation, suggesting norm internalization, while cooperation decreased after the first day of the experiment in each village, suggesting leakage in the village (Travers *et al.*, 2011). Therefore we set the previous treatment and day effects to their baseline (*i.e.* estimators equal to zero), to control for these two effects.

- C_{group} is the BLUP of group effect. We set group effect to zero, meaning that individual behaviour will be measured as if individuals were playing in an average group.

- $C_{intercept}$ is the GLMM intercept BLUE. It is the remaining unexplained effect, therefore it could be attributed to players, micro-situational settings or the broader context. As it is common to all players, we included it in micro-situational settings.

- $C_{treatment_j}$ is the BLUE of Treatment j. However, treatment also acts through interaction terms between round and treatment, and through the proportion of decisions made under the treatment. That is why we accounted for the treatment effect by comparison with the baseline micro-situational settings.

Baseline micro-situational settings. Let us denote S_j as the micro-situational settings estimator for treatment j, that we obtain by aggregating micro-situational settings estimators and predictors as described above:

$$\begin{aligned} S_j = \ & \frac{1}{5}\sum_{r=0}^{5}(C_{round_r} + C_{treatment_j * round_r}) + \\ & C_{decision} * \frac{\#(\text{Decision rounds})_j}{\text{Rounds}_j} + \\ & C_{intercept} + \\ & C_{treatment_j} \end{aligned}$$

Then S_1 is the baseline micro-situational settings estimator. Let us denote T_j as the additional effect of treatment j compared to the peer-pressure treatment, then:

$$T_j = S_j - S_1$$

Defined as such, the sign of T_j directly indicates the effect of treatment j on individual fish extraction, which is increased (respectively decreased) if treatment j effect T_j is positive (respectively negative).

Table 5.1 summarises how individual attributes and micro-situational settings estimators were built from the fitted GLMM estimators and predictors.

Table 5.1: Definition of individual attributes and micro-situational settings estimators from GLMM estimators and predictors.

Estimator		:	Variables						
Individual attributes		:	Village	,	Gender	,	Education	,	Individual
Player i, $i \in [1..317]$	P_i	$=$	$C_{village_i}$	$+$	$C_{gender} * gender_i$	$+$	$C_{education} * education_i$	$+$	$C_{individual_i}$
Baseline player	P_0	$=$	0	$+$	$\frac{C_{gender}}{2}$	$+$	$C_{education} * \overline{education}$	$+$	0
Micro-situational settings		:	Round	,	Decision	,	Previous+Day+Group+Intercept	,	Treatment
Treatment j settings, $j \in [0..8]$	S_j	$=$	$\frac{1}{5}\sum_{r=0}^{5}(C_{round_r} + C_{treatment_j * round_r})$	$+$	$C_{decision} * \frac{\#(\text{Decision rounds})_j}{\text{Rounds}_j}$	$+$	$C_{intercept}$	$+$	$C_{treatment_j}$
Baseline M-S Settings	S_1								
Treatment j effect, $j \in [0..8]$	T_j	$=$	$S_j - S_1$						

5.1.3 Individual fish extraction

Estimators and predictors were the ouptut of a fitted GLMM with a logit link function. Therefore, for each fish player i has the opportunity to extract under treatment j, the probability that player i does so is:

$$\pi(P_i, T_j) = \frac{1}{1 + e^{-(P_i + T_j + S_1)}}, \text{ which we will denote: } \pi_{ij}$$

The number of fish extracted by player i under treatment j then follows a $\mathcal{B}(10, \pi_{ij})$ binomial law (Zuur *et al.*, 2009). We defined two absolute indicators of individual fish extraction: expected fish extraction, and the probabilities of extracting more, fewer or as many fish as the baseline player.

Expected fish extraction

Expected fish extraction $f(P_i, T_j)$ for player i under treatment j is the expected value of $\mathcal{B}(10, \pi_{ij})$. Expected fish extraction $f(\cdot, \cdot)$ is thus:

$$f : \left| \begin{array}{ccccc} \mathbb{R} & \times & \mathbb{R} & \longrightarrow & [0; 10] \\ (P_i & , & T_j) & \longmapsto & 10 * \pi_{ij} \end{array} \right.$$

which we will denote more conveniently: f_{ij}.

Probabilities of extracting more, fewer or as many fish as the baseline player

Players have a discrete set of choices $\{0, 1, ..., 10\}$. While expected fish extraction is a continuous variable with values in [0;10], we accounted for the discrete nature of fish extraction by defining for player i, the probability of extracting more fish than the baseline player under treatment j, $p_{sup}(i, j)$.
Let X_{ij} be the fish extraction random variable for player i under treatment j. Then:

$$p_{sup} : \left| \begin{array}{ccccc} \mathbb{R} & \times & \mathbb{R} & \longrightarrow & [0; 1] \\ (P_i & , & T_j) & \longmapsto & P[X_{ij} > X_{0j}] \end{array} \right. , \text{ denoted } P_{sup_{ij}}$$

Hence:

$$p_{sup_{ij}} = \sum_{k=0}^{9} \sum_{l=k+1}^{10} P[X_{0j} = k] * P[X_{ij} = l]$$

$$p_{sup_{ij}} = \sum_{k=0}^{9} \sum_{l=k+1}^{10} \binom{10}{k} \pi_{0j}^{k} (1 - \pi_{0j})^{(10-k)} * \binom{10}{l} \pi_{ij}^{l} (1 - \pi_{ij})^{(10-l)}$$

Similarly, we defined the probabilities of extracting less fish than and as many fish as the baseline player, respectively $p_{inf_{ij}}$ and $p_{eq_{ij}}$.

Indicator selection

To select the best indicator among the two individual fish extraction indicators, we computed their distributions for all players under baseline settings, then calculated the shape parameters of the distributions, and simulated confidence intervals for each point.

We estimated confidence intervals using the ‘arm’ package version 1.6-06.01 (Gelman & Su, 2013). Confidence intervals for GLMM fixed effects are not available with the ‘lme4’ package, as they would require advanced bayesian inference techniques (Bates, 2010). The ‘arm’ package approximates GLMM fixed effect structure to a normal one. We used it to simulate (n = 1000 times) the fitted GLMM, then computed for each player and each GLMM simulation the two fish extraction indicators, and finally extracted for each player and each indicator 2.5 and 97.5 percentiles of the 1000-point distribution. As the ’arm’ package assumes normal distributions both for fixed effects and random effects, distributions for each player and each indicator are theoretically symmetric, so the interval between percentiles 2.5 and 97.5 can be used as a 95% confidence interval.

This method provides confidence intervals that are approximate. Nevertheless, it is useful to compare the magnitude of confidence intervals of the two fish extraction indicators.

5.1.4 Individual Sensitivity to Treatments

To analyse individual response to incentives, we defined the function $\delta(\cdot,\cdot)$ that computes the gap between player i's fish extraction under treatment j and under baseline settings:

$$\delta : \left| \begin{array}{ccccc} \mathbb{R} & \times & \mathbb{R} & \longrightarrow & [0;10] \\ (P_i & , & T_j) & \longmapsto & f_{ij} - f_{i1} \end{array} \right. , \text{ denoted } \delta_{ij}$$

As the effect of treatment j T_j is characterized by a single predictor, all players are expected to decrease (increase) their fish extraction if the effect of treatment j is negative (positive). As a consequence, though response to treatment j is not uniform due to non-linearity of the expected fish extraction function, this response has a sign common to all players.
Therefore, we defined individual sensitivity to treatment j by comparing individual response to treatment j with the baseline player's response to the same treatment. $\Delta(P_i, T_j)$ is the difference between the gap defined above for player i under treatment j, and for the baseline player under treatment j:

$$\Delta : \left| \begin{array}{ccccc} \mathbb{R} & \times & \mathbb{R} & \longrightarrow & [0;10] \\ (P_i & , & T_j) & \longmapsto & \delta_{ij} - \delta_{0j} \end{array} \right. , \text{ denoted } \Delta_{ij}$$

Properties

A formal analysis of $\Delta(\cdot,\cdot)$ was performed with Matlab version v7.14.0.739 (The MathWorks Inc., 2012). Variations and root values of $\Delta(\cdot, T_j)$ were found to fall within five configurations, dependent on the treatment effect T_j. Details on the five cases are available in Appendix B.
When the effect of treatment j reduces fish extraction ($T_j < 0$), individual sensitivity to treatment j first decreases then increases with individual attributes estimator P_i. Three domains can be identified, which are illustrated in Figure 5.1:

- *Players expected to extract less than the baseline player* ($P_i < P_0$): they are expected to extract less than the baseline player, under the baseline settings and therefore under treatment j as well (because treatment effect does not affect expected fish extraction ranks), although their deviation from the baseline player is reduced under treatment j ($\Delta_{ij} > 0$ & $P_i < 0$). These players are cooperative in both settings.

- *Players expected to extract more than the baseline player, but below a threshold dependent on the effect of treatment j ($P_0 < P_i < -2 * S_1 - T_j - P_0$)*: they are expected to extract more than the baseline player in both settings, but get closer under treatment j, as they are expected to reduce fish extraction more than the baseline player ($\Delta_{ij} < 0$ & $P_i > 0$). These players are therefore particularly sensitive to the incentive for cooperation.

- *Players expected to extract more than treatment j threshold* ($P_i > -2 * S_1 - T_j - P_0$): they are expected to extract more fish than the baseline player in both settings, and increase their fish extraction relative to the baseline player ($\Delta_{ij} > 0$ & $P_i > 0$). These players show no sign of cooperation.

This behavioural interpretation is consistent with the common categorisation of players behaviour described earlier (*cf.* "Categorisation of players", Background chapter, section 2.2, subsection 2.2.2). Therefore it allows us to define, for a treatment that reduces fish extraction, a dummy variable $\Delta_{cat}(\cdot, j)$ that categorises players according to their sensitivity: unconditional cooperators (UC), conditional cooperators (CC) and free-Riders (F). As this categorisation takes into account both the values of sensitivity to treatment and individual attributes estimator, it is an indicator of both responsiveness to treatment and cooperativeness under the treatment.

Treatment selection

Two treatments were representative of real-life institutional arrangements under which we assessed real-life behaviour.

Treatment 3 implemented a strongly enforced penalty rule (*i.e.* with a high economic penalty). Although PLUP boundary enforcement in the PAs was suggested not to be highly efficient (Winney, 2011), it led to an actual reduction in illegal land clearance cases in the study area after PLUP implementation (Clements,

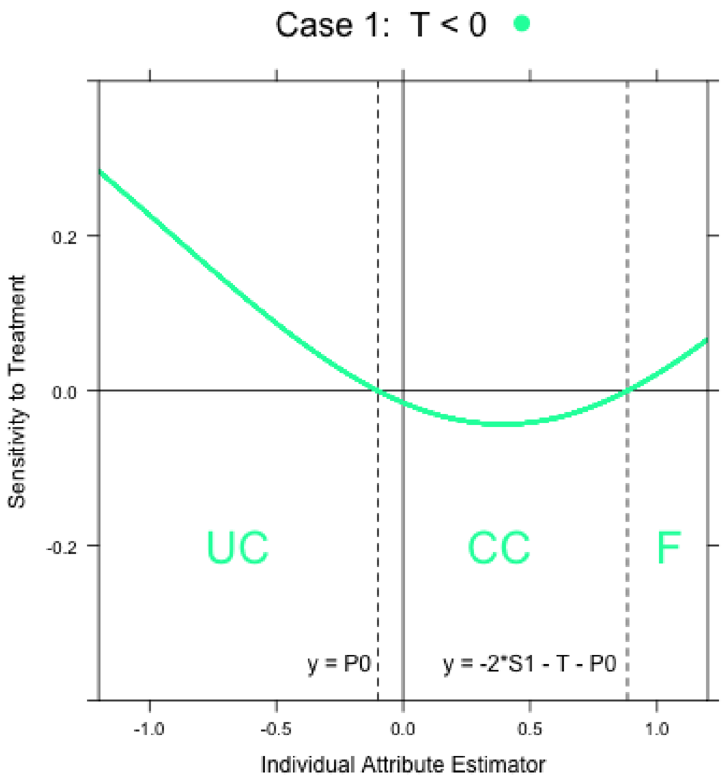

Figure 5.1: Illustration of sensitivity to treatment versus individual attributes estimator curve, in the case of a treatment that reduces fish extraction ($T < 0$). The curve was computed with empirical values, including $T = T_4$ (individual positive incentives Treatment), except P_0 which was set to -0.1 for illustrative purposes. Three domains are highlighted, in which players are interpreted as unconditional cooperators (UC), conditional cooperators (CC) and free-Riders (F).

2012). As treatment 2, which consisted in a low penalty rule, was shown to entail an increase in fish extraction in the game (Clements *et al.*, 2011), treatment 3 was the best proxy for the PLUP restrictions set in the study area.

Treatment 4 implemented individual, externally provided economic incentves. As this study focuses on individual behaviour, and that the three PES schemes of the study area included individual payments, treatment 4 was chosen as the proxy for the PES schemes.

Hence, individual sensitivities were computed for treatment 3 and 4 in accordance with the method detailed previously, that is, respectively *sensitivity to positive incentives* and *sensitivity to penalty rules.* The effects of treatment 3 and 4 fall in the range of treatments such that $T_j < 0$, which enables us to define players types according to the UC-CC-F categorisation as described in the previous subsection. We, therefore, computed the categorical variables *player type under positive incentives* and *player type under penalty rules* associated respectively with treatments 3 and 4. The player categorisation was applied the same way to the baseline settings by extrapolation to $T_j = 0$ of player types under negative treatment effect (*cf.* Appendix B for a justification of the extrapolation).

Selfish defection

Selfish defection was defined as the proportion of cases where player i chose to extract more fish than the group decided, when a group-decision was made. This indicator was associated with a number of disadvantages, in particular because players did not all have the same opportunity to defect, which depended not only on the existence of a group-decision, but also on the value the group chose. Nevertheless, the correlation between selfish defection and expected fish extraction was tested to confirm the validity of expected fish extraction of an indicator of cooperativeness.

Table 5.2 summarises the game indicators that were defined and the behaviour they target.

5.2 Individual real-life behaviour

Real-life behaviour was assessed through observed behaviour and responses to surveys. Data sources and data collection methods reported here are reported based on a more detailed description by Clements (2012). Real-life behaviour variables are summarised in Table 5.2.

5.2.1 Observed behaviour

Illegal land clearance

Household land clearance was the only individual-level indicator of rule compliance that could be measured (*cf.* table 3.1). Land clearance was monitored at household level from the 1st of January, 2008 to the 31st of December, 2010. As the PLUP in the four villages was agreed on in 2008, illegal land clearance outside the boundaries specified by the PLUP was monitored subsequently for two years. Four sources of information reported household illegal land clearance: *i)* village committees, that were in charge of land-use boundaries management and definition, *ii)* WCS teams assisting village committees, *iii)* research teams collecting data on the field and *iv)* PA rangers taking action around the study villages. Although cases of illegal land clearance were confirmed both by the village committee and through a second field visit, the reliabillity of the data could have been weakened by non-reported cases, as the quality of the PLUP enforcement was questionable (Winney, 2011). We defined household *illegal land clearance* as a binary variable observed for the whole population of the study area.

PES participation

Response to economic incentives was measured through individual PES participation, defined as a binary variable: *PES participation* is true when the household was involved in at least one of the three PES programmes, for at least one year, up to and including 2010. Over that time, Bird Nest and Ibis Rice programs were implemented in two villages, and all three programs were implemented to the other two villages, so that all players had a high, though not equal, opportunity to be involved in a PES program. On the one hand, this variable had the merit of providing a balanced sample (116 participants versus 91 non-participants), and allowed to gather enrollment in conservation actions under one variable, while splitting it into three variables would have created unbalanced samples and demanded to apply corrections on correlation tests to account for the multiplication of hypotheses, which both would have considerably decreased the ability to detect linkages. Moreover, a continuous variable such as the amount of money earned through PES participation would have included a higher selection bias, as for instance revenues earned through the Ibis Rice programme were dependent on farmers' land and equipment. On the other hand, this variable also included a selection bias due to non-eqal opportunity to be involved in two programmes: the Eco-tourism programme (only two villages among four, and a abnormally high proportion of participants held a position in these two villages) and the Ibis Rice programme (requirements for entering the programme excluded poor farmers).

5.2.2 Stated behaviour

Semi-structured interviews were performed in a subset of households in the study villages by the Center for Development Orientated Research into Agriculture and Livelihood Systems (CENTDOR) between December 2009 and January 2010. Interviewers were not known to the villagers. Topics included attitudes toward conservation, the PES programmes, perception of stakeholders, and social norms.

We built dummy variables based on questions related to three relevant topics. Each variable was computed as an index ranging between 0 and 1 by aggregating and normalizing the answers to several questions. For example, to compute Index A from questions B and C whose answer values are indices respectively in $[0..b]$ and $[0..c]$, we computed $A = \dfrac{c * B + b * C}{b * c}$. A is therefore an index in [0..1] in which B and C have an equal weight.

Interpersonal Trust

The survey included three yes/no questions related to interpersonal trust:

- "Generally speaking, would you say that most people in the village can be trusted or that you can't be too careful in dealing with people?"

- "Do you think most people in the Village would try to take advantage of you if they got a chance, or would they try to be fair?"
- "Would you say that most of the time, people in the village try to be helpful, or that they are mostly just looking out for themselves?"

These three questions are part of the General Social Survey (GSS) that has been carried out extensively in the United States from 1972 (National Opinion Reseach Center, 2013), and of the World Values Survey that has been conducted later on from 1981 in about a hundred societies in the six inhabited continents (World Values Survey, 2013). Previous research has provided evidence that interpersonal trust measured by the three questions was correlated with actual individual behaviour such as firearm crime (Kennedy *et al.*, 1998), civic engagement (Brehm & Rahn, 1997), or communication (Fisman & Khanna, 1999).

We defined *interpersonal trust* variable as the aggregate normalized index of the answers to these three questions.

Perception of authorities

It has been suggested that trust in authorities could be an extension of interpersonal trust (Brehm & Rahn, 1997). Besides, compliance with rules has been shown to be strongly correlated to monitoring efficiency in the case of illegal hunting (Leader-Williams & Milner-Gulland, 1993), which suggests a link between rule compliance and effectiveness of monitoring institutions. That led us to focus on two questions of the survey about individuals perception of authorities: opinion on village committee (between 0 and 2) and perception of PA rangers' effectiveness (between 0 and 3). We defined *perception of authorities* variable aggregating and normalizing the answers to the two questions.

Opinion on conservation interventions

For each PES scheme, the survey included questions on the PES scheme fairness (yes/no), its benefits for the people involved (yes/no), for their own household

(yes/no) and for the whole village (between 0 and 2). *opinion on PES* is the aggregate, normalized index of the 12 questions.
People were asked their opinion on the PLUP process (good/bad), and on the benefits it brought to the village (between 0 and 2). *opinion on PLUP* is the aggregate normalized index of the two answers.
We defined *opinion on conservation interventions* as the aggregate normalized index of *opinion on PES* and *opinion on PLUP*.

Table 5.2: Summary of individual behaviour indicators

Game

Targeted behaviour	Settings	Indicator	Symbol	Data type	Value range
Cooperativeness	Any treatment	Expected fish extraction	$f(\cdot, j)$	Continuous	[0;10]
	Any treatment	Probability to extract more fish than the baseline player	$p_{sup}(\cdot, j)$	Continuous	[0;1]
	-	Selfish defection	-	Proportional	[0;1]
Responsiveness to incentives	Any except baseline	Sensitivity	$\Delta(\cdot, j)$	Continuous	[0;10]
Both	Any treatment	Player type	$\Delta_{cat}(\cdot, j)$	Categorical	{UC,CC,F}

Real life

Targeted behaviour	Variable type	Indicator	Data type	Value range
Response to positive incentives	Observed	PES participation	Binary	{0,1}
Rule compliance		Illegal land clearance	Binary	{0,1}
Preferences	Stated	Interpersonal trust	Proportional discrete	[0;1]
		Perception of authorities	Proportional discrete	[0;1]
		Opinion on PES	Proportional discrete	[0;1]
		Opinion on PLUP	Proportional discrete	[0;1]
		Opinion on Both	Proportional discrete	[0;1]

5.3 Correlation between individual game and real-life behaviours

5.3.1 Data Matching

The two databases that provided individual player data and real-life household data did not include a common and unique identifier for individuals/households. Individuals were matched based on variables present in both databases. We added a confidence index to every match we found, and kept only players matched with high confidence, who were 207 in the whole set of 317 players. As the real-life database provided data at household level, matched players' behaviour in real-life was proxied by the behaviour of the household they belonged to.

Among the 207 players for whom real-life data was available, all of them were associated with land-clearance behaviour and PES participation, except two players for whom land-clearance behaviour was set to Non Assessed as it was reported to be unclear. The survey was answered by 91 players. Counts of players associated with real-life variables are provided in Table 5.3.

5.3.2 Subset representativeness

Due to incomplete overlaps between datasets, correlation tests were run for subsets of various sizes. The representativeness of subset means (for continuous variables) and proportions (for categorical and binary variables), and the representativeness of the subset distributions were assessed through Welch t-tests, Pearson χ^2 tests and Kolmogorov-Smirnoff tests respectively. Detailed results are provided in Appendix D, Table D.1. No significant differences were found between the subsamples and whole samples, both for means and proportions and for distributions. The only exception was the opinion on PLUP, which was lower on average in the subsample (0.35 on average for 91 players) than in the whole sample (0.43 on average for 192 players; $t = -2.01$, $d.f. = 186.7$, $p = 0.046$). This might have stemmed from the limited number of levels accessible to players for this index (5 levels in $[0; 1]$), that could have exaggerated the opinion gap between datasets.

5.3.3 Correlation analysis

Correlation tests between the selected game and real-life indicators were finally performed. Table 5.3 summarises the tests and associated hypotheses we expected to be positive. Statistical tests included Welch t-tests, Pearson χ^2 tests, Analyses of Variance (ANOVAs) and linear regressions that were run with the 'stats' package version 2.14.1, and positive results for ANOVAs were further analysed through Least Significant Difference (LSD) tests with the 'agricolae' package version 1.1-1 (de Mendiburu, 2012).

More comprehensive analyses were also undertaken: each indicator was modelled taking all others into account, that is, both real-life and game variables. We used stepwise backward selection on linear regressions to model continuous variables (with the 'stats' package version 2.14.1), on generalized linear models with binomial link function to model binary variables (with the 'lme4' package version 0.999375-42; Bates, 2010) and on multinomial logistic regression to model categorical variables (with the 'nnet' package version 7.3-1; Ripley, 2013).

Table 5.3: Summary of correlation tests and associated hypotheses. Hypothesis numbers refer to hypotheses described in Table 4.1.

Real-life indicator		Obs.[1]	j[2]	Game behaviour indicator		
				Cooperation	Response to incentive	Player type
				$f(\cdot, j)$	$\Delta(\cdot, j)$	$\Delta_{cat}(\cdot, j)$
PES participation		207	4	$H1_1$	$H1_2$	$H1_1$ & $H1_2$
Illegal land clearance		205	3	$H2_1$	$H2_2$	$H2_1$ & $H2_2$
Opinion on	PES	91	4	$H3_{a1}$	$H3_{a2}$	$H3_{a1}$ & $H3_{a2}$
Opinion on	PLUP	91	3	$H3_{b1}$	$H3_{b2}$	$H3_{b1}$ & $H3_{b2}$
Opinion on	Both	91	1	$H3_c$	-	$H3_c$
Perception of authorities		91	3/4	$H4_1$	$H4_2$	$H4_1$ & $H4_2$
Interpersonal trust		91	1	$H5$	-	$H5$

[1] Counts of players for whom each real-life indicator was computed

[2] Treatment under which the correlations are expected:

1: T1 (Baseline); 3: T3 (individual penalty rule); 4: T4 (individual positive incentive)

Chapter 6

Results

6.1 Individual game behaviour

6.1.1 Socio-demographic variables

Descriptive demographics

The set of $n = 317$ players used to compute game behaviour is characterized by near-parity (50.5% of men, 49.5% of women), and an almost equal distribution among villages (25.2% of players living in Tmatboey, 24.9% living in each of the three other villages). Time spent in education ranged from none to 12 years, with a mean of 2.49 years. A large proportion of players did not spent any time in education (42.6%). A large proprtion received few education (41.3% spent less than five years, included, in education), while only 16.1% spent six years or more in education.

Influence on individual attributes estimator

Given the distribution of temperament BLUPs $(C_{individual_i})_{i\in[1..317]}$, individuals are associated with an individual rank within that distribution.

The BLUE for gender predicts that women extract significantly fewer fish. We found that adding gender to temperament shifted women on average 15.2 ranks toward the bottom of the distribution, and men 15.0 ranks toward to top (Table 6.1).

Once gender effect was added to temperament, women were ranked significantly lower than men in the distribution (Welch t-test, $t = 2.40$, $d.f. = 315.0$, $p = 0.017$).

Similarly, the village BLUPs predict that players living in Dangphlat extract fewer fish than average, while players living in Tmatboey, Narong or Prey Veng extract more than average. Variation in absolute rank generated by adding the village effect to temperament BLUPs ranged from -104.3 ranks for Dangphlat to +65.0 ranks for Narong. It resulted in individual ranks significantly different between villages ($F(3, 313) = 89.39$, $p < 0.001$): on average players living in Narong were ranked significantly higher than players living in Prey Veng and Tmatboey, themselves significantly higher than players living in Dangphlat (Narong: 224.7, Prey Veng: 181.3, Tmatboey: 173.3, Dangphlat: 56.6, Least Significant Difference: 21.1).

The BLUE for education predicts that each year spent in education increases individual fish extraction. Adding education effect to temperament BLUPs shifted players without any education of -9.4 ranks on average, and shifted educated players of +1.4 ranks per year spent in education. Once education was added, a linear regression of ranks versus education showed that the effect was significant ($F(1, 315) = 2.95$, $d.f. = 315$, $p = 0.003$).

The addition of all three variables simultaneously to temperament BLUPs led to a mean absolute variation in ranks equal to 54.5, for which all the effects mentioned previously remain significant (linear regression with ranks as response variable, $d.f. = (5, 311)$, Women: $t = -2.73$, $p = 0.007$, Education: $t = 2.52$, $t = .012$, Danghplat: $t = -10.0$, $p < 0.001$, Narong: $t = 4.24$, $p < 0.001$).

Table 6.1: Individual rank variation generated by the addition of socio-demographic variables to temperament BLUPs distribution (n=317 players).

	Variable	Mean rank variation
Gender	Men	+15.0
	Women	−15.2
Village	Tmatboey	+16.1
	Dangphlat	−104.3
	Narong	+65.0
	Prey Veng	+23.1
Education	No education	−9.4
	Mean per year	+1.4

Variable	Mean absolute rank variation
Gender + Village + Education	54.5

6.1.2 Individual fish extraction

Expected fish extraction versus
Probability of extracting more than the baseline player.

Comparison between the two functions showed that they generated moderate shape transformations, though the probability indicator tended to highlight extreme players at the expense of average ones. Moreover, the interpretation of variations in the probability indicator value was delicate, because Treatment effects were harder to detect, and because a variation in the probability of extracting more fish than the baseline player was dependent on the variations in two other indicators (probabilities of extracting fewer fish and as many fish as the baseline player). So that opposite variations in the probability indicator could *not* be interpreted directly as actual opposite effects. The detailed comparative analysis of the two indicators is provided in Appendix C.

These two conclusions suggested that expected fish extraction was a more robust indicator coupled with a more straightforward interpretation. Therefore, it was selected as the game indicator for cooperation to test against real-life behaviour.

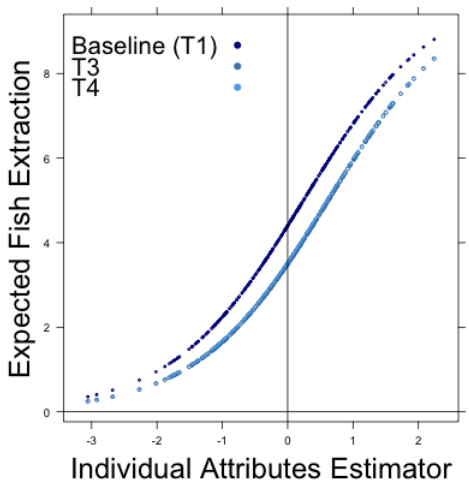

Figure 6.1: Expected fish extraction versus individual attributes estimator, plotted under three different micro-situational settings: baseline, individual penalty rule (T3) and individual positive incentive (T4). T3 and T4 curves are nearly indistinguishable.

Expected fish extraction

Characteristic values The baseline player was found to be characterised by an individual attributes estimator $P_0 = -0.01$ close to the mean estimator of the distribution. The difference between the two is actually indistinguishable at precision 10^{-2}. Under the baseline micro-situational settings, expected fish extraction is found to range from 0.36 to 8.81 fish from the possible [0;10] interval. Table 6.2 presents some characteristic values of individual attributes estimator and expected fish extraction. The effects of the two treatments of interest, *i.e.* individual positive incentives and individual penalty rule led the baseline player to reduce her extraction from 4.36 fish under the Baseline settings to 3.47 (respectively 3.51) fish under penalty rule treatment (respectively positive incentive treatment, Figure 6.1).

6.1.3 Sensitivity to treatments

Treatment effect is characterised by a single estimator T_j. In this model the sign of T_j determines the qualitative impact on extraction, which is common to all players

Table 6.2: Characteristic values for individual attributes estimator and associated expected fish extraction under the three micro-situational settings of interest (n=317 players).

Variable		j[1]	Individual attributes estimator			
			Lower $min_i(P_i)$	Upper $max_i(P_i)$	Mean $\overline{P_i}$	Baseline P_0
Individual attributes estimator	P_i	-	-3.06	$+2.24$	-0.01	-0.01
Expected fish extraction	f_{ij}	1	0.36	8.81	4.37	4.36
		3	0.25	8.35	3.47	3.47
		4	0.25	8.38	3.52	3.51

[1] Treatment. 1: Baseline settings, 3: Individual Positive Incentives, 4: Indivisual Penalty Rule

(Table 6.3). In particular, individual penalty rule and individual positive incentive treatments were found to generate a reduction in expected fish extraction for all players (Table 6.3, Figure 6.1).

Sensitivity to treatments variable accounts for the non-uniformity of individual responses to treatments (illustrated by the variable gap between the treatments and the baseline curves in Figure 6.1).

Empirically, all treatments that introduced strong incentives for cooperation were found to achieve an actual reduction in expected fish extraction (high individual penalty rule, individual positive incentives, communal positive incentives with strong payment conditionality; negative values in Table 6.3). Under these circumstances, the associated sensitivities to treatments curves are convex, displaying a minimum for the players *expected to reduce most* their fish extraction under each treatment (Figure 6.3). Compared to the baseline player, who is also expected to reduce her fish extraction, they are expected to achieve a stronger reduction (they fit into the fraction of the distribution associated with a negative sensitivity to treatment). Please note that zero sensitivity do *not* mean the player is not

Table 6.3: Treatment effects. Positive (Negative): all players are expected to increase (decrease) their individual fish extraction. Bold cases highlight the treatments of interest.

Treatment	Treatment effect	
Baseline	$T1 =$	0
Low enforcement	$T2 =$	+0.42
High enforcement[1]	$T3 =$	−0.38
External individual[2]	$T4 =$	−0.36
Internal individual	$T5 =$	−0.38
Weak communal	$T6 =$	+0.33
Low communal	$T7 =$	−0.61
High communal	$T8 =$	−0.57
Control	$T0 =$	+0.52

[1] Individual penalty rule treatment

[2] Individual positive incentives treatment

affected by the treatment, but rather that its behaviour matches the behaviour of the baseline player.

Treatments providing low incentives for cooperation were found to actually increase expected fish extraction (low individual penalty rule, communal payments with weak conditionality, Table 6.3), as well as the interdiction of communication (control treatment). Sensitivities to treatment are concave in this case, and the range of empirical treatment effect values was such that most sensitive players, associated with positive sensitivities in this case, behaved nearly as the baseline player (sensitivities are close to zero).

The distribution of player types according to indiviual sensitivity to individual positive incentives and penalty rule is plotted in Figure 6.3 (Right figures). We found that 143 players, or 45.1% of the sample were identified as unconditional cooperators, under baseline settings as well as under individual penalty rule and individual positive incentive treatments (Table 6.4). The effect of both treatments incited a number of free-riders to become conditional cooperators: the proportion of free-riders decreased from 29.0% under baseline settings to 15.5% (respectively

15.8%) under individual positive incentives (respectively under individual penalty rule), whereas the proportion of conditional cooperators increased from 25.9% under baseline settings to 39.4% (respectively 39.1%) with individual positive incentives (respectively individual penalty rule).

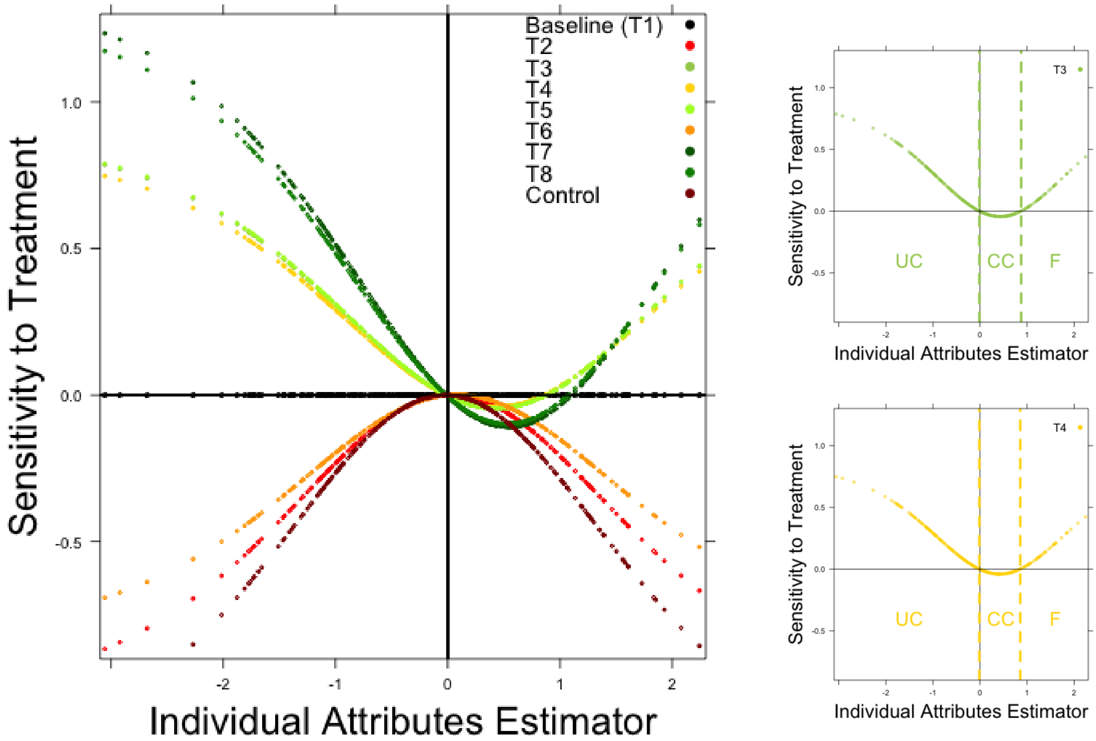

Figure 6.2: Sensitivities to treatments versus individual attributes estimator. Figures computed for the whole set of players ($n = 317$), with $P_0 = -0.01$, $S_1 = -0.24$.
Left: all treatments, as defined in Table 3.4. The color gradient was defined from red for increase in expected fish extraction to green for reduction. Treatment 3 (individual penalty rule) and treatment 4 (individual positive incentives) effects are nearly indistinguishable.
Right: individual positive incentives (top) and individual penalty rule (bottom) treatments. These two treatments allow the definition of three categories of players delimited by the dashed vertical lines: UC= unconditional cooperative, CC= conditional cooperative, F= free-riders.

Table 6.4: Counts and proportions of player types under baseline settings, and under individual positive incentives and individual penalty rule treatments ($n = 317$).

Treatment	T_j [1]	Player type [2]					
		Counts			Proportions (%)		
		UC	CC	F	UC	CC	F
Baseline settings	$T_1 = 0$	143	82	92	45.1	25.9	29.0
Individual positive incentives	$T_4 = -0.36$	143	124	50	45.1	39.4	15.5
Individual penalty rule	$T_3 = -0.38$	143	125	49	45.1	39.1	15.8

[1] Treatment effect.

[2] UC: unconditional cooperator, CC: conditional cooperator, F: free-rider.

6.1.4 Indicators interpretation

The expected fish extraction indicator is interpreted as a measure of cooperation, while sensitivity to treatment measures the response to treatments.

The analysis showed that expected fish extraction (under individual penalty rule treatment) was strongly correlated with selfish defection as described in the Methods part (linear regression, $F(1, 304) = 100$, $p < 0.001$), which confirms that expected fish extraction reflects cooperative behaviour.

ANOVAs performed on expected fish extraction for the three types of players unsurprisingly showed that expected fish extraction was strongly correlated with player types (*e.g.* under individual positive incentives, $F(2, 314) = 821, p < 0.001$), and LSD tests subsquent to the ANOVAs added that differences between all pairs of groups were significant (*e.g.* mean extraction under individual positive incentives, $UC : 2.13$, $CC : 4.42$, $F : 6.67$, $LSD : 0.22$). Similar tests on sensitivitities to treatments yielded similar results: strong correlation with player types (*e.g.* individual positive incentives, $F(2, 314) = 135$, $p < 0.001$), and significant differences between all groups (*e.g.* mean sensitivity to individual positive incentives, $CC : -0.03$, $F : 0.12$, $UC : 0.22$, $LSD : 0.04$).

More importantly, the mean group values confirm that players sensitive to a trea-

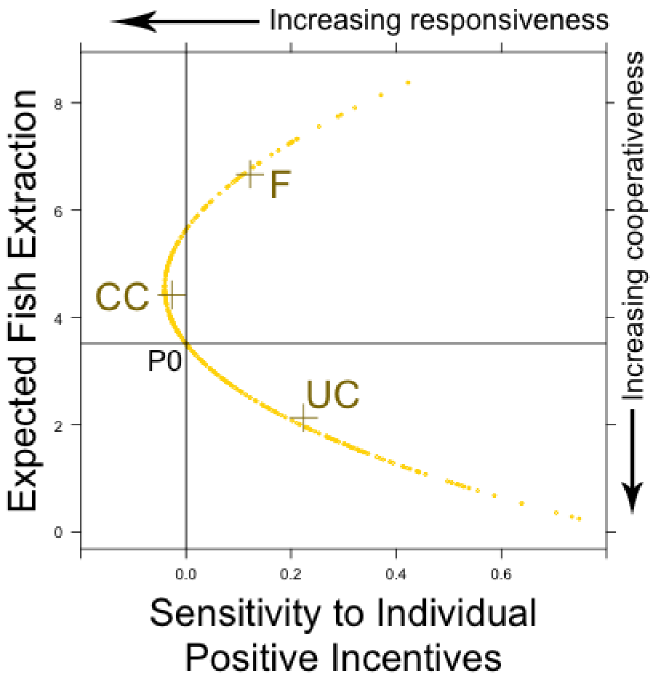

Figure 6.3: Expected fish extraction versus sensitivity to treatment, under individual positive incentives treatment. Expected fish extraction measures individual cooperativeness under the treatment, while sensitivity measures responsiveness to positive incentives. The crosses locate the means for unconditional cooperators (UC), conditional cooperators (CC), and free-riders (F). X-values and Y-values for the three groups are all significantly different. The origin is set to the indicators value of the baseline player.

ment and cooperative players under the same treatment are not the same ones. Player categorisation, therefore, combines both interpretations, as UC players are distinct from CC and F players in terms of cooperation, and CC players are distinct from UC and F players in terms of response to treatments. Figure 6.3 shows the mean cooperativeness/responsiveness behaviour of the three groups under individual positive incentives.

However, player type is a categorical variable whereas expected fish extraction and sensitivity to treatment are continuous. It has been suggested that categorical variables might be weaker than continuous variables for correlation tests when testing external validity of lab experiments (Laury & Taylor, 2008).

6.2 Individual real-life behaviour

6.2.1 PES participation

Among the 207 players matched with high confidence, therefore for whom data on PES participation was available, 116 (56.0%) were involved in at least one PES scheme for at least one year before, and including, 2010. Among the participants, 26.7% had taken part in the Bird Nest protection programme, 57.8% in the Ibis Rice programme, and 48.7% in the Eco-tourism programme in the two villages where it was implemented. Let us note that in the two villages where the Eco-tourism programme was implemented, 21.5% of the PES participants were involved only in the Eco-tourism programme. We are aware that players from the two sets of villages did not have the same opportunity to get involved in PES schemes; however the non-availability of the Eco-tourism programme might have had a positive impact on enrollment in the Ibis Rice and Bird Nest programmes, so that the extent of this potential bias is unpredictable. Yet this concern is reinforced by the observation that PES participation was significantly higher for players living in the two villages where Eco-tourism was available (75.0% and 64.2%) than for players living in the two others (37.7% and 54.7%; $\chi^2 = 15.6$, $d.f. = 3$, $p = 0.001$).

6.2.2 Illegal land clearance

Illegal land clearance cases were reported for 44 players (21.5%) among the 205 players for whom data on illegal land clerance was available. The proportions of land clearance cases in the four villages ranged from 9.9% to 30.0%, a difference whose significance was close to 5% ($\chi^2 = 7.54$, $d.f. = 3$, $p = 0.057$). Various interpretations could be put forward: rule compliance as a norm might be embedded differently among players at a village level, but the strength of rule enforcement and land clearance monitoring by the authorities might have also differed between villages.

6.2.3 Stated preferences

Opinion on conservation interventions

Opinion on PES was an index with 33 accessible levels in $[0;1]$. 24 levels were actually accessed by players, and opinion indices ranged from 0.13 to 1. The distribution of values was relatively even, except for a particularly high number of players with a moderately high opinion on PES schemes (28 players associated with an index in $[0.6;0.8]$, while 16, 17, 13 and 17 players were respectively associated with an index in $[0;0.2]$, $[0.2;0.4]$, $[0.4;0.6]$ and $[0.8;1]$; Figure 6.4). No isolated points were identified, though some specific levels were filled by high numbers of players (in particular, 16 players at 0.13, 11 players at 0.38 and 13 at 0.75). The mean opinion index value for the 91 players who answered the survey was 0.54.

Opinion on PLUP was an index with 5 accessible levels, evenly distributed in [0;1]. All levels were accessed by players, though the distribution was uneven. Contrary to the PES schemes, the PLUP was on average moderately negatively perceived, as 19 and 43 players (20.9% and 47.3%) were respectively associated with an opinion index of 0 and 0.25, whereas only 14, 3 and 12 players (15.4%, 3.29% and 13.2%) had an opinion index respectively equal to 0.5, 0.75 and 1 (Figure 6.4). The mean opinion on PLUP was 0.35.

Opinion on all conservations interventions. Averaging the previous indices, Opinion on all conservation interventions took 33 values in $[0;1]$. Most opinions were close to neutral (28 players, *i.e.* 30.8% of opinions in [0.4;0.6]; Figure 6.4). However, there were more negative opinions, as 21 (23.1%) were strongly negative (in $[0;0.2]$), and 21 other moderately negative (*i.e.* in$[0.2;0.4]$), whereas 14 (15.4%) were moderately positive (in $[0.6;0.8]$) and 7 (7.7%) strongly positive (in $[0.8;1]$). On average, the mean opinion on conservation interventions was 0.45.

Perception of authorities

Perception of authorities indices covered 10 levels in $[0;1]$ out of possible 11, for a mean equal to 0.57, that is, moderately positive on average. The definition of the variable might have caused a bias against strongly negative perceptions, as only one level, 0, was accessible between 0 and 0.2. What is more, only one player was associated with an perception index equal to 0. While indices were evenly distributed in [0.2; 1] (Figure 6.4), the presence of a unique strongly negative perception constituted an outlier that might need be discarded in later analysis.

Interpersonal trust

A majority of players answered positively to the GSS questions: the interpersonal trust mean index was 0.64 for 91 players, which is imputable mostly to the question about helpfulness (*"Would you say that most of the time, people in the village try to be helpful, or that they are mostly just looking out for themselves?"*, 78% of positive answers), and to a lower extent to the other two (57.1% of positive answers to *"Generally speaking, would you say that most people in the village can be trusted or that you can't be too careful in dealing with people?"*, and also 57.1% for *"Do you think most people in the Village would try to take advantage of you if they got a chance, or would they try to be fair?"*). Interpersonal trust index had four levels. Similarly to the case of authorities, one outlier was found with zero value, whereas 22 (24.2%), 51 (56.%) and 17 (18.7%) players were characterized by index values respectively equal to 0.33, 0.67 and 1 (Figure 6.4).

6.2.4 Correlations between real-life indicators

Prior to testing real-life indicators against game indicators, we looked for correlations between real-life indicators.

We found PES participation to be correlated to illegal land clearance: while 30% of players who had never been involved in PES schemes had illegally cleared land, only 14.8% of PES participants did so, and the effect was significant ($\chi^2 = 6.1$, $d.f. = 1$, $p = 0.014$). This result is in line with results from Clements (2012), who found the correlation to be true for the Ibis Rice and Eco-tourism programmes.

Few correlations were found among stated preferences as well. Higher interpersonal trust was strongly associated with a higher opinion on PLUP ($F(1, 89) = 9.57$, $p = 0.003$), and by extension with a higher opinion on conservation interventions, though to a lower extent ($F(1, 89) = 6.08$, $p = 0.016$). No other statistically significant link was found within the set of variables {opinion on PES or PLUP or

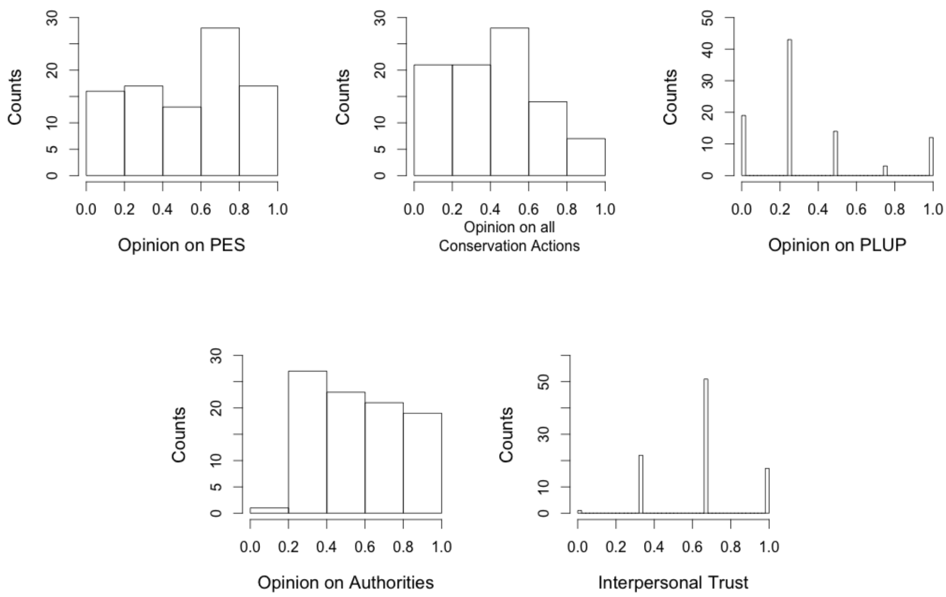

Figure 6.4: Distributions of stated preferences ($n = 91$ players).

all conservation interventions, perception of authorities, interpersonal trust}.
In addition to that, we did not find any correlation between observed behaviour variables and stated preference variables. Most notably, opinions on PES schemes and PLUP were expected to reflect intentions to get involved in PES schemes and to comply with the land-use plan. This conclusion casts doubts on the adequation between observed behaviour and stated preferences.

6.3 Correlation between game and real-life behaviour

Table 6.5 summarises the tests described in this section, including their significance, and whether they support or not the hypotheses that were formulated in Tables 4.1 and 5.3. The detailed analysis correlation patterns is provided in Appendix E.

On the one hand the continuous game indicator for responsiveness to incentives, sensitivity to treatment, could not be linked with any real-life indicator. On the other hand the game indicator for cooperativeness, expected fish extraction, provided a weak support for correlation with observed real-life variables: a strong correlation with PES participation was found ($t = 2.24$, $d.f. = 186.4$, $p = 0.026$; Figure 6.5, top left figure), and there appeared to be a link to illegal land clearance, though the effect was not significant ($t = -1.33$, $d.f. = 63.3$, $p = 0.19$; Figure 6.5, bottom left figure). In the light of this result, player categorisation strengthened these findings by identifying correlations to both observed real-life variables (with PES participation: $\chi^2 = 5.71$, $d.f. = 2$, $p = 0.058$; Figure 6.5, top right figure, with Illegal Land Clearance: $\chi^2 = 6.80$, $d.f. = 2$, $p = 0.033$; Figure 6.5, bottom right figure).

Stated preferences yielded negative results overall. No stated preference indicator supported any correlation with game variables. Nevertheless, player categorisation showed relative mean stated preferences for unconditional cooperators and free-riders that were consistent with expectations (*i.e.* for the two groups of players characterised by a wide gap of cooperativeness), suggesting that cooperativeness might play a role that requires a wide gap of cooperativeness between players, even if it was not possible to statistically confirm this observation.

It is worth underlining that the subset size highly limited the number of players for stated preferences tests. These tests took into account 91 players; the division into player types restricted the number of free-riders, conditional cooperators and unconditional cooperators down to 16 players (under individual positive incentives and penalty rule treatments), 23 players (under baseline settings) and 43 players (for the three treatments) respectively. The sample size for these tests might be partly responsible for the lack of significance associated with differences in means.

Finally, more comprehensive models for all variables were undertaken, regressing each game or real-life variable against the others. Although they confirmed the findings detailed in this section, they did not allow to identify new correlations nor to strengthen the significance of the results displayed in Table 6.5.

Table 6.5: Correlation tests significance. P-values were computed through Chi-square tests (binary variables versus player types), Welch t-tests (binary variables versus continuous variables), ANOVAs (continuous variables versus player types), and linear regressions (continuous variables versus continuous variables).

Real-life indicator		Obs[1]	j[2]	Game behaviour indicator			Hyp.[3]
				Cooperation	Response to incentive	Player type	
				$f(\cdot, j)$	$\Delta(\cdot, j)$	$\Delta_{cat}(\cdot, j)$	
PES participation		207	4	0.026*	0.362	0.058(*)	$H1$
Illegal land clearance		205	3	0.187	0.856	0.033*	$H2$
Opinion on	PES	91	4	0.495	0.709	0.534	$H3$
	PLUP	91	3	0.636	0.599	0.541	
	Both	91	1	0.534	-	0.379	
Perception of authorities		90	3	0.101	0.191	0.176	$H4$
Interpersonal trust		90	1	0.711	-	0.168	$H5$

Notes: significance: $^{(*)}: p < 0.1$, $^{*}: p < 0.05$, $^{**}: p < 0.01$

[1] Counts of players for whom each real-life indicator was tested against all game indicators.

[2] Treatment for which game indicators were computed,

1: Baseline; 3: Individual Penalty Rule; 4: Individual Positive Incentive

[3] Hypothesis tested.

Green/Red: results provide evidence/no evidence to support the hypothesis.

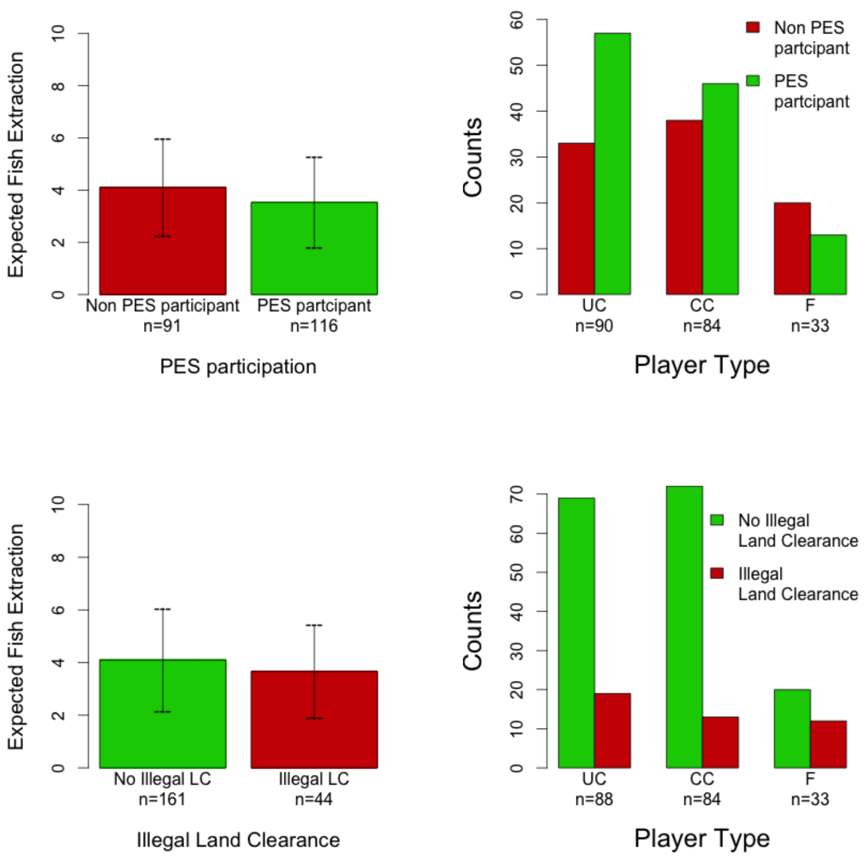

Figure 6.5: Significant correlation patterns between game behaviour and observed real-life behaviour. PES participation (top) and illegal land clearance (bottom) are plotted against expected fish extraction (left) and player types (right). Micro-situational settings for game behaviour were individual positive incentives (for PES participation) and individual penalty rule (for illegal land clearance).

Chapter 7

Discussion

7.1 An innovative method for characterising game behaviour.

The approach adopted for this thesis is innovative both through the methodology and the tools it delivers.

First, the methodology used consisted in predicting game behaviour at an individual level under selected micro-situational settings, based on a regression analysis model that accounted for a wide range of individual attributes and micro-situational settings. To our knowledge, most CPR game studies have focused on cooperation at a group-level and based on raw extraction data (*e.g.* Cardenas, 2004; Ghate, Ghate & Ostrom, 2013, Gelcich *et al.*, 2013). Among the studies that have tested the external validity of CPR games (*cf.* Table 2.1), only Castillo *et al.* (2011), Hayo and Vollan (2012), Janssen *et al.* (2013) and Prediger, Vollan and Frölich (2011) have used regression models to link game behaviour and individual behaviour. The four studies have used this method to investigate the correlation between empirical CPR extraction and a real-life indicator; however, none of them has utilized regression models as a tool to predict individual extraction under selected settings. Carpenter and Seki (2011) have modelled individual conditional and unconditional cooperation in a PG game through linear regression as two individual coefficients depending on individual and group contributions.

However, the experimental game they played did not involve the complex set of micro-situational variables that a CPR game played under various institutional arrangements does. As such, the methodology we developed was not based on anything similar in previous research.

Second, the approach has provided innovative tools to analyse individual game behaviour. Indeed, although individual CPR extraction has been extensively used as a proxy for cooperation in experimental games (*cf.* Table 2.1), we are not aware of any study developing an indicator of individual responsiveness to incentives. This indicator, as well as the player categorisation that was built from a dual cooperativeness-responsiveness characterisation does not have a match in the literature.

7.1.1 Player categorisation is plausible

Consistent figures

Various methods have been proposed in previous research to categorize players according to their cooperativeness. Althoug three types of players consistently emerge as unconditional cooperators, conditional cooperators and free-riders, protocols and thresholds of identification differ. Some do not allow to identify unconditional cooperators, also termed altruistic players (*e.g.* Fischbacher, Gachter & Fehr, 2001; Kocher *et al.*, 2008), some also define "hump-shape" players who conditionally cooperate up to a certain point where they drift toward free-riding (*e.g.* Fischbacher, Gachter & Fehr, 2001; Rustagi, Engel & Kosfeld, 2010), and some allow for unclassified players (*e.g.* Boone, Declerck & Kiyonari, 2010; Kurzban & Houser, 2007). As a result, proportions of players display considerable variation across studies. Table 7.1 gives an overview of figures that can be found in the literature. In this thesis, under treatments that induce a reduction in expected fish extraction, all players who are more cooperative than the baseline player are defined as unconditional cooperators. As a consequence, the proportion of unconditional cooperators (respectively conditional cooperators) is higher (respectively lower) than in most previous papers. Nevertheless, the range of figures reported in the literature is wide enough to surround the figures found in this thesis (Ta-

Table 7.1: Player categorisation in the literature

Paper	Game[1]	Nb.[2]	Proportions[3] (%)		
			UC	CC	F
Bouma, Bulte & van Soest (2008)	TG	3	20	31	49
Fischbacher, Gachter & Fehr (2001)	PG	5	-	63	38
Rustagi, Engel & Kosfeld (2010)	2-pl CPR	5	3	79	19
Laury & Taylor (2008)	PG	3	27	46	26
Boone, Declerck & Kiyonari (2010)	PD, AG	4	30	32	38
Kurzban & Houser (2005)	PG	4	14	66	21
English (2012)	PG	3	17	45	38
Ishii & Kurzban (2008)	PG	3	3	72	25
Rodriguez-Sickert, Guzman	5-pl CPR:	3			
& Cardenas (2008)	Baseline		7	5	88
	Penalty Rule		63	17	20
Kocher *et al.* (2008)	PG	4	-	71	29
Herrmann & Thöni (2009)	PG	4	-	90	10
This study	10-pl CPR:	3			
	Baseline		45	26	29
	Incentives[4]		45	39	16

[1] Game used for categorization, AG: Assurance game, TG: Trust game, PD: Prisoner's dilemma, PG: Public goods game, "x"-pl CPR: x-player Common-pool resources game

[2] Number of categories established by the authors.

[3] Categories may not have been termed the same by the authors. For comparison between papers, proportion sums have been normalized to 100%. Sums might not be strictly equal to 100% due to round numbers.

[4] Individual penalty rule and positive incentives yield the same figures.

ble 7.1). Let us note that although the baseline player was defined as a 'neutral' player, she is arbitrary. Therefore figures would vary if a different reference for comparison was elected instead of the baseline player.

Consistent interpretations accross treatment effects

The reasoning that was followed to categorise players with respect to their cooperativeness and responsiveness to treatments is detailed in the Methods part, in the case in which the treatment effect is negative (*i.e.* entails a reduction in fish extraction), which we extrapolated to the baseline treatment. We would argue that this reasoning can also be held for positive treatement effects, which extends the use of this method and reinforce its consistency across treatment effects. Detailed features of player categorisation depending of the treatment effect can be found in Appendix B.

When the treatment effect is positive, *i.e.* when players are expected to increase their fish extraction compared to baseline settings, players who are identified as most sensitive to the treatment can be either players extracting more than the baseline player and increasing the gap with her (moderate treatment effect; Figure 7.1, left figure), or players extracting less than the baseline player and reducing the gap with her (high treatment effect; Figure 7.1, right figure). This observation can be interpreted to categorise players as well: as the positive treatment effect increases, more players are incited to act as free-riders, and conditional cooperators, who now negatively reciprocate (whereas they positively reciprocate under negative treatment effect), are stronger cooperators. This might be interpreted in terms of crowding-out of social norms. For moderate positive treatment effects, a wide range of moderately uncooperative players are slightly drawn toward free-riding, and as the effect grows stronger, some becomes actual free-riders. Finally for sufficiently high positive treatment effects, all uncooperative players have become free-riders, and cooperative players begin to be drawn toward free-riding. In other words, as the effect inciting to increase fish extraction grows stronger, the population which is the most sensitive is a more cooperative one, *i.e.* a population in which social norms for cooperation are more strongly embedded.

Moderate treatment effects match the cases of crowding-out effects commonly reported in the literature, where a treatment designed to bring a reduction in CPR extraction does actually slightly the opposite, either through penalty rule (Cardenas, Stranlund & Willis, 2000; Vollan, 2008), or positive incentives (Narloch, Pascual & Drucker, 2012). High positive treatment effect could stem from any rule that strongly reduce cooperation. Among the nine treatments whose effects are summarised in Table 6.3, penalty rule with weak enforcement and communal payments with weak conditionality were found to be moderate treatment effects

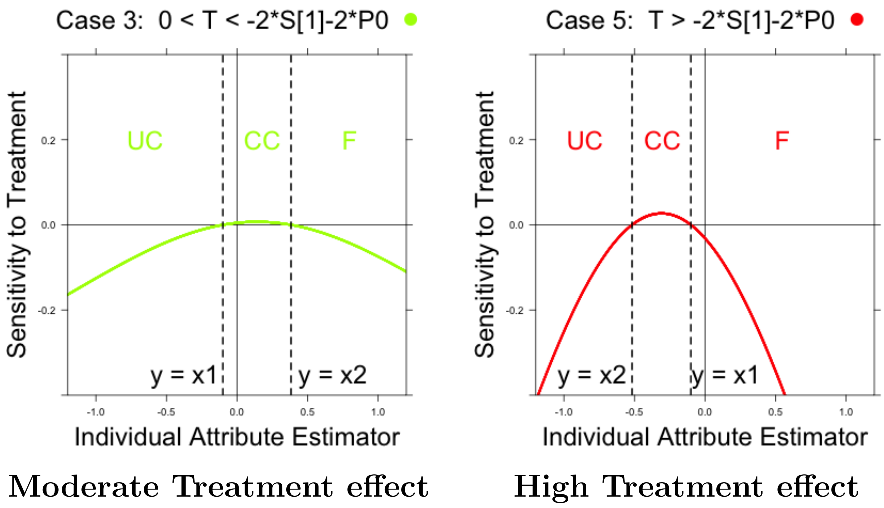

Figure 7.1: Categorisation of players under moderate incentive to increase fish extraction (left) and strong incentive to increase fish extraction (right). As the effect grows stronger, conditional cooperators are more cooperative players, which entails first an increase in free-riders number, then a decrease in unconditional cooperators numbers. More details on the figures are available in Appendix B.

(according to the threshold defined in Appendix B), and the control treatment, that is, the treatment forbidding communication, to be a high treatment effect. This observation confirms the interpretation of moderate treatment effects as highlighting a crowding-out effect.

Therefore we believe that the dual interpretation of cooperativeness-responsiveness in terms of players categorisation can be extended to the full range of possible treatment effects, and that the reasoning held in this section on positive treatment effects lends credence to the approach we adopted with negative treatment effects in this thesis.

7.1.2 Player categorisation yields encouraging results

Players categorisation was associated with positive results against real-life observed behaviour: it allowed to identify a correlation with illegal land clearance that the continuous indicators failed to detect with a satisfactory level of confidence, and indicated a correlation with PES participation, although at a lower confidence level, slightly below 95%. The latter result, which was weaker than with the continuous indicator for cooperativeness, could be interpreted in line with Laury & Taylor (2008), who noted that the parametric indicators they used for individual game behaviour were less efficient to look for external validity than the corresponding continuous indicators. Player categorisation allowed to gather some information from two variables, cooperativeness and responsivess, but necessarily lost information through the conversion.

Besides, conditional cooperators, who were defined as players particularly sensitive to framing, yielded intermediary results for observed behaviour and unpredictable ones for stated preferences. As a consequence, it is worth considering that player categorisation might have merely allowed to establish differences between highly cooperative players (unconditional cooperators) and highly uncooperative players (free-riders), by gathering a number of average players (conditional cooperators) in a separate category. In this case, the method would still receive the merit of identifying a category of player which is neither uncondionally cooperative nor free-riding.

7.2 Contrasted evidence for the external validity of CPR games

7.2.1 Positive but fragile results for observed behaviour

The analysis of correlations between real-life observed indicators and game indicators provided valuable results; in particular, player types were correlated both with real-life response to positive incentives (PES scheme participation, $p = 0.058$) and to real-life rule compliance (illegal land clearance, $p = 0.033$).

However, this conclusion must be drawn cautiously. Further investigation showed that the robustness of these findings might be weak, as the correlation between game behaviour and real-life observed behaviour might not remain under alternative hypotheses that we would yet also expect to be true.

First, some alternative choices of real-life variables yield negative correlation test results. Selecting participation in any PES as the indicator of response to positive incentives was justified as it constituted a balanced sample (116 participants and 91 non-participants). However, selecting the amount of money earned through PES involvement could have made sense. Though this continuous variable had the disadvantage of a non-normal structure (due to a large number of players, non-PES participants, who were associated with zero revenue from PES), it would have allowed to discriminate participants who were barely involved in PES schemes (*e.g.* selling products non-related to Eco-tourism to tourists) from the others. Yet correlation tests between game indicators and this variable instead of PES participation did not yield positive results (versus expected fish extraction under positive incentives: $F(1, 205) = 0.000$, $p = 0.98$; versus player types under positive incentives: $F(2, 204) = 1.92$, $p = 0.15$). Clements (2012) found that rule compliance was correlated to Ibis Rice programme participation and employment in the Eco-tourism programme. Therefore it would have been justified to define enrollment in any one of these two activities as a substitute to PES participation (though it would not have allowed to control for Bird Nest programme participation and Eco-tourism involvement, employment excluded). Once again, correlations would not have been found (versus expected fish extraction: $t = -0.43$, $d.f. = 184$, $p = 0.66$; against player types: $\chi^2 = 4.19$, $d.f. = 2$, $p = 0.12$).

Second, game indicators rely on the assumption that treatment effects satisfactorily mimic real-life incentives, either the PLUP enforcement through penalty rule treatment, or PES incentives through positive incentives treatment. If treatments are not perceived in the game as strong as in real-life (*e.g.* if rewards or sanctions in the game are too low or too high, or if stakes are not perceived accurately), the treatment effect values would not reflect real-life incentives. Yet we found that given the treatment effects for penalty rule and positive incentives in Table 6.3, correlations with real-life observed behaviour can be detectable for only a narrow range around them (*e.g.* for penalty rule, the treatment effect must be in $[-0.39; -0.34]$ to be linked to illegal land clearance at 95% confidence level, and in $[-0.47; -0.26]$ at 90% confidence level).

These two observations show that although linkages were found between game behaviour and real-life observed behaviour, slight deviations, either in the definition of real-life variables or game variables, would make correlations undetectable, which indicates a low robustness of the results. Previous research report a fair number of PG games where individual contributions were correlated to real-life observed behaviour (Table 2.1). CPR game external validity at an individual level is on the contrary particularly rare in the literature. Indeed only Gelcich *et al.* (2013) identified a correlation among fishermen between individual fishing effort in a CPR game and their union status in real-life, which was strongly expected. Cooperativeness in a CPR game and voluntary collective actions have not yet been found to be linked: Prediger, Vollan and Frölich (2011) and Ruffle and Sosis (2006) obtained unconclusive results, while Hayo and Vollan (2012) concluded to a link between sheep extraction in the game and effort in collective action in real-life only at a group-level, and under condition of group homogeneity. We hypothesize that the complexity of CPR games makes difficult the control of variables to predict behaviour consistent across contexts. Following the observation that Gelcich *et al.* provided the unique support in favor of external validity at an individual level, we take the view that analysing CPR games that make participants face nearly identical situations in the game and in real life are required to gain better insight on the robustness of these correlation.

7.2.2 Exploring why there was no evidence for stated preferences

The negative results described in this thesis for stated preferences are in line with many previous studies.

More specifically, trust has been explored in external validity studies and yielded mostly negative conclusions. Based on an experiment very similar to the one of this thesis, that is, a framed field CPR experiment, Castillo *et al.* (2011), Janssen *et al.* (2013), and Prediger, Vollan and Frölich (2011) all concluded that CPR individual extraction was *not* correlated to the measure of trust they had defined.

Similarly to this thesis, they had used an aggregate index of answers to general questions about Trust.

What is actually measured through survey questions about trust is worth being discussed. Evidence has indicated that the three GSS questions we have used might measure more adequately trusworthiness than trusting behaviour (Glaeser *et al.*, 2000; Karlan, 2005). In addition, trustworthiness has been found to be positively correlated to rule compliance when trust was not (Karlan, 2005). This implies that the interpersonal trust variable that we defined represents an uncertain social preference, while targeting adequate social preferences matters for external validity. Regardless of the social preference measured, GSS questions have been associated with higher cooperation in PG games (Anderson, Mellor & Milyo, 2004). However the field of applicability of this finding might be narrow, as a single measure of trust has been found to be simultaneously correlated to PG contributions, and not to CPR extraction (Parks, 1994)

This discussion therefore casts doubts on what was actually measured with the interpersonal trust variable, and warns that negative results could occur regardless of the social preference measured.

These limits can reasonably be extended to the other stated preferences we measured. In addition, the use of questions on the PLUP and on the PES schemes as a proxy for opinion on conservation interventions, and of questions on village committees and on the PA rangers for perception of authorities is a matter of debate. One could argue that these questions were embedded in a very specific, factual context in which answers could be more strongly affected by daily interactions in the village and isolated events (*e.g.* an individual's opinion on authorities could decrease after a personal conflict with the village committee) than if they had been generalities on conservations actions and authorities. So that the *post hoc* definition of preferences from a survey conducted independtly from this thesis might have constituted inadequate variables to test against game behaviour.

7.2.3 Validation of hypotheses

We drew the following conclusions on the hypotheses conceptually formulated in Table 4.1, adapted to technical formulations in Table 5.3, whose results are in Table 6.5 :

H1. PES scheme participation was expected to be more likely for cooperative players and players responsive to positive incentives. Evidence supported the link between cooperativeness and PES participation, which may indicate that cooperative players are more conservation-minded and hereby more willing to engage in conservation schemes.

H2. Illegal land clearance, as a measure of non-compliance to conservation rules, was expected to be more unlikely for cooperative players and players sensitive to penalty rules. Analysis results attested significant differences, where unconditional cooperators (highly cooperative players) were the least likely to break the rule in real life, free-riders (poorly cooperative players) the most likely, and conditional cooperators (highly sensitive to the rule implementation) in between.

H3. Opinion on conservation intervention was expected to reflect intentions on actual behaviour related to conservation interventions, that is, opinion on PES mirroring observed enrollment in PES schemes, and opinion on PLUP mirroring observed compliance with the land-use plan. Yet game behaviour was not associated with opinions on PES schemes, PLUP nor all conservation interventions.

H4. Perception of authorities was expected to be linked to game behaviour, as cooperative players could have been more obedient to conservation authorities, and players who are more responsive to incentives could have been more easily influenced by them. No correlation pattern between perception of authorities and game behaviour was found.

H5. Interpersonal trust was believed to play a role according to a large body of literature on the subject. The game did not allow the identification of trusting and non-trusting players.

7.3 Broader implications: experimental games as a decision-making tool

At a time when targeting conservation effort is a priority (Engel, Pagiola & Wunder, 2008; Ferraro & Kiss, 2002), evidence for the external validity of experimental games is a prerequisite to their use as a decision-making tool (Voors *et al.*, 2012). Indeed beyond the external validity of a CPR game, what was at stake was the relevance of experimental games as a decision-making tool for conservation policy. Establishing external validity could empower games with two purposes: to assess policy efficiency, and to target populations particularly responsive to conservation incentives.

The first option was investigated in Colombia by Attanasio and Phillips (2008) and by Coleman and Lopez (2010). They both explored whether programmes designed to encourage community-mindness at a local scale achieved their goal, based on PG games, by comparing programme beneficiaries and non-beneficiaries. Assessing policy efficiency requires a control population to be performed (*e.g.* the beneficiary population before the programme implementation, or another village with similar characteristics where the programme is not implemented), so that our case study did not allow us to evaluate the effect of conservation actions undertaken before 2010.

The second option is more closely related to the aim of this thesis, that is, identify in the game individuals who are particularly responsive to incentives in real-life (either rules or payments). Succeeding would provide a method for targeting conservation effort at a moderate cost (Voors *et al.*, 2012). The methodology developed in this thesis suggested it might be used to deliver valuable insight at an individual-level, hence opening an avenue for ruling-out free-riders. Furthermore, evidence from the literature of conclusive group-level external validity analyses (Carpenter & Seki, 2011; Hayo & Vollan, 2012), and even conclusive only at group-level (Attanasio & Phillips, 2008), infers that this method could prove best used at a larger-scale, to discriminate villages/areas comprising a high or low proportion of inhabitants responsive to conservation incentives. Indeed, Gelcich *et al.*'s positive results suggest that external validity might be more easily found when players are tied together by a group-scale factor linked to cooperation (in their case fisherman unions differing in their cooperativeness level; Gelcich *et al.*, 2013).

It is now widely accepted that a unique institutional approach cannot solve all commons dilemmas (Ostrom, Janssen & Anderies, 2007), so that governance design demands to take into account local conditions (Dietz *et al.*, 2003). CPR games allow for rich institutional variants, therefore designating them as a particularly suitable game type to explore diverse local-scale policies. This study provides a weak support in favor of CPR games to target populations who are more likely to actually join conservation mechanisms and to comply with conservation rules. However, we believe the game complexity requires that game situations closely match the real-life behaviour it aims at predicting or at assessing to achieve robust outcomes, which may have been the main weakness of this study.

7.4 Further research

At the methodological level, the method for categorising players developed in this thesis delivered encouraging outcomes for treatments that induce an actual reduction in CPR extraction. We discussed the extension of this method to treatments that have an opposite effect, through crowding-out effect of social norms or explicit rules against cooperation. Testing the plausibility of this extension would require new analyses, to both broaden the use of the method, and reinforce its consistency across treatment effects. Whether the three players types characterised in this thesis are actually distinct or vary only in their cooperativeness level would deserve further exploration.

As regards to external validity itself, a weak support was brought for this case study. However, real-life indicators may have been weakened for various reasons, including selection biases for PES participation, a lack of reliability of the indicator for compliance with land-use plan, and inadequate stated preferences constructed *post hoc* from survey answers. In addition motivations in the game and in real-life (*i.e.* notably reasons for adopting a conservative behaviour) may have differed considerably. As a consequence we believe that further analysis with other real-life variables and/or populations of interest is needed to confirm or infirm implications for policy-making, and that focusing in the future on a CPR game that matches more closely the real-life behaviour it aims at identifying might overcome the challenges posed by the complexity of CPR games.

7.5 Conclusion

The external validity of a framed field CPR game was investigated in this thesis. Based on a considerable body of evidence that cooperation and reciprocation are salient determinants of individual behaviour, we have hypothesized that cooperativeness and responsiveness to incentives in the game, could predict in real-life enrollment in conservation programmes and rule compliance at an individual level. We have developed game indicators for individual cooperativeness and individual responsiveness to incentives in conditions designed to mimic real life circumstances, and used them to make comparisons with real-life behaviour, either actually observed or inferred by stated preferences. It revealed that observed behaviours, that included involvement in PES schemes and compliance with the village land-use plan, were correlated to a player categorisation built from a dual measure of cooperativeness-responsiveness to incentives in the game. The outcome was however poorly robust to deviations from game and real-life assumptions, and did not yield any significant result for stated preferences. This suggests either that the *post hoc* real-life data used was not entirely adequate to test the CPR game external validity, or that the complexity of a CPR game prevents it from predicting real-life behaviour with satisfactory confidence. We believe that further research is needed to confirm that CPR games that mimic closely real-life situations can be used to predict behaviour in conservation dilemmas, and hereby to target future conservation interventions or assess existing conservation mechanisms.

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Appendix A

Model selection

Table A.1: Model selection, as described in Methods part, Model Selection subsection.

Model	Interaction term	AIC	Comment
19	None	13788	Model fitted by Travers *et al.* (2011)
19_2	$Treatment * Round$	13591	Best fit
19_3	$Treatment * Decision$	-	GLMM cannot be run (empty levels)
19_4	$Round * Decision$	13775	-
19_5	$Treatment * Round * Decision$	-	GLMM cannot be run (empty levels)

Fitted model:

Fish ~ Treatment * Round + Education + Decision + Gender + Day + Previous + (1 | Group / Village) + (1 | Individual),
Observations: 4745, d.f.: 31.

Appendix B

Sensitivity to treatments: five configurations

Analysis of sensitivity to treatments properties led us to distinguish five configurations determined by the value of treatment effect. Individual behaviour can be interpreted and categorised based on the roots and curve shapes of the associated sensitivity distribution.

The two critical values for treatment effect were found to be: $T = 0$ and $T = -2S_1 - 2P_0$.

$T = 0$ is the critical value for the shape of the distribution, which is convex for treatment effect $T < 0$ and concave for $T > 0$.

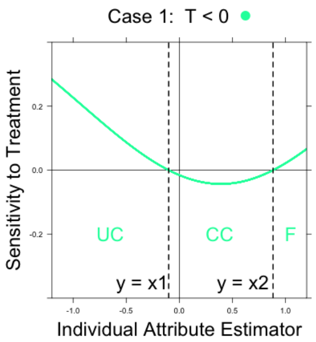
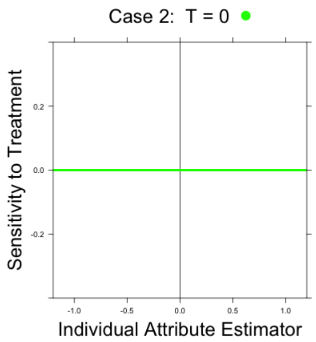
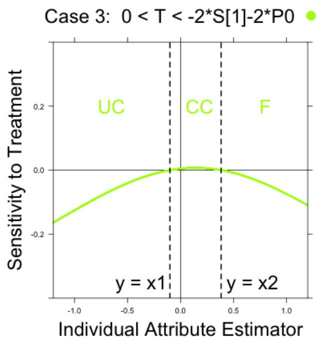
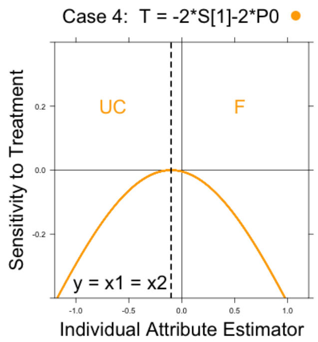
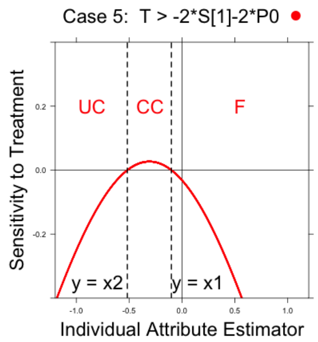
$T = -2S_1 - P_0$ is the threshold for the relative position of the roots. Roots formal expression was solved for with Matlab software v7.14.0.739 (The MathWork Inc., 2012) and found to be: $x_1 = P_0$ and $x_2 = -2S_1 - P_0 - T_j$. As a consequence, root x_1 does not depend on treatment effect and is the trivial solution corresponding to the baseline player. The position of root x_2 is therefore also its position relative to the baseline player.

The five configurations are illustrated and their characteristics summed up in table B.1. Case 1 interpretation has been described in the Methods part of this thesis. Conditional cooperation is here understood as cooperation conditional to the current micro-situational settings.
Similarly to Case 1, UC-CC-F interpretation can be made for treatments under which individual are expected to increase their extraction ($T > 0$, Cases 3-4-5, table B.1). This

interpretation is discussed in the Discussion part of this thesis. Conditional cooperators thus defined for $T > 0$ are players who can be expected to extract more (Case 3) or less (Case 5) fish than the baseline player. Case 4 is the threshold case in which no CC players can be identified.

Please note that player types are interpreted here as a characterisation of players confronted to a perturbation (that is, the treatment effect). Variation in the intensity and sign of the perturbation incite some players to switch from one type to another. Under low treatments effects, the perturbation has a low intensity, so that individual sensitivities are harder to detect (absolute values for sensitivities are lower). A main advantage of the categorization is that it allows to distinguish player types based on the sign of the players' sensitivities and not on the sensitivities values themselves, so that the categorisation is possible regardless of the perturbation intensity.
However in the case $T_j = 0$ (Case 2), no perturbation is implemented, so that sensitivity is uniformly zero, which makes player types undetectable. Nevertheless, the evolution of the numbers of players in each category is monotonous for $T_j < -2S_1 - 2P_0$, which spans zero.
This reasoning justified the definition of the player type categorisation for $T_j = 0$ the same way as for Case 1 and Case 3 (*i.e.* with threshold values P_0 and $-2S_1 - P_0 - T_j$), by extrapolation of these cases to Case 2.

Table B.1: Sensitivity to treatments: five configurations depending on treatment effect T.

Case	1	2	3	4	5
T. effect on Extraction[1]	Reduction	None	Moderate increase (below threshold)	Increase (Threshold)	High increase (Above threshold)
Graphics[2]					
Shape	Convex	Straight	Concave	Concave	Concave
Roots[3]	$x_1 < x_2$	None[5]	$x_1 < x_2$	$x_1 = x_2$	$x_1 > x_2$
CC/BP[4]	Above	None[5]	Above	None	Below

Notes:

[1] Treatment effect on expected individual extraction.

[2] Illustrative graphics computed with $P_0 = -0.1$, $S_1 = -0.24$. P_0 was not set to its empirical value for illustrative purposes.

[3] $x_1 = P_0$, $x_2 = -2S_1 - P_0$

[4] Position of conditional cooperators players relative to the baseline player.

Above (Below): CC players extract more (less) than the baseline player. None: the configuration *a priori* does not allow to identify CC players.

[5] By extrapolation of Cases 1 and 3, x_1, x_2 can be set as thresholds, and CC players are then above the baseline player ($x_1 < x_2$). See justification in the text.

Appendix C

Comparison of individual fish extraction indicators

C.1 Characteristic values

Table C.1 provides characteristic values of individual attributes estimators and individual fish extraction indicators.

The baseline player is found to be characterised by an individual attributes estimator $P_0 = -0.01$ close to the mean estimator of the distribution. The difference between the two is actually indistinguishable at precision 10^{-2}. Under the baseline micro-situational settings, expected fish extraction is found to range from 0.36 to 8.81 fish from the possible [0;10] interval, and the probability of extracting more fish than the baseline player ranges from 0.00 to 0.98 from the possible [0;1], so that the probability indicator stretches the distribution of individual attributes estimators over the possible range of values more than expected fish extraction. The effect of the two treatments of interest, *i.e.* individual positive incentives and individual penalty rule, is found to appear clearly on expected fish extraction at precision 10^{-2}, leading for instance the baseline player to reduce her extraction from 4.36 fish under baseline settings to 3.47 (respectively 3.51) fish under penalty rule treatment (respectively positive incentive treatment, Figure C.1). The treatment effect on the probability indicator is unnoticeable at 10^{-2} (identical value for baseline and incentive treatments).

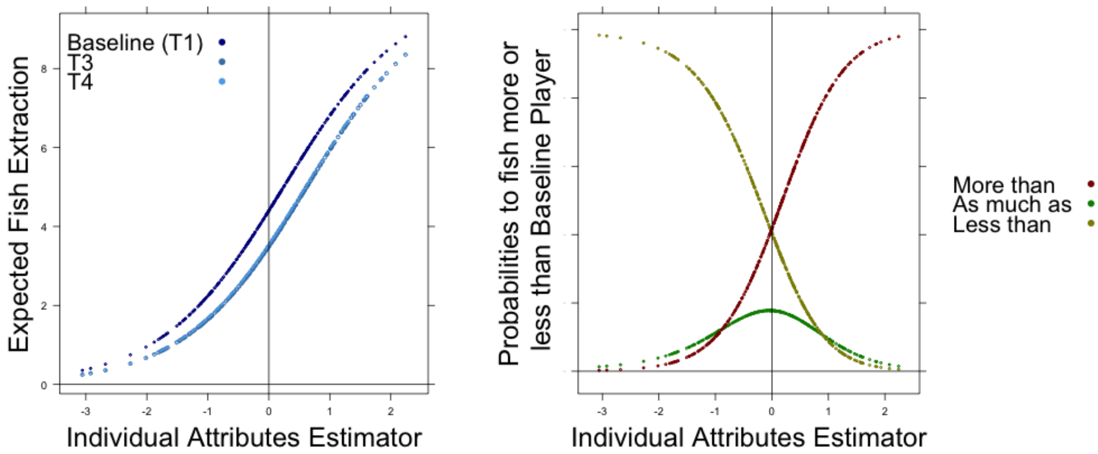


Figure C.1: Individual fish extraction indicators versus individual attributes estimator: expected fish extraction (Left) and probabilities to extract more fish, fewer fish, and as many fish as the baseline player (Right). Three different micro-situational settings are taken into account for expected fish extraction: baseline, individual penalty rule (T3) and individual positive incentive (T4). T3 and T4 curves are nearly indistinguishable.

Table C.1: Characteristic values for individual attributes estimator, and associated expected fish extraction and the probability to extract more fish than the baseline player, under the three micro-situational settings of interest (n=317 players).

Variable		j[1]	Individual attributes estimator			
			Lower $min_i(P_i)$	Upper $max_i(P_i)$	Mean $\overline{P_i}$	Baseline P_0
Individual attributes estimator	P_i	-	-3.06	$+2.24$	-0.01	-0.01
Expected fish extraction	f_{ij}	1	0.36	8.81	4.37	4.36
		3	0.25	8.35	3.47	3.47
		4	0.25	8.38	3.52	3.51
Probability of extracting more fish than the baseline player	$p_{sup_{ij}}$	1	0.00	0.98	0.41	0.41
		3	0.01	0.99	0.41	0.41
		4	0.01	0.99	0.41	0.41

[1] Treatment. 1: Baseline settings, 3: individual positive incentives, 4: indivisual penalty rule

Table C.2: Shape parameters for the distributions of individual attributes estimator and individual fish extraction indicators estimated under the baseline micro-situational settings.

Variable		Kurtosis	Skewness
Individual attributes estimator	P_i	0.16	-0.31
Expected fish extraction	f_{i1}	-0.76	0.02
Probability of extracting more fish than the baseline player	$p_{sup_{i1}}$	-1.15	0.12

C.2 Distribution shapes

Figure C.2 shows the distribution of each indicator. It suggests that the probability indicator tends to force the distinction between average players (the cluster of average values in individual attributes estimator is linearised in the probability indicator distribution). Kolmogorov-Smrinoff tests confirmed that the probability indicator distribution is less similar to the normal distribution than the individual attributes estimator and the expected fish extraction distributions (significance of Kolmogorov-Smirnoff similarity tests with normal distributions, respectively: $p = 0.028$, $p = 0.19$ and $p = 0.16$). Shape parameters showed that the individual attributes estimator distribution was slightly leptokurtic and negatively-skewed (Table C.2). Both the expected fish extraction and the probability indicator functions increased the distribution skewness into a slightly positive one, that is, extended the upper tail at the expense of the lower tail and hereby enabled to distinguish more easily extreme extractors. Both functions decreased the distribution kurtosis to a negative value, so that extreme values are favored at the expense of average values. Nevertheless, the effect is stronger for the probability indicator (kurtosis $= -1.15$) than for expected fish extraction (kurtosis $= -0.76$).

C.3 Precision

Individual confidence intervals for the values of individual attributes estimators and the two individual fish extraction indicators are plotted in Figure C.2. Both expected fish extraction and the probability indicator tended to create a precision gap between average and extreme values, average players being associated with the widest confidence intervals. The effect was found to be stronger for the probability indicator, as the magnitude ratio of confidence intervals between the probability indicator and expected fish extraction increased from around 0.2 for most extreme values to around 1.7 for average values.

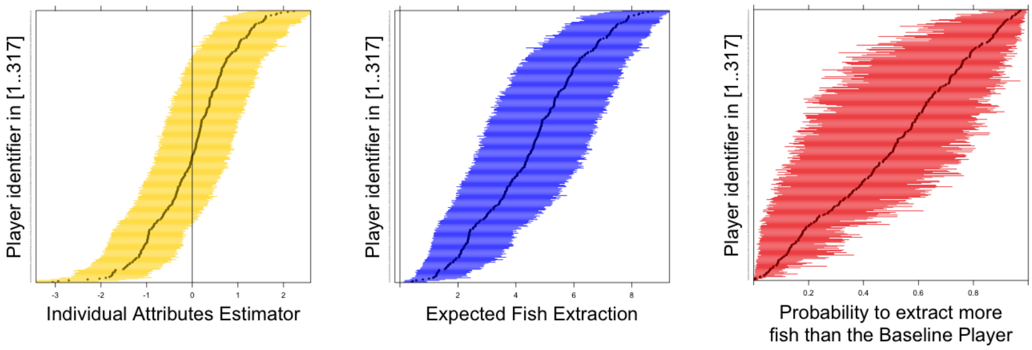


Figure C.2: Simulated individual attributes estimator (left), and associated expected fish extraction (center) and probability of extracting more fish than the baseline player (cight). $m = 1000$ simulations, horizontal lines display 95% confidence intervals for each player in [1..317].

C.4 Conclusion on indicator selection

The three previous subsections have detailed similarities and differences between the two indicators, expected fish extraction and the probability of extracting more fish than the baseline player. They have indicated that the two functions generated moderate shape transformations, though the probability indicator tends to highlight extreme players at the expense of average ones (lower kurtosis value plus lower precision for average players).

Moreover, the interpretation of variations in the probability indicator value is delicate, because the treatment effects are harder to detect, and most of all because a variation in the probability to extract more fish than the baseline player is dependent on the variations in two other indicators (probabilities of extracting fewer fish and as many fish as the baseline player, Figure C.1). So that opposite variations in the probability indicator could *not* be interpreted directly as actual opposite effects.

These two conclusions suggested that expected fish extraction is a more robust indicator with a more straightforward interpretation. Therefore it was selected as the game indicator for cooperation to test against real-life behaviour.

Appendix D

Subset representativeness

Table D.1 shows the results of homogeneity tests that have been performed to assess the representativeness of subsets. No significant difference was found between the subsamples and whole samples, both for means and proportions (tested with respectively Welch t-tests and Pearson χ^2 tests) and for distributions (tested with Kolmogorov-Smirnoff tests for continuous variables). The only exception was the Opinion on PLUP, which was lower in the subsample (0.35 on average for 91 players) than in the whole sample (0.43 on average for 192 players; $t = -2.01$, $d.f. = 186.7$, $p = 0.046$).

Table D.1: Results of homogeneity tests

Variable	Obs. 1[1]	Obs. 2[2]	test 1[3]	KS[4]
Game[5]				
Expected fish extraction	317	207	0.83	1.00
		205	0.77	0.99
		91	0.90	1.00
Sensitivity to treatment		207	0.98	0.98
		205	0.99	0.98
		91	0.87	0.99
Player type		207	0.93	-
		205	0.88	-
		91	0.78	-
Real-life				
PES participation	616	207	0.22	-
Illegal land clearance	609	205	0.51	-
Opinion on PES	192	91	0.31	0.40
Opinion on PLUP			0.05	0.71
Opinion on Both[6]			0.39	0.95
Perception of authorities			0.96	0.99
Interpersonal trust			0.16	0.90

[1] Size of the whole dataset available for the variable.

[2] Size of the dataset used for Game versus Real-life correlation tests.

[3] t-test p-value for continuous variables, χ^2 p-value for categorical variables

[4] Kolmogorov-Smirnoff test p-value.

[5] Results for individual positive incentives treatment only are displayed here.

[6] All conservation interventions

Appendix E

Correlation patterns between game and real-life behaviour

E.1 Observed behaviour

E.1.1 PES participation

PES participants were found in the game to extract fewer fish under individual positive incentives than non-PES participants, as their mean expected fish extractions under these settings were respectively 3.53 and 4.10 (Figure E.1, Column A, Row 1), which was significantly different ($t = 2.24$, $d.f. = 186.4$, $p = 0.026$). This indicates that cooperativeness was associated with PES participation with reasonable confidence.

Sensitivity to individual positive incentives, however, was not correlated to PES participation: though PES participants were more responsive to the treatment ($\Delta(i, 4) = 0.10$ on average for PES participants, $\Delta(i, 4) = 0.12$ for non-participants, Figure E.1, Column B, Row 1), the effect was not significant ($t = -0.91$, $d.f. = 204.7$, $p = 0.36$).

Player type categorisation was able to confirm the correlation between cooperativeness and PES participation. Indeed, the proportion of PES participants increased from 39.4% among free-riders, to 54.8% among conditional cooperators and to 63.3% unconditional cooperators (Figure E.1, Column C, Row 1). The correlation was weaker than with expected fish extraction, but valid at a confidence level close to 95% ($\chi^2 = 5.71$, $d.f. = 2$, $p = 0.058$).

E.1.2 Illegal land clearance

As hypothesized, expected fish extraction under individual penalty rule treatment was found to be higher for players who had illegally cleared land than for those who had not (on average, respectively 4.10 and 3.66 fish, Figure E.1, Column A, Row 2). The gap, however, was not statistically significant ($t = -1.33$, $d.f. = 63.3$, $p = 0.19$).

Responsiveness to penalty rule did not allow to differentiate players who had illegally cleared land and those who had not. Indeed, mean sensitivities to individual penalty rule treatment of the two groups were nearly indistinguishable (respectively $\Delta(i, 3) = 0.12$ and $\Delta(i, 3) = 0.11$; Figure E.1, Column B, Row 2; $t = 0.18$, $d.f. = 88.5$, $p = 0.86$).

Player categorisation under penalty rule allowed to identify distinct land clearance behaviours: it confirmed the unconclusive previous observation that uncooperative players were more likely to illegally clear land (37.5% of free-riders did), but also indicated that conditional cooperators were more compliant with the rule than unconditional cooperators (respectively 15.30% and 21.60% of illegal land clearance cases, Figure E.1, Column C, Row 2). Contrary to the test with expected fish extraction, the effect was significant at 95% confidence level ($\chi^2 = 6.80$, $d.f. = 2$, $p = 0.033$).

E.2 Stated preferences

E.2.1 Opinion on conservation interventions

Indicators of cooperativeness were exepcted to increase with opinions on conservation actions. Linear regressions for expected fish extraction under individual positive incentives, individual penalty rule and baseline settings versus opinions on respectively PES schemes, PLUPs and all conservation interventions all failed to identify any correlation (Figure E.1, Column A, Row 3 to 5; respectively $F(1, 89) = 0.47$, $p = 0.49$; $F(1, 89) = 0.22$, $p = 0.63$; $F(1, 89) = 0.52$, $p = 0.47$).

Responsiveness to incentives, which was also expected to be positively correlated with opinions on conservation interventions, yielded similar figures. No significant relation between sensitivity to individual positive incentives and opinion on PES were found through linear regression (Figure E.1, Column B, Row 3; $F(1, 89) = 0.14$), $p = 0.71$), nor between sensitivity to individual penalty rule and opinion on PLUP (Figure E.1, Column B, Row 4; $F(1,89) = 0.28$), $p = 0.60$).

Nevertheless, a closer look at opinions for each player type provided a few consistent figures: free-riders had lower mean opinion indices than unconditional cooperators both regarding PES schemes (respectively 0.48 and 0.55; Figure E.1, Column C, Row 3) and PLUPs (respectively 0.33 and 0.39; Figure E.1, Column C, Row 4). The position of conditional cooperators relative to the other player types is more unclear: while they expressed the highest opinion on PES schemes (0.57 on average), they also expressed the lowest opinion on PLUP (0.31 on average), which on average located them between conditional cooperators and free-riders (on average 0.40 for free-riders, 0.46 for conditional cooperators, 0.47 for unconditional cooperators; Figure E.1, Column C, Row 5). Overall, ANOVAs performed to measure the differences between the three player types did not yield any significant result, neither for PES only ($F(2,88) = 0.63$, $p = 0.53$), PLUP only ($F(2,88) = 0.62$, $p = 0.54$), or both ($F(2,88) = 0.98$, $p = 0.38$).

E.2.2 Perception of authorities

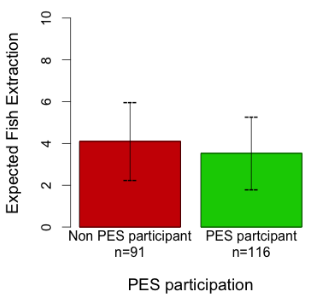
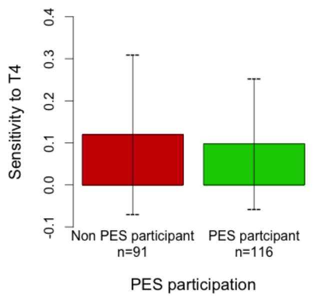
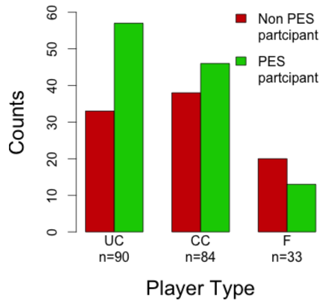
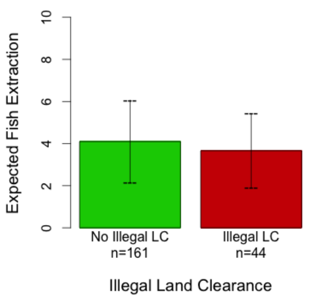
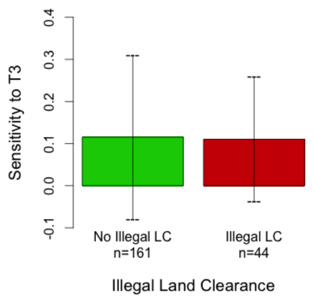
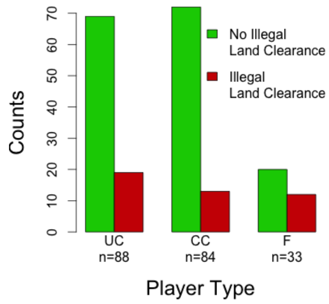
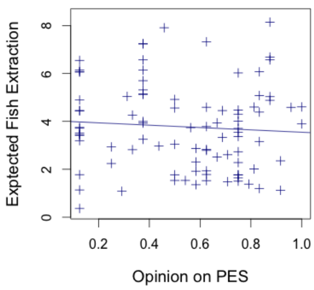
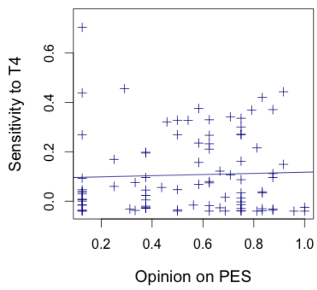
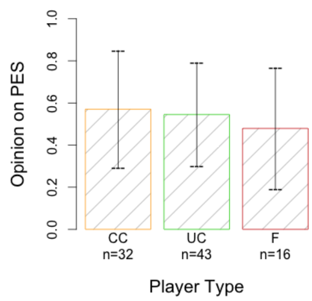
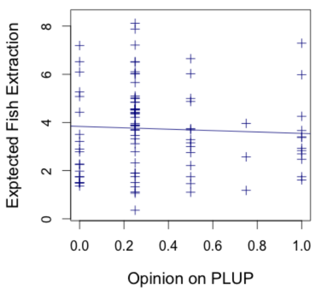
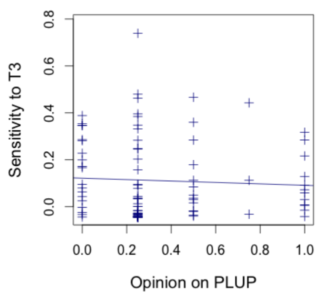
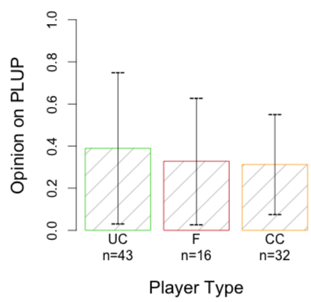
Tests performed on the sample of 91 players suggested that both cooperativeness and responsiveness to incentives were correlated to perception of authorities. Indeed, expected fish extraction under individual positive incentives was found to linearly increase in perception of authorities (Figure E.1, Column A, Row 6), with a confidence slightly below 95% ($F(1,89) = 3.71$, $p = 0.057$), and sensitivity to individual positive incentives to linearly decrease in perception of authorities (Figure E.1, Column B, Row 6), to a lower extent ($F(1,89) = 2.78$, $p = 0.099$). These observations suggested that perception of authorites was lower for cooperative players, which is contrary to expectations, and for players who were responsive to Incentives. Similar correlation figures were found under Individual Penalty treatment, so that these conclusions hold for both kinds of incentives. However, discarding the oulier mentioned in the Results section (Individual real-life behaviour section) indicated that correlations did not hold anymore with the reduced sample of 90 players (at a 90% confidence level, with expected fish extraction: $F(1,88) = 2.74$, $p = 0.102$ and with Sensitivity to Treatment: $F(1,88) = 1.74$, $p = 0.19$).

Investigating perception of authorities for each player type confirmed these conclusions. Although the relative position of mean perceptions for players types suggested similar trends (on average, 0.54 for unconditional cooperators and 0.68 for free-riders, Figure E.1, Column C, Row 6), the mean opinions of the three groups were not significantly different at a 95% confidence level, nor at 90% level ($F(2, 87) = 1.77$ $p = 0.176$).

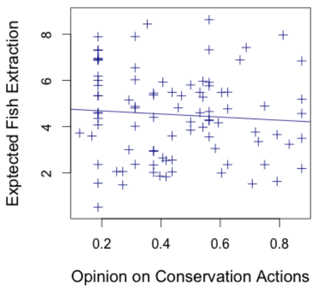
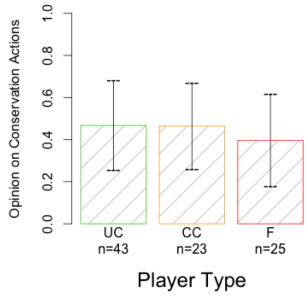
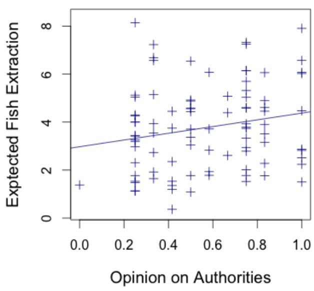
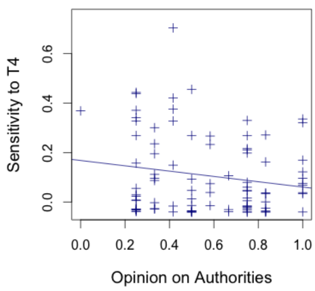
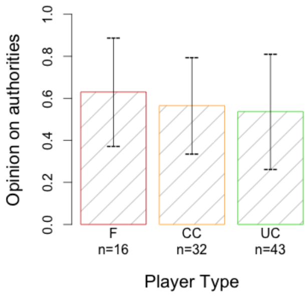
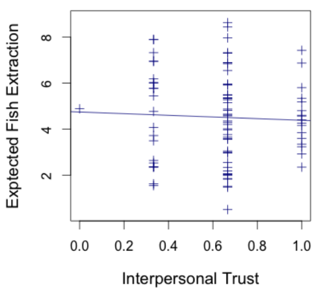
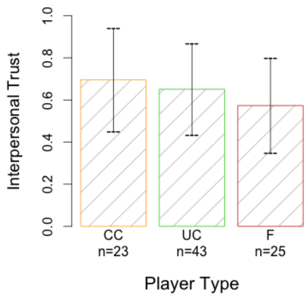
E.2.3 Interpersonal trust

Similarly to previous preferences, a robust link between expected fish extraction and interpersonal trust index was not found through linear regression (Figure E.1, Column A, Row 7). The test performed with the sample of 91 players did not yield any significant result ($F(1, 89) = 0.17$, $p = 0.68$). Discarding the outlier mentioned in the Results part did not change this conclusion ($F(1, 88) = 0.14$, $p = 0.71$).

Like in most opinion and perception cases described previously, the relative mean group values for unconditional cooperators and free-riders followed our expectations: unconditional cooperators were more trusting players than free-riders (on average respectively 0.65 and 0.57; Figure E.1, Column C, Row 7). Once again however, the position of conditional cooperators relative to the other two groups was harder to interpret. Interpersonal trust of conditional cooperators was the highest of the three groups (0.65 on average), and the difference between the three groups failed to be significant ($F(2, 88) = 1.82$, $p = 0.17$).

RL[2]	N[3]	A	B	C
1	207			
2	205			
3	91			
4	91			

Game indicator[1]

		Game indicator[1]		
RL[2]	N[3]	**A**	**B**	**C**
5	91		-	
6	91			
7	91		-	

[1] Game indicator, A: Expected fish extraction, B: Sensitivity to treatment, C: Player type.
[2] Real-life indicator, 1: PES participation, 2: Illegal land clearance, 3: Opinion on PES, 4: Opinion on PLUP, 5: Opinion on all conservations interventions, 6: Perception of authorities, 7: Interpersonal trust.
[3] Number of observations.

Figure E.1: Correlation figures between game and real-life indicators. The significance of correlation tests is displayed in Table 6.5. Bar whiskers display 95% confidence interval bounds; blue lines in scatterplots are linear regressions outputs.