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Received: 15 May 2019 | Revised: 30 July 2019 | Accepted: 3 September 2019

DOI: 10.1111/conl.12677

Conservation Letters
A journal of the Society for Conservation Biology
Open Access
WILEY

LETTER

Operationalizing vulnerability for social–ecological integration in conservation and natural resource management

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Funding information
Fondo de Fomento al Desarrollo Científico y Tecnológico, Grant/Award Numbers: Basal 0002, Fondecyt 1190109; Agence Nationale de la Recherche, Grant/Award Number: ANR-14-CE03-0001-01

Abstract

Sustaining human well-being is intimately linked to maintaining productive and healthy ecosystems. Avoiding trade-offs and fostering co-benefits is however challenging. Here, we present an operational approach that integrates biodiversity conservation, human development, and natural resource management by (1) examining resource and resource user interactions through the lens of social–ecological vulnerability (i.e., encompassing exposure, sensitivity, and adaptive capacity); (2) identifying "ecocentric" and "sociocentric" interventions that directly address the ecological or social sources of vulnerability; (3) prioritizing those expected to yield co-benefits and minimize trade-offs; and (4) selecting interventions that are best suited to the broader local context. Application of this approach to a coral reef fishery in French Polynesia recommended a portfolio of development-, livelihood-, and ecosystem-based interventions, thus suggesting a shift from the current resource-focused approach toward a more social–ecological perspective. Our vulnerability-based approach provides practitioners with a valuable tool for broadening their set of management options, leading to escape from panacea traps.

KEYWORDS
co-benefits, human–nature interactions, interventions portfolio, policy diversification, resilience, social–ecological fit, trade-offs

1 | INTRODUCTION

Achieving sustainability on our overexploited planet is one of the grand challenges of our time (Rockström et al., 2009). This global challenge has local expressions that are both social and ecological in form, because people and nature are linked and interdependent (Fischer et al., 2015). Such strong social–ecological relationships are especially apparent in resource-dependent settings such as forestry communities or coastal fisheries, where unsustainable use of natural resources can lead to serious and tangible impacts on both ecosystems and the people that depend on them (IPBES 2019; Ostrom, 2009).

Many governmental agencies and nongovernmental organizations are beginning to embrace a more nuanced view of sustainability that sits at the nexus between social and ecological perspectives (Bakker et al., 2010; Díaz et al., 2015). As a result, strategies aiming to improve conservation and social outcomes increasingly incorporate both elements in design and implementation (Mace, 2014). Indeed, through initiatives such as multiple-use protected areas and ecosystem-based management, social considerations are now embedded in the design of many "ecocentric" measures, hence broadening a predominantly ecological view of conservation and natural resource management (Ban et al., 2013; Kittinger et al., 2014). Correspondingly, the sustainable livelihood approach illustrates how the human development community, whose "sociocentric" entry-point has been predominantly centered around reducing poverty or fostering development opportunities, increasingly recognizes good environmental status as part of the conditions affecting the success of interventions (Krantz, 2001; Roe et al., 2015; Wicander & Coad 2018).

Integration of a social–ecological science perspective into human development, conservation, and natural resource management has enhanced the long-term equitability and effectiveness of the initiatives of each. Moreover, decades of applications of eco- and sociocentric strategies in various settings have offered important insights and experience that provide valuable foundations upon which more integrated, cross-disciplinary approaches can be built. Although still imperfect, we now have a better understanding of what can work and what cannot, in what contexts, why, and how to avoid potentially undesirable outcomes (Barnes, Craigie, Dudley, & Hockings, 2017; Barrett, Lee, & McPeak, 2005; Cox, Arnold, & Villamayor, 2010; Wicander & Coad 2018; Wright et al., 2016). Despite these positive developments, responses to sustainability problems continue to be dominated by strategies focusing mostly on either the human or environmental elements of the social–ecological systems.

Successfully dealing with conservation and sustainability requires a diverse portfolio of interventions. Therefore, the challenge now is to stop striving for ecocentric or sociocentric strategies, and instead seek synergies of the two. Indeed, and although they may diverge in many ways, ecocentric and sociocentric approaches are often complementary: when well designed, ecocentric interventions can enhance elements of human well-being, and sociocentric interventions can improve ecological condition (Ban et al., 2019; McClanahan et al., 2008; Naidoo et al., 2019; Roe et al., 2015). Yet, neither intervention is likely to provide a "silver bullet" (Ostrom, Janssen, & Anderies, 2007). Instead, we should be looking for a "silver buckshot," where several tools in the box are used (Brock & Carpenter 2007).

Insights offered by social–ecological systems thinking and the extensive and mature knowledge supporting human development, natural resource management, and conservation together provide momentum for developing and institutionalizing a new generation of management practices that positions the links between people and nature at its core. Here, we aim to address the narrower, but still difficult challenge of improving integration across independent but complementary sustainability-seeking strategies while ensuring relevance to decision makers and practitioners. To do so, we have developed an approach based on "vulnerability profiles", which represent the system's social and ecological elements that are favoring or undermining sustainability, thus revealing the internal features that can most effectively be targeted by sustainability interventions. This approach ultimately makes apparent a portfolio of interventions that can help realize co-benefits across goals relating to conservation, resource sustainability, and human well-being. We illustrate our approach using the case of a small-scale coral reef fishery in French Polynesia, where fishing activity represents both an invaluable source of benefits for local communities and an important pressure on the ecosystem.

2 | A VULNERABILITY-BASED APPROACH FOR INTEGRATED MANAGEMENT OF SOCIAL–ECOLOGICAL SYSTEMS

The approach we present here draws on recent developments in vulnerability and social–ecological system thinking (Cinner et al., 2013; Thiault et al., 2018a; Supporting Information Appendix A). It involves a four-step procedure that leads to the identification of practical interventions that most appropriately echoes the needs and opportunities of a particular social–ecological system (Figure 1). It is intended to serve as an operational guide for the place-based management of resource and resource user interactions, where ecological vulnerability refers to the vulnerability of the resource (e.g., water, wild food, and landscape) to use by the resource users (e.g., farmers and fishers) and social vulnerability refers to the vulnerability of the resource users to use-induced resource degradation. Therefore, it does not necessarily aim to address

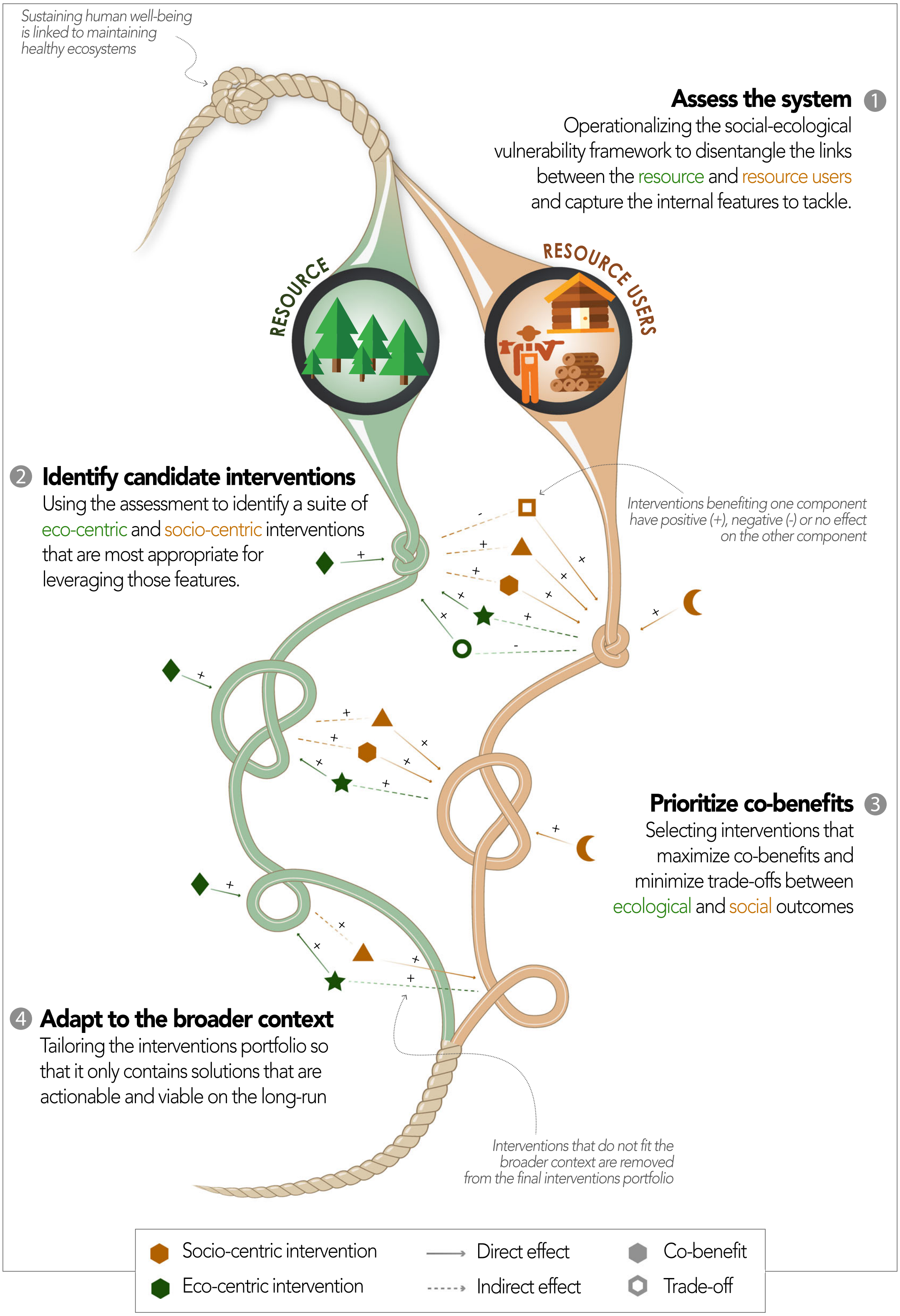

FIGURE 1 Integrating social and ecological perspectives when designing sustainability interventions. (a) Step 1: The social–ecological system is assessed by analyzing the linked vulnerabilities of the resource (green) and associated resource users (orange). (b) Step 2: This assessment enables to identify social (users' sensitivity and/or adaptive capacity to resource depletion) and ecological (resource' exposure and intrinsic resilience to exploitation) elements that are favoring or undermining sustainability and derive a set of candidate interventions (represented by shapes; green = ecocentric; orange = sociocentric) that can be leveraged to address them. (c) Step 3: Interventions that are expected to have negative indirect effects (open shapes) are withdrawn to retain only those who can foster co-benefits (i.e., solid shapes). (d) Step 4: To be locally viable and actionable, the final portfolio must only include interventions that suit the broader historical, cultural, institutional environment

all drivers of change in the social–ecological system of interest. It assumes that the system's boundaries have been identified and that analysts aspire to achieve social and ecological outcomes.

2.1 | Step 1: Assessing resource and resource user interactions through the lens of vulnerability

The approach first guides analysts to independently assess each key dimension of social–ecological vulnerability (Cinner et al., 2013; Thiault et al., 2018a), namely, resource exposure, sensitivity, and adaptive capacity to exploitation (ecological vulnerability), and users' exposure, sensitivity, and adaptive capacity to resource decline (social vulnerability). Social exposure is determined by ecological vulnerability (Supporting Information Appendix A; Figure S1) and thus does not need to be assessed explicitly. Ecological sensitivity and adaptive capacity can be difficult to untangle because they are determined by similar processes. Here, we refer to their combination as "intrinsic resilience" but acknowledge that resilience entails far more complex processes that are not captured by this model. The four remaining dimensions can then be combined to allocate ecological and social components to one of four quadrants, hereafter referred to as vulnerability profiles (Figure 2). Profiles are labeled as "lower concern," "potential adapter," "high latent risk," and "greater concern" and characterize the main elements that best determine social and ecological vulnerabilities, highlighting what needs to be targeted to reduce vulnerability. Analysists can draw on the many social and ecological science research methods and tools available to characterize vulnerability profiles in a way that aligns best with their specific planning context (Supporting Information Appendix B).

2.2 | Step 2: Selecting interventions that can reduce source(s) of vulnerability

Step 2 involves identifying relevant interventions that target the elements identified in the previous step. They could include interventions focusing on the resource ("ecocentric" interventions such as ecological engineering, permanent closures, or output controls), on resource users ("sociocentric" interventions such as livelihood-focused interventions, market-based approaches, or assets enhancement), or a combination of those depending on the elements that need addressing. Analysts may be interested in implementing participatory mechanisms to develop this initial list of interventions. All options should be explored carefully for holistic management. To help in the screening process, we propose a typology of interventions commonly used by development, natural resource management, and conservation communities, and describe their expected impacts on ecological and social vulnerability profiles (Table 1). Analysts might look to this template as a starting point, adapting and rearranging as necessary.

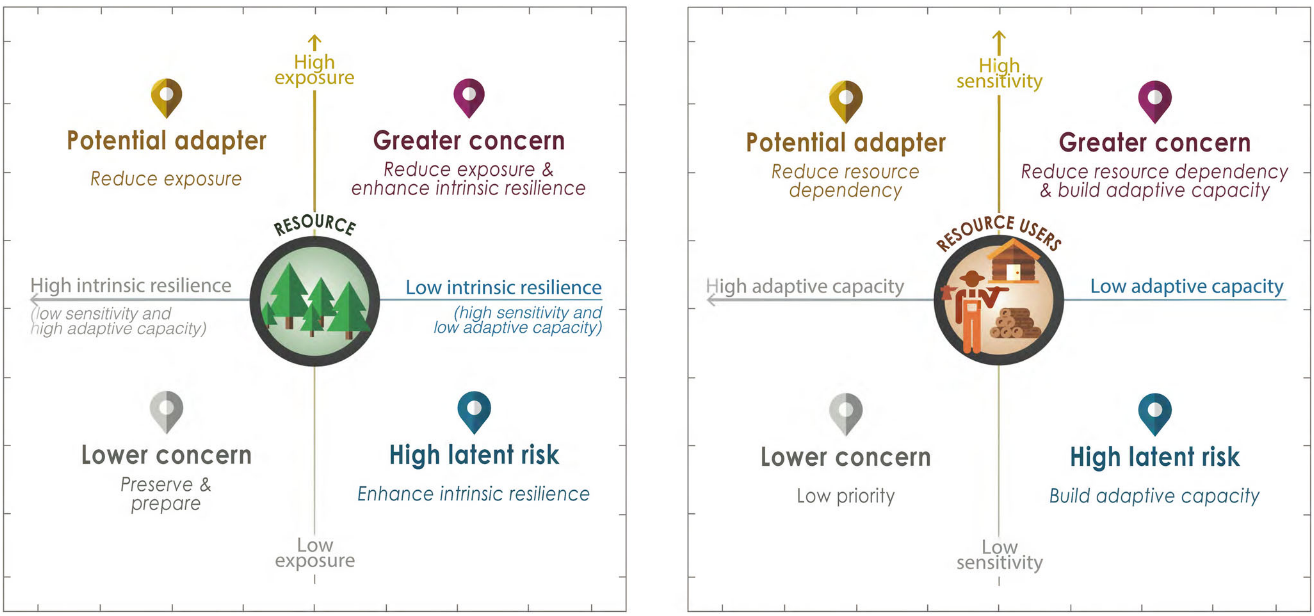

FIGURE 2 Social and ecological vulnerability profiles and associated management targets (Step 1). Each profile is identified through the combinations of exposure and intrinsic resilience gradients (ecological vulnerability), or sensitivity and adaptive capacity gradients (social vulnerability), and thus reveals the internal elements that can most effectively be targeted by sustainability interventions. Note that "intrinsic resilience" refer to the combination of ecological sensitivity and adaptive capacity. See Supporting Information Appendix A for full description of vulnerability profiles

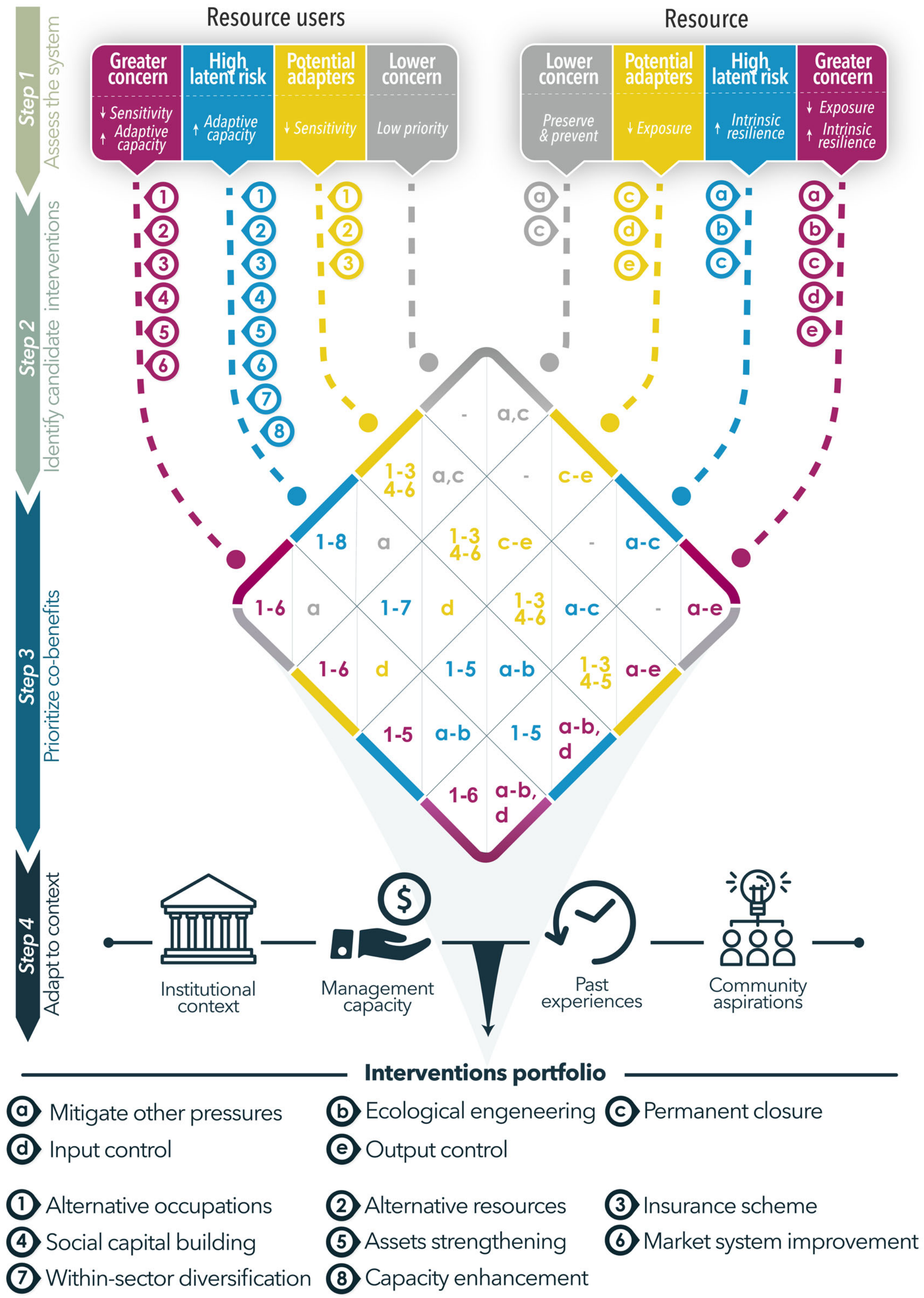

FIGURE 3 Flowchart illustrating the key steps of the approach proposed. Step 1: Identify the key vulnerability driver(s) to address through social and ecological vulnerability profiles. Step 2: For each component, determine a set of potential interventions to reduce each component's driver(s) of vulnerability. Step 3: Consider the vulnerability profile of the associated component and determine a portfolio of potential interventions that minimizes trade-offs and promotes co-benefits. Step 4: Ensure the viability of the interventions portfolio by reviewing identified interventions in the local context (e.g., institutional, management capacity, past experience, and community aspirations). This generic framework can be adapted to each context by identifying specific interventions falling into each generic typology (see Table 2 and Supporting Information Appendix C and Figure S1 for a fishery-specific application of the generic approach)

2.3 | Step 3: Prioritizing interventions that can advance social–ecological co-benefits

Step 3 entails being critical of negative collateral impacts that some interventions might have, as well as employing those initiatives that benefit each system (Howe, Suich, Vira, & Mace, 2014; Sayer et al., 2013). Indeed, in order to be successful and balanced, management interventions identified in step 2 must be appropriately positioned in the social and ecological context in such a way that they do not further undermine any component of the system. Instead, they should be employed to reduce negative impacts and/or induce positive change. In Table 1, we summarize how various types of commonly used interventions implemented on one component may have indirect effects on others, and how this can be interpreted using the ecological and social vulnerability profiles from step 1. Like in the previous step, this template can be further adjusted to accommodate the planning context.

2.4 | Step 4: Developing an interventions portfolio that suits the broader social–ecological environment

The last step captures the wider context in which the local interactions between resource and resource users are embedded to ensure the feasibility and viability of previously identified interventions. This step includes documenting the social norms, values, cultural practices, aspirations, place attachment, and historical and environmental characteristics that can facilitate or hinder specific interventions (Armitage, De Loë, & Plummer, 2012; Ostrom, 2009). To ensure interventions are durable in their implementation, information on individual, institutional, and logistical capabilities, power asymmetries, and social networks is also relevant. Mixed methods approaches and triangulation of qualitative and quantitative data from various sources (Supporting Information Appendix B; Game et al., 2018) can create a cohesive picture that will help analysts assess whether each candidate intervention is appropriate, equitable, and legitimate (Kittinger et al., 2014).

Our vulnerability-based approach thus consists of four steps eventually leading to the selection of one or more interventions that are important and actionable to reduce social and ecological vulnerabilities (Figure 3). By effectively considering the linkages between key social and ecological components, it enables to identify management strategies that are likely to deliver better outcomes for people and nature than if only one criterion was considered. It offers practical insights that can inform integrated management strategies and planning in a broad range of contexts.

3 | ILLUSTRATING THE APPROACH: A CORAL REEF FISHERY CASE STUDY

We use the coral reefs and the associated small-scale fishery of Moorea, French Polynesia, to illustrate the application of the approach described above. Overall, the Moorea fishery is highly challenging to manage due to inextricable yet diffuse links between people and the reef (Leenhardt et al., 2016). The marine spatial plan in which fisheries management is embedded was under revision when this study was conducted (Hunter, Lauer, Levine, Holbrook, & Rassweiler, 2018), and our pilot assessment was undertaken in parallel of the revision process.

In order to consider linked social–ecological vulnerabilities in the specific context of fish (the resource) and fishing households (the resource users), we compiled data on marine resource dependency (i.e., social sensitivity) and adaptive capacity from 6,698 households, and combined it with reef-wide models of target fish assemblages, characterized by their intrinsic resilience and exposure to fishing. The combination of each dimension of social and ecological vulnerabilities was represented spatially to visualize the vulnerability profiles (step 1; Figure 4). We then applied the general typology of eco- and sociocentric management interventions (Table 1) into the context of small-scale fisheries (steps 2 and 3; Table 2). Finally, we used a combination of archival research, semi-structured interviews from key informants, and participant observations to gain insights into the broader context and capture elements that could facilitate or hinder each potential intervention (step 4; Table 2). See Supporting Information Appendix B for a full description of the methods.

The current management approaches implemented in Moorea to manage local fisheries are not aligned with the approaches suggested by our approach. For example, the fore reef generally shows high intrinsic resilience and relatively low exposure to fishing (Figure 1; Supporting Information Appendix C and Figure S2). Our results suggest that such configurations may support the development of fully protected areas because these ecologically efficient but socially restrictive measures are easier to implement and represent lower opportunity costs for local households. Yet, despite the large permanent fisheries closure system (20% of the total reef area), the fore reef only represents 7.7% of the total area protected (Supporting Information Appendix C and Figure S3). In contrast, lagoon areas closed to fishing are in some cases located in front of poorly adaptive, and sometimes highly sensitive households (Figure 3; Supporting Information Appendix C and Figure S3), creating a policy setting that could exacerbate social vulnerability and certainly lead to challenges for compliance. Given the

TABLE 1 Typology of interventions to manage resource-user interactions, and implications for social and ecological vulnerability profiles

		Ecological Component (resource)				Social Component (resource users)				Rationale
	Vulnerability profile / Type of intervention	Greater concern	Potential adapter	High latent risk	Lower concern	Greater concern	Potential adapter	High latent risk	Lower concern	
Eco-centric interventions	a - Mitigate other pressures	●	○	●	●	●	●	●	●	Reducing exposure of the resource to other pressures without affecting the use of concern may improve ecological intrinsic resilience to human use through better ecosystem functioning without negatively impacting social component.
	b - Ecological engineering	●	○	●	○	●	●	●	●	Ecological engineering can help mitigate damage to, or improve, natural habitats while also increasing ecosystem services supply. Does not represent an opportunity cost to users but requires high economic investments.
	c - Permanent closure	●	●	●	●	⊗	●	⊗	●	Permanent closures are an extreme type of input control (d) that has different implications for both the ecological component and its associated social component. By preventing impact from direct use, permanent closures enhance intrinsic resilience of the resource unit. However, this can involve significant social costs and thus requires high social adaptive capacity to avoid negative social outcomes or poor compliance from resource users (and therefore reduced effectiveness of strategy).
	d - Input control	●	●	○	○	●	●	●	●	Input controls are limits on the amount or type of effort users put into their activities. They indirectly control the amount of resource extracted, allowing resource recovery by reducing resource use or access by resource users (temporally, in space, etc.), which reduces resource exposure but does not necessarily improve its intrinsic resilience. Opportunity cost depends on the design, regulations and other parameters, but are generally lower than permanent closures.
	e - Output control	●	●	○	○	⊗	●	⊗	●	Output controls directly limit the amount of resource that can be extracted. They generally require a high level of social adaptive capacity (organization, good access to information, assets, collective action, etc.) to be implemented effectively as well as strong leadership and administrative investments.
Socio-centric interventions	1 - Alternative occupations	●	●	○	○	●	●	●	○	Alternative occupations the risk of livelihood failure by spreading it across more than one income source. Reduces resource dependency and enhances the ability to exit the sector, but depends on community aspirations and must satisfy the same range of benefits (job satisfaction, prestige, nutrition) singular of the original activity.
	2 - Alternative resources	●	●	●	○	●	●	●	○	Incentivizing a culturally appropriate shift in uses and consumption toward more nutritive or more resilient or diverse resources and can reduce demand volume and/or improve the stability of benefits derived from resource use. In some rare cases, incentives for targeting invasive species can enhance ecological intrinsic resilience in the case of wildlife harvesting.
	3 - Insurance scheme	●	●	●	○	●	○	●	○	Insurance schemes provide a safety-net in case of environmental perturbation that may cause a loss of resource supply, avoiding escalation of unsustainable resource use.
	4 - Social capital building	●	●	●	○	●	●	●	○	Building social capital increases the adaptive capacity of users, enhances bargaining power in relation to traders/market, improves logistics and access to information, manage risk through collective action and facilitates the use and adoption of new (potentially more sustainable) practices. May help removing critical barriers to social adaptation.
	5 - Assets strengthening	○	○	○	○	●	●	●	○	Direct improvement of adaptive capacity components. May help removing critical barriers to social adaptation.
	6 - Market system improvement	⊗	○	○	○	●	●	●	○	Improved value chains, marketing, eco-labeling and supply chain simplification with middleman can create higher and/or more stable income for resource users. May induce a shift in use practices that may displace use effort leading to new areas being exposed to use. May help removing critical barriers to social adaptation.
	7 - Within-sector diversification	⊗	○	⊗	○	⊗	⊗	●	○	Flexibility to move across different resource use strategies is important for adaptive capacity but may push part-time users into full-time operations to repay loans and to earn an adequate return on the increased investment (i.e., increase social sensitivity). May also increase pressure on resource (i.e., ecological exposure).
	8 - Capacity enhancement	⊗	⊗	⊗	○	⊗	⊗	●	○	Improves use efficiency, increases incomes across users only if the resource remains relatively under-exposed and highly resilient. May increase resource dependency due to economic investment. May induce distal impacts on adjacent resources.

Note. Symbols indicate the effect of interventions (● positive; ⊗ negative; ○ no effect) on each vulnerability profile (Step 1: greater concern: purple; potential adapter: yellow; high latent risk: blue; lower concern: gray; see Figure 2). Intervention types a–e: "ecocentric" interventions. Intervention types 1–8: "sociocentric" interventions. Clear boxes indicate direct effects on the component (e.g., effect of ecocentric interventions on the resource; Step 2) and shaded boxes indicate indirect effects (e.g., effect of ecocentric interventions on the resource users; Step 3). See Supporting Information Appendix B for details on the typology.

criticisms against the current network of fully protected areas and their lack of ecological effectiveness likely due to, in part, to poaching (Thiault et al., 2019), such conservation measures should be prioritized on the fore reef or in lagoon areas where associated people are weakly sensitive and can adapt to the loss of fishing grounds (Figure 4). Where households are most vulnerable (e.g., Figure 4b), less restrictive interventions such as size and species regulations, or temporal closures, could be used to reduce fishing effort (i.e., ecological exposure) at a lower opportunity cost for users. Although these types of interventions can be more difficult to enforce, and the perceptions on which are the best modalities can differ among stakeholders, they are generally supported by users and can be underpinned by preexisting legislation (Table 2). In parallel to addressing ecological exposure, ecological intrinsic resilience needs to be enhanced, particularly within the lagoon (Figure 4). Although managers may for instance replicate previous stock enhancement interventions of targeted herbivores (Taiarui, Foale, Bambridge, & Sheaves, 2019), improving the management of land-based activities is likely to have the greatest positive impact on ecological intrinsic resilience (Leenhardt et al., 2017). This last type of approach is in line with principles from traditional "ridge-to-reef" management, but its implementation would require greater collaboration among relevant agencies (Table 2).

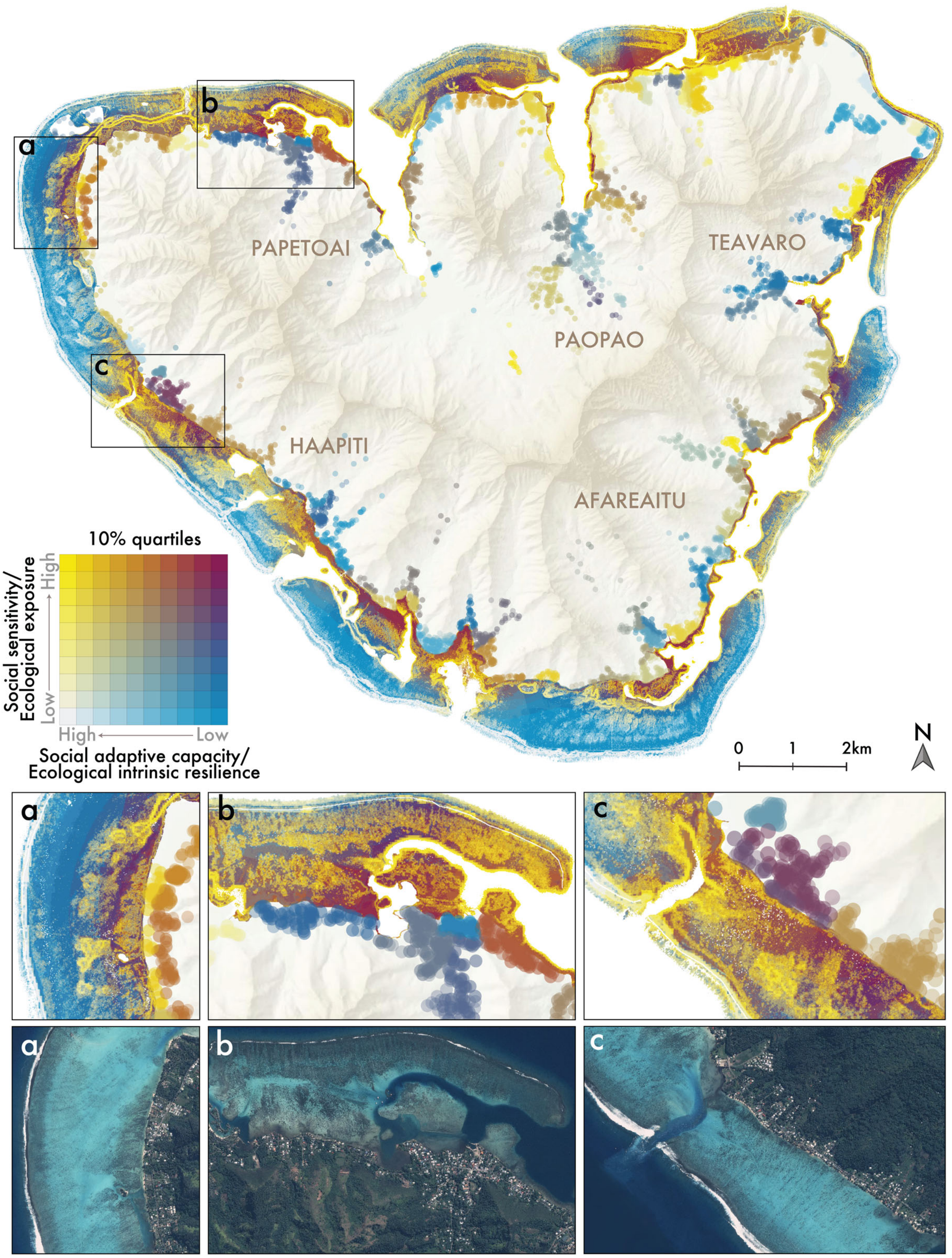

FIGURE 4 Assessment of the coral reef fishery of Moorea, French Polynesia, using spatially explicit profiles of social and ecological vulnerability (Step 1). Since households mostly depend on resource located on adjacent reefs for provision and cultural services associated with fishing, combinations of social and ecological vulnerability profiles are spatially linked. Insets highlight different combinations of profiles requiring specific portfolio of interventions (Figure 3; see Supporting Information Appendix C and Figure S1 for a fishery-specific application of the general approach)

TABLE 2 Application of the generic typology of eco- and sociocentric interventions (Table 1) to a small-scale coral reef fishery. Examples of interventions are presented, together with how they would be filtered in Moorea according the island's broader context (Step 4), which may facilitate or prevent successful implementation of particular interventions

	Type of intervention	Examples of interventions in the context of small-scale coral reef fisheries	Elements of broader context in Moorea (Step 4)	
			Enablers	**Challenges**
Eco-centric interventions	(a) Mitigate other sources of impact	- Integrated coastal zone management (ICZM) - Marine Spatial Planning (MSP) - Ridge-to-reef management	- Aligns with principles from traditional ridge-to-reef management - Main sources of impact identified	- Lack of political will to enforce law regulating embankments - Lack of funding sources for integrated management - Lack of effective collaboration among administrative agencies working on land and at sea
	(b) Ecological engineering	- Artificial reefs - Active habitat restoration - Restocking and stock enhancement	- Aquaculture and related technologies available locally for key target species - Similar initiative successfully implemented in analogous context - Several local associations actively involved in restoration programs	- Economic cost of engineered solutions - Focus on too few species - Environmental impact still uncertain
	(c) Permanent closures	- Marine reserves, no-take zones, fully protected areas	- Aligns with methods from traditional management (*rahui*) - Suitable legislative framework - Relatively easy to monitor - Some groups already actively enforced previous fully protected areas	- Previous experiences created a sense of distrust - Lack of surveillance capacity (most fishing occurs at night)
	(d) Input control	- Temporal closures/closed seasons (fishing taboos) - Restriction on target species - Size restrictions (protect young, protect breeders) - Licenses & exclusive access rights - Gear regulations (minimum mesh size, gear restriction)	- Aligns with methods from traditional management (*rahui*) - Suitable legislative framework - Extensive local ecological knowledge - Strong social pressure within community encourages self-enforcement	- Overlap with other national-level regulations may create confusion and complexity - Top-down enforcement difficult due to the diffuse nature of the fisheries - Intractable disagreements among stakeholders - Reef area too small to grant exclusive rights that would not create inequities among fishers
	(e) Output control	- Total Allowable Catches (TACs) and quotas - Output rights	- Fishers have recently self-organized into management committees that operate at the municipality level - Ongoing marine ecological monitoring to estimate quotas	- Most catch for self-consumption rather than for economic purposes - Risk creating inequities among fishers - Estimating quota remains challenging in coral reefs settings - No centralized selling point (catch sold on roadside)
Socio-centric interventions	1. Alternative occupations	- Provide land for agriculture or aquaculture - Develop sustainable tourism	- Many alternative occupations align with some community members' aspirations and needs - Relevant local agencies and legal framework already in place - High level of unemployment - High tourism potential - Municipality-owned land available	- Aspirations are highly heterogeneous within the community - Land tenure system disrupted by colonialism and globalization - Alternative occupations are typically used to increase income rather than reducing resource use - Powerful external interests associated with the tourism industry - Lack of effective collaboration among administrative agencies working on land and at sea

(Continues)

TABLE 2 (Continued)

Type of intervention	Examples of interventions in the context of small-scale coral reef fisheries	Elements of broader context in Moorea (Step 4)	
		Enablers	Challenges
2. Alternative resources	- Incentivize diet shifts (new target species) - Promote imported animal protein	- Variety of alternative species available - Morea's population is not food insecure - Fishers regularly adapt target species in response to ecological changes	- Cultural barriers to resource change (tradition, taste) - Lack of capacity to induce behavioral change - External sources of protein generally more expensive (e.g., imported meat) or unsustainable (e.g., high nutrient loadings from pig farms)
3. Insurance schemes	- Corporate insurer - Government or informal insurances	- Strong centralized government in Tahiti	- Targeting fishers difficult due to the diffuse nature of the fisheries
4. Social capital building	- Knowledge-sharing and learning platforms - Fisheries cooperatives - Associations and other organizational forms	- Fishers have recently self-organized into management committees that operate at the municipality level - Many groups already in place to support knowledge sharing, community cohesion, and/or environmental stewardship	- Intractable political positioning - Lack of funding sources for learning platforms
5. Assets strengthening	- Access to health services - Education (formal education) - Infrastructure (fish freezer) - Information (mobile phone)	- Developed country with subsidies from Metropolitan France	- No wish for a centralized market (past experiences failed)
6. Market system improvement	- Strengthen relations among actors - Upgrade value chains - Simplify supply chains		- No centralized selling point (catch sold on roadside) - No export to external market (all catch consumed locally)
7. Within-sector diversification	- New gear - Alternative fishing methods	- Highly selective local fishing practices - Highly versatile - Economic incentives already in place for registered fishers	- Certain net fishing practices perceived as overly effective and unfair/unsustainable
8. Capacity enhancement	- Improved boats - Subsidizing motorization	- Attractiveness of fore reef	- May disrupt spatial organization of fishing activities (informal ownership/access) - Will dramatically increase pressure on the resource

In various locations around Moorea (e.g., Figures 4b and 4c), it is particularly relevant to couple the above ecocentric interventions with sociocentric ones focusing on the root cause of social vulnerability. This implies moving beyond stakeholder consultation processes to also investing in strategies that directly tackle social adaptive capacity and sensitivity. This may entail livelihood-focused measures such as incentives to diversify occupations (e.g., agriculture, tourism, or aquaculture) and catch, although challenges regarding sociocultural barriers need to be anticipated to avoid discrepancies between expectations and actual outcomes (Table 2). Community buy-in may for instance be leveraged via churches and other stakeholder groups, whereas land tenure issues can be overcome through enabling local community members to lease land cheaply for agricultural purposes. If well designed, and if new livelihoods are effectively created as alternatives rather than supplementary sources of outcome (Wright et al., 2016), such interventions have the potential to reduce both social (reduced dependency and enhanced flexibility) and ecological vulnerably (released pressure on the resource). Enhancing adaptive capacity through social capital building, and encouraging learning and cooperation may, in Moorea, build on established stakeholder groups like cultural associations, whereas the recently created decentralized management committees provide an obvious forum for discussion on reef-related issues and solutions within the community (Table 2). Investments in market-based interventions and insurance schemes do not seem applicable for Moorea due to the absence of markets and the difficulty of identifying individual fishers (Table 2). Island-wide, and in particular in high socially sensitive areas (Figures 4b and 4c), it is essential to develop strategies that do not make local communities more dependent on reef-based resources that are already highly vulnerable. This is why island-scale incentives for motorized boats or new fishing gear should be avoided.

Instead of constraining decision makers to a single strategy-focused approach defined a priori (i.e., eco- or sociocentric), our results compel decision makers to consider multiple entry points. Although many challenges remain to ensure the success of Moorea's management (Hunter et al., 2018), our results suggest that the current strategy could be upgraded by shifting from a focus exclusively on the resource to account more specifically for social–ecological linkages in each location, and embracing a broader range of management options that include eco- and sociocentric interventions.

4 | REFLECTIONS ON THE VULNERABILITY-BASED APPROACH

Our four-step process represents a significant departure from more mainstream approaches to vulnerability conceptualization and practice. First, the framing is new. At its core, it builds on, and brings together insights from social–ecological science and vulnerability, moving the latter from its original natural hazards and climate perspective toward a sustainability one that includes people, both as a factor affecting environmental outcomes and as a recipient of environmental benefits that require human well-being to be improved (Thiault et al., 2018a). Second, it builds on previous applications and uses of the vulnerability construct, providing guidance not only for prioritization, but also for real, pragmatic, and balanced interventions. Third, our framework fosters diversification of environmental policy (Brock & Carpenter, 2007) by uniting approaches that have heretofore been used in isolation, such as ecosystem-based management (Levin, Fogarty, Murawski, & Fluharty, 2009) and resilience-based management (Mcleod et al., 2019), and the sustainable livelihood approach (Krantz, 2001).

Based on our experience, we suggest that this approach is likely to infuse a more comprehensive vision into conservation and natural resource management (Guerrero et al., 2018), and empower practitioners to develop more diversified management strategies. The spatial representation of the vulnerability profiles revealed potential interventions best suited to each location around the island, thus allowing local managers to examine previously unexplored, yet locally relevant management possibilities. The approach leading to the selection of the interventions portfolio is transparent and can be replicated through time (Fawcett, Pearce, Ford, & Archer, 2017; Thiault et al., 2018b), providing a structure for implementing an adaptive management process that supports responsive strategies (Kaplan-Hallam & Bennett, 2018).

The use of vulnerability in a resource management context is relatively recent, and its use as practical tool is still unsettled (Supporting Information Appendix A and Table S1). Most commonly, critiques relate to the potential "top-down" nature of vulnerability assessments, where local communities' input into the process can be left aside (Cameron, 2012). In our approach, each step can rely on a community-based, participatory process, for instance by involving stakeholders into the design and collection of indicators (step 1), the identification of candidate interventions (steps 2 and 3), or analysis of the overall context (step 4). This would not only be critical for improving the quality of the assessment, but may also promote opportunities to reflecting a richer knowledge that aligns with local people's perspectives and insights (Dacks et al., 2019; Reed, 2008). Our approach is not meant to be prescriptive and should rather be used to initiate and support discussions around management options.

5 | CONCLUSION

Achieving biodiversity conservation, securing resource sustainability, and improving human well-being are intimately linked goals. They should therefore be integrated within the same framework. Our proposed vulnerability-based approach illustrates that there is much scope for improved integration of data, ideas, and management practices across various fields and disciplines. Although this will not solve all the challenges facing conservation and natural resource management, it offers a transparent and flexible decision-support tool that broadens the range of options.

ACKNOWLEDGMENTS

We thank CRIOBE Service d'Observation CORAIL and ISPF for providing the ecological and social monitoring data, respectively. L.T. PhD grant was funded by Pierre and Marie Curie University (PDI-MSC grant). This project received financial support from Agence Nationale de la Recherche (ANR-14-CE03-0001-01). S.G. thanks Conicyt Basal 0002 and Fondecyt 1190109.

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SUPPORTING INFORMATION

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

How to cite this article: Thiault L, Gelcich S, Marshall N, Marshall P, Chlous F, Claudet J. Operationalizing vulnerability for social-ecological integration in conservation and natural resource management. *Conservation Letters*. 2019;e12677. https://doi.org/10.1111/conl.12677