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Bridging the gap between researchers, conservation planners, and decision makers to improve species conservation decision-making

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Abstract

Species distribution modeling (SDM) is a promising tool for priority setting, conservation decision-making and overall support for species conservation. We developed a participatory modeling process (PMP) to ensure both the proper use of SDMs as well as their efficacy and impact as a conservation tool. The PMP using SDM has assisted conservation planning in a number of situations, including more than 25 endangered species and supported IUCN SSC Red List assessments. PMP focuses on stakeholder engagement to co-develop SDMs that will in turn support and guide conservation decisions. This participatory approach to SDMs allowed us to: (a) update potential species distributions; (b) evaluate environmental suitability; (c) identify potential corridors and priority areas for implementing different conservation and management actions; (d) identify new potential areas for species searching; (e) predict potential impact under deforestation and climate change scenarios; and (f) provide valuable input for population viability analysis (PVA). Most often the level of successful stakeholder engagement will influence how the model will guide the decision-making process. The modeler must play a technical role as well as act as a translator and facilitator to engage and bridge the gap between researchers, conservation planners and decision makers, which is essential for effective conservation.

KEYWORDS

conservation planning, conservation researchers, endangered species, facilitation, participatory process, planners, policy-makers, species distribution modeling, stakeholders

1 | INTRODUCTION

In recent decades, the biodiversity crisis has revealed great challenges for researchers, conservationists and decision makers, mainly with regard to planning and prioritizing conservation actions (Ceballos, Ehrlich, & Dirzo, 2017; Collins, 2010; Ward et al., 2019). In many cases, conservation actions need to be taken before uncertainties are resolved and necessary data are obtained (Burgman, 2005; Lin et al., 2018). To minimize those uncertainties, a variety of tools has been used to assist in developing effective strategies for averting extinction of endangered species (e.g., IUCN SSC CPSG science-based tools at http://www.cpsg.org/our-approach/science-based-tools). Species distribution models (SDMs) have emerged as one of the promising tools to both support and guide decision-making in conservation (Ferraz, Ferraz, Paula, Beisiegel, & Breitenmoser, 2012; Guisan et al., 2013; Sofaer et al., 2019; Urbina-Cardona et al., 2019). Species distributions reveal ecological, biogeographic and evolutionary patterns that are essential for conservation planning and decision-making (Gaston, 2003). SDMs rely on the prediction of probability of species presence (or the suitability for its occurrence) across a landscape through a correlative approach that searches for associations between species presence (museum records or field data) and variable predictors (bioclimatic, topographic, anthropogenic, landscape, etc.) to explain the species distribution in a geographic space (Elith & Leathwick, 2009; Franklin, 2009; Guisan & Zimmermann, 2000).

SDMs have been used for a wide range of conservation purposes, such as identifying priority areas for conservation (Morato, Ferraz, Paula, & Campos, 2014; Paviolo et al., 2016), predicting potential landscape restoration effects on species conservation (Angelieri, Adams-Hosking, Ferraz, Souza, & McAlpine, 2016), forecasting and managing biological invasions (Barbet-Massin, Rome, Villemant, & Courchamp, 2018; Ficetola, Thuiller, & Miaud, 2007; Jarnevich, Young, Talbert, & Talbert, 2018) and predicting future responses of biodiversity to climate change (Freeman, Kleypas, & Miller, 2013; Porfirio et al., 2014; Vale, Souza, Alves, & Crouzeilles, 2018; Wiens, Stralberg, Jongsomjit, Howell, & Snyder, 2009). Despite their potential for conservation application, it is still difficult to find evidence of SDMs effectively guiding conservation actions and decision-making process in the scientific literature (Guisan et al., 2013). In addition, the lack of clarity in parameterization of SDMs causes uncertainties in the use of SDM outcomes, leading stakeholders to question their usefulness in the conservation planning process (Kujala, Moilanen, Araujo, & Cabeza, 2013). There is still insufficient effort to convey SDM output to decision makers and to demonstrate its practical utility by effectively using SDMs to link science to policy and decision processes (Guisan et al., 2013; McShea, 2014; Tulloch et al., 2016).

We developed a participatory modeling process (PMP) that focuses on stakeholder (researchers, species experts, conservations planners and decision makers) engagement and commitment in every step of modeling to ensure both the proper use of SDMs as well as to improve their efficacy and impact as a conservation tool. Previous studies highlighted the benefit of engaging end users and other stakeholders in the planning process (Enquist et al., 2017; Reed, 2008), and even specifically in the modeling process to achieve the stated objectives (Jarnevich et al., 2019). Also, the IUCN SSC Guidelines for Species Conservation Planning emphasize the importance of involving a wide range of stakeholders in the conservation planning process, including quantitative model development (IUCN SSC Species Conservation Planning Sub-Committee, 2017).

To build a bridge between modelers, researchers and species experts on one side, and conservationists, planners and decision makers on the other, facilitation processes can be used to promote information exchange and SDM development in an integrative way. We incorporate facilitation as part of the process when problem solving is required (Kaner, 2014; Papamichail, Alves, French, Yang, & Snowdon, 2007; Rosenhead, 1996). Specifically, we facilitate the gathering of stakeholders who bring different information and different perspectives to reach pre-established goals (Shaw, 2006), despite personal agendas, values or assumptions (Kaner, 2014). This promotes the value and use of SDMs to influence policy development and support public actions for conservation and management decisions.

We report here on how the PMP approach was developed and applied to SDM, pointing out important aspects that determine the success or failure in the practical use of SDMs for conservation decisions. PMP appropriates the theoretical approach of translational ecology, since it embodies intentional processes in which ecologists, stakeholders, and decision makers work collaboratively to develop the best SDM (Enquist et al., 2017). As a practice, it could support decisions in conservation not just by adding information, but also guiding to appropriate use of the information available (Beier, Hansen, Helbrecht, & Behar, 2017). Ensuring stakeholder understanding and credibility is essential to achieve relevant results (Jacobs, Garfin, & Lenart, 2005). Therefore, we adopted two main practices to ensure their participation and the use of solid ecological knowledge in decision-making: (a) participation based on the philosophy of empowerment, equity, trust and learning, and (b) highly qualified facilitation throughout the process (Enquist et al., 2017).

2 | PARTICIPATORY MODELING PROCESS

We have designed and implemented the participatory modeling process (PMP) as part of the endangered species conservation planning workshops, such as National Action Plans (NAPs) in Brazil, led by the Chico Mendes Institute for Biodiversity Conservation (ICMBio), a Brazilian Ministry of Environment's administrative (MMA) arm, and Population and Habitat Viability Assessments (PHVAs), designed by the Conservation Planning Specialist Group (CPSG) of the International Union for Conservation of Nature's (IUCN's) Species Survival Commission (SSC). PMP takes advantage of the opportunity provided by having the stakeholders assembled for NAPs and PHVAs dedicated to conservation planning for the species, so that the SDMs can be effectively matched to the conservation planning needs. Although the PMP was developed under the endangered species conservation workshops (NAPs and PHVA), the process can be applied in any other context where the involvement of the stakeholders is taking into account as an essential part of the decision.

NAPs provide a detailed proposal of actions that need to be undertaken to "save" a species, reinforcing the participatory and collaborative characteristic of the process to prepare and implement the strategy through the adherence of the various sectors of society (MMA and its agencies; other ministries and their agencies; state and local governments; representatives from academia, civil society and private sector) (Ministry of the Environment, 2017). The PHVA process combines traditional population viability analysis (PVA)—most notably, the use of computer simulation models of the extinction process in small populations of threatened species (Lacy, 2019)—with structured facilitation tools for issue formulation and interdisciplinary problem solving among a group of engaged workshop participants from a broad range of disciplines (Rutherford, Gibeau, Clark, & Chamberlain, 2009). Through this integrative process, stakeholders develop more effective recommendations for species conservation action, including the identification of personal responsibilities and timelines for action to ensure that the recommendations agreed upon by the participants become reality (Westley & Byers, 2003).

The PMP is led by an expert modeler that must possess good facilitation, communication and mediation skills, assuring the proper use of the SDMs, guiding decisions and reaching the goals of endangered species conservation planning. But the PMP can also be led by a third party expert in communication that understands both modeling and the stakeholder priorities. The modeler should be able to listen, understand, translate and inform participants, as well as take advantage of needs and opportunities to best explore SDMs based on the factors that drive species distribution. Those skills consist of a repertoire of tools and methods related to structured problem solving (Kaner, 2014; Montibeller & Belton, 2006). Therefore, a facilitation style choice may have several impacts on workshop outcomes (Papamichail et al., 2007), since the communication among stakeholders is necessary to ensure SDMs use (Villero, Pla, Camps, Ruiz-Olmo, & Brotons, 2016). However, PMP is a systematic process with well-defined phases, which makes use and values knowledge and needs of all those involved, ensuring not just good communication, but the engagement of all stakeholders in SDMs building and use in decision making. We structured the PMP in two different phases, which are described as follow (Figure 1).

2.1 | Workshop planning: Model conceptualization, building and running

The first phase consists of workshop planning (Figure 1a), scheduled to occur 6–12 months before the species conservation workshop. Planning may involve a physical meeting or may occur only through electronic communication. The host organization (e.g., ICMBio-NAPs and IUCN SSC CPSG-PHVA) invites researchers and species experts, based on their knowledge in the focal species to co-develop the preliminary SDMs, with

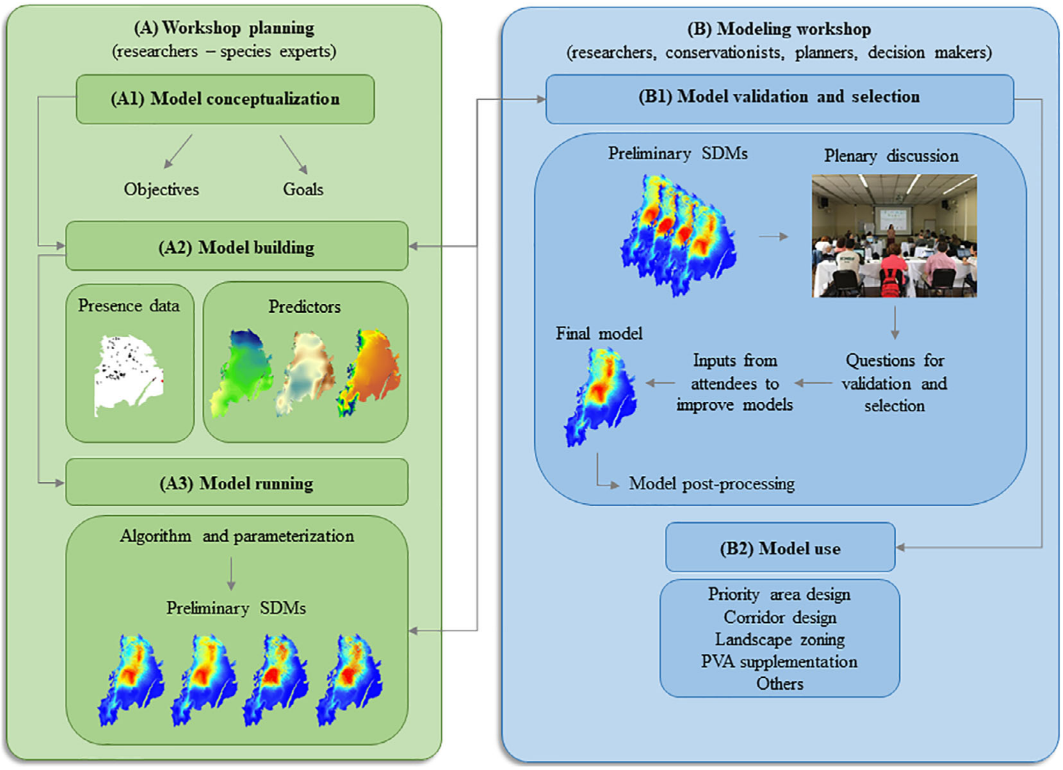

FIGURE 1 Participatory modeling process (PMP) structured in two phases: (a) workshop planning (with researchers and species experts) and (b) modeling workshop (with all stakeholders—researchers, species experts, conservationist, planners, decision makers). Modeling workshop is part of the National Action Plans (NAPs), Population and Habitat Viability Assessments (PHVAs) or other Species Conservation Planning Workshops

subsequent model validation, selection and use occurring in the next phase.

The first step in the workshop planning is the model conceptualization (Figure 1a1). The modeler works with the researchers and species experts, previously invited for the workshop, to set objectives and goals for model use and to and define the state-of-art underpinning knowledge about the target species and modeling methods. Typically, the goal is to provide a high-quality potential distribution model to help guide the discussions and make decisions on conservation action for the species (e.g., identifying the most suitable areas for searching for a rare species, finding potential suitable corridors to connect protected areas or subpopulations, identifying suitable patches for design new protected areas).

High quality spatiotemporal presence records are crucial to assure an excellent performance of SDMs (Araújo et al., 2019; Vaughan & Ormerod, 2003). In the PMP the modeler invites the researchers and species experts to provide GPS locations of their confirmed presence (e.g., signs, telemetry, camera-trapping, chance observations, capture) of the target species, avoiding bias (false positive errors) and uncertainties in the current extent of the species' range. This enables the modeler to prepare up-to-date and high-quality data on the species' distribution to be used in modeling (model building; Figure 1a2).

The identification of conceptually meaningful predictors that best explain the current species distribution is crucial for guarantee SDMs satisfactory outcome (Araújo et al., 2019; Elith & Leathwick, 2009; Guisan & Zimmermann, 2000). In the PMP, the modeler invites researchers and species experts to provide useful information about species biology and habitat requirements to define a set of bioclimatic, topographic, anthropogenic and landscape variables as predictors to best represent the multi-dimensional space (environmental space) for the species distribution (Figure 1a2). For the Chacoan peccary (*Catagonus wagneri*) distribution model, Ferraz et al. (2016) incorporated the deforestation rate, provided by the Guyra Paraguay, in the land cover map available (ESA GlobCover, 2009) to better represent the drastic habitat loss and fragmentation that was affecting the species' distribution. For predicting jaguar distribution in the Atlantic Forest, Paviolo et al. (2016) generated a variable labeled accessibility cost (measured as the hours needed to access the focal cell from the nearest town or city, considering the protected areas as barriers that reduce accessibility) as a proxy of human impact. It was considered as an important predictor limiting jaguar presence at the biome.

The algorithm choice and parameterization (model running; Figure 1a3) depend more on the skills and preferences of the modeler than on the researchers and species experts' knowledge. The modeler rigorously assures that all model parameters are set properly, and model is statically acceptable.

2.2 | Modeling workshop: Model selection, validation and use

The second phase of this process is the modeling workshop (Figure 1b) that, in general, occurs as part of the NAP, PHVA or other species conservation planning workshop, and focuses more broadly on the stakeholders' (e.g., researchers, conservationists, planners, decision makers, landowners, farmers, etc.) engagement for model validation, selection and use. Again, the host organization invites the stakeholders considering the representativeness of different sectors of the society, including federal and state government agencies, non-governmental organizations, industry, farming, agriculture, mining, logging, landowners and traditional and indigenous people. Despite the importance of having a broad representation of different sectors of the society, it is important to mention that a large number of participants may hamper the expected outcome, so we suggest limiting the number of participants to 30 or fewer people. The modeler leads the model validation and selection in a plenary discussion (Figure 1b1), presenting the preliminary SDMs and asking all stakeholders to address two main questions: "*Are there some areas where the species occurs but that was not predicted by the model (omission or error type II)? Yes? No? If yes, where?*" and "*Are there some areas where the species was predicted to occur, but you believe it is actually not present? (commission or error type I)? Yes? No? If yes, where?*". Participants are invited to answer these questions pointing out the omitted and over predicted regions in each model. Information not necessary for model evaluation and that can cause biases in the model choice (i.e., environmental variable used) are hidden from the stakeholders at this stage, as the model should be chosen considering only its predictive ability. This is important to avoid the model being chosen based on beliefs and perceptions that are more related to the biology of the species in a given area, and not to its distribution pattern or ecological niche. For example, water may be vital for the species, but distance from water may not be a significant predictor of its spatial distribution. After finishing the model choice, the modeler provides all information about the final model (e.g., relevant predictors) for the participants.

The modeler will endeavor to incorporate all inputs from participants to improve model accuracy, preferably in the same workshop, although it may be necessary to convene additional workshops, resulting in an iterative process that continues until reaching consensus about final model choice. The PMP allows that the model selection incorporates expert opinion, taking into account not only statistical parameters, which means that the final model may not be the one that has no the best statistical parameters (AUC, Kappa), but the one that, in addition to having good statistical parameters, is also the one that incorporates expert opinions, improving accuracy and reducing uncertainties.

PMP reduces uncertainties associated with parameterization and interpretation of SDM outcomes, because it includes expert opinions based on knowledge (and not on beliefs or perceptions) of all those involved in the process and guarantees the correct use of SDMs by the stakeholders to guide decisions and actions. Even after model selection, several steps may be necessary to reach the initial goal, which may include model postprocessing, priority area design, and landscape zoning, corridor design, among others. The final model (i.e., the model that best represents the current known—or expected—species distribution) will then be used during the workshop (Figure 1b2) by the stakeholders to provide information based on a robust and evidence-based method, which will guide decisions and actions for species conservation, and to stimulate debates and discussions which otherwise may not have occurred (Ferraz et al., 2012). Here, we highlight the appropriate use as well as constraints of the model to avoid its misapplication, which can have negative consequences (e.g., temptation to estimate population size by multiplying the suitable area by a known density for the species in one locality). The final model, as well as model building procedures, should be part of a communication plan that includes Action Plans, policy briefings, scientific papers and technical reports. A well-documented report of the process, detailing the modeling methods and data used, is crucial to allow additional analyses, future validations and updates, when necessary.

The effectiveness of the process can be assessed by some indicators related to stakeholder engagement (number of hours of dedication analyzing models, frequency of participation in the workshops, improvement in knowledge about modeling, number of interventions in model validation) and to the process per se (number of times that a model was taken into account in a decision-making, number of actions/decisions based on model outcome, number of times that a model was up taken in policy, the extent of a conservation action based on model outcome etc).

3 | ADVANCES IN BRIDGING THE GAP BETWEEN THEORETICAL AND PRACTICAL APPROACHES

PMP as part of the conservation workshops has been tested and used to assist the conservation of more than 25 endangered species (terrestrial mammals and birds) worldwide in the past 10 years, in collaboration with the ICMBio and IUCN SSC CPSG. The use of SDMs in the context of endangered species conservation planning allowed us to: (a) update current species distribution (e.g., for dhole, Javan leopard, jaguar, Brazilian harpy eagle, Brazilian parrot species, Chacoan peccary, Brazilian small felids, Brazilian merganser, bush dog, blue-eyed ground-dove, Alagoas antwren, black-fronted piping-guan); (b) evaluate the environmental suitability for current species distribution across the landscape (e.g., for Chacoan peccary, jaguar, Brazilian Atlantic Forest parrots, Brazilian merganser); (c) identify potential corridors and priority areas for implementing different conservation and management actions (e.g., Morato et al., 2014; Paviolo et al., 2016); (d) identify new potential areas for species occurrence (e.g., Brazilian Atlantic Forest parrots); (e) predict potential impact under deforestation and climate change scenarios (e.g., Altrichter, Desbiez, Camino, & Decarre, 2016; Ferraz et al., 2016); and (f) provide valuable input for population viability analysis (PVA) modeling and contributing to IUCN SSC Red List assessments of endangered species (Brazilian Atlantic Forest parrots, Brazilian harpy eagle, black-fronted piping-guan, Javan leopard, dhole). Here, we report, in detail, one of the best example that elucidate how SDMs have been used to influence decisions in conservation under PMP framework and on the building of base for the public policies (Supporting Information).

We used SDM to predict the distribution of the critically endangered jaguar (*Panthera onca*) in the Caatinga biome, Brazil (Morato et al., 2014), as part of PMP in the Jaguar Action Plan in 2009 (Desbiez & de Paula, 2012). The Jaguar National Action Plan (NAP) was produced in 2009 as one of the precursors NAPs of the ideal model of Action Plans officially installed by ICMBio in 2012. Although the meeting followed the protocols proposed by the institution for the composition of the stakeholders group based on as more diverse as possible, the assemblage attending still had a majority of experts from research institutions and academia. This had two reasons: first due to the lack of confidence of several stakeholders coming from different sectors of the economy towards the government and its conservation proposals; second, because of the need of a great scientific base to build the first distribution models and the subsequent products such as priority areas for conservation and connectivity's corridors. Thus, although the organizers invited 49 people from different backgrounds, 70% participated of the workshop. Of the 35 participants, half were researchers, experts on the species, apportioning information from all the Brazilian biomes. The 18 left were businessmen, from tourism sector, from agribusiness, protected area managers, national and state government agencies such as the agriculture, rural assistance, besides landowners and cattle ranchers. Also, there were representatives of universities and from the Brazilian Zoo Association. There were international representatives from the wild felids conservation institution Panthera, and also IUCN's Cat Specialist Group (CSG) and the Conservation Planning Specialist Group (CPSG). The first step of the workshop was to define the general objective that would drive the construction of an action plan. Thus, the participants defined as objective to "Reverse the trend of Jaguar population declines in each of the five biomes where the species is encountered and reduce the category of threat in each biome in the next 10 years." After the definition of the objective, the next step was to discuss the threats for the species and define its status among the six Brazilian biomes with the exercise of defining populations. Here lies the great importance of the experts on the species from several institutions across the entire country. We then defined the species "CR—Critically Endangered" in Atlantic Forest and in the Caatinga biomes, "EN—Endangered" in the Cerrado, "VU—Vulnerable" in Pantanal and Amazon, and "PEx—Probably Extinct" in the Pampas. All the participants were separated into smaller working groups to start the discussion and the proposals for the actions. For this, all the threats versus biomes were consolidated into six group topics: communication and education, public policies, research, habitat loss and fragmentation, hunting, and human-jaguar conflicts. The goals and relative actions were proposed in a general plenary. In parallel, modelers were working on the population viability and SDMs, engaging the stakeholders in the model steps (Supporting Information, Figure S1). The modeling processes were conducted together with the definition of actions. The validation of models happened prior to the end of the meeting and this directed few changes in previous predefined actions in order to prioritize areas indicated by models. From this stage, a number of 46 goals with their 167 actions were proposed. We emphasize here five goals (or specific objectives as we define on the NAPs) within the topic of "Habitat Loss and Fragmentation":

- To identify and make official the jaguar priority areas in 1 year (4 actions);
- To identify and indicate at least one area per biome (under the pressure of deforestation and extraction of

renewable and non-renewable natural resources) to propose the creation of protected area of full protection, within the polygons of priority areas (1 action);
- To sustain or to reestablish gene flow among jaguar populations isolated areas or critical population size (3 actions);
- To avoid or mitigate the impact of human occupation within the jaguar priority areas (3 actions);
- To reduce or compensate the environmental impacts in areas of influence of energetic entrepreneurs (dams, wind fields), within the jaguar priority areas (4 actions).

These five goals and their relative 15 actions could be only implemented if priority areas were defined. The priority areas were proposed with the SDMs as part of the PMP framework and secondary inputs from the population viability models. Thus, this exercise resulted on 20 "Jaguar Conservation Units," the JCUs, encompassing 2.46 million km^2. The JCUs were classified on type I (areas with a self-sustainable population of at least 50 breeding individuals and stable prey base population); type II (areas with population smaller than 50 breeding individuals, but suitable habitats and stable prey base population—where population can be recovered if human impacts were neutralized); and type III (also called as pJCU—potential JCU or research JCU: where there is lack of information of jaguar presence and stable prey base population although there are non-confirmed records). The models proposed 9 JCUs type I, 9 JCUs type II, and 2 JCUs type III. Among all the 20 JCUs, one stands for the importance and isolation. It holds one of the most isolated population for the species. The JCU #7, a region called Boqueirão da Onça. The region is within the western Caatinga in the northeast of Brazil, the biome where jaguars had the status defined in the meeting as critically endangered by the specialists. An area with low human density but high expansion of energetic powerplants (from wind energy). The wind power come from extensive wild parks that consists of sets of dozens of towers installed on top of mountains. In order for the installment, a large area must be deforested, and population increases in the area for the labor, increasing also poaching, specially of animals that are part of jaguar's prey base community. Water resources are greatly consumed as well for the construction and operation. The isolation of the Boqueirão da Onça region and its low human density allowed for centuries the stable jaguar population. With the new possibilities of occupation and land use destined for the energetic production, jaguar status became more critical. Considering one of the last stable population of the entire Brazilian northeast, connecting smaller population of the biome, urgent actions must be directed. Then, an old proposal of creating a highly restrictive protected area in the region to preserve the entire region against human development was recovered by the ICMBio with the help of scientific data presented by CENAP. By using the Jaguar NAP information and model generated, specific and precise models of priority areas and connectivity corridors for the Boqueirão da Onça region and for the Caatinga as a whole were produced (Morato et al., 2014). With the models proposed by the high specialized researchers and attested by several other stakeholders during the Jaguar NAP together with the implementation of actions within the goals presented above and the new models derived from the NAP's baseline models we had then enough technical arguments to create two protected areas. Thus, in 2018, 9 years after the Jaguar National Action Plan meeting, it was decreed by the president of Brazil the two new protected areas in the region, the Boqueirão da Onça National Park and the Boqueirão da Onça Environmental Protected Area (a low restriction protected area), encompassing together 8,500 km^2, the largest protected area continuum in the eastern Brazil and of the biome (Concone, Bueno, & Ferraz, 2018; Decreto n° 9.336, de 5 de abril de 2018). This achievement was especially important since this area was a source of conflicts for many years by stakeholders such as wildlife researchers, conservationists, social scientists, local communities and private energy and mining companies. The SDM developed under PMP framework helped to reinforce the importance of preserving a highly suitable area for jaguar conservation. With this protection, all the other actions within the five goals mentioned before could be implemented to ensure the long-term survivorship of this important and critically endangered jaguar population.

4 | FUTURE DIRECTIONS

SDMs should be integrated with other important tools that are used to support researchers and practitioners towards conservation decisions. One of the most important tools used to define conservation actions is the IUCN Red List (Butchart & Bird, 2010; IUCN, 2001; Mace et al., 2008; Rodrigues, Pilgrim, Lamoreux, Hoffmann, & Brooks, 2006), which classifies species in terms of extinction risk, using mainly geographic distribution data (Criterion B) and Population Data (Criteria A, C, D and E) (IUCN, 2001). This way, the Red List organizes species according to their conservation priority, classifying them into seven categories, ranging from "Least Concern" (in practice, nonthreatened) to "Extinct." The most widely used measure of geographic distribution in the assessment process is the "extent of occurrence" (EOO), currently calculated as a minimum convex polygon

(MCP) around the known species locations (MCP; IUCN, 2013). However, when the species is poorly sampled, the MCP method can measure only part of the species distribution (Burgman & Fox, 2003). This demonstrates the need to make use of other inference methods such as SDM, which offer the opportunity to increase the objectivity of IUCN conservation assessments (Seyfert et al., 2014). However, Seyfert et al. (2014) reinforce the need to use SDM together with specialists. The PMP approach discussed here does exactly that and therefore suggest a process that can increase the efficiency and reliability of SDMs (Marcer, Sáez, Molowny-Horas, Pons, & Pino, 2013; Seyfert et al., 2014).

Another important quantitative tool for conservation planning is Population Viability Analysis (PVA), which has been used for three decades to assess threats and evaluate conservation options for wildlife populations (Lacy, 2019). PVA is accomplished using computer population modeling software such as Vortex (Lacy & Pollak, 2020), a commonly used program for risk assessment of threatened species associated with species conservation planning. PVA models incorporate important life history characteristics of a species as well as the impacts of threats to project future population viability under expected and alternative management conditions. CPSG conducts risk assessments using a stakeholder participatory process for PVA model development similar to that described here for SDM. SDM outcomes can be integrated as model inputs for PVA, for example by improving the estimates of potential population size and habitat carrying capacity (using the suitability maps), and for estimating metapopulation structure and potential connectivity among habitat fragments. We used SDM and PVA collaboratively, both developed by the PMP, to assess species distribution and relative population viability of fragmented Javan leopard (*Panthera pardus melas*) populations (Traylor-Holzer, Holst, Leus, & Ferraz, 2020).

Spatial prioritization analyzes can also be used to select priority areas for conservation based on SDMs (e.g., Adams-Hosking, McAlpine, Rhodes, Moss, & Grantham, 2015; Carvalho, Brito, Pressey, Crespo, & Possingham, 2010; Guerrero, Knight, Grantham, Cowling, & Wilson, 2010). SDMs are useful for conservation planning in global (Wilson, McBridge, Bode, & Possingham, 2006), continental, national (Moilanen, Anderson, Arponen, Pouzols, & Thomas, 2012) and local scales (Whitehead et al., 2014). There are also compelling synergies in Systematic Conservation Planning (Margules & Pressey, 2000; Pressey, Cabeza, Watts, Cowling, & Wilson, 2007) and SDM to plan strategies for species conservation. These two tools may be combined in a way to develop scientific-based land management plans that can provide insights and policy-relevant information towards conservation action benefits and costs in realistic scenarios (considering land use change projections and climate change models). Based on an approach that integrates benefits, costs, and threats, this combination may use existing field studies and available databases to explore species' habitat selection, and to establish conservation priorities. Currently, not many conservation planners actually engage in the use of SDMs (Tulloch et al., 2016). SDM and Systemic Conservation Planning algorithms may not replace negotiation and public participation processes, but they should be carried out for the elaboration and implementation of real conservation actions (Ferrier & Wintle, 2009; Margules & Pressey, 2000). Nevertheless, we believe that implementing the above items would allow ecological science to be translated into actual conservation actions, being capable of achieving both scientifically defensible and socially acceptable results.

5 | CONCLUDING REMARKS

The development of a procedure that involves stakeholders from the beginning of the modeling process has turned the use of SDM into both a feasible as well as decisive tool for species conservation. PMP leverages the formation of an alliance for species conservation with the purpose of integrating the biological knowledge and provides evidence for modeling and decision-making. Communication was improved between stakeholders, building a trustful and transparent relationship, translated scientific results for conservation goals, and shared results and advances among all stakeholders. The end users of the SDMs have not been only researchers, but also decision makers and policy makers, helping policy development supporting public actions for conservation and management decisions. The level of stakeholder engagement in the process will determines the relative value and success of the model for guiding decisions in conservation. As research question and conservation needs are raised from on-the-ground—as opposed to the top-down or expert-oriented perspectives of traditional science—high levels of trust and commitment between partners are built determining the level of success (Enquist et al., 2017). Researchers and species experts were engaged in the process providing not only data and biological information, but also participating actively in the model evaluation, selection and use with all stakeholders. Decision makers were trained to make successful use of the SDM output to support conservation decisions. Our successful experience relies on the modeler playing not only a technical role, but also the role of a translator and facilitator, engaging and bridging the gap between researchers, conservation planners and decision makers.

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CONFLICT OF INTEREST

The authors attest no conflict of interest to declare.

AUTHOR CONTRIBUTIONS

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DATA AVAILABILITY STATEMENT

This article does not use any data. So, there are no data for sharing.

ETHICS STATEMENT

The authors agree with the ethics statement.

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of this article.

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