Essay

Research priorities for conservation and natural resource management in Oceania's small-island developing states

R. Weeks [1]* and V. M. Adams[2]

[1]Australian Research Council Centre of Excellence for Coral Reef Studies, James Cook University, Townsville, QLD 4810 Australia
[2]School of Biological Sciences, University of Queensland, St Lucia, QLD 4072, Australia

Abstract: *For conservation science to effectively inform management, research must focus on creating the scientific knowledge required to solve conservation problems. We identified research questions that, if answered, would increase the effectiveness of conservation and natural resource management practice and policy in Oceania's small-island developing states. We asked conservation professionals from academia, governmental, and nongovernmental organizations across the region to propose such questions and then identify which were of high priority in an online survey. We compared the high-priority questions with research questions identified globally and for other regions. Of 270 questions proposed by respondents, 38 were considered high priority, including: What are the highest priority areas for conservation in the face of increasing resource demand and climate change? How should marine protected areas be networked to account for connectivity and climate change? What are the most effective fisheries management policies that contribute to sustainable coral reef fisheries? High-priority questions related to the particular challenges of undertaking conservation on small-island developing states and the need for a research agenda that is responsive to the sociocultural context of Oceania. Research priorities for Oceania relative to elsewhere were broadly similar but differed in specific issues relevant to particular conservation contexts. These differences emphasize the importance of involving local practitioners in the identification of research priorities. Priorities were reasonably well aligned among sectoral groups. Only a few questions were widely considered answered, which may indicate a smaller-than-expected knowledge-action gap. We believe these questions can be used to strengthen research collaborations between scientists and practitioners working to further conservation and natural resource management in this region.*

Keywords: biodiversity, horizon scanning, Pacific Islands, policy, priority setting

Prioridades de Investigación para la Conservación y el Manejo de los Recursos Naturales en los Estados Micro-Insulares en Desarrollo de Oceanía

Resumen: *Para que la ciencia de la conservación informe efectivamente al manejo, las investigaciones deben enfocarse en la creación del conocimiento científico requerido para resolver los problemas de la conservación. Identificamos las preguntas de investigación que, si son respondidas, incrementarían la efectividad del manejo de la conservación y los recursos naturales y las políticas en los estados micro-insulares en desarrollo de Oceanía. Les pedimos a profesionales de la conservación de organizaciones académicas, gubernamentales y no-gubernamentales a lo largo de la región que propusieran dichas preguntas y después identificaran cuáles eran de prioridad alta en una encuesta en línea. Comparamos las preguntas de prioridad alta con las preguntas de investigación identificadas globalmente y en otras regiones. De las 270 preguntas propuestas por los respondientes, 38 fueron consideradas de prioridad alta, incluyendo: ¿Cuáles son las áreas de mayor prioridad para la conservación de frente a la creciente demanda de recursos y al cambio climático?*

*email rebecca.weeks@jcu.edu.au
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¿Cómo deberían conectarse las áreas marinas protegidas para que tomen en cuenta la conectividad y el cambio climático? ¿Cuáles son las políticas de manejo más efectivas de las pesquerías que contribuyen a la pesca sustentable en los arrecifes de coral? Todas preguntas de prioridad alta relacionadas con los retos particulares del emprendimiento de la conservación en estados micro-insulares en desarrollo y la necesidad de una agenda investigativa que sea receptiva al contexto sociocultural de Oceanía. Las prioridades de investigación en Oceanía en relación con otras regiones fueron generalmente similares pero difirieron en temas específicos relevantes a contextos particulares de conservación. Estas diferencias enfatizan la importancia de involucrar a los practicantes locales en la identificación de las prioridades de investigación. Las prioridades estuvieron razonablemente bien alineadas entre los grupos sectoriales. Sólo unas cuantas preguntas fueron consideradas ampliamente como respondidas, lo que puede indicar un vacío de conocimiento-acción menor a lo que se esperaba. Consideramos que estas preguntas pueden utilizarse para reforzar las colaboraciones de investigación entre los científicos y los practicantes que trabajan para avanzar la conservación y el manejo de recursos naturales en esta región.

Palabras Clave: biodiversidad, escaneo del horizonte, establecimiento de prioridades, Islas del Pacífico, política

Introduction

For conservation science to effectively inform conservation action, research must focus on creating the scientific knowledge required to solve conservation problems, and researchers must effectively communicate that knowledge to practitioners (Arlettaz et al. 2010; Walsh et al. 2014). Participatory processes that involve both scientists and practitioners in identification of research priorities may be a way to develop research agendas that are more responsive to practitioners' information needs (Mihók et al. 2015). Numerous exercises have been conducted to identify priority research questions for conservation globally (e.g., Sutherland et al. 2009; Parsons et al. 2014) and nationally (e.g., Sutherland et al. 2006; Kark et al. 2009; Rudd et al. 2010).

Region-specific or national assessments are particularly important for the development of research and policy that are relevant to local contexts (Varma et al. 2015). For example, for Australia (Morton et al. 2009) questions on altered fire regimes (which are critical to environmental management there) feature more prominently than for other continents.

Small-island developing states (SIDS) are poorly represented in global assessments of research priorities but are recognized as having extraordinary biological and cultural diversity, high dependence on natural resources for livelihoods and food security, particular vulnerability to invasive species and climate change impacts, and strong cultural connections to land and sea (Kingsford et al. 2009; Brodie et al. 2013). Thus, information needs for conservation and natural resource management in SIDS might be expected to differ from those identified for other regions. Given that much scientific knowledge is generated by researchers from developed countries, misalignment between research outputs and SIDS' information needs might be particularly acute. For example, coral reef research effort is positively correlated with per capita gross domestic product, indicating a geographic mismatch between where knowledge is created and where it is required to inform management (Fisher et al. 2010).

We had 3 objectives. First, we sought to identify research questions that, if answered, would increase the effectiveness of conservation and natural resource management practice and policy within Oceania's SIDS in the next 10 years. These questions constitute a research agenda designed to meet the needs of practitioners in this region and could be used to prioritize funding allocations. Second, we sought to identify questions posed by practitioners for which scientific understanding presently exists but has not been adequately communicated to end users, indicative of a knowledge-action gap (Arlettaz et al. 2010). Third, we sought to compare research priorities among conservation scientists in academia, practitioners in nongovernmental organizations (NGOs), and those in government agencies (Rudd & Fleishman 2014). Although cross-sectoral priorities may indicate opportunities for collaborative research, if scientists' and practitioners' priorities diverge, there may be a need to refocus research programs to better align with practitioners' information needs. We also compared research priorities for Oceania' SIDS with those previously identified globally, for Australia, and for India.

Question Solicitation and Prioritization

Our geographic scope was the Pacific Islands of Micronesia, Melanesia, and Polynesia (Fig. 1). We focused specifically on information needs that could be met through scientific research.

Our approach to identifying research priorities broadly followed that of Sutherland et al. (2011). We solicited research questions from a diverse group of individuals, collated these, and subsequently reduced the list of suggested questions through a process of voting (Fig. 2). Rather than conducting a priority-setting workshop to refine a list of research questions, we engaged participants online in both eliciting and short-listing questions. This was primarily due to logistical and resource difficulties associated with holding a workshop with participants from >20 SIDS scattered across a broad geographic region. Because participants did not meet face to face, iterative

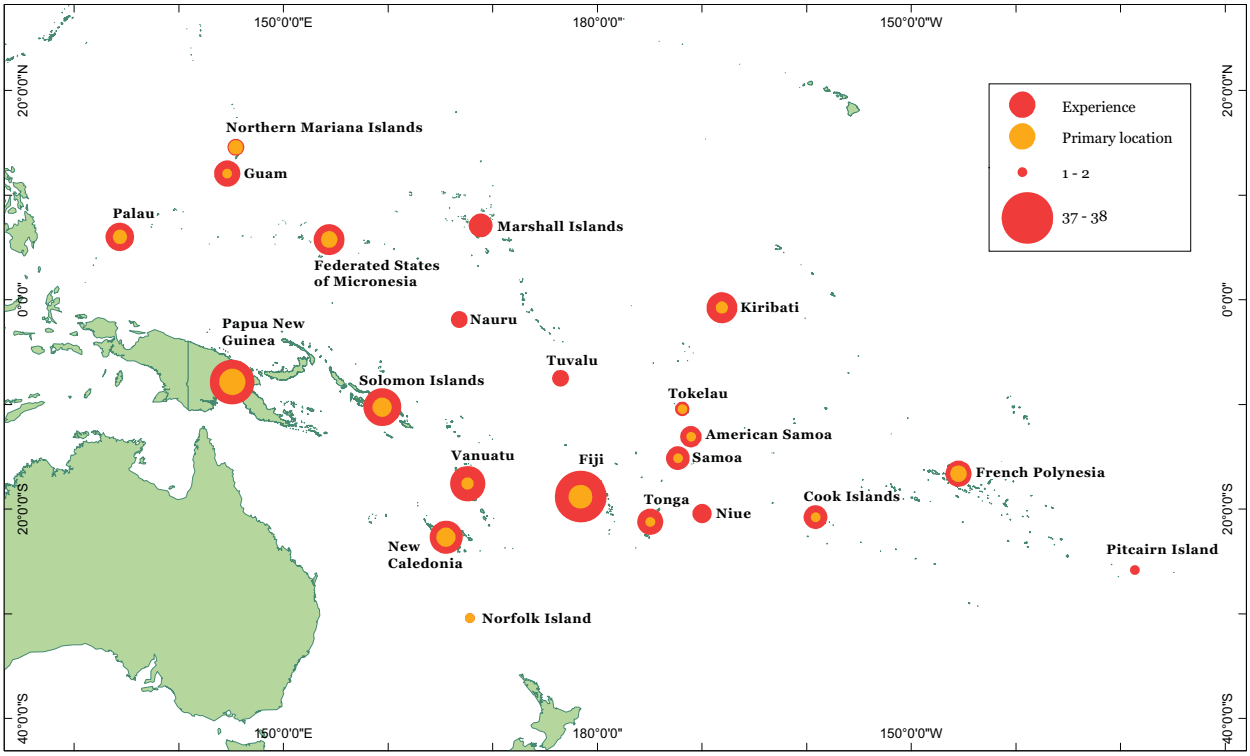

Figure 1. The focal region for identifying research priorities for conservation and natural resource management in small-island developing states within Oceania. Indicated are locations in which respondents proposing research questions work primarily (yellow) and have relevant experience in (red). Respondents included representatives from academic or research institutions (45), government agencies (27), nongovernmental organizations (19), and independent consultants (9). The larger the circle the greater the number of respondents. Some respondents indicated they worked primarily in Micronesia (n = 2), Melanesia (n = 1), Polynesia (n = 2), or regionwide (n = 19).

refinement of questions (likely to improve the clarity and focus of research priorities) and incorporation of new questions missed during the initial solicitation (Sutherland et al. 2011) were not possible.

We asked respondents to suggest up to 3 questions that, if answered, could increase the effectiveness of conservation or management of natural resources in Oceania's SIDS within the next 10 years via an online survey form. We targeted a purposive sample of three sectoral groups: academics, government agency employees, and representatives from NGOs (details in Supporting Information). Within these sectors, we sought a diverse set of participants stratified by geography (Fig. 1), discipline, and subject-matter expertise.

Similar to previous priority-setting exercises (Sutherland et al. 2011), questions were required to meet the following criteria: if answered, would increase the effectiveness of management actions or policies aimed at conserving species, ecosystems, or ecological processes or management of natural resources for human benefit; answerable on the basis of facts rather than value judgments; not answerable by yes, no, or it depends; formulated as a specific research question, rather than a general topic area; and of a spatial and temporal scope that reasonably could be addressed by a research team.

We removed or combined overlapping questions and refined wording as necessary to improve clarity and eliminate subjective language. This resulted in 115 questions (see Supporting Information) in 11 thematic areas, which closely follow those used by Sutherland et al. (2009).

We sent an online survey aimed at short-listing high-priority research questions to all government agency and NGO contacts from our initial search, prolific corresponding academic authors only, and respondents who proposed questions and expressed interest in further participation in the project (147 recipients). From the initial list of research questions respondents indicated which they considered of high priority (i.e., top 20%), secondary priority, or not a priority and those for which they considered current knowledge or understanding sufficient. Respondents were permitted to skip questions or thematic sections for which they thought their expertise was insufficient. We received 38 complete responses for the short-listing exercise (response rate = 26%).

We ranked questions based on the proportion of respondents who assessed each question ($n \geq 30$ for all questions). To allow comparison of priorities between

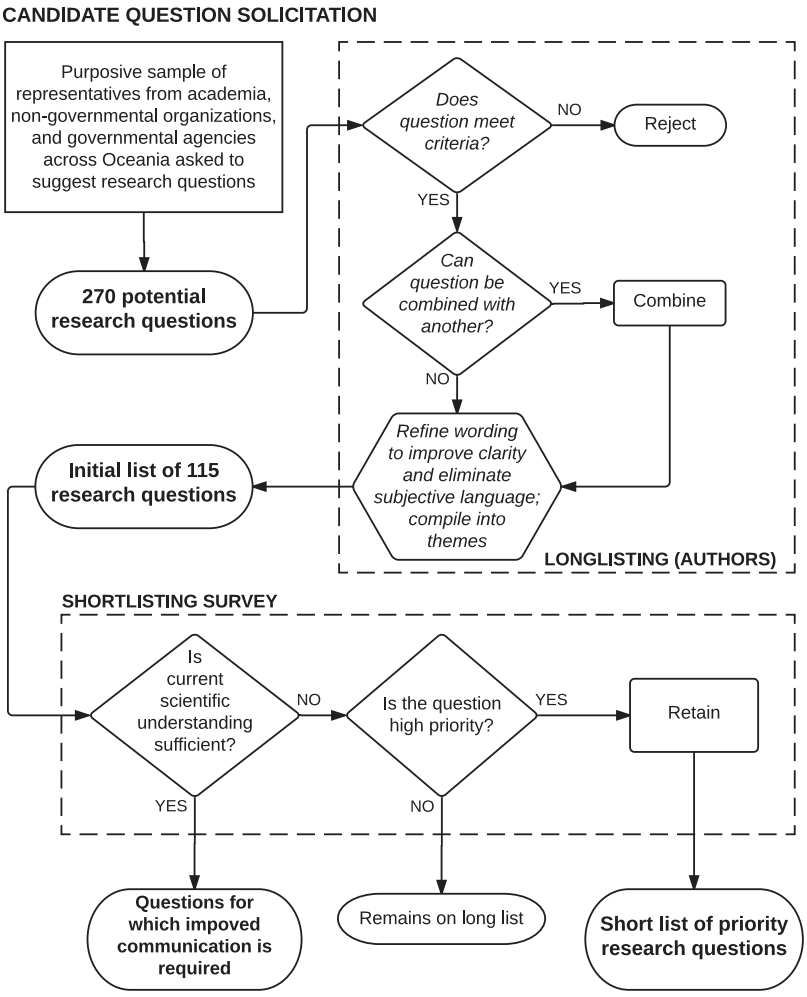

Figure 2. Schematic showing the method used to identify priority research questions.

sectoral groups, we calculated the proportion of respondents from each sectoral group (academic = 16, NGO = 12, government = 10) who rated each question as high priority.

To determine whether research priorities for Oceania's SIDS emphasized issues different from those identified for other regions, we compared our initial list of research questions to lists generated by Morton et al. (2009), Sutherland et al. (2009), and Varma et al. (2015). These studies allowed us to assess the extent to which questions identified for Oceania's SIDS showed thematic overlap with priorities identified globally, within the region (Australia), and for another developing country (India). Anticipating that research priorities for Oceania's SIDS would have a marine focus, we also compared our list of research questions with those specifically focused on marine biodiversity (Parsons et al. 2014) and ocean governance and sustainability (Rudd 2014). Although the goal of all these studies was to identify research priorities, their methods differed somewhat. Australia priorities were identified by an expert group rather than through question solicitation, and the global-oceans priorities were synthesized from 22 prior research-scanning exercises.

For each initiative, we calculated the total number and percentage of questions that fell within 13 thematic areas: 12 themes identified by Sutherland et al. (2009) plus our fisheries theme. This required us to reclassify questions that were reported in thematic areas unique to those studies.

High-Priority Questions

We considered the response rates for both the candidate question solicitation and short-listing survey adequate. A total of 270 research questions were suggested by 105 respondents (41% from academic or research organizations, 25% from government, 23% from NGOs, and 11% independent or consultants) (Fig. 1). Thirty-eight people responded to the short-listing survey.

The short list of 38 high-priority research questions is in Table 1. We did not set out to prioritize a specific number of research questions; rather, we defined questions as high priority if they were ranked within the top 20 overall, or for any sectoral group (academic, NGO, government). These questions were rated as high priority by ≥50% of respondents who assessed that question. Below

Table 1. Thirty-eight high-priority[a] research questions for conservation and natural resource management in Oceania's small-island developing states and question ranks among 3 sectoral groups.

Theme	*Question*[d]	*Overall Rank*[b]	*Academic*	*NGO*[c]	*government*
Marine ecosystems	Q4. How can spatial management be designed to account for the ecology of commercially important macroinvertebrate species (e.g. sea cucumbers, giant clams, *Trochus*, etc.)?	4*	16	1*	13
	Q11. Where are areas of critical importance (breeding, feeding) to oceanic, pelagic and migratory species within Pacific Island nations, and are there areas of overlap for multiple species?	11	3*	41	3*
	Q22. Which characteristics of oceanic coral reefs confer resilience to natural and human disturbances?	22	79	9*	14
	Q47. How do larval dispersal patterns vary among species and how spatially or temporally consistent are these patterns for a given species?	47	35	16	78
Terrestrial & freshwater ecosystems	Q8. What are the minimum areas needed to sustain populations of terrestrial island species?	8*	2*	38	9*
	Q18. How can we manage water resources to preserve and yet utilize?	18	23	28	25
Fisheries	Q3. What minimum level of protection is needed to ensure the long-term sustainability of coastal fisheries stocks under future projected changes to coastal habitats and species?	3*	17	14	1*
	Q7. What are the most effective fisheries management policies that contribute to sustainable coral reef fisheries?	7*	10*	7*	8*
	Q15. Which fish species are especially vulnerable to fishing impacts and require strict management?	15	11	12	21
	Q20. What are the key economic, policy, and management changes that need to be implemented to better sustain tuna stocks in the region?	20	18	8*	46
	Q23. How can we measure total fisheries catch of Pacific Islands, given that fish landings are often dispersed and unreported?	23	44	18	22
	Q24. Which fisheries need to be protected most for future generations after coral reefs collapse from climate change and ocean acidification?	24	19	27	24
	Q33. How should periodically harvested closures be designed and managed to maximize their ability to conserve fish stocks and provide for short term needs?	33	20	58	30
Ecosystem function & services	Q30. How much habitat loss, fragmentation, and degradation is occurring on Pacific islands and what impact is it having on native wildlife?	30	12	13	58
	Q39. What are the stress points at which ecosystems flip from a desirable state to an undesirable one and how can this be avoided?	39	29	15	77
Species management	Q10. How can invasive species be most effectively controlled with the few resources available?	10*	13	26	17
	Q41. What are the specific local- and landscape-scale habitat requirements of Pacific at-risk endemics?	41	5*	56	59
	Q64. Can we develop novel molecular or genetic approaches to small mammal pest control (including lethal viruses) that will be socially acceptable?	64	15	57	102
Ecosystem management and restoration	Q1. What are the highest priority areas for conservation (and sustainable development efforts) in the face of increasing resource demand and climate change?	1*	1*	4*	7*
	Q54. How can surveillance be better targeted to mitigate the risk of movement of invasive species?	54	56	67	12
Protected areas	Q2. How should marine protected areas be networked to account for connectivity and climate change?	2*	6*	5*	2*

(Continued)

Table 1. ***(Continued).***

Theme	*Question*[d]	*Overall Rank*[b]	*Academic*	*NGO*[c]	*government*
	Q16. What is the true cost of implementing effective protected areas in Oceania, and who will pay that cost?	16	32	30	6*
Climate change	Q6. How will the anticipated loss of biodiversity associated with climate change, sea level rise and ocean acidification impact local economies and human health throughout the Pacific?	6*	4*	11	15
	Q14. How can protected areas be designed to address impacts of future climate change?	14	43	32	5*
	Q43. How do we build long term climate change planning into an environment focused on short-term disaster risk reduction?	43	88	10*	64
	Q67. How will ongoing climate change impact the ability of coral reefs to recover from routine disturbances (e.g., cyclones) or anthropogenic disturbances (e.g., overfishing)?	67	61	88	19
Policy and governance	Q9. How do we move from a donor dependent conservation ethic to a self-sustaining approach to incentivizing or funding protected areas?	9*	9*	6*	69
	Q36. How can scientific information be communicated effectively to Pacific Island politicians to influence decision-making?	36	28	61	11
	Q44. How do we align policies, laws, rules, and regulations across levels of government to have a holistic approach to conservation and management of natural resources?	44	47	19	89
Societal context and change	Q13. What incentives can be provided to local resource owners to contribute towards national conservation and management of natural resources?	13	22	42	4*
	Q19. How can governments work effectively with communities to help them take ownership of managing their own resources in a more sustainable way?	19	69	2*	20
	Q34. How can we combine the best modern science with the best indigenous and local knowledge as a basis for biodiversity conservation and sustainable use in Oceania?	34	14	103	31
	Q17. How can conservation oriented natural resource management interventions contribute to livelihood improvement in the Pacific Islands?	17	55	20	16
	Q28. What alternative livelihoods from fishing can sustainably provide economic gains and food security to island communities?	28	38	17	41
	Q49. How can we determine ecological carrying capacity for tourism in small island developing states?	49	70	69	18
Impacts of conservation interventions	Q5. What is the comparative feasibility and cost-effectiveness of different land- and marine-based conservation actions to mitigate key threats to coastal-marine ecosystems?	5*	7*	3*	45
	Q12. What conservation strategies are most successful in engaging isolated communities in the Pacific?	12	8*	25	23
	Q27. What conservation intervention has the largest impact on restoring native species and indigenous cultures?	27	33	39	10*

[a]*Questions were considered high priority if they ranked within the top 20 overall or for any sectoral group. Question numbers indicate overall ranking.*
[b]*The top 10 questions for each sector are marked with an asterisk (*).*
[c]*Rankings from 3 independent consultants were most similar to, and consequently merged with, this group to facilitate comparison.*
[d]*Question wording is presented as proposed by respondents (with minor grammatical corrections to improve clarity); thus, questions variously refer to the focal region as either the Pacific Islands or Oceania.*

we discuss the research priorities within the context 11 thematic areas that emerged. These groupings are imperfect, and many questions could fall within 2 or more areas.

Marine Ecosystems

Although home to some of the world's most remote and pristine coral reefs, many of Oceania's marine ecosystems are under increasing pressure from habitat degradation, overexploitation, pollution, and climate change. Understanding factors that confer resilience on these reefs is a research priority. Recent progress in quantifying larval dispersal (e.g., Harrison et al. 2012) has raised questions about the spatial, temporal, and interspecific variability of connectivity, knowledge of which is required to inform management planning. Although an increasing body of literature describes how to design marine management for key finfish species (e.g., Green et al. 2015; Weeks et al. 2016), critical knowledge gaps in the fisheries ecology of targeted invertebrates undermine the effectiveness of management strategies for those species (Purcell et al. 2013). Invertebrate fisheries, such as those for bêche-de-mer and *Trochus*, are very important for export and consumption in the western Pacific, where overexploitation has led to the closure of several national fisheries.

Terrestrial and Freshwater Ecosystems

For many SIDS, the extent of marine ecosystems vastly exceeds land area. Many islands are isolated, which limits organism dispersal and results in high species endemism and vulnerability to local threats such as habitat loss (Jupiter et al. 2014*a*; Keppel et al. 2014). Freshwater resources are similarly limited, under increasing pressure from growing human populations, and vulnerable to climatic change (Australian Bureau of Meteorology & CSIRO 2014). High-priority questions within this theme relate to the challenges of sustaining terrestrial populations and freshwater resources in the face of these anthropogenic pressures.

Fisheries

Fisheries are central to the economies and food security of most SIDS within Oceania. Fisheries range from artisanal and subsistence fishing for coastal finfish and invertebrates to industrial harvest of high-value tuna stocks. Thus, the scope of management actions required ranges from local management of reef-associated fisheries to determination of total allowable catch of commercially valuable and migratory stocks by regional fisheries management organizations and negotiation of international agreements. Many coastal fishery resources are heavily fished and show signs of overharvest (Gillett 2014). Future human population growth (along with habitat degradation) is expected to exacerbate this trend, making improved fisheries management a top regional priority (Gillett 2014). Questions within this theme emphasize the unique challenges involved in managing multispecies, data-poor fisheries (Johannes 1998; Pauly & Zeller 2014) and suggest a desire to triage and prioritize species, stocks, and management actions. Questions also relate to the use of specific management tools employed in this region, including periodically harvested fishery closures and fish aggregation devices.

Ecosystem Function and Services

There is an increasing understanding that biodiversity loss affects human communities through the loss of ecosystem services (Costanza et al. 2014). This is particularly true in SIDS, where there is a high reliance on ecosystems for food security and livelihoods, for example through subsistence agriculture and fisheries. Given population growth and associated demands on ecosystems, the relative importance of functioning ecosystems to support livelihoods and human well-being is set to increase. Questions within this theme focus on the threats to ecosystem function and services and how to best manage these threats to ensure long-term provisioning of services. Questions also address how to adequately value ecosystem services, taking into account the unique cultural context of SIDS, to inform natural resource management decisions.

Species Management

The high endemism and specialized flora and fauna in SIDS has resulted in low alpha diversity, small population sizes, and gaps in functional groups that make biodiversity highly vulnerable (Keppel et al. 2014). Of particular concern is the threat posed by invasive vertebrates and vascular plants, which have irreversibly altered small-island species assemblages (Brodie et al. 2013). Although the risks of invasive species to biodiversity are recognized, effective control or eradication programs may require long periods of funding with large associated costs (Simberloff 2008). Natural resource management budgets are limited, and cost-effective allocation of budgets is critical. Although this is true for all natural resource management actions, it is particularly true for invasive species, where the environmental damage costs of inaction are particularly high for biosecurity and invasive species control (Jupiter et al. 2014*a*; Adams & Setterfield 2016). To design cost-effective species management strategies, knowledge gaps concerning the ecology of at-risk endemics and effective approaches to managing threats to these species must be resolved.

Ecosystem Management and Restoration

Key threats to biodiversity within SIDS in Oceania include habitat loss and degradation, overharvest, and invasive

species (Brodie et al. 2013). As with species management, ecosystem management and restoration programs must be cost-efficient. This relies on an understanding of both the ecosystem and the response to threats and management as well as the costs of management, much of which remains unknown.

Protected Areas

In most Pacific Island cultures, conservation is inextricably linked with environmental stewardship and sustainable use. Protected areas commonly comprise a blend of traditional and Western management practices, and their implementation proceeds most effectively though participatory planning processes involving local communities (Govan & Jupiter 2013). Understanding how protected-area networks can be designed to account for connectivity, climate change, and species' movement ecology remains an important knowledge gap. Although these questions have been addressed recently (e.g., Green et al. 2015), they remain pertinent here, perhaps because protected-area planning is undertaken by many parties (requiring interpretation of best practice in many different contexts) rather than through a few national-scale initiatives. Although community-based approaches may offer the most practicable way of achieving international obligations for protected-area coverage on land and in nearshore marine areas (which may be under customary tenure), questions are raised regarding how these protected areas should be financed and how costs and benefits of their establishment can be distributed equitably.

Climate Change

Although SIDS are among the least responsible for climate change, they are likely to be subject to disproportionately adverse effects. Higher temperatures, rising sea levels, and increasing climate variability have far-reaching consequences that will affect natural resources, economies, infrastructure, food security, and human health throughout the region (Australian Bureau of Meteorology & CSIRO 2014). Sea-level rise has already led to the loss of islands and relocation of communities (Albert et al. 2016), more frequent coral bleaching events and further ocean acidification threaten vital coral reef ecosystems (Hoegh-Guldberg et al. 2007), and projections for less frequent but more intense tropical cyclones (Knutson et al. 2010) are of concern following the devastating impacts of recent cyclones. Enhanced understanding of future climate-change impacts and management strategies to ameliorate them will be critical to building the capacity of countries to plan appropriate adaptation responses. This includes understanding cumulative effects of multiple stressors and interactions between climate change and other anthropogenic stressors such as fishing pressure (Brown et al. 2013).

Societal Context and Change

Conservation actions are designed, planned for, and implemented within complex social–ecological systems (Ban et al. 2013). Conservation decisions and outcomes are shaped by the political, economic, and cultural context within which they occur (Waylen et al. 2010) and can shape future development and livelihood opportunities. Many SIDS in Oceania have parallel systems of governance, with customary law and resource tenure playing a fundamental role in resource management (Clarke & Jupiter 2010). Understanding the relative strengths and weaknesses of state and customary institutions and how to build effective relationships between these is a priority area for research. Conservation initiatives in developing countries are more likely to achieve positive outcomes if they recognize and where possible provide for (or at least not impede) the development aspirations of local communities and governments (Keppel et al. 2012). How to achieve such outcomes is unresolved (Chaigneau & Brown 2016). Understanding how to integrate traditional and modern scientific knowledge systems may be a necessary precursor to effectively engaging local communities and traditional leaders (Drew 2005).

Policy and Governance

The research priorities within this theme broadly focus on the challenges of implementing policy: communicating scientific information to decision makers, developing coherent and robust laws, and funding necessary management actions. Although this indicates a general need to develop capacity, these questions would benefit from research to understand why different approaches have worked or failed and to connect those observations with relevant theory. A particular challenge for the region is that legal pluralism and decentralization of natural resource management require that conservation policies be coordinated across levels of government and across jurisdictional boundaries (Clarke & Jupiter 2010; Weeks et al. 2014). Moving from project-oriented funding models to sustainable financing mechanisms is another important, yet seemingly intractable, challenge (Keppel et al. 2012; Bos et al. 2015).

Impacts of Conservation Interventions

As is the case globally, conservation policies and initiatives have been implemented across Oceania without funding for effectiveness monitoring (Ferraro 2009). The emphasis of research questions prioritized for Oceania's SIDS is not only on understanding which conservation interventions produce the greatest benefits for biodiversity but also on which interventions are most feasible or effective within the context of community-based management. Understanding characteristics of management interventions that confer social success or

Table 2. Thematic comparison of number and percentage of priority research questions identified in 5 different priority-setting initiatives, including this study.[a]

	Oceania's SIDS[b] (%)	*Global[c] (%)*	*Global ocean[d] (%)*	*Marine[e] (%)*	*Australia[f] (%)*	*India[g] (%)*
Total number of questions	115	100	67	71	22	152
Terrestrial ecosystems	8 (7)	7 (7)	0 (0)	0 (0)	0 (0)	16 (11)
Freshwater ecosystems	1 (1)	5 (5)	0 (0)	0 (0)	1 (5)	8 (5)
Marine ecosystems	6 (5)	7 (7)	9 (13)	10 (14)	2 (9)	0 (0)
Fisheries	12 (10)	1 (1)	4 (6)	10 (14)	0 (0)	2 (1)
Ecosystem function & services	13 (11)	8 (8)	14 (21)*	2 (3)	3 (14)	26 (17)*
Species management	13 (11)	8 (8)	3 (4)	2 (3)	0 (0)	10 (7)
Ecosystem management & restoration	5 (4)	8 (8)	4 (6)	6 (8)	2 (9)	18 (12)
Protected areas	8 (7)	4 (4)	1 (1)	2 (3)	0 (0)	4 (3)
Climate change	11 (10)	14 (14)	14 (21)*	14 (20)*	9 (41)*	10 (7)
Policy & governance	12 (10)	6 (6)	7 (10)	14 (20)*	2 (9)	17 (11)
Societal context & change	17 (15)*	17 (17)*	5 (7)	10 (14)	2 (9)	24 (16)
Technological change	0 (0)	4 (4)	3 (4)	1 (1)	0 (0)	6 (4)
Impacts of conservation interventions	9 (8)	11 (11)	3 (4)	0 (0)	1 (5)	11 (7)

[a] *The thematic area with the greatest number of questions for each study is marked with an asterisk (*).*
[b] *This study.*
[c] *Sutherland et al. (2009), correlation with Oceania $\rho = 0.46$, $p = 0.12$.*
[d] *Rudd (2014), $\rho = 0.46$, $p = 0.12$.*
[e] *Parsons et al. (2014), $\rho = 0.42$, $p = 0.15$.*
[f] *Morton et al. (2009), $\rho = 0.25$, $p = 0.42$.*
[g] *Varma et al. (2015), $\rho = 0.45$, $p = 0.12$.*

failure is especially important where communities are small and failed conservation projects might impede future initiatives. The emerging field of social-impact evaluation (Ferraro 2009; Gurney et al. 2014) will help address these questions. Management strategies that deliver conservation benefits while engaging and incentivizing local communities are likely to be those that simultaneously achieve social, economic, or cultural objectives (Jupiter et al. 2014*b*).

Comparison of priorities among sectors

We identified 3 research questions as cross-sectoral priorities. They were in the top 10 questions for all 3 sectors and ranked first, second, and seventh overall (Table 1): What are the highest priority areas for conservation in the face of increasing resource demand and climate change? How should marine protected areas be networked to account for connectivity and climate change? What are the most effective fisheries management policies that contribute to sustainable coral reef fisheries?

In addition to 3 cross-sectoral priorities, research-question ranks were positively correlated across all 3 sectors. Academic respondents' priorities were most closely aligned with those of respondents in both NGOs (Spearman's rank correlation $\rho = 0.60$, $p < 0.001$) and government ($\rho = 0.58$, $p < 0.001$), although all sectors had positive correlations (NGO and government $\rho = 0.52$, $p < 0.001$). The smallest positive correlation was between practitioners from NGOs and government agencies. This might call into question whether NGOs can effectively act as boundary organizations between science and policy making (Cook et al. 2013). For example, the number one question for NGO respondents (How can spatial management be designed to account for the ecology of commercially important macroinvertebrate species?) was not in the top 10 questions for respondents from other sectors. Alternatively, NGO-based practitioners may be more likely to prioritize research that will inform local-scale management, whereas those in government agencies focus on broader policy issues. Given our relatively modest sample size, this result is not conclusive.

Comparison with global and other regional priorities

Across the priority-setting initiatives we examined, the distribution of research priorities by theme (Table 2) is largely similar to the distribution for SIDS, with a few notable differences. Research priorities for Oceania's SIDS placed much greater emphasis (10% of questions) on fisheries management relative to the global (1%), Australian (0%), or Indian (1%) exercises. This is unsurprising, given the importance of fisheries to livelihoods, economies, and food security in the region. However, just 6% of the global ocean research priorities focused on fisheries. Oceania also placed greater focus on protected areas than any other studies. We speculate this might be due to the need to adapt approaches to protected-area design and implementation to fit the diverse sociocultural contexts of Oceania's SIDS. The challenges associated with implementing protected areas in regions with high dependence on natural resources are considerable, and the

need to resolve such trade-offs may translate to greater information needs.

Only 1% of research questions for Oceania's SIDS focused on freshwater ecosystems (5% for Australia, India, and globally), despite the vulnerability of freshwater resources on low-lying islands, increasing pressures on water resources, and potential impacts from climate variability (Australian Bureau of Meteorology & CSIRO 2014). This may indicate that management of freshwater resources is thought to be related to infrastructure or development, rather than natural resource management, or simply that there are few experts (or survey respondents) working on freshwater ecosystems.

Similarities in the proportion of questions in each theme across the priority-setting initiatives mask differences in the subject matter of questions posed. For example, the percentage of questions within the societal context and change theme was similar for the global (17%), Oceania (15%), and India (16%) lists (Table 2). In Oceania's SIDS, questions within this theme focused on issues relating to customary tenure or local ownership of resources and incorporating traditional knowledge into management. Traditional knowledge also featured in the Indian questions, but was absent from the global agenda, which had 1 question on how resource-tenure systems shape conservation outcomes. This indicates resource-management problems common to developing countries contexts may be overlooked in global prioritizations. In contrast, questions posed in the global study focused on impacts of global economic markets, trade agreements, and subsidies, for which there was 1 question for Oceania's SIDS and none from India. These differences underscore the importance of identifying research priorities for specific regions and contexts.

Questions for which enough is known

We sought to identify research questions for which scientific understanding presently exists but has not been adequately communicated to practitioners. Three questions on the initial list were considered answered by >25% of respondents overall: Which fishing gears and methods are more or less sustainable (31% academic, 20% government, 17% NGO respondents)? How should marine protected areas be designed to conserve marine biodiversity (19% academic, 10% government, 34% NGO respondents)? What is the role and relative importance of human population growth in the overexploitation of marine resources (19% academic, 10% government, 34% NGO respondents)?

However, for 70% of questions on the initial list and 79% of questions on the short list, at least 1 respondent thought sufficient understanding exists. For a few of these, respondents offered evidence that questions have been resolved. For example, a question on the initial list was: How can crown of thorns starfish outbreaks be managed in remote communities who have no access to chemicals and other fancy gadgets? A respondent commented that household vinegar can be used, as demonstrated in recent scientific publications (Boström-Einarsson & Rivera-Posada 2016) and highlighted in the *SPC Fisheries Newsletter* (Dumas et al. 2015), which disseminates scientific research to practitioners in the region. To verify whether other questions have been answered would require either a broader pool of respondents or targeted research beyond the scope of this study.

Two questions were considered answered by >10% of respondents yet were ranked as high priority. Both related to coral reef fisheries management: What are the most effective fisheries management policies that contribute to sustainable coral reef fisheries? Which fish species are especially vulnerable to fishing impacts and require strict management?

This could be interpreted as a failure to effectively communicate research outputs from this area of research to practitioners. However, given that resources such as the *SPC Fisheries Newsletter* publish articles (e.g., Cohen et al. 2014) on these topics, it is more likely indicative of differing opinions over the level of understanding required to undertake management.

The NGO respondents were most likely to rate questions as already answered (mean proportion of questions rated enough known = 10% NGO, 4% academic, and 2% government agency). This was counter to our expectation that academic respondents would be most likely to consider that questions had been answered, given their presumed greater familiarity with primary scientific literature. Comments provided by survey respondents (e.g., "I think fishing gear impacts are well known. We just need to enforce and manage them." "We can still do conservation . . . even where the taxonomy is poorly known.") suggest this reflects practitioners' pragmatism and willingness to act with incomplete information, particularly where knowledge gaps relate to underlying mechanisms that do not affect the best course of management action.

Conclusions

It is likely that insufficient scientific understanding is less of an obstacle to effective conservation and natural resource management in Oceania's SIDS than are inadequate resources and local capacity to implement management actions (Brodie et al. 2013; Weeks et al. 2014). Nevertheless, we identified through our priority-setting exercise areas where scientific research could improve the effectiveness or efficiency of conservation practice or policy in this region within the next 10 years.

Many of the research questions prioritized by scientists and practitioners point to the need to resolve trade-offs between objectives related to livelihoods and

biodiversity conservation or to decide how best to invest limited resources. These questions speak to the particular challenges of undertaking conservation within SIDS and the need for a research agenda that is responsive to the sociocultural context of Oceania.

Research priorities of scientists working within academia aligned reasonably well with those of practitioners in this region. However, our sample of academics was likely biased toward those committed to creating actionable knowledge and may not reflect the distribution of research effort in the region overall.

Our results highlight the importance of identifying research priorities for specific regions and contexts. Although global horizon scanning (Sutherland et al. 2016) and identification of research priorities can identify commonalities and emerging trends, context-specific research challenges may be tackled successfully by smaller research teams and students. Although our sample size did not permit within-region comparison of research priorities, differences will exist due to the diversity of island geographies, economies, and systems of governance. For example, countries whose economies rely almost exclusively on fisheries may place less emphasis on strict habitat protection than those who depend on tourism.

Finally, although following an established method permits qualitative comparison of our results with those from previous studies, we acknowledge that other approaches may be more effective in engaging practitioners in this region in formulating research questions. Ideally, research to inform conservation and management should be designed and conducted collaboratively among scientists, practitioners, and, where possible, resource owners or users (Almany et al. 2010). This is true both for Oceania's SIDS and globally. We hope our list of research questions forms a starting point to making those connections where they do not presently exist. Many high-priority questions are broad in scope but could be broken into constituent components or addressed within a specific locality or context. Answering these questions will require both ecological and social-science research, most of which would be best undertaken in close collaboration with practitioners in the region.

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Supporting Information

A complete list of the 115 initial questions, the content of surveys, and information on survey respondents (Appendix S1) are available online. 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.

Table S1. Breakdown of respondents to the shortlisting survey, by primary geographic region of expertise and sector.

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