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Poor alignment of priorities between scientists and policymakers highlights the need for evidence-informed conservation in Brazil

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ABSTRACT

There is a worldwide claim by environmentalists and scientists that environmental policy usually lacks support based on scientific evidence. In this work we studied the gap between science and conservation actions in Brazil. We mapped scientific literature on conservation and conducted online surveys with science experts on biodiversity and policymakers working on a federal sphere. Our results show that environmental issues considered as priority for policymakers did not relate to those suggested by scientists and the peer-reviewed literature. According to policymakers, the main barriers to access scientific literature were time available to read papers, difficulty in understanding technical language and reading in English. Our results confirm that, in general, scientific knowledge is not being sufficiently applied to support policies in Brazil. Both scientists and policymakers are responsible for improving communication between their institutions: researchers need to know in advance what are professional policymakers' needs and direct their research towards answering policy-related questions; and policymakers need that scientific evidences be available in accessible language and up to date. We recommend the development of science communication departments at all governmental levels and the establishment of evidence-based research groups and tools. Our findings help to explain the mismatch between science and policy in Brazil and represent a warning to everyone engaged in biodiversity conservation worldwide.

Introduction

Communication between producers and users of knowledge has been identified as essential for developing credible and relevant institutional and technological solutions to environmental management challenges (Cash et al., 2003; Sarewitz and Pielke, 2007). Unfortunately, there are worldwide examples of public policies for biodiversity conservation lacking support of scientific evidence, such as the recently sanctioned Brazilian Native Vegetation Protection Law (also referred to as the New Forest Code; Metzger, 2010; Brancalion et al., 2016; Soares-Filho et al., 2014), the Canadian Fisheries Act (Favaro et al., 2012; Schindler et al., 2012), and the establishment of the National Representative System of Marine Protected Areas in Australia (Devillers et al., 2014). There is a widely recognized gap between the data obtained by researchers and the information required by decisionmakers (Sutherland et al., 2011). It is also common to observe a lack of engagement of conservation scientists in the implementation or execution of conservation actions (Arlettaz et al., 2010).

Collaborations between decisionmakers and scientists may benefit both parties. Academic scientists could understand how to make their research more relevant to conservation practice. Conservation decisionmakers could gain different perspectives (Stinchcombe et al., 2002), besides backing-up their decisions with scientific evidence. The key point in this context is the degree to which scientists are able to communicate results to decisionmakers in a clear, useful and timely fashion (Sutherland and Freckleton, 2012; Rose, 2015).

Several barriers seem to contribute to such communication gaps between science and the decision making. Scientific writing is usually hard to understand for many professional

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policymakers, although it is vital for scientists as it allows them to recognize more credible results from less credible ones (Chytry et al., 2014). Also, primary literature is considered too time consuming to locate, access and read, being also difficult to interpret in the context of local decision making (Pullin and Knight, 2005). In addition, the major part of credible information in conservation science is published in English (Chytry et al., 2014) and restricted to subscribers of that given journal (Matzek et al., 2013), playing as barriers to the public as to accessing scientific knowledge (for non-English native speakers). In fact, conservation decisionmakers frequently rely on their own personal experience rather than on scientific evidence (Sutherland et al., 2004). For example, common sense and speaking to other managers were pointed to as the main sources of information used by professional policymakers in the United Kingdom, while primary scientific literature accounted for only 2% of answers (Sutherland et al., 2004).

In Brazil, the gap between science and policy making is also a challenge for biodiversity conservation outcomes. For example, in 2012 the reformulation of the Brazilian Forest Act was approved, which heavily undermined our main environmental legislation on private lands (Brancalion et al., 2016), despite a strong academic and social mobilization to warn policymakers about the threats arising from the reformulation. Alternatively, the development of Brazilian Red Lists of Threatened Species (e.g. Martinelli and Moraes, 2013) and the establishment of priority areas for biodiversity conservation in Brazil illustrate a positive effort from the Ministry of the Environment to gather information to support the development of conservation policies. In the late 90s, several workshops were held with representatives from the government, NGOs, private sector and scientific community to discuss the establishment and the design of protected areas (PAs). Since then, both methods and outcomes have been updated with the support of scientific evidences to select PAs in Brazil (MMA, 2007; Loyola et al., 2014), although the actual establishment of protected areas is still driven by opportunities that sometimes are not related to scientific advice.

Here we assess if scientists' priorities for biodiversity conservation are in alignment with the priorities on top of the desk of Brazilian decision and policymakers, and if scientific knowledge supports the development and the implementation of conservation policies in Brazil. To achieve these objectives, we evaluated (i) to which extent scientists and decision and policymakers agree about conservation priorities, (ii) the sources of information used by decision and policymakers and (iii) the barriers to access scientific knowledge.

Methods

We distributed data collection into three steps. First, based on broad conservation issues, we generated a list of topics in conservation biology that deserve the attention of both scientists and decisionmakers. Secondly, we conducted online surveys and asked scientists and decision/policymakers to rank by priority the topics generated in the previous step. The comparison between scientists' and decision/policymakers' rankings of topics allowed us to test to which extent both groups agree about conservation priorities. We also consulted decision and policymakers about their sources of information on conservation topics, in order to evaluate if scientists' opinions reach decision/policymakers through scientific literature, and the barriers to access scientific knowledge. Finally, we made a systematic review of scientific publications related to each one of the topics categorized in the list generated previously in order to evaluate if scientific production reflects what scientists and decisionmakers consider to be priority topics for conservation. Below, we provide more details on each of these steps.

Definition of conservation biology main topics

We defined major topics in conservation through revision of scientific literature published in peer-reviewed journals to generate lists of central topics (Sutherland et al., 2011). The starting points were the categories used to classify the main questions of importance relating to biodiversity conservation (Sutherland et al., 2009). Our objective was to cover the major direct threats to biodiversity and the main topics of interest relating to conservation and sustainable development. This resulted in 14 subjects (Table 1).

Interviews with decision and policymakers

We divided decision and policymakers into two groups: legislators and environmental managers. All legislators interviewed were members of at least one of the environmental related commissions from both the Brazilian Deputy Chamber and Federal Senate (total of 214 deputies and 42 senators). We collected all names available on the institutional websites in April 2015 (http://www2.camara.leg.br/atividade-legislativa/comissoes/comissoes-permanentes and http://legis.senado.leg.br/comissoes/?5#). First contact was made by phone and e-mail, followed by personal visit to legislators' offices in Brasília/DF (the Federal Capital of Brazil) in May 2015. Legislators' advisors mediated all interviews.

Table 1
Priority rankings of topics in the Conservation Biology agenda in 2015 for scientists, legislators and environmental managers. Positions are sorted according to scientists ranking to facilitate results view.

Topic	Scientists	Legislators	Managers
Habitat loss and fragmentation	1	8	1
Impact and control of human population growth	2	11	12
Management and conservation of endangered species	3	6	3
Priority areas for the establishment of protected areas	4	9	11
Impact and control of greenhouse gas emissions and global climate change	5	7	8
Sustainable ecosystems' management	6	1	3
Landscape management	7	14	13
Social participation in conservation interventions	8	10	6
Impact and control of invasive species	9	12	7
Preserving the integrity of water bodies	10	2	2
Environmental degradation	11	3	5
Development of renewable energy sources	12	4	10
Science communication	13	13	14
Control and reduction of waste production	14	5	9

We selected environmental managers from the two main Brazilian government environmental agencies: directors of federal PAs from ICMBio (the Chico Mendes Institute for Biodiversity Conservation – totaling 63 directors) and technical coordinators from IBAMA (the Brazilian Institute of Environment and Renewable Natural Resources – totaling 51 coordinators). We used randomized block sampling design in order to select PAs directors, within all Brazilian regions (North, Northeast, Midwest, Southeast, and South) being considered as blocks. The number of interviewees selected in each region was proportional to the numbers of PAs in the region. We selected all technical coordinator names available online in April 2015. We collected all names available on the institutional websites in April 2015 (http://www.icmbio.gov.br/portal/unidades-de-conservacao.html and http://www.ibama.gov.br/acesso-a-informacao/cargos-e-responsaveis). All environmental managers were contacted exclusively by e-mail.

We asked legislators and environmental managers to rank conservation biology main topics and to answer eight objective questions about their sources of information on conservation themes and the barriers faced in accessing scientific knowledge (Supplementary material 1) through an online survey hosted on Google Forms.

Online interviews with conservation scientists

We generated scientists' samples through purposive sampling (Sutherland et al., 2011) among worldwide researchers with *h*-index > 10 specifically for the biodiversity area calculated in January 2015 by Web of Science index tool. All selected scientists ($n = 80$) were contacted by e-mail in January 2015 and invited to rank conservation main topics (Supplementary material 2). Among the researchers that completed the survey ($n = 24$), we identified 10 cases in which the scientist ranked subjects related to their own study area among their ranking's first 4 positions. Although it is expected that researchers work with themes they consider very relevant, we disregarded these cases to avoid bias (only that given rank was disregarded, not the respondent). Both decision/policymakers and scientists were informed about the scientific purpose of the study and received identification and contact information about the study's authors and their professional filiations.

Review of scientific publications

We searched for scientific papers related to each one of the 14 main conservation topics. We focused on papers published between 2012 and 2014 in journals indexed by ISI/Web of Science platform, the largest and the most accessed multidisciplinary scientific data base (Azevedo et al., 2010). We generated a set of keywords related to each topic (Supplementary material 3). Each set was created by searching words/expressions (and their variations) related to the subject.

We filtered results by research domain (science and technology), area (biodiversity conservation), language (English) and by the word *tropic*. We did not apply the *tropic* filter to Science Communication and Impact and control of human population growth categories, because researches on these themes are not necessarily related to a geographic study area. We also filtered the census results by country (Brazil) to get a national census (considering authors' filiations country). Because of the high correlation found between scientific production of Brazilian scientists and the scientific community efforts worldwide, we used only international production for comparisons with the rankings obtained in the interviews. Finally, we analyzed each paper by title and by the abstract, and excluded results focusing on subjects other than biodiversity or conservation despite the occurrence of the selected keywords (4520 were excluded from a total of 9101 outputs).

Data analysis

The individual ranking generated by each interviewee brings the priority rankings on conservation biology ranging from 1 (top priority) to 14 (lowest priority). We tested the correlation between the rankings obtained for each individual interviewed using the nonparametric Spearman correlation test (Zar, 1999). Thus, we generated a matrix of correlation coefficients ($\bar{\rho}$) for all interviews, and then separated it into correlations between academics and legislators and between academics and managers.

In this study, $\bar{\rho}$ served as an index of agreement between the responses of the three surveyed categories (scientists, legislators and managers), where a $\bar{\rho} = 1$ would imply perfect agreement in prioritization, a $\bar{\rho} = -1$ would imply a complete reversal of priorities, and a $\bar{\rho} = 0$ would mean no correlation among priorities. We also tested the correlation between rankings of each respondent, by category, with the ranking of topics generated by the census papers using $\bar{\rho}$ test, whose results also generated a correlation matrix. For each group of comparisons the means and confidence intervals of $\bar{\rho}$ were obtained. This analysis allowed us to capture the central tendency and variation of agreement in responses of each respondent group and scientific production. Data analysis was carried out in R program, version 3.2.2 (R Core Team, 2015).

Results

The number of respondents varied among groups. Twenty-eight legislators (17% – 19 congressmen and nine senators) and 37 managers (32% – 21 PAs directors from ICMBIO and 16 coordinators from IBAMA) completed the survey. The experience of legislators working with conservation (in years) ranged between 1 and 48 years (average of 15.6 years). Among managers, experience ranged from 4 to 36 years (average of 11.6 years). Representatives from all five Brazilian regions were part of the decisionmakers' sample. Among scientists, 24 completed the survey, representing a response rate of 30%. Researchers from South Africa, Australia, Brazil, USA, France, England, Italy, and Mexico completed the survey.

Interviews with scientists, legislators and managers resulted in the ranking of priority topics for each group (Table 1). Priorities for scientists and decisionmakers were not correlated ($\bar{\rho} = -0.013$, $CI_{min} = -0.037$, $CI_{max} = 0.011$). For academics and managers, 'habitat loss and fragmentation' made up the most urgent item on conservation agenda nowadays. On the other hand, this topic appeared only as the eighth most important in Brazilian legislators' opinion. Topics related to 'human population growth' were the second most important issue for scientists, but were listed only among the last priority positions for both legislators and environmental managers. Managers were in a little more agreement with scientists than decisionmakers were, although this correlation was also weak ($\bar{\rho} = 0.091$, $CI_{min} = 0.071$, $CI_{max} = 0.1$) (Fig. 1).

Scientific production of Brazilian scientists matched largely with scientific community efforts worldwide ($\bar{\rho} = 0.947$, $n = 14$, $p < 0.005$). Even though showing a low average correlation, managers and scientists tended to prioritize hot topics appearing in scientific publications (scientists: $\bar{\rho} = 0.217$, $CI_{min} = 0.107$, $CI_{max} = 0.326$; managers: $\bar{\rho} = 0.175$, $CI_{min} = 0.081$, $CI_{max} = 0.269$). In contrast, legislators' ranking was not correlated to hot topics in scientific literature ($\bar{\rho} = 0.079$, $CI_{min} = -0.015$, $CI_{max} = 0.173$; Fig. 1).

Scientific production census of each topic revealed that conservation of 'endangered species' has been the main focus for conservation science (Table 2). On the other hand, and as expected,

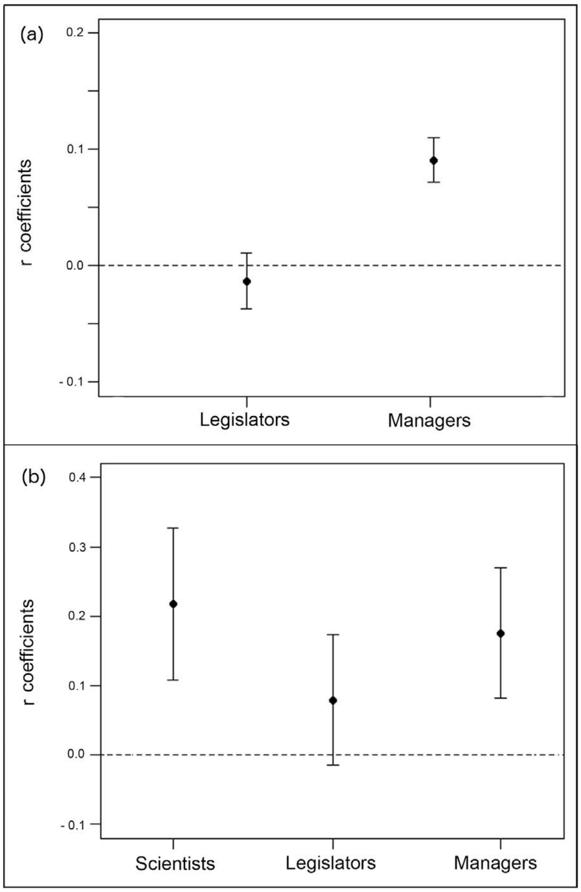


Fig. 1. Index of agreement between (A) scientists, legislators and environmental managers. Spearman coefficients means (+ CI) between scientists ranking and: (i) legislators ($\bar{\rho} = -0.013$, $CI_{min} = -0.037$, $CI_{max} = 0.011$) and (ii) environmental managers ($\bar{\rho} = 0.091$, $CI_{min} = 0.071$, $CI_{max} = 0.1$) rankings; (B) literature and scientists, legislators and environmental managers. Spearman coefficients means (+CI) between hot topics in the world scientific production and: (i) scientists ($\bar{\rho} = 0.217$, $CI_{min} = 0.107$, $CI_{max} = 0.326$), (ii) legislators ($\bar{\rho} = 0.079$, $CI_{min} = -0.015$, $CI_{max} = 0.173$), and (iii) managers ($\bar{\rho} = 0.175$, $CI_{min} = 0.081$, $CI_{max} = 0.269$) rankings.

'science communication' appears in the last position, as this subject is not considered a research topic for conservation biologists.

Sources of information and barriers to access scientific knowledge

Scientific publications were a source of information on conservation for 54% of the legislators and 70% of the managers interviewed. However, when asked about the frequency of access, only 35% of legislators claimed seeking scientific studies always or often (Fig. 2). Among managers, 54% said they do consult the academic literature always or often. When asked directly about the level of information they have on biodiversity conservation in Brazil, 46% of legislators defined themselves as well or very well informed, against 81% of managers.

Interviews confirmed that technical language, difficulty of access and reading in English are the main obstacles for decision-makers who do not read scientific publications. Available time for searching, reading and understanding scientific literature was the main difficulty faced by both legislators and managers (Fig. 3). Also, 89% of legislators and 70% of managers agreed that an increase in the availability of academic literature in Portuguese would widen access to scientific knowledge.

Discussion

Scientific knowledge produced in Brazil is in accordance with international standards, that is, science has been providing evidences to support Brazilian environmental policies. However, it seems these evidences do not reach most policymakers through academic literature (or evidences are being ignored by them). Poor alignment between priorities for biodiversity conservation between scientists and Brazilian policymakers indicates that hot topics for researchers do not reflect legislators needs in their daily practice, and vice versa. Such a mismatch of priorities could have serious consequences for Brazilian biodiversity.

The reformulation of the Brazilian Forest Act in 2012 is already a tangible consequence, as it reduced the total area that should not be deforested by 87% (Soares-Filho et al., 2014; Brancalion et al., 2016; Vieira et al., 2018). Similarly, other legislations have been proposed and await approval by the National Congress, despite going against evidences already provided by science for conservation (Loyola, 2014; Azevedo-Santos et al., 2017). An example is the constitutional amendment (PEC-65) proposed in the Brazilian congress, which will virtually put an end to environmental licensing system, despite increasing understanding by scientists about services provided by the Amazonian ecosystems to Brazil and to the world and how these services are lost when biodiversity is destroyed (Fearnside, 2016). Another proposal also awaiting approval would open indigenous lands to mining (Loyola, 2014; Barros and Barcelos, 2016) and allow "self-licensing" at state level (Guetta, 2016).

Besides the distance between researchers' opinions and the focus of studies within academy there is also an issue related to the lack of dialogue between scientists and legislators. The results of the rankings and the census of scientific publications, in which science communication has not featured at all, confirm the lack of investments in actions to bridge the gap between science and

Table 2
International and Brazil-based scientists scientific production related with biodiversity conservation published between 2012 and 2014 in journals indexed by ISI/Web of Science.

Topic	International	Brazil-based
Management and conservation of endangered species	1393	408
Environmental degradation	822	162
Habitat loss and fragmentation	653	230
Impact and control of greenhouse gas emissions and global climate change	506	56
Landscape management	423	66
Impact and control of invasive species	358	60
Development of renewable energy sources	100	28
Preserving the integrity of water bodies	86	27
Priority areas for the establishment of protected areas	57	14
Sustainable management of ecosystems	56	9
Social participation on conservation interventions	49	6
Impact and control of human population growth	33	0
Control and reduction of waste production	27	13
Science communication	18	2

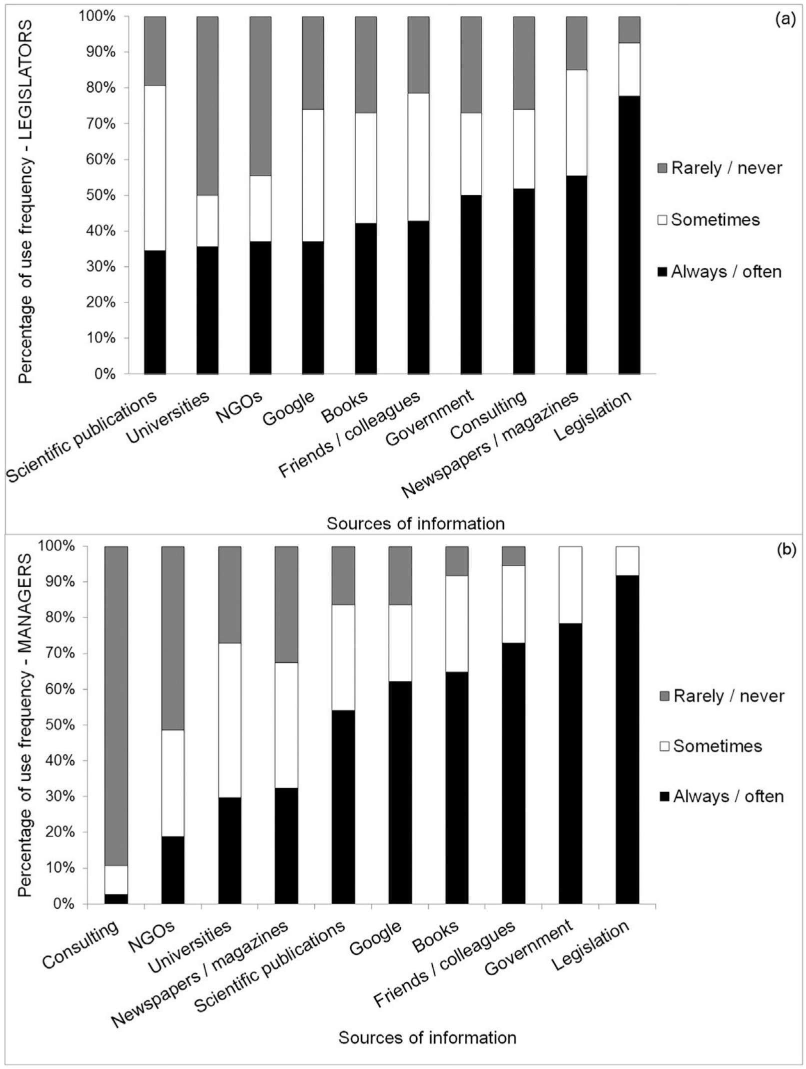


Fig. 2. Sources of information used by decisionmakers. Percentage of use frequency of different sources of information on biodiversity conservation categorized as always/often, sometimes and rarely/never by (a) legislators and (b) managers.

society in Brazil. In fact, it was not expected that scientific communication would be a priority, since it is not a specific research topic in conservation biology, but the number of articles published on the subject in the 3-year period is notoriously low. Evidence-based management requires that researchers provide answers to ecological issues of interest for decisionmakers (Sutherland et al., 2006).

The needs of decision and policymakers should be taken into account by scientists to identify lines of research that allow decision making with scientific evidence in a timely manner to be subsidize. It is notable that legislators have rarely been invited to suggest priority areas for the development of research (Sutherland and Freckleton, 2012). Similarly, scientists also need to be driven about decisionmakers needs for the development of legal instruments for conservation (Loyola and Bini, 2015). Alternatively, to ensure the applicability of scientific data, it is essential that the evidence generated by science may be translated into the less technical language as possible and understandable for non-scientists, a need pointed out by managers and by legislators in this study. For example, scientific publications focusing only on statistical results, despite the biological interpretation of results, prevent studies from being accessible outside the academy (Milberg, 2014) and exclude non-scientists as possible readers of publications. In practice, it is a two-way approach that involves efforts from both science and

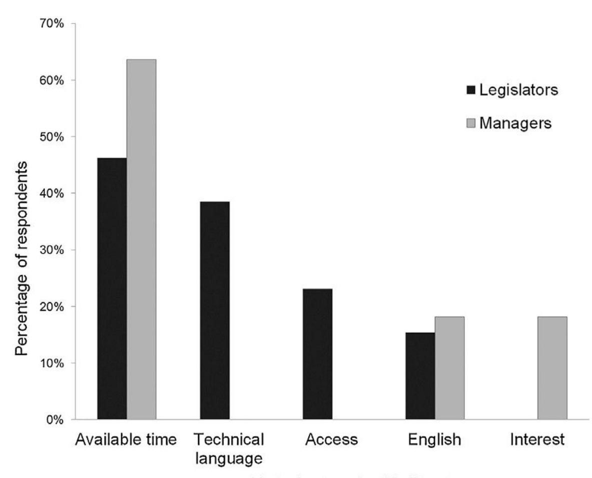
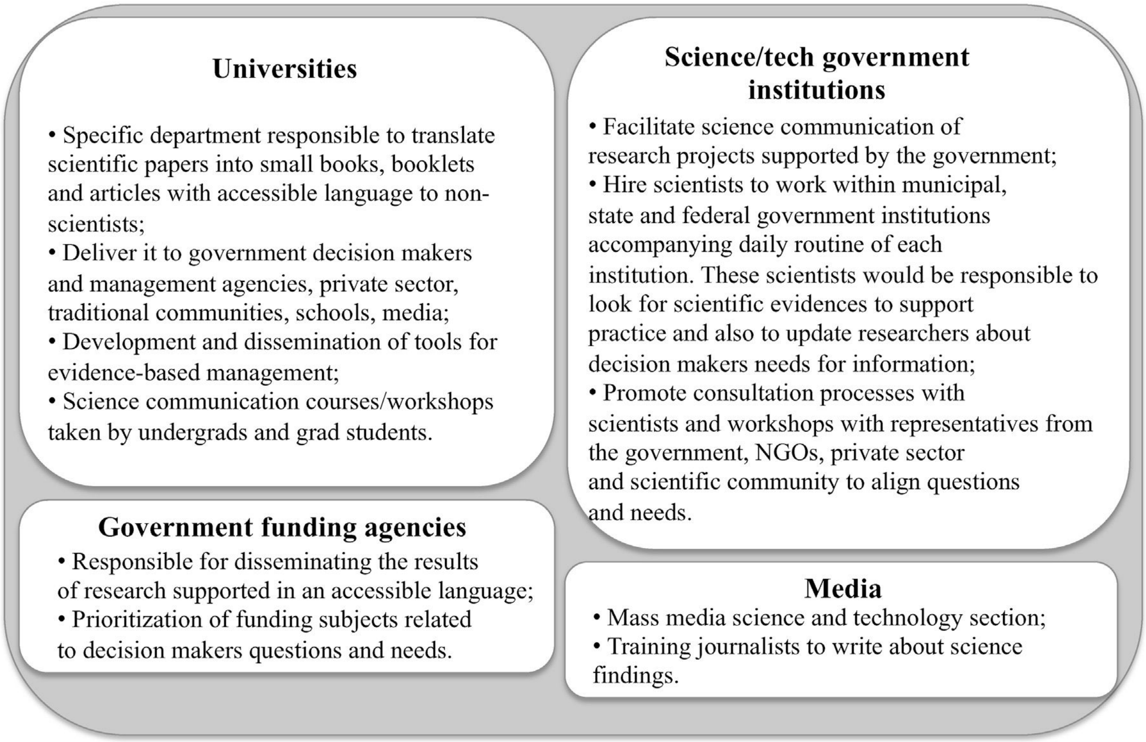


Fig. 3. Access to available scientific literature. Obstacles raised by legislators and managers to read scientific publications on biodiversity conservation.

decisionmakers seeking to maximize results for biodiversity conservation in Brazil.

Box 1: Initiatives to bridge the gap between science and practice performed by universities, the media and the government (through funding agencies and science and technologies governmental institutions).



An important initiative in this matter was the establishment of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES), and its Brazilian counterpart, the Brazilian Platform on Biodiversity and Ecosystem Services (BPBES). Both were created with the function of translating scientific orientations into policies (Goymer, 2017; Díaz et al., 2018). Assessments yet to be provided by these bodies will have profound implications in the Brazilian policy. For example, they will likely support government strategies to reduce deforestation and protect endangered species and ecosystems. Another arena where scientists can play a key role in translating science into practice and supporting policy making is at national, state, municipal environmental and protected area councils. Academy has seat in these councils, which offer a genuine relationship between science and decision making.

Despite scientists being increasingly encouraged to invest in communication of their research findings (Rose, 2015; Costa, 2012; McNutt, 2013), science outreach often requires from scientists the technical skills that were not even part of their formal education. A common strategy is the training of journalists specialized in science communication (UNESCO, 2000), withdrawing scientists communicator role. Thus, the researchers could concentrate on their core business, which involves a lot of time and public money (doing research), and the scientific journalist/communicator would be responsible for translating the data generated by science into an accessible language and delivery of this content to society. We also strongly recommend investments in science communication, in an attempt to ensure that the resources invested in conservation biology, an applied science by definition, return to society through scientific evidences useful to support public policies for conservation. Such investment, in particular in training and capacity building, would allow for the devolution for communities and public bodies of what has been studied and concluded in students' theses and dissertations. Science communication could be improved through the development of specific departments and initiatives in universities, in mass media vehicles, and in government agencies (see Box 1).

Our findings on the barriers to access scientific literature corroborate studies about the difficulty of decisionmakers related to (i) time available to consult literature (Pullin and Knight, 2005), (ii) understand the technical language of the articles (Pullin and Knight, 2005), (iii) read in English (Chytry et al., 2014) and (iv) access journals restricted to the scientific community or by purchasing content (Matzek et al., 2013). We also confirmed that reading in English is an additional difficulty for both politicians and managers. Technical language and access are more frequent barriers for legislators than they are for managers, which also can be explained by managers' academic curriculum. These results explain why decisionmakers in Brazil do not read scientific publications on environmental conservation currently. Some authors (e.g. Walsh et al., 2015) showed that improving access of managers to scientific evidence by providing it in an easily accessible clearly summarized format changed almost half of their environmental management decisions. Therefore, developing accessible tools of evidence-based practice is highly recommended in Brazil.

Summarizing, we showed that the conservation policy in Brazil needs more support from conservation science. We consider that both scientists and decisionmakers are responsible to improve this scenario. However, it is essential to consider also the influence of strong economic groups and political interests in environmental decision making. As suggested by Loyola (2014), "in terms of national policies, Brazil is consistently making decisions that go against the global policies it ratifies". Then, environmental decision making seems to involve much more complexity and depend largely on the political will of governors. Will it be possible to reconcile the interests of economy and politics, marked by the great country's industrial expansion after World War II and the recent return to a commodities producer condition, with biodiversity conservation? Future studies focusing on the gap between science and the development and management of public policies for conservation in Brazil must identify the main current demands of decisionmakers and evaluate funding agencies calls, in order to characterize the priority areas that have received funding for the development of research in conservation. Also, it would be interesting to analyze the devolution stage for communities and public bodies after the conclusion of post-graduation thesis and dissertations focused on biodiversity conservation agenda.

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Conflict of interest

The authors declare that they have no conflict of interest.

Research involving human participants

All interviews followed standard ethical procedures. The protocol we used was approved by an internal commission within the Federal University of Mato Grosso. We also obtained a license from SISBIO, the governmental Biodiversity Authorization and Information System (available from https://www.ibama.gov.br/sisbio/sistema/, license number 48875) to interview environmental managers. All interviewees for this study were informed about the scientific purpose of the study and consented to participate.

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Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at doi:10.1016/j.pecon.2018.06.002.

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