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A systems approach to planning for human-wildlife coexistence: The case of people and jaguars in the Brazilian Pantanal

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Abstract

Human-wildlife coexistence as a concept and management objective has received increasing attention from researchers and decision makers. The coexistence approach will benefit from the recognition that, at broader scales, human-wildlife interactions (HWI) are best understood and managed collaboratively and as complex systems, that is, dynamic, non-linear, emergent, adaptive and, therefore, unpredictable. We present a planning process for human-wildlife coexistence that provides a platform for collaboration between researchers and decision-makers—and other stakeholders as well—and recognizes the complex nature of HWI. The three elements that define the process are: coexistence instead of conservation or conflict mitigation as a goal, systems thinking as the approach, and an emphasis on verifiable results rather than actions. As a way of illustration, we describe a 3-day planning workshop for human-jaguar coexistence in the Pantanal, Brazil. The 15 participants representing the academic, governmental, and non-profit sectors identified 12 interactions directly involving 27 stakeholders and indirectly another 55. A theory of change was produced, connecting 20 actions—to be performed by 22 actors—with the 57 factors that directly and indirectly drive the interactions. How these results complement other approaches such as Action Plans is discussed. The proposed approach favors the pragmatism of adaptive co-management over the often unrealistic expectation of a linear path to solution, or in other words, a shift from the notion of human-wildlife coexistence as a quantifiable target to that of coexistence as a desired system state.

KEYWORDS

Brazil, human-wildlife interaction, monitoring and evaluation, *Panthera onca*, social-ecological system, systems thinking, theory of change

1 | INTRODUCTION

Evidence-based and structured decision-making to turn problematic human-wildlife interactions (HWI) into large-scale coexistence (IUCN, 2023) requires the collaboration between researchers, decision makers and practitioners. However, academic researchers tend to place more effort into recording, describing and explaining the problem than testing interventions and measuring their efficacy (Lozano et al., 2019; Sutherland et al., 2021; van Eeden et al., 2018,b). And we argue that decision makers and practitioners in the governmental and non-governmental sectors dedicated to strategy design and implementation, in turn, have not used the scientific evidence available to set goals, guide actions and evaluate results with the degree of detail that they could. This gap between research and implementation has hindered sustainable changes (Ferraz et al., 2021; Knight et al., 2008; Toomey et al., 2017). Furthermore, decision-making in management, planning and policy aimed at HWI issues has mostly failed to recognize that they should be better examined and managed as complex socio-ecological systems, that is, dynamic and self-regulating and therefore unpredictable. (Fischer et al., 2009; Game et al., 2014; Knight et al., 2019; Preiser et al., 2018).

In this article, we present a planning process for human-wildlife coexistence that explicitly recognizes the complex nature of the problem and provides a platform for collaboration between researchers, decision-makers, practitioners, and other stakeholders. More specifically, we (i) discuss how the planning for coexistence approach broadens the scale at which decision making in HWI takes place and (ii) illustrate the process by describing a planning workshop involving decision-makers and practitioners for the coexistence between people and jaguars in the world's largest wetland, the Pantanal, in Brazil.

2 | PLANNING FOR HUMAN-WILDLIFE COEXISTENCE

Planning for Coexistence (Plan4Coex) is the process of making informed decisions regarding HWI (Marchini et al., 2021). The workshop process has been in development for the past 5 years and since the first pilot in 2019 with Jaguars of Iguaçu Project, in Brazil, has been applied to planning for coexistence with a variety of wildlife, from sea turtles in Costa Rica to aquatic mammals (multiple species) in the Amazon to tapir and peccary in the Brazilian Atlantic Forest. Workshops are typically 3 days long and involve a group of 12 to 40 participants. The composition of this group ranges from team members of a single project to heterogeneous groups with representatives from academia, governmental and non-governmental organizations, and local and indigenous communities.

Like any other strategic planning, the Plan4Coex process follows the components of adaptive management, namely situation assessment and goal setting, strategy formulation and implementation, and evaluation of success (Decker et al., 2012). What distinguishes it from how negative HWIs have traditionally been addressed in planning and management is the breadth of its scope and basis for decision-making. Plan4Coex broadens the basis for decision-making in terms of goal (from conflict mitigation to coexistence), approach (from predictive modeling to systems thinking) and emphasis (from actions to verifiable results). The process was developed precisely to help project teams and programs to advance in the following questions, respectively, *where do we want to go*? *what are the paths and steps to get there*? and *how can we monitor progress in that direction*?

2.1 | Goal: From conservation and conflict mitigation to coexistence

Management and policy decisions regarding human-wildlife interactions have mostly been taken within the conservation paradigm, focusing—mainly from an ecological perspective—on the negative impacts of human activities on endangered wildlife (Frank, 2016; IUCN, 2023). Planning for large-scale coexistence, however, considers the full spectrum of interactions between humans and wildlife, as long as they have significant impacts, that is, require management attention, according to stakeholders (Decker et al., 2012). Impacts can be both negative or positive, tangible (e.g., loss of livestock, income) or intangible (e.g., fear, happiness), on people and wildlife, whether native and endangered or exotic and abundant (Marchini et al., 2019; Marchini et al., 2021).

The framework used for situation assessment and goal setting in Plan4Coex—the Human-Wildlife

Interaction Diagram (HWID, Marchini et al., 2021)—defines the four archetypal HWI representations based on the impact of the interaction for both the wildlife and the people directly involved (Figure 1), namely, (i) Human-wildlife conflict: negative for both sides, as when there is a preventive or retaliatory killing of jaguars due to an actual or expected attack by the jaguar on livestock; (ii) Overexploitation of wildlife: negative for wildlife while some people benefit from the interaction, as when vulnerable species like the jaguar in Brazil are killed for commercialization and use of their parts for medicinal purposes; (iii) Nuisance wildlife: negative only for people, as in the case of pests (e.g., rats and pigeons), but also as when a jaguar breaks into a backyard causing a hassle and is then removed by the authorities and returned to the wild, and (iv) Human-wildlife coexistence, positive for both sides, as when part of the income generated by jaguar-watching tourism is allocated to conservation actions for the species.

In the left half of the HWID, the interactions are of conservation concern as they have negative impacts on wildlife. In the lower half, the concern is about their effects on the well-being of the people involved. The goal of Plan4Coex is to 'move' the interactions in the left and lower halves of the HWID not only to the right, which has been the focus of conservation, but also upwards. This shift does not necessarily have to be up to the win-win condition of the upper-right quadrant, which is sometimes unrealistic, but at least until a condition is reached where neither of the parties involved—wildlife and humans—receives a significant negative impact from the other, so that they can continue to "exist together" in a sustainable way (Marchini et al., 2021). In the HWID diagram, this coexistence threshold line corresponds to the parts of the two axes that delimit the upper right quadrant called coexistence.

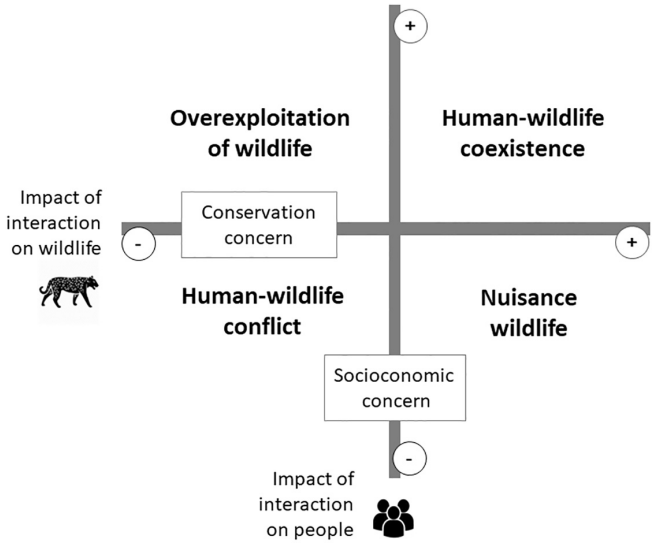

FIGURE 1 Human-wildlife interaction diagram (HWID). The two axes inform the impact of the interaction—from very negative to very positive—on the wildlife (horizontal) and people (vertical) involved, and together they define the four archetypal human-wildlife interactions: human-wildlife conflict, wildlife overexploitation, nuisance wildlife, and human-wildlife coexistence.

2.2 | Approach: From predictive modeling to systems thinking

Systematic efforts to plan for the conservation of biodiversity were initiated in the mid-1970s in response to the limited funding and ad hoc way in which protected areas had generally been established (Groves, 2003; Knight et al., 2013). Ever since, there has been an increasing application of techniques using computational tools for informing decisions about conservation in the face of limited financial resources (Knight et al., 2013). These approaches contribute to the development of plans for the implementation and continued application of conservation actions with the aim of reducing biodiversity declines in a transparent and socially responsible manner (Ball et al., 2009; Margules & Pressey, 2000). The term 'conservation planning' has been used in such studies, as the ultimate goal of planning is to conserve endangered species and/or their habitat. Conservation planning has indeed evolved in two different and mostly independent fronts: species-focused and ecosystem- or area-based planning.

Decision making in species conservation planning has relied on the results of ecological research and modeling, such as population viability (Desbiez et al., 2012; Lacy, 2019) and species distribution modeling (Ferraz et al., 2012; Ferraz et al., 2021). Decisions regarding spatial conservation prioritization have been based on cost-effectiveness analysis (McIntosh et al., 2017; Pressey et al., 1993), which can be supported by computational tools such as Marxan (marxansolutions.com) and Zonation (zonationteam.github.io/Zonation5/). The last decade has also seen an increasing emphasis on more rigorous measurement of effectiveness and disciplined recording of activities, such as that provided by the Open Standards for the Practice of Conservation (CMP, 2013) and its software platform Miradi.

In all cases, the fundamental assumption is that the conservation problem can be understood and predicted through the separate analysis of its parts and that there is an action or set of actions that, when implemented, results directly and definitively in the solution. Effectively grappling with the complexity of large-scale HWI

problems, however, may require explicit recognition of the four fundamental types of systems in which HWIs can be embedded, namely simple, complicated, complex, and chaotic (Figure 2) (Gorzeń-Mitka & Okręglicka, 2014), and that in the last two some or none of the causal relationships are known and therefore the way these systems respond to action is unpredictable.

In simple systems the relationship between cause and effect is clear to anyone involved: if you do X, expect Y. The advice in such a context is to assess the situation, categorize it, and then base your response on best practice. The solution to problems understood as a simple system usually has an established "correct" answer, based on an existing process or procedure. Simply put, it is about following the recipe or protocol and no expertise is required. For example, if the depredation of livestock by jaguars on a ranch is understood as a simple system where livestock in pens without electric fences are more vulnerable to jaguar attack, then the solution is the installation of electric fences; there is a better way to install it and the instruction to do so can be found in a manual.

On the other hand, problems understood as complicated systems may contain multiple right answers. Because the complicated system calls for analyzing several options, good practice, as opposed to best practice, is more appropriate. No single person knows enough about all facets of a complicated system; therefore, the choice of good practice must be made by a group of experts. For example, jaguar persecution in a given region can be understood as a complicated system involving economic, social, cultural and institutional factors; no manual has a ready-made solution for this and therefore a group of people with complementary expertise is needed to decide together how to deal with the problem.

On sufficiently large scales, however, HWI can be better understood and managed as systems that are more than complicated, they are complex. A complex system is composed of many components that interact with each other. It has distinct properties that arise from these interactions, such as nonlinearity, emergence, feedback loops, and adaptation. The system cannot be understood in terms of its parts separately. With emergent properties, the whole is more than the sum of the parts, as when the change in end results is not proportional to the change in inputs. While a positive feedback loop can magnify the effect of a small input, a negative feedback loop can render the system resilient (Figure 3). As a hypothetical example, community outreach can increase community engagement, which in turn can increase social trust in the management agency, which in turn can increase even further community engagement, so that a small input in

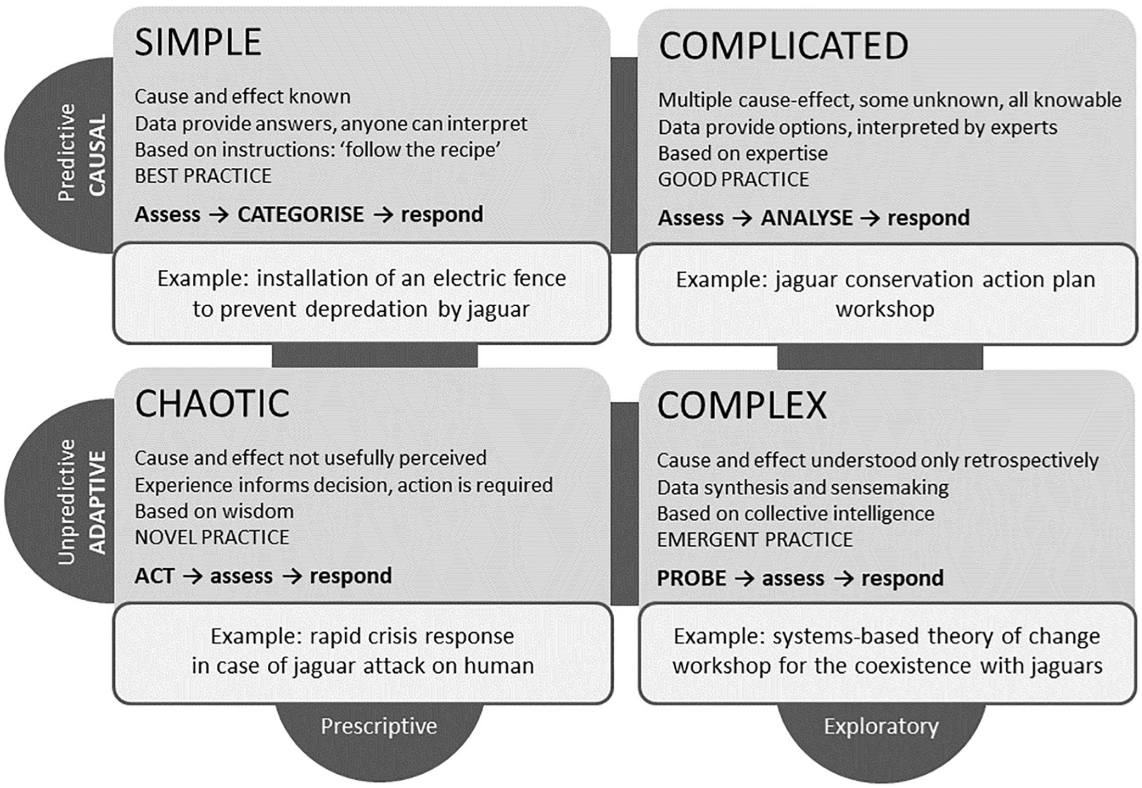

FIGURE 2 Types of systems and their implications for decision-making in the management of human-wildlife interactions (adapted from Snowden, 2002).

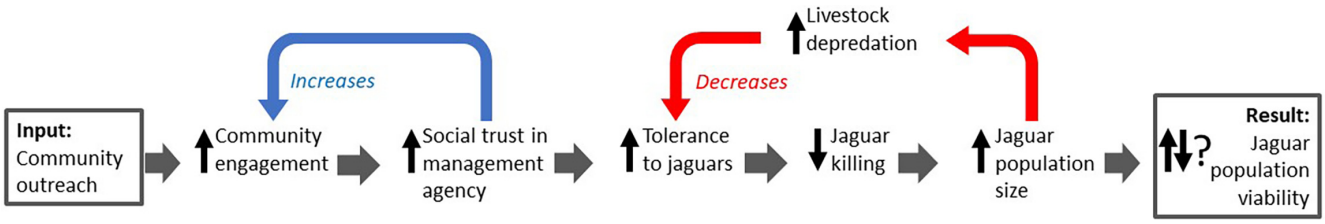

FIGURE 3 Hypothetical chain of results in a complex system. Nonlinearity and positive and negative feedback loops (blue and red arrows, respectively) confer emergent properties to the system, for example, resilience, so that the end result—whether or not community outreach will increase jaguar population viability—can only be known retrospectively.

community outreach results in a disproportionately big change. Conversely, it is conceivable that increased tolerance to jaguars reduces retaliatory killing, which increases jaguar population size, which increases livestock depredation, which reduces tolerance, so that the system returns to its initial state. In complex systems, cause and effect can only be deduced in retrospect. Instead of expert analysis, as in complicated systems, experimentation and sensemaking are more appropriate. Instead of linear, predictable paths to solution, continual adaptive management is a more realistic expectation when dealing with a complex system.

Finally, in the chaotic system, no cause-and-effect relationship is evident. An example of a chaotic system is a crisis, in which a decision must be made without time to systematically take into account expert opinion, as in complicated systems, or to understand how the system behaves in response to inputs, as in complex systems. A jaguar attack on a human, for example, can suddenly turn a complicated or complex system into a chaotic one.

We argue that, due to the analytic tradition of wildlife science, and the expectation of ready-made one-size-fits-all solutions by the stakeholders, decision-making in HWI planning and policy tends to take as complicated—or even simple—systems that are, in fact, complex (Note: a complex system can contain complicated systems and simple systems). This can render such plans and policies ineffective.

In the Plan4Coex workshops, participants model the factors that directly and indirectly determine the HWIs of interest, articulating the evidence versus assumptions behind each causal relationship, aware of the parts of the system that should be understood as simple, complicated, and complex. With proper facilitation, they are guided through the different dimensions of the system—ecological, behavioral, personal, social, institutional, and societal (Marchini et al., 2021). The model produced reflects the collective knowledge and opinion of the participants. The more diverse the group of participants, the more complete, reliable, and useful the system map produced will be.

2.3 | Emphasis: From actions to verifiable change

The prevalent process and product of conservation planning, particularly for national-scale plans, is the Action Plan (CBD, 2011). The process consists of bringing together experts, who analyze the conservation status and threats, and generate a list of recommended actions (Desbiez & Paula, 2012). As the name suggests, the emphasis of such plans is on actions. The monitoring and evaluation component of action plans typically focuses on action outputs.

Plan4Coex shifts the emphasis from actions to verifiable results by considering the intermediate outcomes that causally connect action outputs to the ultimate impact on HWIs, in other words, by creating a Theory of Change (ToC, Center for Theory of Change, 2013; Marchini et al., 2023). Fundamentally, the participants describe the causal pathways in terms of inputs, actions, outputs, short- to long-term outcomes and desired final impact, choose indicators for each product and effect and, in doing so, generate a framework for monitoring, evaluation and learning (McLellan, 2020). Adequate monitoring of changes in key elements of the system—which implies choosing the right indicators—is crucial for decision-making in the adaptive management of complex systems.

The development of a ToC serves as a platform for researchers, decision-makers, practitioners, and community members involved in HWI management to collaboratively and more fully and explicitly address the pathways needed to achieve the desired change. It also allows the various and diverse stakeholders understand how and why a system works and changes unfold. A ToC can also serve as a communication tool for the various sectors, groups and individuals embedded in an HWI system.

The use of ToC in planning and evaluation has increased among philanthropies, government agencies, development organizations, universities, international NGOs, the UN, and many other major organizations in both developed and developing countries (McLellan, 2020).

Although it was in the mid-1990s that ToC emerged as a new way of analyzing the theories motivating programs and initiatives working for social and political change (Weiss, 1995), it has only been in the last decade that the approach has become increasingly incorporated into the human-wildlife conflict and coexistence literature (Figure 4).

3 | PLANNING FOR HUMAN-JAGUAR COEXISTENCE IN THE PANTANAL

The Pantanal is one of the most important strongholds of the jaguar, where 64% of the biome is adequate habitat for the species (Tortato et al., 2021) and the population size is estimated to 1668 individuals (Barros et al., 2022). However, with the remarkable prevalence of cattle ranching, people and jaguars have a long history of conflict in the region, where jaguars negatively impact livelihoods by preying on livestock and ranchers in turn perpetuate a long tradition of killing jaguars in retaliation or prevention of livestock depredation (Marchini & Macdonald, 2012; Porfirio et al., 2016). In recent decades, human-jaguar interactions have become more diversified in the Pantanal, both in terms of their impacts on both jaguars and people and in terms of stakeholders directly and indirectly involved in the interactions.

In light of this trend, along with the vast expanse of the biome and the large number of institutions dedicated to jaguar research and conservation in the region, the Plan4Coex approach is particularly appropriate as part of a biome-wide strategy to improve human-jaguar interactions. Below is a brief contextualization of human-jaguar interactions and a description of the Plan4Coex workshop with institutions involved in jaguar research and conservation in the region.

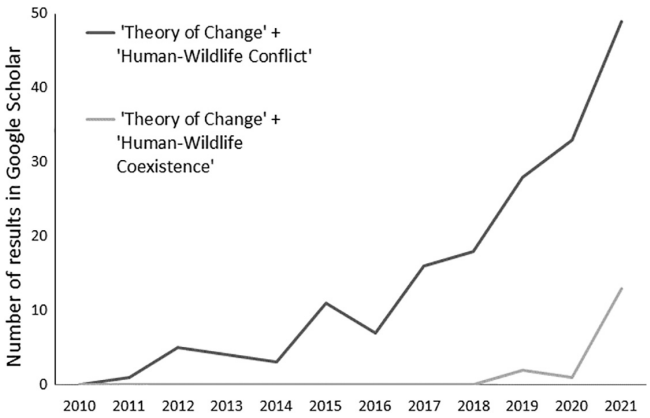

FIGURE 4 Number of peer-reviewed articles on theory of change in the human–wildlife interaction literature published from 2010 to 2021 based on literature search in the Google Scholar database. Search strings are "Theory of Change + Human–Wildlife Conflict" and "Theory of Change + Human–Wildlife Coexistence".

3.1 | Context: People and jaguars in the Pantanal

Livestock was introduced in the Pantanal over 200 years ago. Ever since, predation on cattle has been a justification for preventive and retaliatory killing of jaguars (Marchini & Macdonald, 2012; Zimmermann et al., 2005). Also, commercial hunting for skin export until the late 1960s decreased jaguar population, although not enough to prevent retaliatory killing, even with the banning of hunting in Brazil in 1967 (Tomas et al., 2018). In the last three decades, this relationship has been causing growing concern among conservationists, who have approached the problem from the perspective of 'human-wildlife conflict' (Quigley & Crawshaw Jr, 1992; Zimmermann et al., 2005: Cavalcanti et al., 2012; Tomas et al., 2019). The jaguar population increased in the Pantanal after the sequence of high flood years that started in 1974 and lasted at least to 1995, which spared large areas of suitable habitats for jaguar and provided less contacts between cattle and these large cats (Tomas et al., 2018). More recently, the jaguar has also taken an increasingly important role as a tourist resource in the region (Tortato et al., 2017; Tortato & Izzo, 2017). The extensive fires associated with the pronounced drought in 2019 and 2020 brought the Pantanal, its people, biodiversity, and jaguars, to the focus of attention and concerns (e.g., Barros et al., 2022; Garcia et al., 2021; Tomas et al., 2021).

Over the last 25 years, conservation plans have been developed aiming at prioritizing areas for conservation within the Pantanal biome and for the conservation of the jaguar within its range, and the recommendation of actions for the conservation of the jaguar on a national scale. These initiatives are, respectively: (i) Priority Areas and Actions for Biodiversity Conservation, (ii) Jaguar Conservation Units (JCUs), and (iii) National Action Plans (NAP) for the Conservation of Endangered Species. The three are briefly described below.

Between 1996 and 2001, The Secretariat of Biodiversity and Forests of the Ministry of the Environment of Brazil, through the Conservation and Sustainable Use of the Biological Diversity Project—PROBIO, supported projects to assess priority areas and actions to biodiversity conservation. The workshop for Cerrado and Pantanal was held between 23 and March 27, 1998, in Brasília, coordinated by the Pro-Natura Foundation (FUNATURA) in partnership with the University of

Brasília, Conservation International Brazil, André Tosello Research and Technology Foundation, Biodiversitas Foundation, and Society, Population and Nature Institute (ISPN). This workshop was attended by more than 200 experts and aimed at producing maps of priority areas for conservation of biodiversity in the Cerrado and Pantanal.

In 1999, the Wildlife Conservation Society (WCS) and the National Autonomous University of Mexico organized a range-wide priority setting and planning exercise for the jaguar by bringing together experts from 18 range countries. These jaguar experts identified currently known jaguar ranges and areas with significant jaguar populations, suitable habitat, and a stable and diverse prey base, called Jaguar Conservation Units (JCUs) (Sanderson et al., 2022; Zeller, 2007). Ninety JCUs (updated by Zeller, 2007), representing 1.9 million km^2 or 10% of the historic jaguar range, were identified as being important to the long-term survival of jaguars. Twenty-six jaguar populations in Brazil were included in the JCU framework; the jaguar population in the Pantanal was one of them.

The first NAP in Brazil—for the conservation of the Southeastern curassow (*Crax blumenbachii*)—was produced in 2004, by the Brazilian Institute of the Environment and Renewable Natural Resources (IBAMA) (Vercillo et al., 2022). As a signatory to the Convention on Biological Diversity (CBD) and by ratifying the Strategic Plan and the Aichi Targets, Brazil assumed the international commitment to act for the conservation of biodiversity. This commitment was received through the National Commission of Biodiversity (CONABIO). For that, a methodology was established for the elaboration and monitoring the implementation of NAP for the conservation of endangered species. The methodological design of the NAP provides for the definition of a vision of the future, general objective, specific objectives, and actions, focusing on the main threats to be reduced or suppressed within the timeframe of 4 or 5 years (Vercillo et al., 2022). The NAP for the conservation of the jaguar was produced in 2010 (Desbiez et al., 2013) and another one for the conservation of the puma was produced in 2012. In 2018, the two plans were revisited and merged into one, the NAP for the conservation of big cats (NAP Big Cats).

We believe that Plan4Coex makes a timely contribution to the above initiatives and can complement the NAP by broadening the spectrum of HWIs of interest beyond the conservation focus and, in doing so, expands the stakeholder base and engagement. Furthermore, by providing a more accurate basis for monitoring and evaluating results, the approach provides more solid bases for decision-making in adaptive management.

3.2 | The Plan4Coex workshop

A Plan4Coex workshop for jaguars in the Pantanal was conducted on May 10–12, 2022, in the city of Campo Grande, State of Mato Grosso do Sul, Brazil. The workshop was an initiative of World Wide Fund For Nature in Brazil, WWF-Brasil, which is a Brazilian NGO and part of the WWF network. WWF-Brasil has been supporting conservation projects in the Pantanal over the last 16 years. Work includes research on the impacts of land use and climate change, the calculation of ecological footprints and monitoring of vegetation cover. Together with Instituto Pró-Carnívoros, WWF-Brasil carried out in 2021 an assessment of conflicts with jaguars in the Pantanal based on the SAFE methodology employed by the WWF network (NPPC and WWF-Bhutan, 2016).

As a follow-up to the assessment, WWF-Brasil organized the Plan4Coex workshop described below, bringing together 15 representatives from the institutions behind jaguar-related research and decision-making at the scale of the Pantanal biome, namely, Embrapa Pantanal, CENAP-ICMBio, Instituto Pró-Carnívoros, Panthera Brasil, Onçafari, SOS Pantanal, Instituto Homem Pantaneiro, and Ampara (Table A1). The workshop objectives included the extraction and integration of information from the perspective of decision makers, with a view to exploring the application of this process to other planning approaches, such as NAPs. In the 3 days of the plan4coex workshop, the participants were firstly introduced to the conceptual bases of 'planning for coexistence' and then guided through the fundamental parts of the workshop process: (i) scoping and goal setting, (ii) system mapping, and (iii) theory of change and monitoring & evaluation framework.

3.3 | Part I: Scoping and goal setting

Using the HWID as a framework (Figure 1), participants positioned all the human-jaguar interactions of interest in the Pantanal, informing the importance of each one in relation to the others in terms of its impact on both jaguar and people, and listed the stakeholders directly and indirectly involved in each interaction. Figure 5 illustrates the results. The 27 stakeholders directly involved in these interactions and the 54 indirectly involved are shown in Table A2. The parameters to assess the situation of jaguars and people, and the changes within 5 years, were (i) risk of death and (ii) financial and psychological impact, respectively.

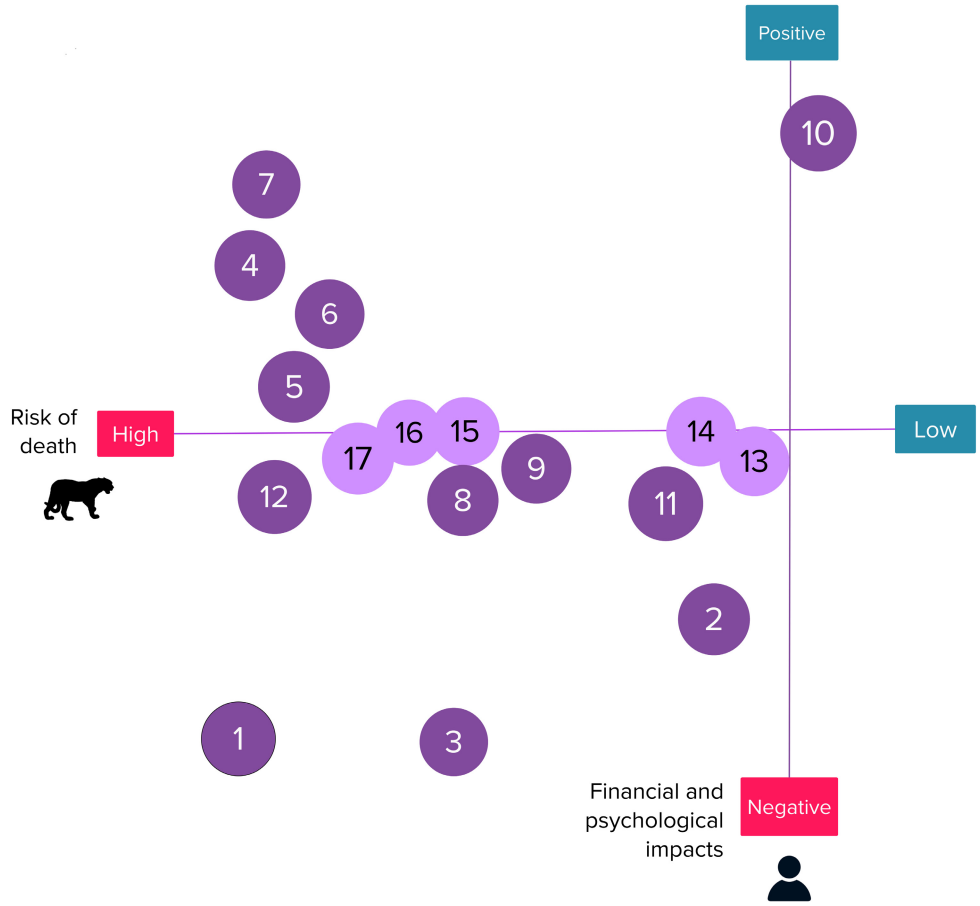

FIGURE 5 Human-wildlife interactions diagram (HWID) for jaguars in the Pantanal: parameters to explicitly describe the situation of the jaguar (horizontal axis) and the people involved (vertical axis), and the relevant interactions (dark purple circles): 1. depredation of farm animals, 2. depredation of pets, 3. attacks on people, 4. jaguar killing due to conflict, 5. opportunistic jaguar killing, 6. recreational killing of jaguars, 7. commercial jaguar hunting, 8. jaguar invasion of urban areas, 9. baiting jaguars for tourism purposes, 10. jaguar-watching (tourism), 11. jaguar collision with vehicle, and 12. changes to the ecosystem. Light purple circles are threats to jaguars pointed out by the participants, but which do not have a direct impact on humans (therefore, they are not a coexistence issue): 13. zoonosis, 14. use of jaguar as pet, 15. pollution, 16. wildfire, and 17. habitat fragmentation.

3.4 | Part II: System mapping

Once the 'what', 'who', 'where' and 'when' of the human-jaguar interactions (and desired changes) were completed, the next question was 'why' is this so? Taking as a starting point the focal interactions to be changed, the participants examined the factors that directly and indirectly determine each interaction. Predictive causality relationships supported by literature or local knowledge were pointed out, defining the parts of the system that can be understood as simple or complicated.

A central premise at this point, however, is that interactions are embedded in complex systems so that the participants should be attentive to hidden links, including unanticipated side effects and feedback loops. Appropriate facilitation is used to get participants to think about the different levels of the system, which go beyond the direct ecological and behavioral determinants of HWI to also include the social, institutional, and societal dimensions and their issues, such as governance and policy.

3.5 | Part III: Theory of change and monitoring & evaluation framework

Once the system map was produced, the question was 'how' to bring about the desired changes. Participants identified 27 leverage points (Table A3), that is, factors on which it is possible to target interventions and whose effects should result—directly or indirectly—in the desired changes. A total of 37 determining factors are directly or indirectly affected by the actions. The actions should be performed by 22 different actors in the academic, government, non-profit and private sectors (Tables A2 and A3).

Lastly, the participants produced a framework for monitoring and evaluation of results (Table A3). More specifically, indicators and respective means of verification were listed for each of the action outputs, outcomes, and interactions. The monitoring and evaluation framework is a tool that allows the assessment of the (i) effectiveness of the project: degree to which it achieves the final impact on human-jaguar interactions, (ii) efficiency of the actions: output/input ratio; the more outputs with fewer inputs—money, time, personnel—the more efficient, and (iii) efficacy of the actions: degree to which they cause the specific expected direct and indirect outcomes.

4 | DISCUSSION AND CONCLUSIONS

The process of planning for human-wildlife coexistence outlined above, with its emphasis on verifiable change, enables the connection between research and implementation, providing an effective evidence-based, structured, and participatory decision-making mechanism. Furthermore, by explicitly recognizing that the system in question is complex and therefore largely unpredictable, the proposed approach favors the pragmatism of adaptive management instead of the often unrealistic expectation of a linear path to solution (Mahajan et al., 2019), or in other words, a shift from the notion of human-wildlife coexistence as a quantifiable target to that of coexistence as a desired system state. The larger the scale of the plan, both spatially and in terms of the number of stakeholders involved, the more useful this approach can be. Considering the size of the Pantanal and its institutional setting, we believe that the approach can provide a particularly promising path for coexistence between people and jaguars in the region.

The two parts of the workshop that precede the choice of actions—populating the HWID and producing the system map, both based on graphic representations—offer a unique platform for participants to clearly define the scope of the plan and articulate the expected results in a consensual and more precise and detailed way. While the NAP Big Cats currently addresses five 'independent' interactions in more general terms, namely livestock depredation, conflict-driven persecution, jaguar-vehicle collision, jaguar-watching tourism, and poaching, in the Plan4Coex workshop participants raised a total of 17 specific interactions that relate with each other, indicating the importance of each one relative to the others in terms of its impact on both jaguars and humans. In fact, some of the interactions—pollution, wildfires, habitat fragmentation, zoonosis and use as pet—were of conservation relevance only, lying on the horizontal axis on the left side of the diagram, meaning they have negative impacts on jaguars, but no relevant impact on the people directly involved. Because the coexistence approach emphasizes mutual impacts, these interactions were not addressed in the system mapping.

The system mapping is based on scientific evidence and local knowledge, revealing both the collective intelligence about the interactions as well as knowledge gaps, thus serving as guidance for research efforts. The 'backwards' construction of the ToC, starting with the human-jaguar interactions and then adding their most immediate drivers followed by the indirect causal factors and finally the interventions—and appropriate facilitation that encourages participants to reflect on different levels of the drivers of interactions, from ecological to psychological to social to societal—inevitably surfaces drivers that tend to be overlooked when researchers and decision makers are unfamiliar with the human dimensions of HWI. While the causal relationships involving ecological and environmental factors are in general corroborated by empirical evidence (e.g., 'outdated agricultural practices' is a driver of 'wildfires', Teodoro et al., 2022), several connections between social factors are suppositions that require support from social science research (e.g., 'preventive/retaliatory killing' caused by 'perceived risk' which is changed by 'social marketing campaign').

On the other hand, the systems thinking behind the ToC is a synthetic rather than analytic approach, encouraging participants to make sense of the plan as they visualize and get awareness of both the system as a whole and the specific parts of the system where they can act. This, in turn, can provide a sense of ownership among participants. Compared with the leap between action and final impact of a conventional action plan (e.g., environmental education workshops causing 'reduction of jaguar vulnerability to improve the conservation status of their populations', NAP Big Cats), the detailed mapping of intermediate and more proximal factors allows participants to understand and monitor the changes they actually cause with their actions. For example, while demonstrating the connection between the action 'creating fiscal incentives' and a decrease in the interaction 'opportunistic killing' can be challenging, especially in the short term, monitoring the effects on the intermediate factor 'perceived loss' is more viable. This not only makes adaptive decision-making possible, but also maintains engagement in the face of evidence of shorter-term success. Follow-up monitoring and evaluation workshops with the first projects that implemented the plans, such as the Jaguars of Iguaçu Project, are now being conducted and are providing evidence of the effectiveness of

the adaptive coexistence management made possible by this approach.

The workshop we describe here is part of a broader WWF-Brasil program and aimed to bring together representatives of institutions dedicated to jaguar conservation in the Pantanal to co-create a ToC that could integrate their agendas. Next steps in the strategy for coexistence with jaguars in the Pantanal focus on the participation of ranchers, as in the series of workshops currently underway within the scope of the Pontes Pantaneiras project (led by the Ecological Research Institute [IPE], Embrapa Pantanal, Smithsonian Institution and University College London) in which representatives from several local cattle ranching associations, certification companies and some participants in the plan4coex workshop are designing a ToC for sustainable cattle ranching in the Pantanal in light of the results reported here. Decision makers in the public sectors will also be relevant, ensuring that the plan is aligned with the prevailing public policy context, and increasing the buy-in necessary for the plan to be effectively supported, funded, and implemented.

Different stakeholders may have different understandings of the scientific, legal, economic, and practical aspects of the problem, which can pose a challenge for participatory planning (David-Chavez & Gavin, 2018; Young et al., 2023). The use of appropriate facilitation methods, such as the 'world cafe', guarantees the proper extraction, integration and organization of these understandings, as some recent plan4coex workshops have demonstrated. Two examples are the workshop held by WWF-Brazil for river dolphins in the Amazon in March 2023, and the one held by the San Diego Zoo Wildlife Alliance for jaguars in the Peruvian Amazon in June 2023, which brought together researchers, conservationists and representatives of fishing, riverside, and indigenous communities. The visual and logical approach to the process, based on sense-making rather than analytical thinking, and the explicit aim of promoting coexistence rather than conservation, for the benefit of wildlife as well as the people involved, has proven to provide an effective platform for transdisciplinary collaboration between different stakeholders.

As the workshop process is refined and consolidated, the main challenges become what happens before and after the workshop. In preparing the workshop, selecting the group of participants is crucial. Issues of representation, commitment, availability and timing must be worked on carefully. After the workshop, the challenge is to go beyond the more abstract objectives of a strategic plan to focus on the more concrete tactical and operational objectives, that is, implementation and execution, respectively. A recurring obstacle at this point is—in addition to the usual lack of time and financial resources—the lack of capacity to collect social data that serves as indicators. In this case, participants must receive the necessary assistance, which may take place in a dedicated training workshop. This has been done, for example, with the Jaguars of Iguaçu Project team.

The concept of planning for coexistence (Marchini et al., 2019), and even the very concept of human-wildlife coexistence, is relatively new in the wildlife conservation literature (Frank et al., 2019; Glikman et al., 2021; IUCN, 2023; Pooley et al., 2020). Likewise, the process put into practice at the Pantanal workshop is still a work in progress. However, thanks to the support of key players such as WWF-Brasil, San Diego Zoo Wildlife Alliance and CENAP-ICMBio, Plan4Coex workshops for different species have been conducted in various parts of Brazil and Latin America. The plans for coexistence with jaguars specifically were produced by groups with representatives from governmental and non-profit organizations, the private sector and local communities also in different locations in the Amazon (Southern Amazonas [2021], Paragominas [2022], and Chico Mendes Extractive Reserve [2023] in Brazil, and Loreto and Madre de Dios [2023] in Peru), Atlantic Forest of Brazil and Argentina (Jaguars of Iguaçu and Yaguareté projects [2019], and Large Mammals of Serra do Mar Project [2022]), Caatinga (Boqueirão da Onça, Serra da Capivara and Serra das Confusões National Parks [2021]), and in Costa Rica (Osa Peninsula [2022]). Our expectation is to expand this network of partners and eventually integrate the results to explore the design of a ToC for the coexistence with jaguars on a national scale, as a refined complement to the NAP Big Cats. Another next step will be to assess the performance of the approach in terms of monitoring outcomes and making decisions based on these outcomes, that is, as a basis for actual adaptive management of human-wildlife interactions. Finally, our expectation is that the Plan4Coex fundamentals can be incorporated into the planning and policy-making processes around other species threatened or involved in problematic interactions with humans. As this community of planners, decision makers and practitioners grows, we look forward to learning and supporting each other in advancing the goal of coexisting with wildlife.

AUTHOR CONTRIBUTIONS

Silvio Marchini and Ricardo Boulhosa facilitated the workshop, Silvio Marchini and Walfrido Moraes Tomas conceptualized the article, Silvio Marchini led the writing and the submission of the manuscript. All authors extensively contributed and discussed ideas in the workshop and reviewed the manuscript.

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DATA AVAILABILITY STATEMENT

All data used to generate this study are presented in this article.

ETHICS STATEMENT

The authors are not aware of any ethical issues regarding this study.

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APPENDIX A

TABLE A1 Institutions participating in the Plan4Coex Jaguars in the Pantanal workshop.

Institution	Type	Work with jaguar and/or Pantanal
Ampara Animal	Non-profit	Ampara is an animal protection organization that has been working in the Pantanal since the forest fires of 2020, where it worked directly with the rescue, treatment and rehabilitation of animal victims of the fires. Currently, Ampara Silvestre has a service base for Pantanal fauna, on the Transpantaneira Highway in the Municipality of Poconé, MT. The institution also supports and participates in conservation projects in partnership with the most diverse institutions operating in the Pantanal biome.
CENAP-ICMBio	Governmental	CENAP is a Brazilian center for research, management and conservation of carnivorous mammal species that occur in the country. Its projects are national in scope. It was created by IBAMA in 1994 with the aim of stimulating, coordinating and developing management, research and conservation activities, at a national level, with the species of carnivorous mammals. It is currently a member of the Chico Mendes Institute for Biodiversity Conservation—ICMBio, a federal agency created after the restructuring of IBAMA.
Embrapa Pantanal	Research	Brazilian Agricultural Research Corporation, under the aegis of the Brazilian Ministry of Agriculture and Livestock, has 43 research centers distributed all over Brazil, focused on the development of technological foundations for a tropical model of agriculture, animal farming, natural resources and sustainability. Among them, Embrapa Pantanal is a research center focused on eco-regional approaches for sustainability, including cattle ranching, fisheries, small farms, ecosystem services, and biodiversity conservation.
Instituto Homem Pantaneiro	Non-profit	IHP is a non-profit Brazilian NGO working on the conservation of the Pantanal biome and the local culture. Among the activities carried out by the institution, it is highlighted the management of protected areas, research development and promotion of dialogue between actors with an interest in the area. Since 2016, it has been developing Felinos Pantaneiros Program, whose main objective is to propose and implement management actions that aim to minimize problems caused by the predation of cattle by large cats, ensuring best practices and a reference in the coexistence between production and conservation. In addition to evaluating anti-predation strategies, the project estimates and evaluates, using camera traps, ecological aspects of the felids and develops environmental education actions.
Instituto Pró-Carnívoros	Non-profit	The Institute for the Conservation of Neotropical Carnivores—Instituto Pró-Carnívoros—is a private, civil association, with nongovernmental and non-profit status. Founded in 1996 with the mission of promoting the conservation of neotropical mammalian carnivores and their habitats, the Institute develops research and conservation projects throughout Brazil. It is active in all of the Brazilian biomes and targets all 26 species of the Order Carnivora found in Brazil. Activities include (a) Development of scientific research to provide the information needed for the conservation of carnivores and their habitats; (b) Propose strategies and management actions to ensure the long-term survival of carnivores; (c) Identification and protection of priority areas for carnivore conservation; (d) Guidance in cases of livestock depredation by wild mammalian carnivores; (e) Training professionals specialized in the management and conservation of wild predators; (f) Development of environmental education programs; (g) Production and dissemination of educational and outreach materials; (h) Supporting and development of public policies for species and habitat conservation.
Onçafari		Since 2011, it has collected data and assembled information to grasp a better understanding on jaguar behavior, as well as discover better conservation strategies for the biggest feline of the Americas. Its goals include conserve the biodiversity of the areas in which we operate; socioeconomic development of the regions in which we operate; transformation and upgrade of the Pantanal culture; increased scientific knowledge about jaguars; consolidation of ecotourism as a tool for conservation; increase the number of visitors in the Pantanal and Cerrado; and reintroduction of jaguars into nature.
Panthera Brasil		Panthera Brasil is a Brazilian NGO, founded in 2014, which aims to conserve wild cats. It is dedicated exclusively to the conservation of the nine national species of wild cats and their ecosystems. Representing the most comprehensive effort of its kind, Panthera partners with local and international NGOs, scientific institutions, local communities, governments around the world and citizens who want to help secure a future for jaguars in the Pantanal.

TABLE A1 (Continued)

Institution	Type	Work with jaguar and/or Pantanal
SOS Pantanal	Non-profit	SOS Pantanal Institute works for the conservation of the Pantanal, promoting the improvement of public policies, the dissemination of knowledge and the development of projects for the sustainable use of the biome. We encourage the necessary transformations through science and dialogue with the various sectors of civil society and government. We work on five different fronts: Incidence in Public policies; Wildfire combat and prevention; Socio Environmental restoration; Production and dissemination of knowledge about the Pantanal biome and culture; Water resources monitoring.
WWF-Brasil	Non-profit	Part of the WWF Network, WWF-Brazil is a non-profit Brazilian NGO working to change the current trajectory of environmental degradation and promote a fairer and healthier future for all, in which society and nature live in harmony. WWF-Brazil works with jaguar conservation in various landscapes across Brazil by monitoring populations, producing scientific knowledge, and promoting coexistence.

TABLE A2 Stakeholders of the coexistence between people and jaguars in the Pantanal, Brazil.

	Stakeholder	Directly involved in the interaction	Indirectly involved in the interaction		
			Increase positive/ decrease negative interaction	Increase negative/ decrease positive interaction	Actor of management action
1	Academia		■		■
2	Bad media influencers			■	
3	Bait catcher			■	
4	Baiter			■	
5	Boat pilot	■	■	■	
6	Buyer (wildlife illegal trade)			■	
7	Car driver	■			
8	CENAP—National Center for Carnivore Conservation		■		
9	Certifier		■		
10	Civil Defense Agency		■	■	
11	Coal industry			■	
12	Commodities buyers			■	
13	Cowboy	■		■	
14	CRAS—Wildlife Rehabilitation Center		■		
15	Customs Enforcement		■		
16	Deforestation company			■	
17	DNIT—National Department of Transport Infrastructure		■	■	■
18	Embrapa		■		■
19	Energy sector			■	
20	Environmental educator		■		
21	Federal institutes				■
22	Federal Police		■		
23	Financial institutions				■

(Continues)

TABLE A2 (Continued)

	Stakeholder	Directly involved in the interaction	Indirectly involved in the interaction: Increase positive/ decrease negative interaction	Indirectly involved in the interaction: Increase negative/ decrease positive interaction	Indirectly involved in the interaction: Actor of management action
24	Firefighters		■	■	■
25	Gold miner			■	
26	Hunt operator	■			
27	IBAMA—Brazil's Environmental Agency		■		
28	ICMBio—Chico Mendes Biodiversity Institute	■	■		
29	INCRA—National Institute of Colonization and Agrarian Reform			■	
30	Influencers				■
31	Insurance company		■		
32	Landowner	■	■	■	■
33	Local business				■
34	Local community			■	
35	Local governance		■		■
36	Local resident	■	■	■	
37	Media		■		■
38	Middleman (wildlife illegal trade)			■	
39	Mining industry			■	
40	MP—Brazilian Public Ministry		■		■
41	NGOs Non-Governmental Organizations		■		■
42	OEMA—State Environmental Organization	■	■	■	■
43	OFMA—Federal Environmental Organization	■			
44	OMMA—Municipal Environmental Organization	■			
45	Opportunistic poacher	■			
46	Pet owner	■		■	
47	PMA—Environmental Military Police		■	■	
48	Poacher	■	■	■	
49	Prevfogo				■
50	PRF—Federal Highway Police		■		
51	Professional poacher	■			
52	Ranch hands			■	

TABLE A2 (Continued)

	Stakeholder	Directly involved in the interaction	Indirectly involved in the interaction: Increase positive/ decrease negative interaction	Indirectly involved in the interaction: Increase negative/ decrease positive interaction	Indirectly involved in the interaction: Actor of management action
53	Ranch manager			■	
54	Rancher	■			
55	Research institutes		■		
56	Researcher		■	■	
57	Resettled	■			
58	Riverside dwellers	■			
59	Road concession		■	■	■
60	Rural workers union		■		■
61	SEBRAE—Brazilian Micro and Small Business Support Service				■
62	SENAC—National Commercial Apprenticeship Service				■
63	Sensationalist media			■	
64	Slaughterhouse			■	
65	Small landowner	■			
66	Social service				■
67	State agencies				
68	State transport agency			■	
69	Steel mills			■	
70	Tax authorities				■
71	Tour agent		■		
72	Tour driver	■		■	
73	Tour guide	■	■	■	
74	Tourism developer			■	
75	Tourism enterprise owner	■			
76	Tourist	■		■	
77	Tourist boat pilot	■	■	■	
78	Tourist land owner	■		■	
79	UNESCO—United Nations Educational, Scientific and Cultural Organization	■			
80	Urban population	■		■	
81	Visitor	■			

TABLE A3 Table of indicators and means of verification of impact on human-jaguar interactions, outcomes (i.e., effects on the drivers of interactions) and outputs of actions.

	Interaction	Definition	Indicator	Mean of verification
1	Jaguar predation on domestic farm animals	Jaguars cause death or injuries on domestic animals, such as cows, sheep, horses	Number of properties adopting preventive solutions	Inventory of properties adopting preventive solutions
2	Jaguar predation on pet animals	Jaguars cause death or injuries on pet animals, such as dogs	Number of properties or households reporting losses	Inventory of properties or households reporting losses
3	Jaguar attack on people	Jaguars directly causing death or injuries on people	Number of recorded attacks	Survey of cases (CENAP, hospitals, Environmental Police, firefighters)
4	Jaguar killing due to conflicts	Jaguars are killed as a form of prevention or retaliation due to predation on domestic animals or attacks to people	(1) Number of properties with high potential for jaguar killings (2) Number of properties with domestic animals (3) Number of reported predation cases	Triangulation among the information obtained from different institutions and local stakeholders -INDEA and IAGRO -Institutions in charge of prevention and control
5	Opportunistic killing of jaguars	Jaguars are killed during occasional encounters in which the "hunter" had no intention of killing until this moment	(1) Number of properties that does not provide meat for its employees (forcing them to hunt) (2) Number of areas occupied by traditional communities	Triangulation among information obtained at different local stakeholders/institutions
6	Recreational killing	Jaguars killed as a specific leisure activity; sport hunting	(1) Number of fines applied (2) Number of properties with high potential for jaguar killing occurrences	-Environmental Police, SEMA, IMASUL, Federal Police -Triangulation among information obtained at different local stakeholders/institutions
7	Commercial hunting for jaguars	Jaguars are killed for profit via commerce of body parts (e.g., fangs, skin, etc.)	(1) Number of fines applied (2) Number of properties with high potential for jaguar killings	-Environmental Police, SEMA, IMASUL, Federal Police -Triangulation among information obtained at different local stakeholders/institutions
8	Invasion of urban areas by jaguars	Encounter with jaguars that occasionally enter urban areas	Number of records of jaguars observed/detected urban areas	Survey of records of jaguar occurrence in urban areas, in the files of firefighters, Environmental Police, NGOs
9	Baiting of jaguars	Use of attractants—typically food—to increase the probability of jaguar observation by tourists	Number of cases of baiting reported; number of digital contents on the internet related to baits, number of people fined for jaguar baits, number of companies and public receiving informational materials against the practice of baits, number of informational materials made available	Linha Verde (Green Line) from IBAMA, search in social media, consults to enforcement and control agencies/institutions (federal, state and municipality levels), assessments of the existing awareness-building initiatives
10	Jaguar observation	Deliberate activity of observing jaguars in the wild as a touristic attraction	Number of tourists engaged in this specific type of tourisms, number of tourism enterprises dedicated to this type out tourism, assessments of the lodging capacity dedicated to this type of tourism, number of tourists that successfully observed a jaguar in the wild during the trip, profit generated by jaguar observation tourism, number of employee directly or indirectly hired for this type of tourism, number of job opportunity generated by this type of tourism, diversity of job types associated to jaguar observation tourism	Data from state-level tourism secretaries, data from local and regional tourism associations, standard questionnaires destined for lodges, posadas, hotels to evaluate selected parameters, analysis of social media, data from capacity-building initiatives.

TABLE A3 (Continued)

	Interaction	Definition	Indicator	Mean of verification
11	Vehicle collisions on jaguars	Vehicle collisions involving jaguars, causing deaths or injuries (jaguars and eventually humans), as well as damage in the vehicles	Number of vehicle collision involving jaguars by time and space (km) units	Data from the DNIT and Highway Police reports, as well as from NGOs monitoring wildlife mortality
12	Ecosystem change	Indirect interaction between jaguars and ecosystem modifications by humans, such as deforestation, habitat fragmentation, wildfires, restoration, etc.	-Number of hectares of deforestation -Percentage of converted land -Number of hectares burned -Number of hectares restored -Percent of protected land -Number of land use types -Number of people benefited by best practices	-Land cover and land use monitoring initiatives (LAsA, INPE, MapBiomas) -IBAMA, ICMBIo, IMASUL, SEMA, Embrapa, ONGs, FAMASUL, FAMATO, INCRA, IBGE -Scientific publications -Certification initiatives
	Driver	**Definition**	**Indicator**	**Mean of verification**
1	Inadequate cattle ranch management		Number of properties adopting cattle ranching best practices based on indicators	Application of assessment tools to evaluate productivity/ sustainability based on adequate indicators
2	Lack of anti-predation strategies and practices on cattle ranches		Number of properties adopting recommended anti-predation management practices; extension of the area managed under anti-predation practices	Inventory/ranch monitoring
3	Resistance to innovation		Owner's /employee's attitude regarding the adoption of new management practices	Specific structured questionnaires (Theory of planned behavior and Diffusion of the innovation theory)
4	Lack of human resources		Number of properties assisted by extensionists trained to implement management best practices	Area assisted by extensionists
5	Lack of consolidation/ organization of the knowledge/knowhow		Number of technical publications in an accessible language containing organized knowledge related to best management practices; stakeholders' outreach (landowners, extensionists, employees)	Inventory of the quantity of existing publications, questionnaires evaluating the knowledge, possession, and use of the publications.
6	Extensionists technical training deficiency	Deficiency of technical training relative to the coexistence with jaguars	Existence of specific content related to the problem in the curriculum and/or short-time training	Assessment of the forma curriculum and training course availability
7	Lack of knowledge on the risks of jaguar predation on domestic animals and attack to people	Lack of knowledge related to the predation of pet animals and risk of attack to people	Number of people understanding the jaguar coexistence best practices	Structured interviews to assess the degree of knowledge/adoption of adequate procedures
8	Lack of public sensitization	Lack of sensitization related to risk of attack to pet animals and people, as well as to the practice of baiting jaguars for observation	Degree of sensitization among people exposed to coexistence with jaguars	Questionnaires to assess the degree of sensitization
9	Poaching/hunting directed to other wildlife species	It is related to the risk of jaguar defensive attack to people and opportunist killing of jaguars	Index of hunting/poaching activity	Questionnaires
10	Forms of exposition to interaction with jaguars other than hunting/poaching		Number of reported cases in which people were attacked by jaguars, with and without death, during activities other than hunting/poaching	Inventory of cases

(Continues)

TABLE A3 (Continued)

	Driver	Definition	Indicator	Mean of verification
11	Use of artificial vocalization tools to attack jaguars		Number reports on the use of sound devices ("esturrador", playback)	Interviews in tourism areas to assess the of searching methods applied to enhance the chances of observing jaguars
12	Perception of losses caused by jaguars	Perception of losses related to domestic animals, including pets, generating punitive or preventive jaguar killings	Degree of the perception of losses related to domestic animals, including pets, generating punitive or preventive jaguar killings	Structured questionnaires (Planned behavior theory and Innovation diffusion theory)
13	Perception of predation/ attack risk	Perception of the risk of predation of domestic animals and attack to people	Measurement of the degree of the perception of risk	Structured questionnaires (Planned behavior theory and Innovation diffusion theory)
14	Social norm related to jaguars		Behavior replicated by the majority of the local population	Structured questionnaires (Planned behavior theory and Innovation diffusion theory)
15	Permission by the landowner for poaching jaguars		-Reports	Triangulation among the information obtained from different institutions and local stakeholders
16	Inadequate rangeland/ pasture management		-Number of invasive species per hectare of pasture/rangeland -Herd's average corporal score -Number of fire spot in the prohibition period	Data bank containing the records of fire spots and delimitation of prohibition periods
17	Lack of knowledge on the rules and policies		Number of people/enterprises unaware of the specific legislation on fire management	Questionnaires and reports with published results
18	Guarantees of observing a jaguar offered by tourism enterprises/ guides		Number of reports on jaguar baiting; number of enterprises/people using baiting to attract jaguars	Interviews to assess search and observation methods practices by enterprises/people in areas of jaguar-focused tourism
19	Lack of knowledge on consequences of baiting jaguars for tourism		Number of people/enterprises not aware of specific legislation on jaguar/ wildlife baiting	Questionnaires and reports with published results
20	Protected jaguar populations		Percent of the jaguar distribution range covered by protected areas, and private properties adopting coexistence best practices	Maps of the existing protected areas within the jaguar distribution range -Maps of properties that adopt coexistence best practices
21	Marketing of tourism focused on jaguars		Number of news in the media, number of likes and sharing of social media contents related to jaguars; number of tourism events; number of campaigns on tourism, number of informative materials	Social media; FUNDTUR; SEDTUR; EMBRATUR
22	Income generation from jaguar-focused tourism		Raw profit of jaguar-focused tourism enterprises; number of fix and temporary in the tourism trade; local employment indexes; number of positions of direct and indirect jobs; average familiar income; prices of lodging rates in the tourism enterprises	Rural worker unions: state-level and municipal agencies related with work and employment (profit and employment), and tourism (taxes)
23	Agriculture expansion		Percent of the region's native vegetation that has been converted to agriculture	Mapbiomas Maps from the National Agriculture Confederation (CNA)

TABLE A3 (Continued)

	Driver	Definition	Indicator	Mean of verification
24	Cattle ranching intensification		Percent of the region converted to cultivated pastures; estimates of herd size, percent of the native vegetation converted into cultivated grasslands	Mapbiomas AGRAER EMPAER FAMATO/FAMASUL
25	Inadequate roads and highways		Number of collisions proportional to traffic intensity	Monitoring of roadkill and traffic intensity
26	Permissive legislation		Number of agrochemicals approved by federal agencies (ANVISA, Ministry of Agriculture); number of agrochemicals identified in urban water supply	-ANVISA homepage -https://portrasdoalimento.info/agrotoxico-na-agua/ -FAO
27	Excessive driving speed on roads/highways		Estimates of the average driving speed	Assessments of the average driving speed in the highways

	Action	Definition	Output	Indicator	Mean of verification	Actor that must implement action
1	Increase rural extension		Strategies to amplify rural extension	Number of properties assisted by extensionists	Inventory of geographic coverage by the rural extension (km^2)	Rural unions, OEMAs, local governance
2	Develop incentive strategies	Establishment of incentives via tax breaks and discounts, as well as financial support with differentiated interest rates	Assessment tools capable of providing eligibility rankings for incentives, based on criteria that include coexistence with jaguars	Number of benefited properties	Inventory of the geographic coverage of properties benefits by incentives	Financial/tax agencies
3	Provide training to extensionists in rural technical schools		Short-term courses focused on jaguar coexistence	Number of extensionists trained	Survey of the number of training courses and people trained	NGOs, Embrapa, academia, federal institute
4	Consolidate, organize, and communicate best practices on coexistence with jaguars		Best practices manuals focused on coexistence with jaguars, addressed to different public	Number of existing manuals	Inventory of the existing manuals	NGOs, academia
5	Design and implement educative campaigns on the coexistence with jaguars		-Distribution of printed materials -Educative speeches and seminars -Posts in social media -Local TV and Radio insertions	-Number of printed materials distributed to the public -Number of people attending to speeches and seminars -Number of posts in social media, number of likes, sharing, printings -Number listeners/watchers measured (Ibope)	-Assessment of the distributed materials with the responsible agent -Attendance lists -Assessments in the social media -Audience reports	NGOs, media, social service
6	Prevent poaching in the properties		-Education and awareness campaigns -Increase in the presence of enforcement agencies in areas with	-Number of enforcement operations; number or properties visited by enforcement agency crews	-Assessment of the numbers of enforcement operations with the local agencies	Landowner, local governance

(Continues)

TABLE A3 (Continued)

	Action	Definition	Output	Indicator	Mean of verification	Actor that must implement action
			major risk of jaguar killings -Building up the awareness on the denouncing/ complaining mechanisms and channels	-Number of denounces/ complaints received by the enforcement agencies	-Assessment of the number of denounces/ complaints with the local enforcement agencies	
7	Design and distribute tourism best practices manuals addressed to tourism guides		Best practices manuals for tourism guides	Number of manuals distributed	Assessment of the number of manuals distributed	NGOs, local actors
8	Design and to implement marketing campaigns		-Campaigns in the press media -Posts in social media -Local TV and Radio insertions	-Number os insertion in the press media -Number of posts in social media, number of likes, sharing, printings -Number listeners/ watchers measured (Ibope)	-Assessment of the number of insertions in the press media -Assessments in the social media -TV and radio audience reports	NGOs, agencies, influencers
9	Encourage social organization, and the establishment of social pacts		-Capacity building for social organization and establishment of social pacts	Number of people reached by the training -Number of associations formed -Number of local agreements or standards created"	-Attendance list -Survey of new CNPJs -Survey via third-party information on consolidated agreements	NGOs, local governance
10	Implement effective integrated fire management strategies adhering to the Pantanal culture, training and strengthening fire brigades.		-Trained/equipped local firefighter brigades -Integrated Fire Management plans adherent to the Pantanal traditional management culture -Educative campaigns regarding proper use of fire	-Number of local firefighter brigades established -Number of trained local firefighters -Number of approved Integrated Fire Management plans -Number of people reached out by the campaigns (speech attendants, printed materials, etc.)	-Attendance lists from training courses -Assessment of the number of established local firefighter brigades; Number of approved plans recorded by the local agencies	Integrated management of fire compatible with local culture, creation and strengthening of brigades
11	Engage tourists in the social norms related to practices of jaguar observation	Provide information on proper tourism practices and denounce/ complaint channels	Informative signs along the touristic routes and ports; sings in airports and bus stations; informative materials and posters in tourism agencies and hotels/posadas; post in social media; educative material for open sharing; QR codes for the denounce/complaint channels with	Number of accesses via QR code; number of signs installed in tourism routes, number of tourism agencies and lodging enterprise engaged in the campaigns; number of educative materials produced and distributed	Assessments with the denounce/ complaint channels; ONGs; tourism agencies; FUNDTUR; SEDTUR; EMBRATUR	NGOs, tourist sector, local governance

TABLE A3 (Continued)

	Action	Definition	Output	Indicator	Mean of verification	Actor that must implement action
			additional information on the consequences of the inappropriate tourism practices regarding jaguars and other wildlife			
12	Encourage the establishment of local governance in the tourism sector	Conduction of meetings to discuss and support the establishment/ organization of local governances	Local governances in the tourism sector	Number of meetings conducted; number of participants; number established of local governances	Assessments through ONGs; assessment of local governances in areas of jaguar-focused tourism	NGOs, tourist sector, media
13	Promote jaguar-focused tourism		Posts in the social media; tourism best practices through folders, booklets and manuals; reports in the tv, press media (e.g., Ciência Pantanal); scientific articles; outdoor signs (QR code); technical notes to provide support for public policies	Number of prints (digital metrics) of shared materials; number of printed and distributed materials; number of publications; number of reports on the jaguar coexistence and tourism	ONGs, tourism regulating agencies, social media sites, online search tools	NGOs, tourist sector, media
14	Exert pressure governmental agencies to elaborate and implement jaguar coexistence-focused plans		Registered requirements on the need for elaboration and implementation of jaguar coexistence plans	Number of registered requirements	Assessment of the number of registered requirements placed in the state and federal government environmental organizations	Press for the elaboration and implementation of specific plans
15	Build up capacity for tourism guides and tourism employees		Courses aiming the training and recycling of tourism guides and employees; manuals and booklets; protocols for the tourism focused on jaguars	Number of participants in the training courses; number of manuals and booklets; number of organized protocols	SEBRAE, SENAC, ONGs, lodging enterprises	SEBRAE, SENAC, NGOs, local governance
16	Promote qualification and articulation with local service and product suppliers		Labels for the locally originated products; establishment of collaborative network of producers and local suppliers	Number of labeled products; number of participants in supplier networks; number of products sold to the jaguar-focused tourism	Assessment of cooperatives and networks; municipal registers of cooperatives and networks	SEBRAE, SENAC, NGOs, local governance
17	Implement/ complement the existing road/ highway construction plans		Adequate roads and highways	Extension of the adequate roads/ highways	Assessment of the extension of adequate roads and highways; proportion of adequate roads and highways	Complement and fully implement existing plans

(Continues)

TABLE A3 (Continued)

	Action	Definition	Output	Indicator	Mean of verification	Actor that must implement action
18	Improve the land use regulations		-Revision of the ZEE in Mato Grosso do Sul -Elaboration of the ZEE in Mato Grosso Implementation of the Environmental Recovery Plans (PRAs) -Conclusion of the Rural Environmental Cadaster (CAR)	-Percentage of properties with regularized CAR -Percent of implemented PRAs -ZEEs published or revised	-SICAR -OEMAS -OMMAs	OEMAs, state/local agencies, NGOs, academia, local governance
19	Increase the pressure on decision makers to strengthen the restrictive power of existing rules		-Technical notes -Campaigns in the social media	-Publication outreach -Number of published technical notes -Number of approved agrochemicals -Number of revoked agrochemical licenses	-Reports from social media -Data from ANVISA website	NGOs, media
20	Increase restoration and maintenance of the landscape connectivity		-Plan for maintenance of connectivity and to restores connectivity -Georeferenced data bank -Maps of priority corridors and areas for connectivity restoration -Official adoption of corridors as priority areas to locate the legal reserves	-Plan for landscape connectivity elaborated -Regional index of functional connectivity -Number of hectares of priority corridors that has been restored -Number of hectares protected as private reserves -Territorial planning with corridors adopted by the public sector; -Proportion of legal reserves consolidated in corridors	-Reports -Monitoring of the territorial planning -Mapbiomas -OEMAs (APs) -ICMBio (APs); -Rules establishing corridors as criteria for territorial planning -Assessments of the proportion of priority areas in corridors that have been restored; -Assessment of the location of legal reserves in relation to the mapped corridors	OEMAs, NGOs, local governance, businesses, academia