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## Insights from twenty years of comparative research in Pacific Large Ocean States

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### ABSTRACT

Under global environmental change, understanding the interactions between people and nature has become critical for human survival. Comparative research can identify trends within social-ecological systems providing key insights for both environmental and developmental research. Island systems, with clear land boundaries, have been proposed as ideal case studies for comparative research, but it is unclear to what extent their potential has been fulfilled. To summarize existing research and identify potential gaps and new directions, we reviewed comparative environmental and developmental research on Pacific Large Ocean States. A diversity of case study locations and research themes were addressed within the sample of reviewed studies. Within the reviewed literature climate change, energy infrastructure, trade and fisheries were key themes of environmental and developmental research compared between island systems. Research was biased towards wealthier Pacific Large Ocean States and those with a relatively higher degree of socio-economic development. Our review highlights the potential value of a stronger *a priori* inclusion of spatial scale and conceptual frameworks, such as spatial resilience, to facilitate generalization from case studies.

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Over the last few decades, environmental science has increasingly identified the importance of understanding the human element in environmental problems (Mace et al. 2012; Teel et al. 2018). The ‘social turn’ in environmental science has been supported by the development of conceptual frameworks of ecosystem resilience and sustainability, which seek to identify the critical connections between ecosystems and social, economic, and political systems and explore the ways in which their interactions both drive and respond to environmental change (Holling 2001; Ostrom 2009; Kates 2016). Place and culture are important influences on social-ecological dynamics (Gurney et al. 2017), leading many researchers to focus on a single localized case study such as a city, village, a catchment, or a protected area (McLain et al. 2013; Gerlak et al. 2018).

Place-specific analyses produce a deep understanding of the local context but can also be a barrier to generality and the development of theory because their findings are contingent on unique combinations of variables and may have low relevance outside the study system (Václavík et al. 2016). One potential antidote to localized over-fitting in environmental and development science is a greater emphasis on comparative research (Partelow 2018; Cumming et al. 2020). Comparative research is particularly relevant for understanding questions and generalities

relating to space and scale, such as how geographic location, pattern, and connectivity influence social-ecological dynamics (Cumming 2011; Cumming et al. 2017). For example, altitude, rainfall, location in a catchment, and soil properties are critical for understanding food production in small-scale farming systems; but many of the more general and absolute influences of these variables on food security relative to those of technology, social organization, social networks, and land use patterns can only be understood through comparison between different social-ecological systems (SEs). However, comparative evaluation of spatial dynamics between different SEs is often complicated by a range of potential confounding factors that are usually resolved through subjective decisions. For example, determining where the boundaries of the study system fall is challenging for large or more dispersed systems (Fleischman et al. 2014; Villamayor-Tomas et al. 2014); political and biophysical boundaries are often poorly aligned (Cumming et al. 2020); the many scales at which pattern-process dynamics are relevant to study goals, and the importance of system location along an environmental gradient, may be unclear (Epstein et al. 2015); and economic or ecological flows between locations can be difficult to measure.

On small to medium-sized islands, the land–sea interface provides a clear system boundary and

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geographical center point (Vitousek 2002; Bhatia and Cumming 2020), defining spatial scale and forcing a tight correspondence between ecological, social and economic systems. Many aspects of spatial dynamics are also much clearer on islands, where the difference between within-island and between-island flows and exchanges is simpler to describe. The clarity of spatial relationships in analyses of islands has facilitated a stream of highly influential literature in social-ecological research, including island biogeography (Wilson and MacArthur 1967), the patch-matrix paradigm, habitat fragmentation (Simberloff and Abele 1982; Lindenmayer and Fischer 2006), metapopulation ecology (Hanski 1999), sociopolitical dynamics (Rick et al. 2013) and human migration (Erlandson 2010).

Some ideas from social-ecological research can be directly transferred into analyses of land- and seascape SESs. However, many spatially explicit social and economic elements of frameworks in environmental and developmental research currently lack strong empirical support and testing (Cumming et al. 2020). To characterize generalities and possible strengths, weaknesses, and gaps in environmental and developmental research that use islands as case studies, we reviewed the use of Pacific Large Ocean States (LOS) as units of comparison. Our goals were (1) to summarize locations, subject matter and potential drivers of comparative research using Pacific LOS; (2) to provide insight into how the research agenda in environmental and development research could be strengthened; and (3) to shed light on possible areas of enquiry in which comparisons between islands could be used more fruitfully to build or test general theory and conceptual frameworks of resilience and sustainability.

### Pacific Large Ocean States as case studies

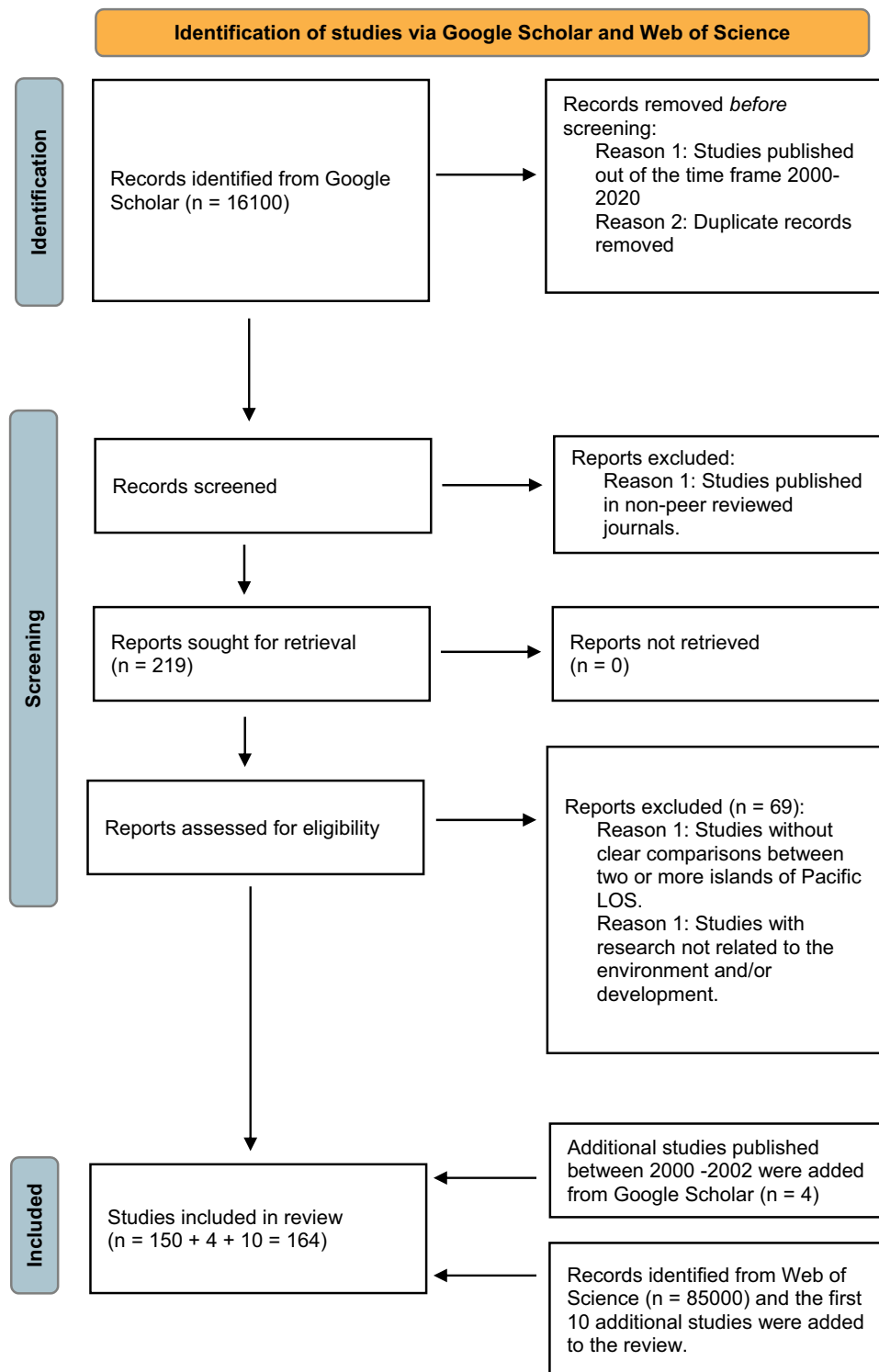
Terminology relating to Pacific LOS has long been contested. We use the term Pacific LOS as it is the classification chosen most recently by island inhabitants themselves (Hume et al. 2021). Pacific LOS are geographically dispersed (unlike islands adjacent to the mainland) and often remotely located relative to continental land masses and the centers of global populations and economies. Their environments cover gradients in temperature, rainfall, wind speed, wave action, and various other biophysical attributes. Islands across the Pacific have been known for long-standing relations between people and the environment and specific customary tenure systems (Vitousek 2002; Campbell 2009; McMillen et al. 2014). Pacific LOS are characterized by rich traditional knowledge and natural resources, with relatively small populations that experience limited global economic opportunities and market access

(United Nations 2014). These factors impact their political landscapes (Fairbairn 1994; Hay 2013; Barnett and Waters 2016; Ahmed and Mishra 2020). Together with their relatively small size, these attributes have been argued to result in Pacific LOS being diverse but both uniquely susceptible and uniquely resilient to some global perturbations (Vitousek 2002; Hay 2013) with many shared developmental challenges (Bolesta 2020). LOS can be seen as microcosms of many important issues and concerns shared globally (United Nations 2014), being both highly susceptible to global environmental change and potentially a frontrunner in resilience and sustainability (Gough et al. 2010; Ahmed and Mishra 2020). Thus, Pacific LOS provide interesting and useful case studies for environmental and developmental research, being simultaneously complex and comparable (Vitousek 2002; Fernandes and Pinho 2017).

### Exploring the degree to which Pacific LOS have been used as models for comparative research: a literature review

As summarized in Figure 1, we chose to use Google Scholar as our first source of publications because its breadth of interdisciplinary literature is greater than other alternatives (Martín-Martín et al. 2018; Gusenbauer 2019). In Google Scholar, we searched using the keyword string “Comparison OR Comparative OR Compare AND Island OR Islands AND Pacific AND “Small Island Developing States” OR “SIDS” OR “PSIDS” OR “Pacific Island Countries and Territories” OR “PICT” OR “Small Pacific Islands”. We included several additional locations that are not typically considered Pacific LOS but are geographically in scope for this review on comparative research: The Hawaiian Islands, Norfolk Island, Pitcairn Island, and Easter Island. For example, the geological gradient provided by the different ages of islands comprising the Hawaiian Islands offers fertile ground for research on agricultural systems. We included the search term “Small Islands” in our search string for geographic reasons and because it had been previously adopted by Pacific Island communities to describe themselves (Mimura et al. 2007).

The first 150 studies that met the following inclusion criteria were included: (1) studies published in peer-reviewed journals; (2) studies published between 2000 and 2020; and (3) studies including clear comparisons between two or more islands of Pacific LOS (broadly interpreted, as described above) in research areas relating to the environment and/or development. We also included studies that used case studies from within the same Pacific LOS, as



**Figure 1.** A PRISMA flow diagram of the Pacific LOS literature review adapted from Page et al. (2021). The diagram outlines the review methodology.

long as two or more islands from that Pacific LOS were considered. We adopted the definition of development used by the United Nations, “a comprehensive economic, social, cultural and political process, which aims at the constant improvement of the well-being of the entire [human] population” (Kiwauka 1988). We used a rarefaction curve (Sanders 1968) to estimate when a sufficiently representative sample size of studies had been reached

(Figure A1). We found that the number of themes discussed within the pool of publications did not change after 110 publications, making 150 papers a suitably rigorous sample for identifying the main disciplines and themes of comparative research within Pacific LOS. To ensure that the entire time period (2000–2020) was thoroughly sampled, we included a minimum of 10 studies per three-year period in the review, leading us to add four

additional studies between 2000 and 2002. Furthermore, to avoid bias resulting from using only one scientific search engine (i.e. Google Scholar), we used the same criteria to conduct a search in Web of Science and the first 10 studies that were not replicates of the Google Scholar output were also included. A total of 114 studies in numerical order were screened in order to retrieve 10 additional studies from Web of Science. The total number of studies included in the final data set was 164.

After finalizing, our sample of 164 publications, we extracted information from each study on its location, subject matter, and attributes relevant to comparative research. Descriptive data extracted comprised of the keywords included, case study locations, funding source, publication year, number of citations and the spatial scale of the case studies compared, that is, was environmental and/or developmental research compared across local communities, a whole island, countries/territories or entire regions. If the keywords were not already stipulated by the study, they were taken from the study title. All keywords used within the literature review were assembled into a database. We then removed all keywords and phrases used in the Google Scholar search string from the database, and kept only the keywords that appeared more than once to construct the final keyword database.

To explore bias in the location of individual case studies, we tested whether independent social-ecological and socio-economic indicators explained their frequency. Social-ecological and socio-economic indicators included Gross Domestic Product (GDP)/Land area (km<sup>2</sup>) (both data were sourced from the World Bank Open Source Data (2019) in order to calculate this indicator), Human Development index (HDI) (United Nations Human Development Reports 2020), Ecological Footprint (EF) (Global Footprint Network) and the percentage of protected area (percentage of territorial area) (World Bank Open Source Data 2019). We used GDP/Land area instead of simple GDP because it provides a rough correction for differences due to island size by describing economic output per area of land. The HDI measures the quality of life (life expectancy, level of education and standard of living) of a given population (Hak et al. 2012). EF is a measure of the degree of human demand on natural capital (Hak et al. 2012; Collins and Flynn 2015). The percentage of protected area included both terrestrial and marine areas designed by national authorities. We used Mardia's Multivariate Skewness and Chi-square analyses to understand the relationship between the different social-ecological and socio-economic indices (GDP)/land area (km<sup>2</sup>), Human Development index (HDI), Ecological

Footprint (EF), the percentage of protected area (percentage of territorial area) and the frequency of study of each Pacific LOS included in the literature review. These analyses produced a skewness statistic ( $z$ ) and corresponding  $p$ -value. A positive  $z$  value above 0.5 indicates that the data is strongly skewed to the right and a negative value above 0.5 indicates that the data is strongly skewed to the left. A significant  $p$ -value ( $\leq 0.05$ ) indicates that there is a significant relationship between the two variables.

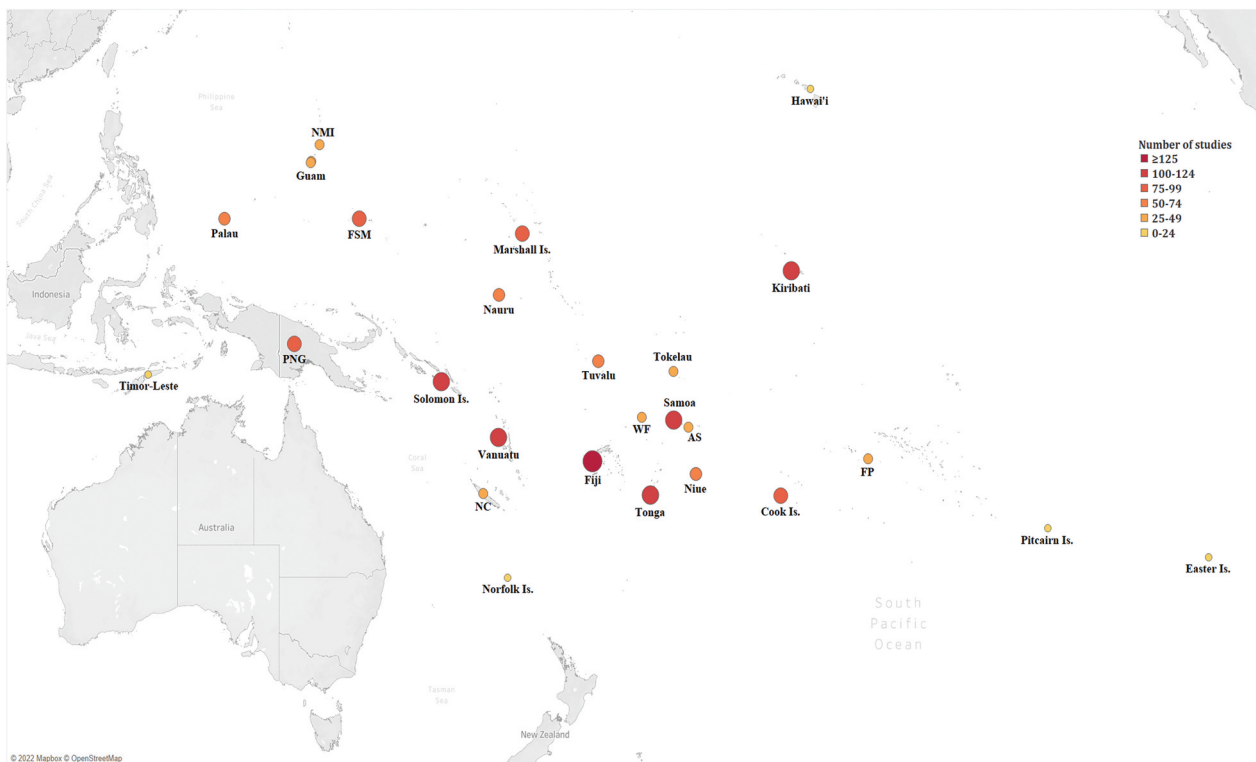
The final disciplines included ecological, economic, social, social-ecological and socio-economic. Studies that considered both social and ecological actors and/or their interactions were then characterized by theme as well as the presence of the overarching conceptual themes of resilience or sustainability. This information was derived from the keyword database as well as a more detailed review of the publications. Categorization was an iterative process by a single reviewer, during which new categories were merged or created as the data set grew. The final themes included agriculture, anthropology and culture, climate change, conservation, development, economics, biodiversity and ecosystem services, fisheries, geology and weather, governance, and health. Studies could belong to more than one discipline and/or theme. However, studies could not be both single-discipline (e.g. social) and multi-discipline (e.g. social-ecological). For example, Laurans et al. (2013), a study on the economic benefits of coral reefs, was deemed both socio-economic and social-ecological and was categorized into the economics and ecosystem services themes. Data were collected in Microsoft Excel and then imported to R (R Core Team 2021) for visualization.

## The “Where” and “What” of comparative research on Pacific LOS

### *Spatial distribution, levels and scales of comparative research*

Pacific LOS identified within the review were American Samoa, Cook Islands, Easter Island, Democratic Republic of Timor-Leste, Federated States of Micronesia, Fiji, French Polynesia, Guam, Hawai'i, Kiribati, Marshall Islands, Nauru, New Caledonia, Niue, Norfolk Island, Northern Mariana Islands, Palau, Papua New Guinea, Pitcairn Island, Samoa, Solomon Islands, Tokelau, Tonga, Tuvalu, Vanuatu and Wallis and Futuna. Research was conducted on many Pacific LOS with Fiji, Vanuatu and Tonga being the most common case study locations of comparative research within the reviewed literature (Figure 2). An average of 10 (SD =  $\pm 7$ ) different islands were included per study.

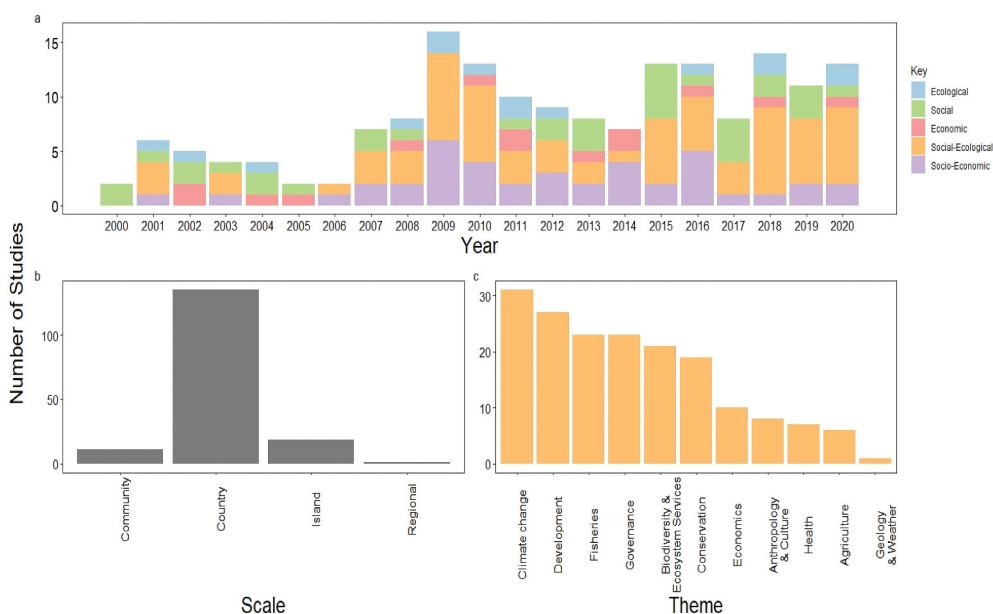




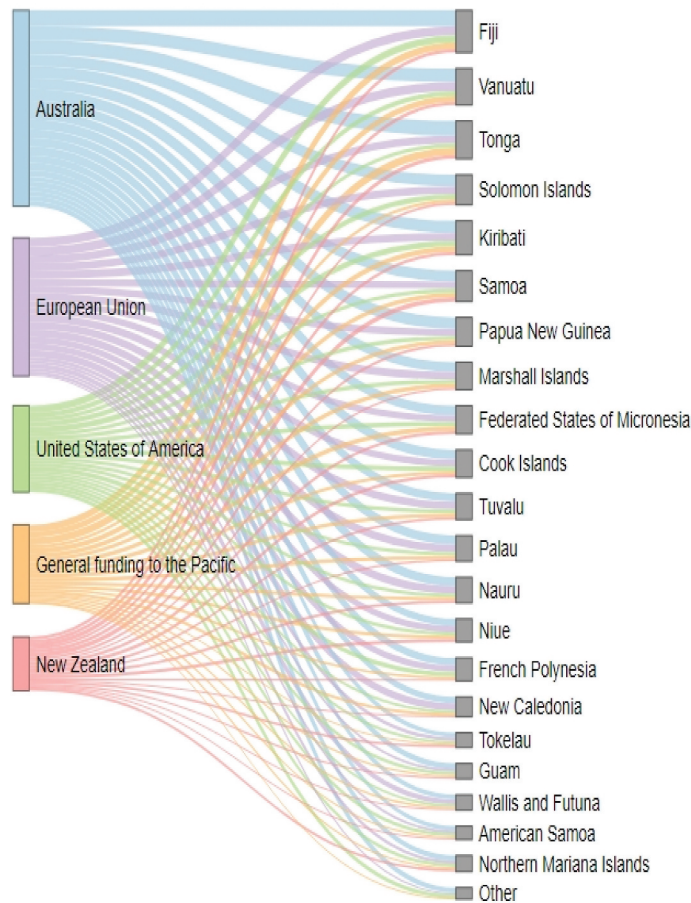
**Figure 2.** A map of the Pacific region indicating the location and frequency of studies of each Pacific LOS small Pacific Islands. As = American Samoa, FP = French Polynesia, FSM = Federated States of Micronesia, NC = New Caledonia, NMI = Northern Mariana Islands, PNG = Papua New Guinea, WF = Wallis and Futuna.

The reviewed published studies considered environmental and/or developmental comparisons across a range of spatial scales. The spatial scales from which comparisons were made ranged from communities to regions

within the Pacific. Studies at the spatial scale of a country/territory were the most common, while regional studies (Micronesia, Polynesia and Melanesia) were the least common within the reviewed literature (Figure 3(b)).



**Figure 3.** Frequency plots indicating the research disciplines of the literature reviewed from 2000 to 2020 (a), the spatial scale of studies (b) and the research themes of only the social-ecological disciplined studies (c). Additional sources that contributed to the figures but are not directly cited in text include Chand 2002; Rasanathan et al. 2007; Mishra et al. 2010; Pak et al. 2014; Ekeroma et al. 2016; Keeley 2016; Lin et al. 2017; Takahashi 2019; Tolkach and Pratt 2019.



**Figure 4.** A Sankey diagram indicating the top five sources of funding of the studies reviewed. The sources of funding were grouped into regions with a single/joint governing body. The ‘Other’ category is an aggregate from Pitcairn Island, the Hawaiian Islands Timor-Leste, Easter Island and Norfolk Island.

### Potential driving forces behind comparative research

There was a significant relationship between frequency of case study location within the review and GDP/Land Area ( $\text{km}^2$ ), and percentage of protected area (percentage of territorial area), indicating comparative research with a strong bias towards wealthier islands and those with a higher area percentage of protected areas ( $z = 5.502$ ;  $4.011$ ,  $p < 0.001$ ;  $< 0.001$ ). HDI and EF were not significantly related to the frequency of study. Values of HDI and EF from the islands represented in this review were wide-ranging but often skewed to the right ( $z = 1.879$ ;  $1.617$ ,  $p = 0.751$ ;  $0.181$ ).

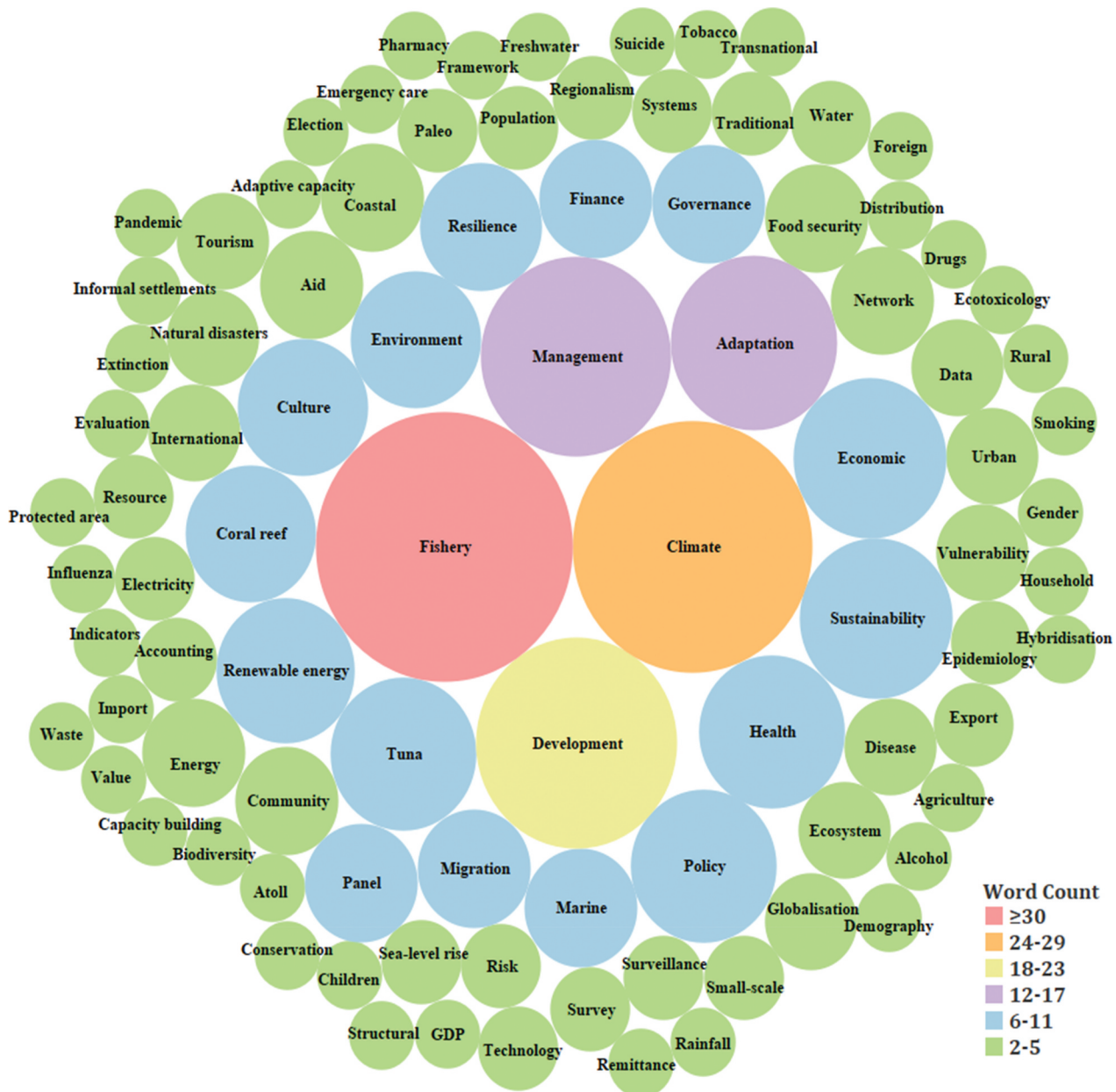
Most funding sources in the reviewed papers originated from members of the Organization for Economic Co-Operation and Development (OECD), with Australia most often funding research across all reviewed studies (Figure 4). The European Union was also a significant funder of social-ecological comparative research within Pacific LOS. Many studies identified aid-derived funds (e.g. via CROP, Council of

Regional Organizations in the Pacific) as general internal funding (Figure 4), making it difficult to determine the extent to which Pacific LOS fund their own research. Within our sample publications, 81 (54%) of studies did not stipulate a funding source and five (3%) studies indicated no funding was received.

### Research disciplines and themes included in comparative studies

We found that 92 keywords were identified more than twice. Common keywords within the reviewed literature included fisheries, management, migration, finance, policy, renewable energy, coral reefs, coast, and environment (Figure 5). These keywords as well as an individual review of each publication were used to identify the themes and disciplines of comparative environmental and development-related research within the Pacific LOS.

Social (30), ecological (14), and economic (14) research disciplines were represented within the literature review (Figure 3(a)). However, the majority



**Figure 5.** A bubble plot indicating the key word counts used within the literature review.

of studies were multi-disciplinary social-ecological (64) and socio-economic (39) (Figure 3(a)). Although our methodology ensured that all periods between 2000 and 2020 were covered, some years were more common than others within the reviewed literature. The year 2002 had the fewest number of comparative studies on Pacific LOS ( $n = 2$ ) and 2009 had the highest ( $n = 15$ ). Interdisciplinary studies (social-ecological and socio-economic) were found to increase across the review period from seven studies within the first 5 years (2000–2004) to 36 studies within the last 5 years (2016–2020) of the review period (Figure 3(a)). The percentage of multi-disciplinary social-ecological comparative studies throughout the review was 39% (60 studies) and in the last 5 years approximately one in every two

comparative research studies on Pacific LOS applied social-ecological theory and/or methods.

After reviewing all social-ecological studies, a total of 11 study themes were detected: climate change (31), development (27), fisheries (23), governance (23), biodiversity and ecosystems services (21), conservation (19), economics (10), anthropology and culture (8), health (7), agriculture (6) and geology and weather (1) (Figure 3(c) and Table A1).

Social-ecological comparative studies of Pacific LOS took place within a range of ecosystems, including coral reefs (Laurans et al. 2013; Dacks et al. 2020), rocky shores (Harris and Weisler 2018), seagrass beds (Brodie et al. 2020), wetlands (Ellison 2009) and forests (Wairiu 2017; Ticktin et al. 2018) including the ecosystem goods and services they provide.



Fisheries were mainly considered as a source of food security (Charlton et al. 2016), with tuna fisheries being widely researched (Read 2006; Hannesson 2008; Hanich and Tsamenyi 2009). Agricultural practices (McGregor et al. 2009; Shelomi 2020) and the challenges of water quality and accessibility (Elliott et al. 2017; Ahmed and Mishra 2020) were also compared across Pacific LOS. Avenues to conserve vital ecosystems and their goods and services that are impacted by a range of anthropogenic perturbations were broadly studied (Keppel et al. 2012). Research on anthropogenic perturbation was dominated by climate change, with climate change impacts and climate policy implementation being compared across Pacific LOS (Turner et al. 2007; Nunn et al. 2016; Mackay et al. 2019; Trundle 2020). Lastly, research on geology and weather included comparative research on topics, such as coastal erosion (Kumar et al. 2018) and natural disasters (Goff et al. 2011; Noy 2016). Reducing natural disaster risks through policy implementation and revenue allocation was a key aim within the reviewed literature (Edmonds and Noy 2018; Noy and Edmonds 2019).

Socio-cultural aspects were also discussed, such as how culture and traditions heavily influence decision-making in environmental management and governance (Saffu 2003; DiNapoli et al. 2018; Oakes 2019). For example, Kingsford et al. (2009) described how effective conservation depends on a range of social-ecological dynamics, such as education, political will, community aspirations, social and economic capacity, and scientific understanding.

Social-ecological comparative research had a strong focus on the degree of development within Pacific LOS, specifically in relation to energy infrastructure (Singh and Leal Filho 2012; Dornan 2015; Michalena and Hills 2018; Joseph and Prasad 2020). Other obvious topics of comparative research on development-related topics within the review included comparing financial aid across different Pacific LOS (Betzold 2016a, 2016b) and both the amount of trade and the different commodities traded by the Pacific LOS (Narayan and Narayan 2004; Purcell et al. 2014; Weber 2017). Research on social welfare and health issues compared the degree of gender equality (Baker 2018), and drug usage (Smith et al. 2007; Martin and de Leeuw 2013; Peltzer and Pengpid 2015), as well as the availability of educators (Iredale et al. 2015), and the profiles of different diseases and infections (Russell et al. 2003; Basuni et al. 2004; Tin et al. 2014; Sarfati et al. 2019) in different Pacific LOS.

The five most cited social-ecological comparative studies (Barnett 2001, Singh et al. 2001, Zeller et al. 2007, Bell et al. 2009, Webb and Kench 2010) within the review addressed climate change, fisheries, social welfare and governance. The most cited social-

ecological study within the review period (2000–2020), Barnett (2001), explored the role of scientific enquiry in climate change adaptation planning. Including the study done by Barnett (2001), the literature review identified a total of 60 social-ecological studies (37%) containing the keywords sustainability and/or resilience (Figure 5). This suggests that around a third of reviewed comparative environmental and developmental research using islands as case studies attempted to link its findings to broad conceptual themes, such as resilience. Social-ecological studies that showed the strongest interest in linking research to resilience or sustainability predominantly had multiple themes, of which social welfare, climate change, governance, biodiversity and ecosystem services were the most popular. For example, Lauer et al. (2013) and Wairiu (2017) aimed to identify management strategies that increased resilience of different ecosystems to climate change, and avenues of sustainable resource use were compared by Erickson and Gowdy (2000) and Read (2006).

### Environmental science and development research: insights and future directions

Our analysis suggested that although solid foundations exist, considerable scope remains for research using Pacific LOS as comparable case studies in environmental and developmental research. This includes the incorporation of existing social-ecological gradients across Pacific LOS, the subject matter under consideration, and the use of data from islands to test broad general theories. Comparative research was spread throughout the Pacific Region, but Fiji, Vanuatu and Tonga were most frequently studied within this review. Fiji, Vanuatu and Tonga are in close proximity to funding countries, such as Australia and New Zealand. Existing networks and facilities in more economically developed countries, such as Australia and New Zealand may assist in research project initiation (Fernandes and Pinho 2017). A reasonable sample of studies within our review existed across some existing socioeconomic gradients (e.g. HDI and EF) but not others (e.g. GDP/Land Area and percentage of protected area (percentage of territorial area)). Our review highlights the possibility that islands with a relatively low degree of wealth per area and total protected area, such as the Federated States of Micronesia and Solomon Islands, could be included more frequently in environmental and developmental comparative research in order to represent a broader range of social-ecological conditions. Islands that were studied less frequently within the review often had comparatively smaller population sizes (World Bank Open Source Data 2019), implying a lower priority for research on sparsely populated islands.

Interdisciplinary research (e.g. social-ecological studies) was dominant across the review period and is likely to increase into the future. The diversity of research themes testifies to the range of different sustainability achievements and challenges in the Pacific, but there was a strong focus on climate change, fisheries, social welfare and sustainability governance.

Climate change is a growing global concern (McMillen et al. 2014; Monroe et al. 2019; IPCC 2021) and one to which LOS show unique vulnerabilities due to their location and size (Nunn 2009; Hay 2013; United Nations 2014). Climate change has been a long-term priority for the people of Pacific LOS as they witness its impacts first-hand (Carter 2015). Pacific Islands contribute less than 1% of global greenhouse gas emissions (United Nations 2014), and research has thus focused on climate change adaptation. The reviewed comparative environmental and developmental research is proactive in this field and has suggested adaptation avenues in a range of sectors, such as food production and environmental management. A number of studies in our sample of studies also focused on implementing climate policy at a country level as well as community-based adaptation (Nunn 2009; Nunn et al. 2014; Mackay et al. 2019; McNamara et al. 2020). Meanwhile, comparative research on natural disasters (e.g. cyclones) was less prominent within the review, despite calls for greater consideration of disaster mitigation (United Nations 2015).

The close dependence of many island communities on nature was evident in the research themes, with biodiversity and ecosystem services being extensively researched within the reviewed literature. Fisheries are a major source of food security and livelihoods in the region (Bell et al. 2009; Hay 2013; Campbell 2015; Charlton et al. 2016), making their thorough coverage a strength of current environmental research. Among the reviewed studies, insights into the governance of fisheries were focused on tuna fisheries (Read 2006; Barclay and Cartwright 2007; Hannesson 2008; Stephens 2008; Hanich and Tsamenyi 2009), excluding many other fisheries, both commercial and subsistence, within the Pacific region. Local agricultural techniques, such as harvest regulation, food preservation and fragmented land use, are widespread and offer food security despite occasional extreme weather conditions (Fairbairn 1994; Campbell 2009). Such adaptive agricultural practices across the Pacific can offer deep insights into spatial scale and social-ecological resilience (Campbell 2009; McMillen et al. 2014), but were not a frequent theme for comparative research within this review. The same is true of minerals and forestry products (Fairbairn 1994; Gilberthorpe and Hilson 2016). Overall, although ecosystem services and

resources were frequently studied, many kinds of ecosystem services and resources, and their contributions to human wellbeing were not considered within the 164 reviewed studies. Marine ecosystem services and impacts were better covered than terrestrial ecosystem services (Thaman 2008; Fernandes and Pinho 2017). For example, invasive species, which pose severe threats to island ecosystems (Hay 2013; Meyer 2014) were not covered within the reviewed literature. Anthropogenic impacts such as species introductions are a challenge for spatial planning (Fernandes and Pinho 2017), further highlighting the importance of comparative analyses that can provide insights across spatial scales. Although marine ecosystems were more thoroughly covered within the review, the number of reviewed studies comparing environmental and/or developmental research across coral reefs (for example, Brewer et al. 2012; Dacks et al. 2018) were surprisingly few. Coral reefs are known to be important for people of Pacific LOS (Bell et al. 2018) and we expected a correspondingly large presence in the reviewed environmental and developmental comparative research literature. This result may have been due to our methodology (for example, comparative research across coral reefs could be using different key words to those used within our search string) or alternatively, coral reef studies may in fact be less interdisciplinary than our preconceptions suggest.

Pathways for (sustainable) development, such as those that are outlined within the United Nations Sustainable Development Goals (SDGs) (United Nations 2015) were of high interest and represent a common research agenda within the reviewed literature, together with understanding the impacts of globalization on connectivity, social and ecological diversity, and resilience (Hay 2013; Lauer et al. 2013). Social development conversations about gender equality ( $n = 3$ ) were present within the reviewed literature, but other critical development concerns, such as unemployment ( $n = 0$ ) were absent from the reviewed literature. Despite having the largest relative health expenditure within LOS, and close linkages between ecosystems and human health, the health systems of many Pacific LOS are impacted by poor support and policy implementation (United Nations 2015; Firth 2018). Healthcare highlights the need to understand different social-ecological dynamics at different spatial scales; for example, the isolation of small island communities challenges the distribution of health care (United Nations 2014) while influencing that of parasites and pathogens. Sanitation and the role of ecosystems, such as green infrastructure and its relationship to waste processing and disposal, were not mentioned within the 164 journal articles – marking a potential blind spot within the reviewed literature. Another area of research that did not

feature within the reviewed literature was tourism, despite it being a substantial contributor to the economy of Pacific LOS (Hay 2013; United Nations 2014; Fernandes and Pinho 2017) and a concern for environmental and sustainable development management. Tourism can create vulnerability within the Pacific Region due to its environmental impacts as well as through exposure to external impacts, such as global recessions and pandemics (Hay 2013; Fernandes and Pinho 2017).

It is integral to consider the range of interactions and feedbacks between people and nature across multiple levels of spatial organization to understand social-ecological dynamics and regional sources of novelty and adaptive capacity (Allen and Holling 2010; Cumming et al. 2017). We found that the majority of comparative studies within the review concentrated at the country level, with an average of 10 islands being included in a single study. While this level of comparison suggests that the potential of Pacific LOS as comparative case studies is being exploited, the strong focus at a national level creates an under-representation of social-ecological dynamics at other societal levels and spatial scales. For example, local traditional knowledge plays an important role in community adaptation to natural and anthropogenic perturbations (Campbell 2009; McMillen et al. 2014; McNamara et al. 2020); comparative environmental and developmental research at the community level could offer deeper insights into influences on social-ecological resilience. Challenges impacting social-ecological resilience across all Pacific LOS frequently relate to their location and size, including the abundance and diversity of natural resources, economic options, and the exposure and sensitivity to external impacts (Barnett and Waters 2016).

Our review methodology had some limitations, such as the replicability of our search results, the exclusion of non-peer reviewed studies, and Google Scholar's focus on English-language articles (Rovira et al. 2021). Nonetheless, as illustrated by the rarefaction analysis, the number of studies reviewed here (164) was sufficiently large to highlight some general conclusions and offer insight into comparative research on Pacific LOS.

## Conclusions

We found a substantial number of studies comparing environmental and developmental research across Pacific LOS. This research makes it clear that Pacific LOS generally have much to offer as subjects for the study of spatial influences on social-ecological processes and dynamics. Comparative research within Pacific LOS is making progress in research diversity and the inclusion of a wide variety of case studies. We found potential biases in the choices of case study,

and these – with their attendant risks for scientific understanding – are also likely to be reflected in case studies in other, mainland locations.

The reviewed literature included a diversity of environmental and developmental comparative research. Key areas of the United Nations SDGs (United Nations 2015) such as social welfare, access to water, climate change, marine ecosystem management, waste management, energy, finance, and trade were covered within the reviewed literature. However, other areas of the United Nations SDGs (United Nations 2015) such as terrestrial ecosystem services, education, unemployment, access to sanitation, natural disasters, and tourism were highlighted less within the reviewed literature.

Relatively few theoretical advances in social-ecological systems research have arisen from comparative studies of Pacific LOS despite their potential as case studies from which to develop a new social-ecological ‘island geography’ that unifies themes about scale, connectivity, markets, and resource use (Cinner et al. 2016). Due to the limitations of the literature review methods and the wealth of existing literature, caution should be taken when applying the findings. However, our review highlights the existing base of comparative studies of Pacific LOS, which could be used to develop collaborations under cohesive frameworks, across multiple scales and levels of organisation, with the potential to offer unique insights into complex global, regional, and local issues. Over time, comparison across localities and scales could contribute valuable empirical evidence for testing and advancing conceptual frameworks such as resilience and sustainability science.

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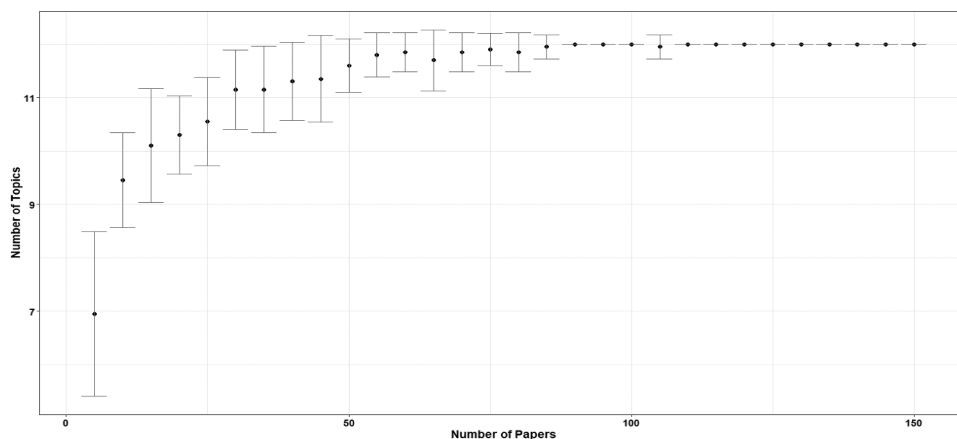
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## Appendix A



**Figure A1.** A rarefaction curve of the number of topics included in different samples sizes of publications. This allowed the prediction of a reliable sample of studies for a thorough review process. The number of themes saturated at 110 papers indicating that the number of studies included within this review (164) was a reliable sample set as the rarefaction curve indicates that no or few themes will be found after 110 studies.



**Table A1.** The social-ecological publications included, and topics discussed under each theme.

Theme	Topics Discussed	Publications
Climate Change	Agriculture, blue economy, climate data, climatic variability, communication, community-based adaptation, coral Reefs, deforestation, development, disaster risk, ecosystem services, ecosystem-based adaptation, environmental change, fisheries, globalization, health impacts, vulnerabilities, informal settlements, management, marine biogeochemistry, migration, natural disasters, networks, policy, salinization, sea-level rise, Sustainable Development Goals, technology, temperature increase, traditional knowledge, urban resilience and weather patterns.	Trundle (2020) McIver et al. (2016) Singh et al. (2001) Oakes (2019) Ahmed and Mishra (2020) Bolesta (2020) White and Falkland (2009) Andrew et al. (2019) Martin et al. (2015) Asch et al. (2017) Campbell (2015) Lloyd (2018) Nunn et al. (2016) McNamara et al. (2020) Corlew et al. (2015) Lauer et al. (2013) Wairiu (2017) Turner et al. (2007) Barnett (2001) Valmonte-Santos et al. (2016) Barnett (2011) Nunn (2009) Dunstan et al. (2018) Hills et al. (2013) Gordon-Clark (2012) Locke (2009) Trundle et al. (2019) Mackay et al. (2019) Salpin et al. (2018) Edmonds and Noy (2018) Noy and Edmonds (2019)
Development	Adaptive capacity, agriculture, climate change, community participation, conservation, cultural adaptation, disasters, disease, economic policy, emissions, energy policy, fisheries, food security, globalization, indices, land degradation, livelihood diversity, local change, migration, models, municipal waste, natural resources, networks, population growth, renewable energy, resilience, rural development, science and technology, solar electricity, structural transformation, sustainable development, sustainable management, targets, tourism, traditional knowledge, urban resilience, vulnerability and waste management.	Andrew et al. (2019) Barnett (2001) Bell et al. (2009) Bolesta (2020) Campbell (2015) Charlton et al. (2016) Dickinson (2003) Elliott et al. (2017) Erickson and Gowdy (2000) Gordon-Clark (2012) Gough et al. (2010) Joseph and Prasad (2020) Keppel et al. (2012) Lauer et al. (2013) Locke (2009) McGregor et al. (2009) Moglia et al. (2009) Murray (2001) Read (2006) Rolett (2008) Singh and Leal Filho (2012) Stephens (2008) Ticktin et al. (2018) Trundle (2020) Valmonte-Santos et al. (2016) Wairiu (2017) Weir (2018)
Fisheries	Aquaculture, artisanal fisheries, body size distribution, commercial fisheries, environmental impacts, management, overfishing, recreational fisheries, resilience, social impacts, subsistence fisheries, total catch, and tuna fisheries.	Asch et al. (2017) Aswani et al. (2017) Barclay (2010) Barclay and Cartwright (2007) Barnett (2011) Bell et al. (2009) Bell et al. (2015a) Bell et al. (2015b) Charlton et al. (2016) Dacks et al. (2020) DeMartini et al. (2008) Dunstan et al. (2018) Foale et al. (2011) Kronen et al. (2010a) Kronen et al. (2010b) Parris (2010) Purcell et al. (2014)

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**Table A1.** (Continued).

Theme	Topics Discussed	Publications
Governance	Adaptation, agriculture, climate change management, community-based management, conservation policies, customary governance, development, disaster risk, economic policies, environmental policies, fisheries, globalization, groundwater management, institutions, land management, local change, resource use, rural development, structural transformation, and sustainability.	Read (2006) Rohe et al. (2019) Stephens (2008) Valmonte-Santos et al. (2016) Zeller et al. (2007) Zeller et al. (2015) Aswani et al. (2017) Barclay and Cartwright (2007) Bell et al. (2009) Bolesta (2020) Edmonds and Noy (2018) Erickson and Gowdy (2000) Kingsford et al. (2009) Kronen et al. (2010a) Kronen et al. (2010b) Mackay et al. (2019) McNamara et al. (2020) Moglia et al. (2009) Murray (2001) Noy and Edmonds (2019) Nunn (2009) Purcell et al. (2014) Read (2006) Rohe et al. (2019) Stephens (2008) Trundle et al. (2019) Valmonte-Santos et al. (2016) Wairiu (2017) White and Falkland (2009)
Biodiversity and ecosystem services	Agriculture, biodiversity, biomass pyramid, body size, coral-reefs, environmental change, extinction, fisheries, freshwater, invertebrates, management, policy, predation, renewable energy, resilience, sustainable development, upwelling and vulnerability.	Ahmed and Mishra (2020) Asch et al. (2017) Aswani et al. (2017) Barnett (2001) Betzold (2016a) DeMartini et al. (2008) Elliott et al. (2017) Erickson and Gowdy (2000) Lauer et al. (2013) Laurans et al. (2013) Moglia et al. (2009) Read (2006) Rohe et al. (2019) Shelomi (2020) Singh and Leal Filho (2012) Skinner et al. (2011) Ticktin et al. (2018) Turner et al. (2007) Weeks and Adams (2018) Weir (2018) White and Falkland (2009)
Conservation	Biodiversity, climate change, community-based management, coral-reefs, environmental change, fisheries, implementation, sustainability, marine reserve/protected areas, overfishing, policy, renewable energy, spiritual attitude, traditional knowledge, traditional management, and vulnerability.	Weeks and Adams (2018) Bartlett et al. (2009) White and Falkland (2009) Martin et al. (2015) Asch et al. (2017) DeMartini et al. (2008) Purcell et al. (2014) Nunn et al. (2016) Weir (2018) Foale et al. (2011) Turner et al. (2007) Aswani et al. (2017) Keppel et al. (2012) Kingsford et al. (2009) Ticktin et al. (2018) McGregor et al. (2009) Gordon-Clark (2012) Moglia et al. (2009) Locke (2009)

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**Table A1.** (Continued).

Theme	Topics Discussed	Publications
Economics	Agricultural, aid, economic impact of natural disasters, ecosystem services valuation, fiscal risks, fisheries, globalization, rural development.	Barclay (2010) Bell et al. (2015a) Betzold (2016a) Betzold (2016b) Kronen et al. (2010b) Laurans et al. (2013) McGregor et al. (2009) Murray (2001) Noy and Edmonds (2019) Stephens (2008) Valmonte-Santos et al. (2016)
Anthropology and culture	Culture, informal settlements, interpersonal violence, pacific island history, migration, spiritual attitude towards nature and warfare.	Corlew et al. (2015) Dickinson (2003) Locke (2009) Nunn et al. (2016) Oakes (2019) Scott and Buckley (2010) Stephens (2008) Trundle et al. (2019)
Health	Accidental injury, climate change health impacts, diarrheal disease, epidemiology, non-communicable disease, poisoning.	Bell et al. (2015a) Charlton et al. (2016) McIver et al. (2016) Noy and Edmonds (2019) Scott and Buckley (2010) Singh et al. (2001) Skinner et al. (2011)
Agriculture	Agricultural sectors, environmental impacts, black soldier fly farming, climate change impacts, food security, traditional smallholder farming.	Murray (2001) Shelomi (2020) Campbell (2015) Barnett (2001) McGregor et al. (2009) Salpin et al. (2018)
Geology and weather	Paleoreefs and paleoshorelines.	Dickinson (2003)