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Drivers of transgression: What pushes people to enter protected areas

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ABSTRACT

The establishment of protected areas is central to biodiversity conservation strategies. However, they often fail in meeting their expectations, especially in the tropics. One core reason for their failure is human pressure. Protected area transgression has tremendous impacts on biodiversity, but also on persecuted rule-breakers whose necessities are often ignored. Despite the increasing enforcement of strict protection rules, non-compliance is a phenomenon experienced in protected areas around the world. To improve biodiversity and social outcomes of any conservation intervention, we need to understand what drives transgressive behavior but also the gazettement of protected areas. By using a role-playing game with Indigenous people in the Colombian Amazon we were able to openly discuss transgression. In the game, park managers designed protected areas primarily for biodiversity conservation but also for restoration. Communication among stakeholders and a resource-abundant landscape were key to increase compliance without exerting enforcement while the violations history of the protected area as well as the abundance of resources within its boundaries encouraged transgression. To achieve voluntary compliance, we recommend to acknowledge transgression's multidimensionality and integrate it into conservation planning.

1. Introduction

The Beijing Call for biodiversity conservation and climate change expresses the intention to "bend the curve of biodiversity loss… by protecting an ever growing part of the planet" (Élisée, 2019). This call builds upon Aichi Target 11 on the expansion of the global protected area (PA) network to cover 17% of the land areas by 2020, a goal not far from the current 15% total land cover (UNEP-WCMC and IUCN, 2019). Despite the reliance placed on them, PAs are increasingly threatened by human pressure—particularly in the tropics (Geldmann et al., 2019)—and biodiversity continues to decline (Díaz et al., 2019; Leclère et al., 2020).

Worldwide, large portions of PAs overlap with indigenous territories (Stevens, 2014). In the global Amazon region, 22.1% of the land is within officially recognized Indigenous territories, 5.4% of which overlaps with PAs. Recent events in Brazil report of increased clashes between Indigenous people and loggers, miners, and other land-grabbers who infringe on PAs and Indigenous territories under the passivity of the state (Andreoni and Casado, 2019; Cowie, 2020). In Colombia, where half of the national PAs overlap with Indigenous and Afro-Colombians' territories, conflicts over land are on the rise (Suarez et al., 2018).

The gazettement of protected areas has been linked to claims of sovereignty through which states—with the direct involvement of corporations and NGOs—demarcate territories with the purpose of gaining control over resources and people (Igoe and Brockington, 2007). The enclosure and dispossession of land in the name of conservation can be a coercive and violent act that deprives people of the means to procure for their own survival (Neumann, 2001). Such actions force conservation refugees to either seek into wage labor an alternative to their traditional activities, or perpetuate them outside the boundaries of legality (Kelly, 2011). Understanding what drives compliance—as in adherence to rules—or its reverse, transgression, is essential to discuss the biodiversity and social outcomes of any given conservation planning (Arias,

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2015). Practitioners' goal is often to achieve voluntary compliance. Compared to top-down approaches, genuine co-managed forms of governance generate a sense of legitimacy and increase compliance's likelihood without excessive monitoring and enforcement (Levi and Sacks, 2009). When involving local people in their co-management, PAs can generate positive outcomes for both conservation and livelihoods (Oldekop et al., 2016). Successful examples exist for the whole Amazon region (Campos-Silva et al., 2017, 2018; De Pourcq et al., 2015; Fisher et al., 2020).

The drivers of non-compliance are plenty and differ not only from one individual to the other but also within the same individual in different contexts (Kahler and Gore, 2012). Their interpretation is multifaceted and does not depend only on people's normative values and social norms but also on the performance of the authority (Stern, 2008). The gazettement of protected areas has historically been motivated by the need to safeguard biodiversity and ecosystem services (Mace, 2014; Watson et al., 2014) but their performance transcends ecological indicators and also relies on people's compliance (Arias, 2015). Understanding the motives underlying the gazettement of protected areas and their relationship to non-compliance can contribute to reveal further drivers of transgressive behavior.

Transgression can have severe consequences on biodiversity (Branch et al., 2013; Wilkie et al., 2011) but also for poachers and rangers that run high risks in either violating or enforcing the rules (Dudley et al., 2014). Exploring transgressive behavior however, is not straightforward as rule-breakers are unlikely to be willing to disclose themselves for fear of punishment or of social condemnation. While methods such as the Unmatched Count Technique are a proven way to gather information on the propensity of illicit or illegal behavior within a population, investigating the root causes behind said behavior remain challenging (Fisher, 1993; Hinsley et al., 2019; Nuno and St. John, 2014).

Games have been proposed as powerful tools to address sensitive issues (Redpath et al., 2018). Experimental games have been used extensively in the study of common-pool resources and the effects of establishing state property rights (Anderies et al., 2011). In this study, we moved beyond the classical tragedy of the commons by exposing players to asymmetries of information and power and to apparently conflicting agendas. Specifically, we used the role-playing game ReHab (Le Page et al., 2016) in order to understand a) the drivers behind the gazettement of protected areas, and b) the resulting transgressive behavior within Indigenous people of the *resguardo* Ticoya in Colombia.

2. Methods

2.1. Study area

The recent demobilization of the FARC rebel group in Colombia has created a political void quickly filled by landholders expanding the agricultural frontier and encroaching PAs home to numerous indigenous people (Clerici et al., 2020; IDEAM, 2018). The government has launched military-backed offensives as a response to the increased deforestation, which often exclude, evict and dispossess the most vulnerable peasant communities leaving unpunished the large-scale deforesters (Volckhausen, 2019). Within this context, Indigenous people are presented as environmental guardians—as long as they live an Indigenous life within an Indigenous territory, or *resguardo* (Bocarejo, 2009). Those who oppose the expected 'green' behavior—which effectively restricts their resources access—lose their indigenousness (Ojeda, 2012).

This study was conducted within the *resguardo* Ticoya, part of the Puerto Nariño municipality in the Colombian department of the Amazonas. The *resguardo* is formally recognized as an administrative-territorial entity under Indigenous administration. It has a population of 5620 inhabitants distributed across 22 communities located along the Amazon, Loretoyacu, Boyahuazu and Atacuari rivers (ATICOYA, 2015). The grand majority of inhabitants are Indigenous from the Ticuna, Cocama and Yagua ethnic groups. The area is characterized by a warm and humid climate with a unimodal-biseasonal rain regime (Moreno Arocha, 2014). The variation in precipitation causes extreme hydrological fluctuations in the level of the water bodies along the year, reaching a maximum in May and dropping to a minimum in September. During the high-water season, large portions of the forests are flooded by either white-waters (*várzea*) or black-waters (*igapó*), while other areas, known as *terra firme*, will remain dry. The *resguardo* extends for 140,623 ha; some 18% of it overlap with the state-owned Amacayacu National Park. The park was created in 1975 (Resolution 283) in order to conserve biodiversity and monitor the illegal trade of natural resources carried out between the frontiers with Peru and Brazil (PNNA, 2006). Following the political Constitution of Colombia in 1991 and the "Parks with People" policy of 2002, the fortress conservation vision evolved towards a more inclusive one which aimed at jointly fostering cultural and biological diversity (PNNA, 2006). Currently, three Indigenous territories—officially recognized only several years after the park creation—lie within the Amacayacu park.

For this work, we focused on nine communities situated outside the park boundaries along the Loretoyacu, an affluent of the Amazon river (see Table B3 in the Supplementary material for more information on the communities).

An increasing economic disparity can be observed between rural and urban areas (Puerto Nariño and adjacent communities). The first are still tied to subsistence activities while the second rely more and more on a monetary economy, where tourism is recently playing a significant role (Trujillo, 2008; Zárate and Ahumada, 2008). Indigenous people benefit little from the flourishing tourism industry (Craven, 2016) and depend on their surrounding forests for their sustenance. Shifting cultivation, fishing, timber extraction and hunting of wild animals—combined with short-term and meagerly-paid jobs—represent their main livelihood (Maldonado, 2010; Trujillo, 2008; van Vliet et al., 2015).

2.2. The game "ReHab"

2.2.1. The workshops

To explore how players react to an external restriction of their harvesting activities, we used a role-playing game called ReHab. We organized nine game sessions in nine communities (Fig. 1). The leader of each community gathered between 9 and 12 people, for a total of 88 participants. All 58 men came from different households while 3 out of the 30 women who took part to the study were related to the man participants. At the beginning of each workshop, the research team and the community leader informed participants about the objectives of the study. Space for feedback and questions was offered throughout the workshop. We decided not to record the workshops due to the sensitivity of the issues discussed.

2.2.2. The game description

ReHab has been developed by Le Page et al. (2016) to explore the role of knowledge production and communication in managing natural resources. It is in itself a complexification of an older game called CherIng developed by Campo et al. (2010). Despite being originally based on a different case study, ReHab can be applied to various contexts dealing with the management of a natural resource. For this study, we have employed the version of ReHab as described by Le Page and colleagues (see Appendix A of this manuscript for a thorough description of the model). From now on, all the elements of the game will appear in italic to ensure they are not confused with the real landscape (the *resguardo* Ticoya) of the workshops' participants. To further clarify the distinction, we use specific terms depending on the context: 1) "player" refers to the game system and outcomes, 2) "participant" refers to the workshop and debriefing and 3) "local communities" or "Indigenous people" refer to the real socio-ecological system.

The game revolves around the management of a renewable resource called *biomass* distributed over a *landscape* divided into 20 *cells* (Fig. 1).

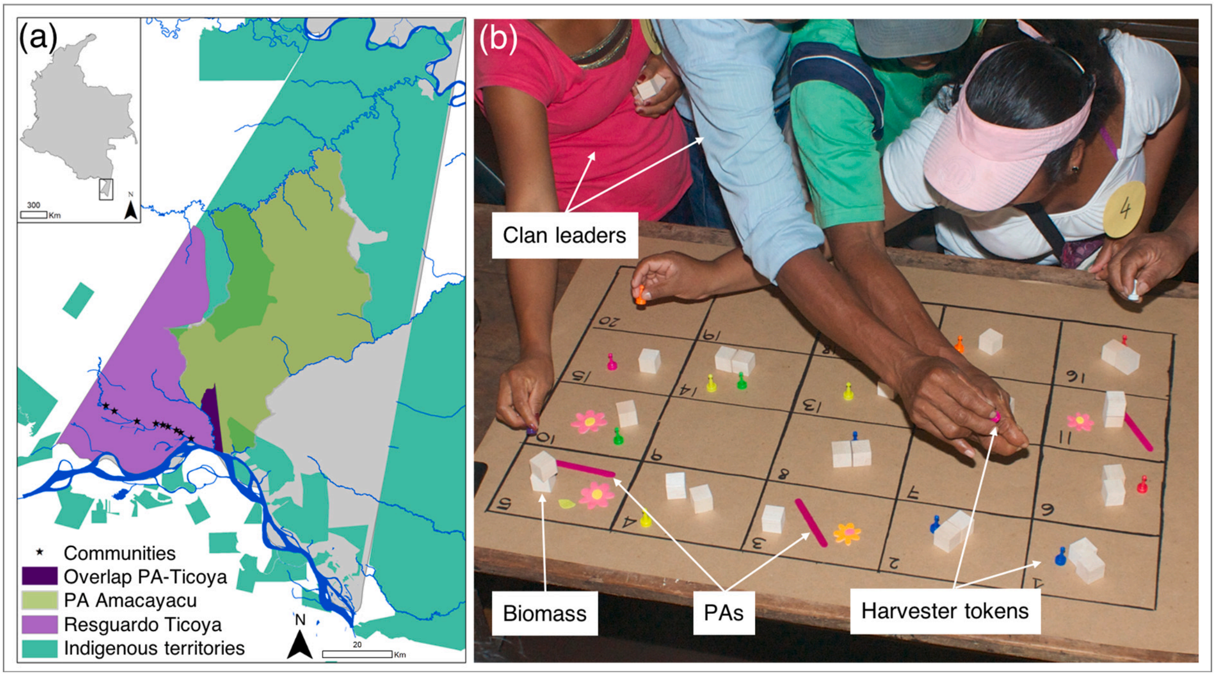

Fig. 1. Study area (A) and extract from a game session (B). The stars in the map indicate the communities where this study took place. Picture by D Cruz-Antia.

Cells differ only in the amount of *biomass* they hold, from 0 to a maximum of 3 arbitrary units. Most players—between 8 and 10—are *clan leaders whose clans* are composed of 2 to 3 *harvesters (tokens)*. *Clan leaders* choose in every round, which *cells* of the *landscape* they want to send their *harvesters* to collect *biomass* in order to feed their *clan*. At the end of every round, *clan leaders* need to have collected a minimum of 1 *biomass* unit per *harvester* to avoid *hunger*. One or 2 players are *park managers (PMs)* seeking to ensure the reproduction of a migratory *bird* by creating a *protected area (PA)* which overlaps with the *clan leaders' landscape*. *Birds* are distinct from *biomass* and cannot be harvested. To achieve their aims, *PMs* can designate a maximum of 3 *cells* as *PA*, visible to all players. *Birds*, managed by the game master, will only nest in *cells* with 2 or 3 *biomass* units, and will only reproduce if there are no *harvesters* in and around the nest. *Clan leaders* can decide to collect the *biomass* in a freely accessible *cell*, or enter a *PA cell* and transgress the *PA* rules. The game is played in two scenarios, of five rounds each. In round 1 of both scenarios, *clan leaders* can decide which *cells* to harvest while *PMs* observe. Starting round 2, *PMs* can decide which *cells* to protect and once the *PA* is established *clan leaders* can decide where to harvest. In the first scenario, there is no time allocated to communication between players. There is also no punishment for transgressors. In the second scenario players have 5 min to discuss and potentially implement *sanctions* for transgressors. All sessions had identical game board set-ups with 30 initial *biomass* units and 20 *harvesters* to be distributed among *clan leaders* (Appendix B). Each *clan* owned either 2 or 3 *harvester tokens*.

The study was done in compliance with the ethical guidelines and principles outlined by the Swiss Commission for Research Partnerships with Developing Countries (Stöckli et al., 2012).

2.3. Statistical methods

To understand drivers of protected area gazettement, we analyzed which *cells PMs* decided to protect by comparing the total *biomass* outside the *PA* with the *biomass* within the *PA*. We fitted a generalized linear model with a Poisson distribution using the *biomass* level as response variable and the *cell* status (inside the *PA* or outside the *PA*), scenario (1 or 2) and the interaction between the two as explanatory variables. As the model with random effects community of origin of workshop participants and round did not converge, they were excluded (Barr et al., 2013). We used the lme4 package (Bates et al., 2017) from R (R Core Team, 2018). We fitted generalized mixed-effect models with *transgression* as response variable to identify the main drivers of transgression. *Transgression* is a binary variable describing whether a *PA cell* has been transgressed (1) or not (0). We considered six explanatory variables: *scenario*, *PA biomass*, *PA transgression history*, *landscape biomass*, *clan leaders' inequality* and *clan leaders' poverty*, and two random effects (Table 1). Most of these variables were raised during the debriefings at the end of each game sessions to explain participants transgressive behavior. Some (*clan leaders' inequality* and *poverty*) were derived from literature (Bragagnolo et al., 2019; Kahler and Gore, 2012; Keane and Jones, 2008). Because the model with all possible variables' combination was overfitting and given the ratio of number of variables versus number of data points, we used a forward and backward selection procedure based on AIC. We retained the most parsimonious model within 2 ΔAIC_c of the model with the lowest AIC_c (Burnham and Anderson, 2002). *Clan leaders' poverty* was excluded while the interaction between *scenario* and *PA transgression history* was retained. The final selected model included five explanatory variables, two random factors and one interaction.

3. Results

In each of the nine communities, we played 10 rounds of the ReHab game with local forest users; five rounds per scenario (Tables C3 and C4 in the Supplementary material). In all game sessions, *clan leaders* placed their *harvesters* on *PA cells* while *PMs* decided never to impose *sanctions*.

3.1. Drivers of gazettement

Protected cells had on average a higher *biomass level* (1.6 sd = 0.94) compared to the landscape average (1.22, sd = 0.82). If *biomass level* was not taken into account by *PMs* when designating *PA*, we would expect to find the same distribution of *biomass* both within the *PA* and outside the *PA*. However, in both scenarios, cells with a *biomass level* of 2 and 3 were chosen more often than at random while cells with 0 or 1 *biomass level* were chosen less often (Fig. 2, Table 2). The only exception is given by

Table 1
List and description of the variables used in the generalized mixed effect model fitted to identify drivers of transgression.

Type	Variable	Description	Values
Response variable	Transgression	Whether a *PA cell* has been entered by a *clan leader* in the current round	0/1
Explanatory variables	Scenario	Absence or presence of communication between players	Scenario 1/ Scenario 2
	PA biomass	Sum of *biomass* units that lie within the *PA*	0 to 9
	PA transgression history	Whether the *PA* has been entered by any *clan leader* in any previous round	0/1
	Landscape biomass	Sum of *biomass* units over the whole *landscape*	0 to 60
	Clan leaders inequality	Measure of the distribution of the *biomass* harvested by *clan leaders* calculated using the Gini coefficient	0 to 1
	Clan leaders poverty	Average shortfall of the total population from the hunger threshold (minimum level of *biomass* needed – 1 unit per *harvester* per round) calculated using the Poverty Gap Index[a]	0 to 1
Random factors	Community	The community where the workshops took place	C1 to C9
	Round	The round of the game where *PMs* could designate a *PA*[b]	2 to 5

[a] E-Handbook on Sustainable Development Goals Indicators, UN 2019. To calculate the poverty gap index per round we used the following formula: PGI = $1/N \sum_{i=1}^{q} \left[\left(z - y_j \right) / z \right]$ where: N = total number of *clan leaders*, q = number of poor *clan leaders* (whose *biomass* harvest < minimum level of *biomass* needed), z = minimum level of *biomass* needed by the *clan* (either 2 or 3 depending on *clan*'s size), y_j= number of *biomass* units collected by poor *clan leaders*.
[b] In round 1, both scenarios, PMs were just observing the harvesters and could not establish PAs.

cells with 0 *biomass* in scenario 2: in this case the probability density distribution of cells within the *PA* is approximately equal to that of cells outside the *PA*. In scenario 2 cells had on average a higher *biomass level* than in scenario 1 (Table 2).

3.2. Drivers of transgression

Clan leaders entered the *PA* less often in scenario 2 compared to scenario 1 (Fig. 3, Table 3). *Clan leaders' inequality* was also negatively related to *transgression*, though this relationship is not strongly supported by the model (Figs. 3 and 4c). *Transgression* increased with increasing *PA transgression history* only in scenario 1 (Figs. 3 and 4a) while this was not the case in scenario 2. *Transgression* also increased with increasing *PA biomass* (Figs. 3 and 4b) and decreased with increasing *landscape biomass* (Figs. 3 and 4d).

4. Discussion

4.1. Drivers of gazettement

There are two main decision pathways to the design of a Protected Area (PA) network. The most common, and indeed the historical source of gazettement, is the desire to prevent human-driven environmental degradation. The other pathway is intent on restoring ecosystems. Protected Areas gazetted with that philosophy will do little to reduce damage, but have the potential to reverse the trend, mending the ecosystem if they are successful. Players in our game sessions opted for both these approaches, though they were generally more inclined to adopt the first pathway in line with the games' objectives (e.g., *Park Managers (PMs)* were instructed to maximize *birds'* reproduction). Overall, *PMs* protected cells with an average *biomass* of 1.6, a value below *birds'* reproduction threshold of 2. There are different possible reasons for *PMs* to protect cells with low *biomass*. They might be compromising with the *clan leaders*, 'granting access' to cells with extractable *biomass*. If so, the strength of this signal is expected to be higher in scenario 2, where communication is allowed and the intention could be stated instead of just demonstrated. Yet, we did not detect a change between scenario 1 and 2; the proportion of cells with maximal *biomass* level was near identical between the two scenarios.

Another reason for protecting *biomass*-poor cells is that *PMs* were hoping to restore degraded areas. This is supported by the fact that in scenario *2, PMs* did not avoid cells with 0 biomass and by players' statements: "*This area of the forest is doing poorly [only 1 biomass unit], we need to protect it in order to have abundance again*" (workshop 3). This statement also suggests that *PMs* intentionally rearranged the location of the *PA* depending on the *biomass* status. The rotation of harvesting pressure, in agriculture as well as hunting or fishing, is a well-known strategy commonly used by Indigenous people to maintain habitat productivity (Gadgil et al., 1993). Traditional PA gazettement practices are rigid in terms of both spatial and temporal boundaries. Management plans that govern the use of natural resources tend to be more flexible taking into account the temporal and spatial fluctuations of forest users' activities (Constantino et al., 2018; De Mattos Vieira et al., 2015). ReHab allows participants to discuss both schemes: in the first scenario the sudden and top-down gazettement mirrored traditional PA policies. In the second scenario, the inclusive and adaptive process was more associated to management and zoning systems.

4.2. Drivers of transgression

There is emerging consensus that communication—via participation, deliberation, accountability and multiple actors' engagement—can lead to more effective environmental governance (Bäckstrand et al., 2010; Campbell et al., 2010). It also generates legitimacy of authorities and decision-makers, a known driver of compliant behavior in conservation (Levi and Sacks, 2009; Oyanedel et al., 2020; Thomas et al., 2016). In ReHab, communication allowed *clan leaders* and *PMs* to voice and share their objectives, needs and values, and to collectively devise strategies that can benefit both sets of stakeholders. A direct outcome of this is better coordination among *clan leaders* and between *clan leaders* and *PMs*.

In *scenario 2*, players, besides discussing about their needs and aspirations, also shared their understanding of the game rules. Having played five rounds in scenario 1, they have gained a better understanding of the system and of their actions' impact on the landscape and on other players. This increased familiarity ensures both *clan leaders* and *PMs* to become better at predicting the outcomes of their actions. Predictability of the resource flow increases the chances that people will invest time managing it (Ostrom, 2002).

Whether through improved understanding or effective negotiation, communication in the game sharply decreased the level of transgression, independently of the *biomass level* within or outside the *PA*. This suggests that communication has a two-sided effect. Communication among *clan leaders* enables the conceiving of more sustainable practices, while communication between *PMs* and *clan leaders* reduces transgression level for any given amount of *landscape* or *PA biomass*.

Past transgressions of the *PA* in the game reinforced transgression when communication was not allowed (scenario 1). When a *clan leader* enters the *PA* and is not punished, the transgressive behavior is normalized and other *clan leaders* are feeling more inclined to enter the *PA*. It is well known in criminology how a broken window—or the violation of a rule—will call for violations, independently of how 'respectable' the neighborhood is (Wilson and Kelling, 1982). It is also known in the conservation context, where a low perceived probability of detection or sanction increases the benefits of non-compliant behavior

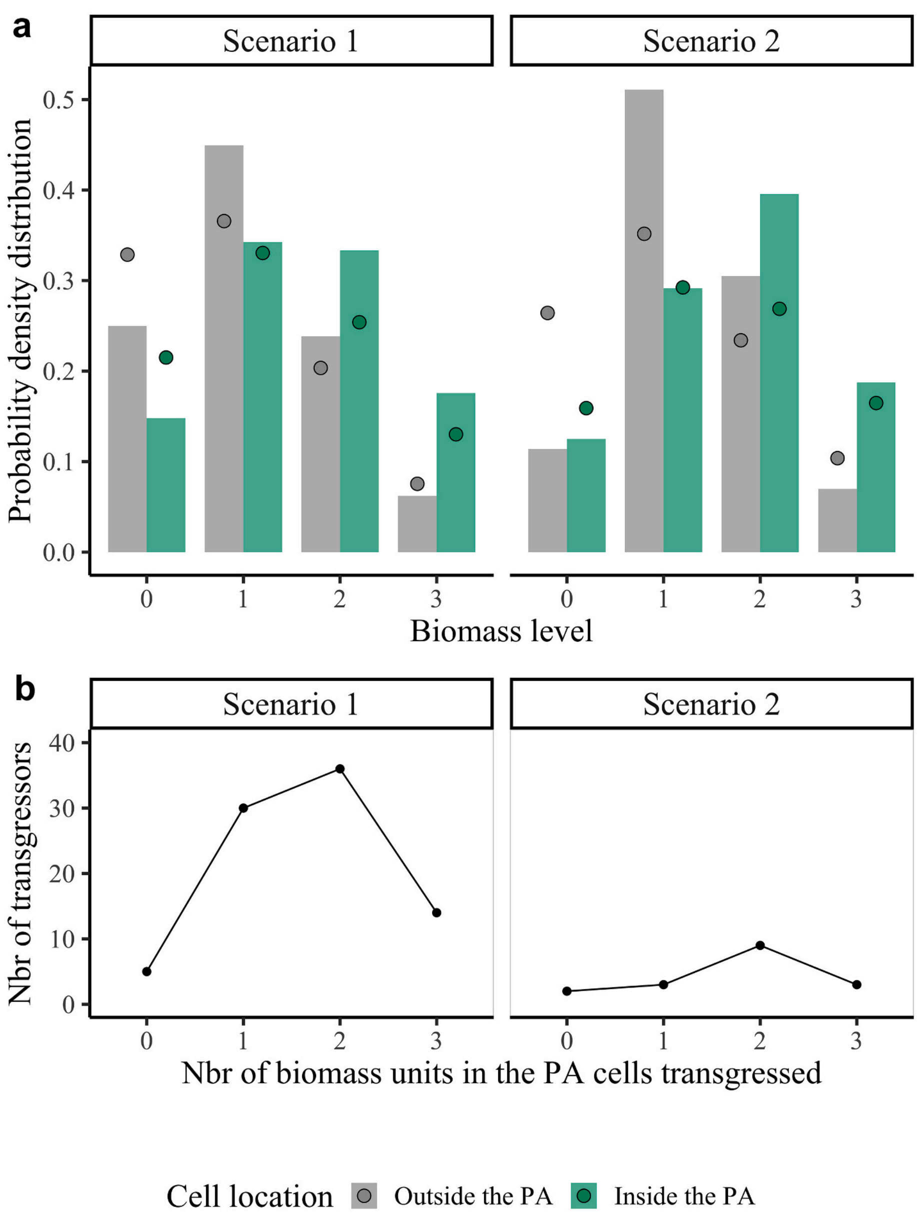

Fig. 2. *Biomass* level density distributions and transgressions. (a) Average *biomass* per *biomass* level inside and outside the *PA* for scenario 1 and scenario 2. The bars are the observed density distributions while the dots indicate the estimated density distributions from the model in Table 2. (b) Total number of transgressors, ie *harvesters tokens* entering the *PA*. Both probability density distribution and *harvesters* are given across all rounds, scenarios and communities. Across all game sessions, *PMs* designated as *PAs* all types of *cells*, even those that lack *biomass* where *birds* do not nest.

Table 2
Output of the model exploring the *biomass* level of *cells* outside the *PA* versus *cells* inside the *PA* in the two scenarios.

Response variable	Variable	Estimate	SE
Biomass level	Intercept	0.107	0.038
	Cells location	0.323	0.087
	Scenario	0.179	0.053
	Cell location:Scenario	−0.111	0.123

versus the potential costs (Arias and Sutton, 2013; Oyanedel et al., 2020). This is effectively the case for many 'paper parks'—designated protected areas which, because of poor governance, lack of enforcement and other issues, cannot ensure the respect of its boundaries on the ground (Barnes et al., 2018; Rife et al., 2013). The "broken window" effect faded once communication was allowed (scenario 2), enabling *PMs* to agree with *clan leaders* on the *PA* location and to reinforce rules' compliance whenever the agreement was broken by free-riders.

The attractiveness of the *PA* also worked as incentive for *clan leaders* to transgress. The higher the *PA biomass*, the higher the likelihood that a player transgressed. Players seem to behave as optimal foragers maximizing yield return for effort invested. They harvested the highest number of *biomass* units per token placed by choosing the PA over a less attractive landscape. Several studies have shown that tropical forest hunters seek to maximize their short-term harvesting rate by, for instance, targeting large-bodied species (Bodmer et al., 1994; Fa and Peres, 2001;Jerozolimski and Peres, 2003). In ReHab, the prospect of high return (i.e., more *biomass*) seemed to persuade players to transgress the *PA* rules independently of the communication among them. *Clan leaders* were also more inclined to enter the *PA* when they perceived the landscape to be degraded, seizing chances of meeting their clan's livelihood requirements.

Surprisingly, individual wealth or the lack thereof—measured as the amount of *biomass* collected individually—seems not to have affected *clan leaders'* decisions to the point it was not retained in the model. Its irrelevance might be related to the multidimensional character of poverty: defining it only in terms of material deprivation is simplistic and can lead to flawed assumptions (Duffy et al., 2016). In the field of conservation, the lack of material wealth is often perceived as a major driver of illegal practices (IUCN SULi, 2015; MacKenzie et al., 2012;

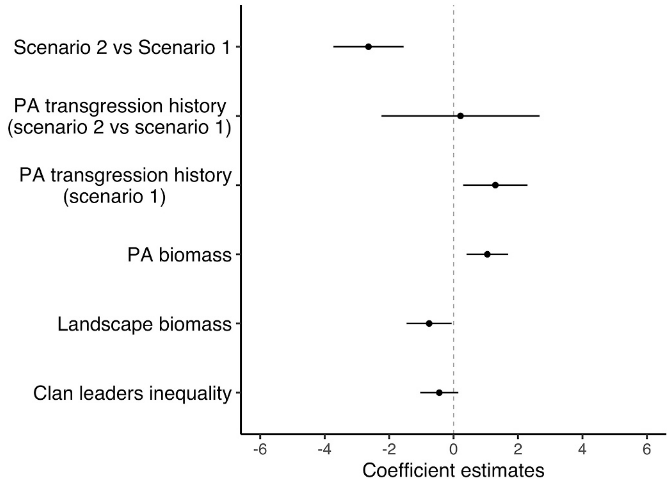

Fig. 3. Coefficient estimates of the drivers of *transgression* of *PAs*. The dots represent the mean coefficient estimate for each variable, the lines indicate the 95% confidence intervals. Coefficient estimates which confidence intervals exclude zero can reasonably be considered to affect the response variable.

Table 3
Output of the model exploring the relationship between *transgression* and *scenario*, *PA transgression history*, *PA biomass*, *landscape biomass* and *clan leaders' inequality*.

Response variable	Variable	Estimate	SE	p-Value
Transgression	Intercept (scenario 1)	0.47	0.45	0.2975
	Scenario 2	−2.64	0.56	<0.001
	PA transgression history (scenario 1)	1.3	0.51	<0.05
	PA transgression history (scenario 2)	−1.08	0.71	0.1254
	PA biomass	1.05	0.33	<0.05
	Landscape biomass	−0.76	0.36	<0.05
	Clan leaders inequality	−0.44	0.3	0.1423

Twinamatsiko et al., 2014). This narrow definition disregards other factors such as cultural identity, social status and customs, or the feeling of entitlement. In many Indigenous societies the concepts of richness and poverty as in accumulation or scarcity of material goods do not exist while common property regimes might play a more important role in regulating individuals' resource use (Bremner and Lu, 2006). In ReHab, the state of the *landscape* explained better a player's behavior than the individual amount of *biomass* collected.

Another surprising result that we observed is the negative—though weak—effect of players' inequality on transgression. *Clan leaders* transgressed less when inequality was high. However, inequality aversion is a well described psychological driver (Bellemare et al., 2008). At this stage, we cannot propose a reasonable explanation for this trend. Given its weak effect, we chose not to provide any ambiguous interpretation.

4.3. ReHab

The ReHab game is a fairly simple, abstract game whose rules and mechanisms have been developed in line with a different context to the one presented in this study. Yet, the discussions that have emerged from playing the game, reflects the workshop participants' reality, the constraints they experience in their everyday lives, their values, and their knowledge. The tokens used for the *biomass*, as well as the wording of the game's introduction, were intentionally meant not to reveal details on the natural resource at stake. Nevertheless, players interpreted the resource based on their own experience: hunters have explicitly identified the *biomass* units as wildmeat, fishermen as fishes and so on.

By involving people, their values, their segmented perception of the system and their agendas, ReHab offers a realistic representation of the social component of any natural resources' management problem. One that is especially difficult to capture in classical models despite being a major driver of socio-ecological systems (Preston et al., 2015; Speelman et al., 2017; Villamor et al., 2014).

5. Conclusions

By using ReHab, we were able to explore and discuss some of the mechanisms that drive transgression of protected areas at the individual and collective levels. Our study shows that *clan leaders* are more inclined to enter the *PA* when it has already been transgressed, when the enclosed *biomass level* is high and when the *landscape* is doing poorly. It does not come as a surprise that when people face a degraded landscape, they are more inclined to violate the rules of the protected area. Communication in the game was crucial to devise more sustainable harvesting strategies, increase the overall *landscape biomass* and consequently reducing the *PA* desirability. Communication improved the perceived legitimacy of the *PA* and, with it, the respect of its boundaries. However, we observed no significant change in the *PM's* gazettement strategy between the two scenarios.

To enhance people's voluntary compliance and to ensure that they adhere to rules because they inherently approve them, we need to understand transgression drivers and integrate them into conservation planning. It is not about persuading or coercing people to comply with rules but to formulate rules together with the people who are most affected by them. True participation and transparency might actually not change the letter of the rule itself but its level of approval and, ultimately, the performance of PAs in protecting and/or restoring the environment.

In the Anthropocene, managing ecosystems is first and foremost about managing humans in and around these ecosystems. Conservation heavily relies on rules compliance. Achieving compliance through coercive interventions can be an effective but volatile strategy losing power as soon as enforcement is relaxed. The challenge is to achieve voluntary compliance and to maintain it in the long run. To do so, we need to look beyond the proximate drivers of transgression and explore individuals' strategies, acknowledging they often drift away from classical models of rational choice (Rabinowitz, 1999). We also need to be able to address transgression leaving behind the "moral boundary drawing" (Neumann, 2004) that characterizes classical conservation discourses and that risk hampering our ability to discuss and understand it. To this end, games create an inclusive, safe space where transgression can be discussed not by condemning players but by empowering them (Ponta et al., 2019).

In Colombia, the conservation rhetoric has been used in either direction, de facto restraining resource access to both Indigenous and non-Indigenous people. Clashes are expected to increase to the detriment of both livelihoods and biodiversity. Properly addressing these conflicts and the inherent transgression is crucial and requires the unraveling of transgressors' underlying drivers (Travers et al., 2019). Our results suggest that a resource-abundant protected area with a history of non-compliance can encourage rule-breakers. On the other hand, a freely accessible, productive landscape outside the protected area boundaries can deter them. However, independently of the status of the landscape, communication is key to enable the inclusion of resource users in the decision-making process driving protected area gazettement and motivate compliance.

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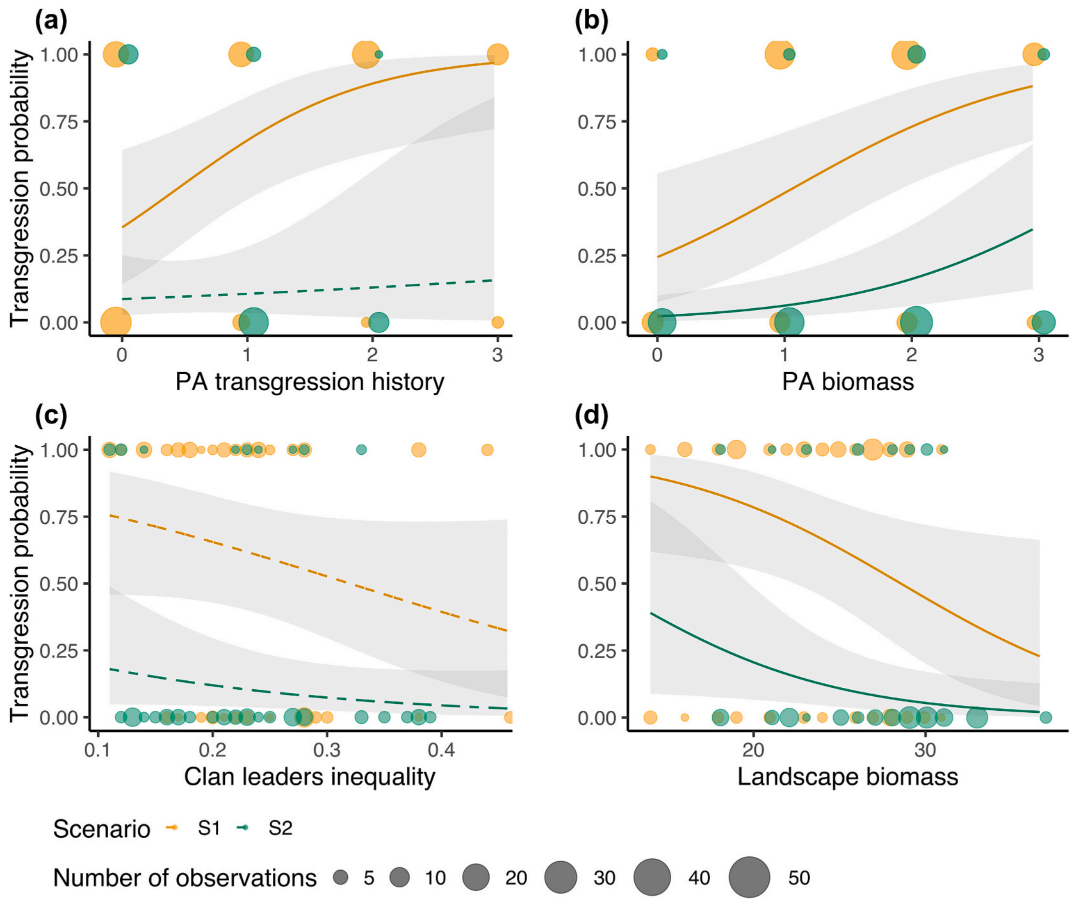

Fig. 4. Relationships between the probability of *transgression* of *PA* and (a) of the *transgression history* of the *PA*, (b) the number of *biomass* units within the *PA*, (c) the *inequality* of players, and (d) *landscape biomass*. The lines are the predictions from the model (with the dashed lines showing no significant relationships); the shaded area indicate the 95% confidence interval.

CRediT authorship contribution statement

N. Ponta: Conceptualization, Methodology, Investigation, Formal analysis, Writing – Original Draft, Visualization. T. Cornioley: Conceptualization, Formal analysis, Writing – Review & Editing. P. Waeber: Conceptualization, Writing – Review & Editing. A. Dray: Conceptualization, Methodology, Writing – Review & Editing. N. van Vliet: Conceptualization, Project administration, Methodology. M.P. Quiceno Mesa: Investigation, Project administration. C. Gracia: Conceptualization, Methodology, Writing – Review & Editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

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