Conservation Biology

Essay

One Hundred Questions of Importance to the Conservation of Global Biological Diversity

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Abstract: *We identified 100 scientific questions that, if answered, would have the greatest impact on conservation practice and policy. Representatives from 21 international organizations, regional sections and working groups of the Society for Conservation Biology, and 12 academics, from all continents except Antarctica, compiled 2291 questions of relevance to conservation of biological diversity worldwide. The questions were gathered from 761 individuals through workshops, email requests, and discussions. Voting by email to short-list questions, followed by a 2-day workshop, was used to derive the final list of 100 questions. Most of the final questions were derived through a process of modification and combination as the workshop progressed. The questions are divided into 12 sections: ecosystem functions and services, climate change, technological change, protected areas, ecosystem management and restoration, terrestrial ecosystems, marine ecosystems, freshwater ecosystems, species management, organizational systems and processes, societal context and change, and impacts of conservation interventions. We anticipate that these questions will help identify new directions for researchers and assist funders in directing funds.*

Keywords: biodiversity, conservation, horizon scanning, policy, priority setting, research agenda, research questions

Cien Preguntas de Importancia para la Conservación de la Diversidad Biológica Global

Resumen: *Identificamos 100 preguntas científicas que, de ser contestadas, tendrían el mayor impacto sobre la práctica y las políticas de conservación. Representantes de 21 organizaciones internacionales, secciones regionales y grupos de trabajo de la Sociedad para la Conservación Biológica y 12 académicos, de todos los continenetes excepto Antártica, compilaron 2291 preguntas de relevancia para la conservación de la diversidad biológica mundial. Las preguntas fueron obtenidas de 761 individuos mediante talleres, solicitudes por correo electrónico y discusiones. Se utilizó una votación por correo electrónico de listas cortas de preguntas, seguida de un taller de dos días, para derivar la lista final de 100 preguntas. La mayoría de las*

preguntas finales fueron derivadas mediante un proceso de modificación y combinación a medida que el taller progresaba. Las preguntas están divididas en 12 secciones: funciones y servicios de los ecosistemas, cambio climático, cambio tecnológico, áreas protegidas, manejo y restauración de ecosistemas, ecosistemas terrestres, ecosistemas marinos, ecosistemas dulceacuícolas, manejo de especies, sistemas y procesos organizacionales, contexto y cambio social e impactos de las intervenciones de conservación. Anticipamos que estas preguntas ayudarán a identificar nuevas direcciones para los investigadores y asistirán a los financiadores en la asignación de fondos.

Palabras Clave: agenda de investigación, biodiversidad, conservación, definición de prioridades, escaneo del horizonte, políticas, preguntas de investigación

Introduction

The prime aim and justification of conservation research is to benefit biological diversity, whether through identifying patterns and mechanisms, quantifying changes, recognizing problems, or testing solutions. Many of the successes in conservation can be attributed to the successful translation of conservation science to conservation practice (Robinson 2006). Nevertheless, there is a widely acknowledged mismatch between the priorities of academic researchers and the needs of practitioners (e.g., Stinchcombe et al. 2002; Linklater 2003; Knight et al. 2008). One part of the solution is to identify the research needs of practitioners.

A previous exercise (Sutherland et al. 2006) identified the questions of greatest relevance to policy makers and practitioners in the United Kingdom. This exercise included individuals from 37 organizations including government, nongovernmental organizations (NGOs), and academia. In that exercise the questions were selected by policy makers and practitioners. The target audience of the resulting paper was the academic community because the objective was for policy makers to set the academic research agenda, but the paper has been used by a wide range of governmental and NGOs to refine their own research agendas. The paper has been very widely read, showing considerable interest in this approach. It is the most downloaded paper ever from any British Ecological Society journal and was the third-most downloaded paper from Blackwell Publishing's 850 journals in 2006.

Our objective here was to compile a list of 100 questions that, if answered, would have the greatest impact on the practice of conserving biological diversity worldwide. To achieve this aim, we gathered a team of senior representatives from the world's major conservation organizations, professional scientific societies, and universities. Our intended audiences are researchers wishing to make their work more applicable to the practice of conservation and organizations (including governments and intergovernmental bodies) wishing to review and direct their conservation research programs and financial support.

Methods

Participants

Twenty-four international organizations nominated representatives to identify the 100 questions of greatest importance to the conservation of global biological diversity. Although most organizations were based in Western Europe or North America, most of the representatives had strong conservation experience outside those regions. In addition, the Society for Conservation Biology's regional sections, Marine Section, and Social Science and Freshwater Working Groups were each invited to nominate a representative. Eleven academics from a range of disciplines, including one from each continent except Antarctica, also participated. A representative from the British Antarctic Survey participated to represent that continent. The list of authors provides details on representatives and participating organizations.

Initial Formulation of Questions

Each representative generated a list of questions from his/her organization through mechanisms such as seminars, informal small-group discussions, and emails. Each participant estimated how many people were actively involved in their process. The estimate included all those attending a workshop or discussion with the aim of generating questions, even if all those individuals did not submit a question. The estimate did not include individuals who did not actively participate, for example, by receiving but not responding to an email request. A total of 761 individuals were involved in generating questions.

Suitable questions met the following criteria: (1) were answerable through a realistic research design, (2) allowed a factual answer that does not depend on value judgments, (3) addressed important gaps in knowledge, (4) were of a spatial and temporal scale that reasonably could be addressed by a research team, (5) were not formulated as a general topic area, (6) were not answerable with "it all depends," (7) if related to impact and interventions, contained a subject, an intervention, and a measurable outcome (thus, question immediately

suggests research design needed to address it), and (8) were not likely to be answerable with yes or no. Because so many potential questions were intellectually interesting, it was useful to remind ourselves repeatedly of the overall goal by asking: Is this really one of the 100 questions that, if answered, would have the greatest impact on the practice and delivery of conserving biological diversity worldwide?

A total of 2291 questions were submitted, a high proportion of which met most (although not all) of the criteria. The questions were classified into major thematic areas (e.g., forest) and then subthemes (e.g., forest: carbon) to group similar questions for ease of discussion and prioritization. The list of original questions with the name and organization of the person who suggested the question is available (see Supporting Information).

Voting and Short-Listing

The list of questions was circulated to each participant to prioritize. Authors' names and affiliations were removed to reduce potential bias. The participants were asked to select questions within any themes of which they thought they had sufficient knowledge. They were asked to retain roughly 5% of the questions (100/2291) within the themes they reviewed. They were encouraged to involve multiple individuals across their organizations and were invited to rephrase questions or identify missing key questions.

A list of the 1655 questions that had attracted at least one vote for retention, together with the number of votes that each question received, was circulated to all participants prior to the workshop. Suggestions for rephrasing identified by the representatives were also provided. At this stage we included all questions that had at least one vote, even if some were similar or did not meet all the criteria outlined above. This was deemed more inclusive and allowed consideration of important ideas that could be rephrased into suitable questions.

Final List of Questions

The participants assembled in Cambridge (the United Kingdom) for a 2-day workshop in September 2008. The retained questions were divided into 15 topical sections, each of which was discussed by a subgroup of participants, with three or four subgroups working in parallel. This process of elimination and rewriting reduced the list of questions to 258 by the end of the first day. Three participants were unable to attend the meeting, but one provided comments overnight on this shortlist that were circulated to all participants. At each stage the participants were asked to focus on the overall goal of identifying questions that, if answered, would have the greatest impact on biodiversity conservation practice.

During the second day three concurrent subgroups of participants each addressed three to five topical sections and identified their 30 priority questions and 10 questions of secondary priority. In the final session the entire group of participants discussed the 90 priority questions. Decisions on whether to retain questions were made by majority vote after discussion. Eight questions were removed or merged as they overlapped with questions produced by different groups.

During the first day the participants realized that a considerable number of overlapping questions relating to the effectiveness of interventions appeared in various forms in the different thematic groups. Two participants collated all these questions and suggested three questions that encompassed the main issues. Their inclusion was accepted by a vote of the entire group.

W.J.S. and D.O. moved between groups during both days and answered questions and made occasional organizational points with the objective of ensuring consistency across groups. This also allowed some exchange of information across groups.

Eighty-five priority questions remained at the end of this process. The participants were then asked to nominate their top 10 questions among the 30 second-priority questions (10 from each group). The 15 questions garnering the most votes were discussed and included. The final list therefore consisted of 100 questions. The questions were edited by volunteers (one for each thematic section) and then circulated for editing by all the authors.

Results

The questions were grouped into the following 12 sections, which is but one of many ways in which the questions could be organized. The groups reflect the thematic areas used during the workshop and are intended for convenience. The final 100 questions were not ranked.

Ecosystem Function and Services

The Millennium Ecosystem Assessment (2005) defined ecosystem services as the benefits people obtain from ecosystems and highlighted the consequences of the loss of biological diversity and degradation of ecosystem services for human well-being globally. There has since been significant interest in converting the concept of ecosystem services into practice, both as a rationale for conservation of biological diversity and as a method to design policies that maximize benefits from the sustainable management of ecosystems. Key research areas include investigating which components of biological diversity are essential for providing ecosystem services, quantifying changes in provision of services that are driven by the loss of biological diversity, and establishing monetary and nonmonetary values placed on ecosystem services by different sectors of society in different regions.

1. Do critical thresholds exist at which the loss of species diversity, or the loss of particular species, disrupts ecosystem functions and services, and how can these thresholds be predicted?
2. What is the effectiveness of different methods for the assessment of ecosystem services?
3. How can biodiversity considerations be integrated into economic policies to reflect the monetary and nonmonetary value of biodiversity, ecosystem processes, goods, and services?
4. How can ecosystems be managed to increase protection of humans and biodiversity from extreme events?
5. How, where, and when has biodiversity loss affected human welfare?
6. What strategies for distributing the material benefits derived from biodiversity most effectively foster environmental stewardship and biodiversity conservation?
7. How can protected area networks be designed to increase carbon storage benefits and mitigate climate impacts, with these benefits as incentives to support conservation actions?
8. How does soil biodiversity contribute to the extent and persistence of ecosystem services, including agricultural productivity?

Climate Change

Many terrestrial, freshwater, and marine systems are already being affected by regional increases in temperatures (Intergovernmental Panel on Climate Change 2007). The most rapid changes have been seen in parts of the polar regions where 2–3°C increases in temperature have occurred in the last 50 years. Concomitant changes in precipitation, ocean biogeochemistry, sea level, and extreme weather events are generating global concerns about the most effective strategies for conserving biological diversity as climate changes. Further concerns that societies may not be able to stabilize greenhouse gases at a level that will result in only a 2°C increase in global temperatures above preindustrial levels (Anderson & Bows 2008) are leading to a growing realization that governments should develop contingency plans for 4°C increases in temperature. Biological diversity at all levels of organization is affected directly and indirectly by climate change and by adaptation and mitigation measures. The challenges to conservation ideology, policy, and practice are profound.

9. What impact will the melting of polar ice and a reduction in permafrost have on the human use of high-latitude ecosystems, and how will these changes in human use affect biodiversity?
10. Which elements of biodiversity in which locations are most vulnerable to climate change, including extreme events?
11. How is the resilience of ecosystems to climate change affected by human activities and interventions?
12. What factors determine the rates at which coastal ecosystems can respond to sea-level rise, and which of these are amenable to management?
13. How will climate change, together with other environmental stressors, alter the distribution and prevalence of diseases of wild species?
14. How will human responses to climate change (e.g., changes in agriculture, resource conflicts, and migration) affect biodiversity?
15. How might biodiversity policies and management practices be modified and implemented to accommodate climate change?
16. How might emerging carbon markets affect biodiversity through their impacts on the protection, management, and creation of habitats?
17. What are the potential effects of feedbacks between climate change and ecosystem dynamics (e.g., drought, forest dieback, and coral bleaching) on the effectiveness of policy measures to sequester carbon and protect biodiversity?
18. How much carbon is sequestered by different ecosystems, including their soils, and how can these ecosystems be managed to contribute most effectively to the mitigation of climate change?
19. How, where, and to what extent can natural and seminatural ecosystems contribute to climate change adaptation and mitigation?
20. How will climate change affect the distribution and impacts of climate-dependent disturbance regimes, such as fire?
21. How will climate change affect global food production, and what are the resulting consequences for ecosystems and agrobiodiversity?
22. How does biodiversity shape social resilience to the effects of climate change?

Technological Change

Rapid developments, such as those in nanotechnology, artificial life, virally vectored immunocontraception, and robotics, are likely to produce a range of novel challenges for conservation research and practice (Sutherland et al. 2008). One likely contentious area is the assessment of the overall implications of potential technological means of mitigating and adapting to environmental change (Sutherland et al. 2008), as had been experienced in the debate over biofuels (e.g., Koh & Wilcove 2008) and wind farms (Lucas et al. 2007). Horizon-scanning approaches (Sutherland and Woodroof 2009) or scenario planning (WCS Futures Group 2007) may increase the likelihood that unforeseen and undesirable consequences are identified before they become unmanageable or irreversible and decrease the likelihood of missed opportunities.

Although current proposals for novel crops concern terrestrial systems, future initiatives in marine and freshwater systems, such as genetically modified algae, are likely.

23. How might nanotechnology have positive or negative impacts on biodiversity conservation?
24. How do the type, location, and associated mitigation measures of renewable energy technologies affect biodiversity?
25. What are the direct and indirect impacts of genetically modified organisms on biodiversity?
26. What are the implications for land use and biodiversity of the new and emerging "bioeconomy" markets (crops for pharmaceuticals, plastics, adhesives, etc.)?

Protected Areas

Approximately 12.9% of Earth's land surface (Chape et al. 2008) and 0.72% of oceans (Spalding et al. 2008) are protected, often with conservation of biological diversity as a primary objective. International agreements, such as the Convention on Biological Diversity, World Heritage Convention, and Convention on Wetlands of International Importance, provide a global framework for cooperation in designing, designating, and managing protected areas. Governments and numerous nongovernmental conservation organizations make substantial investments in protected areas domestically and abroad. Protected areas provide one of the most important opportunities to educate the general public. Yet protected areas also suffer from numerous threats, including unsustainable levels of tourism, financial shortfalls, invasive non-native species, poaching, and expansion of human settlement (e.g., Sodhi et al. 2008). At a global level it appears that protected areas have been established more quickly than our capacity to manage them has grown. Although substantial research continues to be conducted in protected areas, the impact on practical conservation is often limited.

27. How effective are different types of protected areas (e.g., strict nature reserves, hunting reserves, and national parks) at conserving biodiversity and providing ecosystem services?
28. What is the management cost per hectare required to manage protected areas effectively, and how does this vary with management category, geography, and threat?
29. What are the human well-being costs and benefits of protected areas, how are these distributed, and how do they vary with governance, resource tenure arrangements, and site characteristics?
30. How does the management of protected areas affect conservation beyond the boundaries of the protected area, such as through the displacement of human populations, hunting, or fishing?

Ecosystem Management and Restoration

Most of the world's biological diversity currently exists outside protected areas and this is likely to remain true for the foreseeable future. Maintaining the ecological integrity of this matrix is essential because of its intrinsic ability to support biological diversity and maintain the viability of the embedded protected areas (Hunter 2005). Achieving both conservation and resource extraction across the landscape will require considerable knowledge about ecosystem structure and function, including historical conditions, natural disturbance regimes, and the relative merits of intensive and extensive resource use.

31. What is the trade-off for biodiversity between balancing production of natural resources from intensive management systems, such as plantation forestry and aquaculture, versus harvesting those resources from more natural ecosystems?
32. What was the condition of ecosystems before significant human disruption, and how can this knowledge be used to improve current and future management?
33. What, and where, are the significant opportunities for large-scale ecosystem restoration that benefits biodiversity and human well-being?
34. How can ecosystem management systems be designed to better emulate natural processes, notably natural disturbance regimes, and to what extent does this improve conservation effectiveness?
35. To what extent, and under what conditions, does the integration of marine, terrestrial, and freshwater ecosystems within conservation plans yield better outcomes than plans based on single realms?
36. What spatial pattern of human settlement (e.g., clustered vs. dispersed) has the least impact on biodiversity?
37. What is the contribution of areas that are intensively managed for production of commodities (such as food, timber, or biofuels) to conservation of biodiversity at the landscape scale?
38. How can an understanding of factors affecting household decisions to invest in different natural-resource-based productive activities (e.g., agriculture, fishing, or hunting) be used to predict the biodiversity impacts of household responses to environmental change?

Terrestrial Ecosystems

Terrestrial ecosystems are where most people live and where most food, fiber, and biofuels are produced, consumed, and disposed. They are also the catchments for freshwater and coastal ecosystems, with the potential to retain or release vast amounts of carbon, nutrients, and pollutants (Gibbs et al. 2007). Multiple uses of land

(e.g., agriculture, esthetics, and commercial harvest) and the associated rights are governed by complex, sophisticated, and diverse cultural and legal systems. As the human population increases and novel uses of land emerge, including carbon sequestration and the development of nonfood crops such as pharmaceuticals, competition for land will increase to satisfy the needs of human occupation and production. There is consequently a need for an improved understanding of how to achieve operational multiple-use management.

39. What are the impacts on biodiversity and ecosystem services of biofuel production and how will these vary by feedstock type, location, objective, and technology applied?
40. Under what conditions can agricultural intensification contribute to conserving overall biodiversity by reducing pressure to convert natural ecosystems?
41. What are the impacts (on and off site) on agricultural returns and biodiversity of "biodiversity-friendly" agricultural practices, such as organic, minimum tillage, and agroenvironment schemes?
42. Under what circumstances can afforestation, reforestation, and reduced emissions from deforestation and degradation (REDD) benefit biodiversity conservation, reduce emissions, and provide sustainable livelihoods?
43. How do different forms of forest governance influence biodiversity conservation outcomes and the implementation of REDD?
44. How are arid and semiarid ecosystems affected by the interaction of multiple stressors such as grazing by domestic livestock, soil erosion, and drought?
45. What are the contributions of urban nature reserves and other green amenity spaces, such as golf courses, to biodiversity conservation, and how can these be enhanced?

Marine Ecosystems

More than 60% of people now live on coasts, which increases the number and magnitude of stressors on marine systems (WRI 2005). Bycatch, trawling, and cascading effects also extend the impacts of fishing far beyond population reductions of immediate targets (Norse & Crowder 2005). The stagnation of global capture fisheries in the face of increasing demand for marine protein has been countered with enhanced aquaculture production (Pauly et al. 2005), giving rise to a new suite of environmental concerns. Climate change adds to the challenges of sustainably managing the sea, most of which lies beyond national jurisdictions. The United Nations Convention on the Law of the Sea provides a global framework for ocean conservation and management of human activities, but its enforcement is weak. The 2002 World Summit on Sustainable Development set target dates of 2010 to apply an ecosystem approach to ocean and fisheries management, 2015 to restore depleted fish stocks, and 2012 to establish representative networks of marine protected areas, including calls for strictly protected areas amounting to at least 20–30% of each marine ecosystem type.

46. How will ocean acidification affect marine biodiversity and ecosystem function, and what measures could mitigate these effects?
47. What are the ecological, social, and economic impacts resulting from the expansion of freshwater and marine aquaculture?
48. Which management actions are most effective for ensuring the long-term survival of coral reefs in response to the combined impacts of climate change and other existing stressors?
49. Which management approaches to fisheries are most effective at mitigating the impacts of fish extraction and fishing gear on nontarget species and their habitats?
50. How does the effectiveness of marine protected areas vary with biological, physical, and social factors and with connectivity to other protected areas?
51. What will be the impacts of climate change on phytoplankton and oceanic productivity, and what will be the feedbacks of these impacts on the climate?
52. How will multiple stressors, especially fishing, pollution, sea temperature fluctuations, acidification, and diseases, interact to affect marine ecosystems?
53. Which mechanisms are most effective at conserving biodiversity in ocean areas occurring outside the legal jurisdiction of any single country?

Freshwater Ecosystems

Freshwater ecosystems are critical to water supply, sanitation, and the support of livelihoods. Between 1.5 and 3 billion people, including three-quarters of the global poor, rely on these ecosystems for their water supply, with global demand for water increasing four-fold over the last 50 years, mostly for food production (MEA 2005). Major changes in land use, water management, and infrastructure development are lowering the condition of freshwater ecosystems and, by association, hindering food production, harming human health, increasing societal conflict, and limiting economic development (Ashton 2002; MEA 2005; UNDP 2007). In addition, many freshwater ecosystems are particularly vulnerable to climate change impacts, while anthropogenic disturbances of the same systems cause huge carbon emissions.

54. How can freshwater biodiversity and ecosystem service values best be incorporated in the design of water-provisioning schemes for direct human use and food production?
55. Which aquatic species and communities are most vulnerable to human impacts, and how would their

degradation affect the provision of ecosystem services?
56. Where will the impacts of global climate change on hydrology be most extreme, and how might they affect freshwater species and the ability of wetlands and inland waters to deliver ecosystem services?
57. Which multinational governance, cross-sector cooperation arrangements, and finance mechanisms will make freshwater ecosystem management more effective and reduce international conflicts over water?
58. How does investment in restoration of wetlands and riparian areas compare with construction of dams and flood defenses in providing cost-effective improvements in flood management and the storage and retention of water for domestic, industrial, and agricultural use?

Species Management

Much conservation has historically focused on individual species. Nonetheless, as the benefits of ecosystem function to humans become more apparent (MEA 2005), and as we come to appreciate the complex, often indirect ecological effects of our activities, the conservation spotlight has shifted away from individual species. Nevertheless, many remaining questions can only be addressed at the species level, and much legislation mandates a focus on individual species. Some of these questions are important because of the considerable number of species affected by a particular stressor. For example, the wildlife trade affects thousands of species and contributes billions of dollars a year to the global economy (Broad et al. 2003). Similarly, many species will require specific and targeted interventions to persist in the face of climate change and direct land conversion worldwide (McLachlan et al. 2007). Species that have disproportionate positive or negative effects on their communities need to be identified and managed.

59. Under what conditions is trade in captive or wild-harvested species beneficial for wild populations of the traded species?
60. What information is required to enable responsible authorities to decide when and how to manage nonnative species?
61. What is the relative effectiveness of different methods for facilitating movement of a species among disjunct patches of its habitat?
62. What is the cost-effectiveness of different contributions to species conservation programs such as education, captive breeding, and habitat management?
63. What are the ecosystem impacts of efforts to conserve charismatic, flagship, or umbrella species?
64. What are the likely risks, costs, and benefits of reintroducing and translocating species as a response to climate change?
65. What are the most effective approaches for reversing range and population collapse in top predators, large herbivores, and other species that exert disproportionate effects on ecosystem structure and function?
66. How can we best manage diseases that have the potential to move among wild species, domestic species, and people?

Organizational Systems and Processes

Although considerable research has examined the threats to biological diversity and the design and implementation of conservation interventions, little research has focused on the organizations associated with documenting these threats or designing and implementing these interventions. Conservation organizations (including government agencies, civil society organizations, research institutes, private corporations, and community organizations) vary in almost every possible dimension, including mission, structure, decision-making processes, technical capacity, and funding sources. There has been little research on the reasons for this variation or its implications for organizational behavior, conservation policy and practice, and the status of biological diversity. For decision makers eager to strengthen conservation organizations and foster more effective conservation policy and practice, social scientific research examining conservation organizations themselves may yield valuable insights.

67. How do the characteristics of the organizations (e.g., government vs. nongovernment) and their funding (e.g., amount and duration of funds) shape the effectiveness of conservation interventions?
68. What factors affect the extent to which practitioners integrate consideration of human needs and preferences into policy and practice?
69. What is the cost-effectiveness of different approaches for rapidly expanding professional conservation capacity, and how does this vary with circumstances and among countries?
70. What is the effectiveness of the different mechanisms used to foster the evaluation and dissemination of conservation interventions?
71. How effective are the different strategies devised to integrate scientific knowledge into conservation policy and practice?
72. How effective are the different mechanisms used to promote data sharing and collaboration among individuals, conservationists, and conservation organizations?

Societal Context and Change

Societal structures and processes—political, economic, cultural, and demographic—directly and indirectly shape day-to-day interactions among humans and between

people and the environment. The nature, magnitude, and extent of these interactions often have significant—but poorly understood—implications for the distribution and abundance of species and ecosystems. Further complicating analysis and understanding, societal structures and processes, and their implications for biological diversity, differ across spatial and temporal scales and levels of social organization. Earth's increasingly interconnected human population, for example, will continue to grow and migrate to cities in the 21st century. Similarly, global shifts to more neoliberal political and economic systems—with responsibility and authority shifting from national governments and nation-states to more local actors and private corporations—are countered by the (re)assertion of state political and economic authority in many countries. Understanding the effects on biological diversity of societal structures and processes—from armed conflict to trade policy to human dissociation from nature—establishes the scientific foundation for more informed policy development and reform.

73. What are the impacts on biodiversity of shifting patterns and trends in human demography, economic activity, consumption, and technology?
74. How does the relationship between economic growth and biodiversity vary across scales, among different types of ecosystems, and with the type of economic activity?
75. What are the direct and indirect impacts of armed conflict on biodiversity?
76. What are the biodiversity impacts of changes in energy prices?
77. How do resource tenure systems shape conservation outcomes in different social and ecological contexts?
78. What are the impacts of international trade agreements and related policy instruments on biodiversity?
79. How do economic subsidies affect biodiversity within the recipient country and elsewhere?
80. How does corruption influence the effectiveness of conservation, and what are the most effective ways of preventing negative consequences?
81. What are the conservation impacts of improved access to education, employment, and reproductive choice?
82. What is the relationship between individuals learning about environmental problems and their conservation attitudes, knowledge, beliefs, and behaviors?
83. What are the impacts of increasing human dissociation from nature on the conservation of biodiversity?
84. What are the effects of changes in human patterns of food consumption on biodiversity (e.g., shift from bushmeat to domestic meat and from fish to plant-based protein), and how are such human patterns of food consumption shaped by education programs, financial incentives, and other policy instruments?
85. What factors shape human (in)tolerance of the presence and activities of wild animals, especially where those animals induce human–wildlife conflict?

Impacts of Conservation Interventions

Increasing sums of money are spent on conservation policies and programs, but there is a lack of systematic examination of their effectiveness in meeting conservation objectives (Ferraro & Pattanayak 2006). The universality and importance of these facts emphasizes our need to review, evaluate, and learn collectively from the actions we undertake in the name of conservation of biological diversity (Sutherland et al. 2004). There is also a need for increased rigor in assessing interventions, including wider use of controls and replication. Many large conservation programs have goals that include human welfare. Achieving goals related to humans and other species, systems, or phenomena requires multiple interventions and challenges the emerging discipline of environmental program evaluation.

86. What have been the impacts on biodiversity of the Convention on Biological Diversity 2010 targets, and what objectives, mechanism, time frame, and means of measurement would be most effective for future targets?
87. How do different values (e.g., use vs. preservation) and the framing of these values (e.g., ecosystem services vs. species) motivate policy makers to assign public resources to conservation programs and policies?
88. What factors shape individual and state compliance with local, national, and international conservation regimes?
89. What are the consequences of investment in improving knowledge (e.g., status, nature of threat, and effectiveness of interventions) versus expenditure on conservation action, and how does this differ among conservation issues?
90. What are the impacts on biodiversity and human well-being of differing approaches to devolving the responsibility for natural resource management?
91. What are the impacts of different conservation incentive programs on biodiversity and human well-being?
92. How does public involvement, especially of marginalized groups, in conservation decision making shape the effectiveness of conservation interventions?
93. What are the impacts of free, prior, and informed consent policies on the emergence, evolution, and performance of conservation interventions?
94. How does providing information to resource users affect individual behavior and support for collective

restrictions, and how does the effect vary with different means of providing the information?
95. What are the conservation impacts of corporate social responsibility regimes that are biodiversity-oriented?
96. What are the social impacts of conservation interventions, and how and why do these impacts vary among social groups (e.g., elites, poor, women, and indigenous)?
97. What factors shape the likelihood and extent of formal recognition of customary rights and traditional institutions as the basis for conservation policy and practices, and what are the impacts of this formal recognition on conservation outcomes?
98. What are the most cost-effective means of encouraging broad, long-lasting, and active societal support and action for conservation in different contexts and among different actors?
99. What has been the effect of environmental impact assessments on biodiversity conservation?
100. What mechanisms best promote the use of local ideas and knowledge in conservation programs in ways that enhance biodiversity outcomes?

Discussion

The interactive process described here has produced a wide variety of questions that are important to the practice of conservation and therefore need to be addressed by the conservation research community. The approach used in this exercise has a number of limitations. The final questions depend on the initial questions provided, the individuals present at the meeting, and the processes followed. Nevertheless, we attempted to minimize the effect of individual preferences by canvassing a large number of people to produce the initial questions and by convening a large group with diverse expertise to engage in a structured, repeatable, and democratic process.

Previous exercises of this type (Sutherland et al. 2006, 2008) highlight the challenge of identifying questions that can be answered while being sufficiently generic to encompass issues relating to a broad spectrum of biological diversity at a range of spatial scales. Brief questions, such as most of the questions above, undoubtedly mask complexity. This becomes evident when using a question to develop a research project in which answers may vary with local ecological and social conditions. Nevertheless, we believe that most of the questions can be broken down into component parts or projects can be tailored to specific settings.

We hope the results of this exercise will be used by researchers to identify new paths of investigation and by donors and funding organizations to determine how they might target their investments in conservation science. For conservation science to overcome the research implementation gap and deliver effective on-the-ground management, however, the research must be inspired by and useful to the user (Salafsky et al. 2002; van Kerkhoff & Lebel 2006). This will require collaboration between researchers and practitioners throughout the long and often messy process of research, strategy development, and implementation (Sayer & Campbell 2004; Cowling et al. 2008).

We believe that our process can be usefully repeated by a range of countries and organizations and can be focused on specific ecosystem types, conservation issues, or taxonomic groups to clarify research requirements and direction.

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Supporting Information

A list of the original 2291 questions with names and affiliation of their authors (when provided) (Appendix S1) and a Spanish translation of the entire article (Appendix S2) are available as part of the on-line article. The authors are responsible for the content and functionality of these materials. Queries (other than absence of the material) should be directed to the corresponding author.

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