


Roadmap for improving coral reef restoration practices in Southeast Asia

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Summary Coral reefs directly support the well-being of millions of people across Southeast Asia, however, these critical ecosystems are also under immense pressure, threatening their sustainability. Coral reef restoration has emerged as a promising strategy to contribute to safeguarding these critical ecosystems and securing the socioeconomic benefits they provide to local communities across the region. In this paper, we present the outcomes of a week-long of deliberations between policymakers, research funders, practitioners and scientists from Indonesia, Philippines, Vietnam and Australia, which identified four strategies for building improved capacity for coral reef restoration in Southeast Asia; (i) the creation of a learning network, (ii) addressing critical research needs, (iii) improved approaches to communication and engagement to diverse audiences and (iv) the establishment of sustainable funding mechanisms. These strategies are discussed in detail with a view of providing a roadmap to help support coral reef restoration processes across Southeast Asia.

Key words: communication, engagement, network, reef restoration, research needs, sustainable financing.

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Implications for Managers

This paper provides a roadmap to improve coral reef restoration practices in Southeast Asia. In doing so, it calls for a focus on four key focal areas:

- **The Establishment of Collaborative Networks:** Establishing learning networks to enhance knowledge sharing and best practices.
- **A Renewed Research Agenda:** Focusing on critical research areas to inform and improve restoration strategies.
- **Strategies for Enhanced Communication:** Strengthening outreach and engagement with diverse stakeholders to build broader support.
- **Long-term Sustainable Funding:** Developing reliable, long-term funding mechanisms to ensure the success and continuity of restoration projects.

Background

Coral reefs are one of the most diverse and productive ecosystems on our planet, providing critical ecosystem goods and services that directly underpin societal well-being and prosperity of millions of people globally (Moberg & Folke 1999). However, these vital ecosystems face unprecedented threats from anthropogenic pressure such as climate change, overfishing, pollution and habitat destruction. As a result, coral reefs worldwide are experiencing rapid degradation, with flow on effects to the ecological, economic and social benefits that they provide (Woodhead *et al.* 2019). In the face of such challenges, innovative approaches to coral reef conservation and restoration are urgently needed to buy time for coral reefs while efforts are undertaken to mitigate climate change.

Coral reef restoration has emerged as a promising strategy for supporting the long-term protection and sustainability of coral reef ecosystems (e.g. Knoester *et al.* 2023). While many approaches to coral restoration exist (reviewed by Suggett & van Oppen 2022), the key feature is deliberate intervention to promote the growth and recovery of coral reefs through various techniques such as coral gardening, artificial reef structures and assisted natural regeneration. In contrast to traditional conservation measures which primarily focused on mitigating threats to coral reef ecosystems, restoration actively seeks to reverse coral reef degradation and enhance ecosystem resilience, which is considered vital in the face of increasing anthropogenic stressors (Boström-Einarsson *et al.* 2020). Moreover, coral reef restoration holds immense potential to engage local communities, fostering stewardship and empowering stakeholders to actively participate in the conservation of their marine resources. As such, coral reef restoration can potentially not only address the ecological challenges facing coral reefs but also offer long-term solutions that may be socially and economically sustainable.

Coral reef restoration holds particular significance and promise in Southeast Asia. Southeast Asia has a very high proportion of people living on the coasts near coral reefs, with Indonesia and the Philippines having the two largest such populations of any countries in the world (Burke *et al.* 2011). These populations include high numbers of relatively marginalized groups, including low-income small-scale fishers, and maritime Indigenous groups such as the Moken, Orang-Laut and Sama-Bajau (Nimmo 1999; Stacey & Allison 2019). There is therefore a particularly high dependence on the benefits and services that coral reefs provide, including livelihood support for fisheries and tourism (Cabral & Geronimo 2018). Correspondingly, there are also very high levels of human pressures on coral reefs in the region, such as pollution, urbanization and fishing (Heery *et al.* 2018). Despite concerted efforts to conserve coral reefs in the region, including extensive histories of research, community-based and

co-management initiatives and the establishment of marine protected areas (e.g. Cabral *et al.* 2014), the decline of reefs in Southeast Asia continues unabated. For example, a recent assessment of the status of reefs in the Philippines found that about a third of reef corals had been lost over a decade, and half of the reefs surveyed were in the poorest category (Licuanan *et al.* 2019). These combined high levels of dependency, pressure and ongoing declines underscore the urgent need for enhanced conservation and other more active measures—reflected in the high number of coral restoration projects already underway in the region (Razak *et al.* 2022; Matorres *et al.* 2024). By implementing targeted coral reef restoration initiatives tailored to address the specific challenges faced by each country, Southeast Asian nations can contribute to safeguarding these critical ecosystems and securing the socioeconomic benefits they provide to local communities.

In February 2024, the Australian Centre for International Agricultural Research (ACIAR) organized a significant initiative aimed at enhancing coral reef restoration practices across Southeast Asia. ACIAR facilitated a study tour that brought together policymakers, research funders, practitioners and scientists from Indonesia, the Philippines and Vietnam to Australia (i.e. collectively referred to herein as the *delegates*). One of the primary objectives of this endeavour was to foster knowledge exchange and collaboration between the delegates and leading Australian scientists in the field of coral reef restoration and governance. Specifically, the delegation visited a range of different Australian research institutions (University of Technology Sydney, University of New South Wales, James Cook University (Townsville and Cairns campuses)) and a community group (Reef Restoration Foundation in Cairns). At each venue delegates interacted with a range of researchers from diverse disciplines and career stages working on coral reef restoration and related topics (e.g. blue economy, livelihoods and ocean literacy) through a series of formal (e.g. presentations) and informal (e.g. roundtable discussions) formats. The event also included a daytrip to the Great

Barrier Reef, however, adverse weather on the day prevented the group from visiting a coral restoration site. On the final day of the event, the delegates convened in a meeting room in Cairns to debrief on the week's activities through a facilitated discussion that was led by the ACIAR Fisheries and Aquaculture Research Program Manager. Through these discussions and deliberations on the final day of the event, the group worked collaboratively to identify key strategies for building improved capacity for coral reef restoration in Southeast Asia (for a detailed overview of the current status of, and threats to, coral reefs in Southeast Asia please refer to Burke *et al.* 2011, pp. 53–56). Four were identified in total (Fig. 1). This paper will present the key outcomes of these deliberations, offering valuable insights to guide future investments and focus in the region.

Building a Network

The initiation of a collaborative network for coral reef restoration in Southeast Asia emerged as a critical first step for supporting improved practices. The key goal for the network would be to provide a platform for shared learning and exchange of best practices in coral reef restoration techniques across the region, by harnessing the collective expertise and knowledge of academic and non-academic actors, to enhance the effectiveness and scalability of coral reef restoration efforts. The discussions highlighted several key activities that could be implemented as part of the network. Foremost among these is the implementation of targeted training programmes focusing on different coral restoration techniques and approaches. These programmes should be strategically timed to coincide with key events such as

coral spawning, maximizing the effectiveness of hands-on learning experiences.

There was also consensus on the importance of incorporating decision-support tools into restoration efforts, emphasizing the need for training sessions to enhance participants' proficiency in utilizing these tools for informed decision-making. Furthermore, discussions underscored the significance of fostering opportunities for postgraduate student mobility and training between institutes/countries, enabling the next generation of coral reef scientists to gain diverse perspectives and skills in relation to coral reef restoration. Importantly, it was recognized that inclusivity is paramount, and efforts will be made to open these events to a wide range of stakeholders and actors.

The delegates underscored that the establishment and sustenance of a network necessitates substantial resources and commitment from all stakeholders/countries involved. Consequently, consideration must be given to identifying the most appropriate mechanisms for supporting the network effectively, although the identification of such mechanisms was not discussed during the event. Rather, the delegates emphasized key principles that should guide the establishment of the networks. This included (i) the importance of leveraging existing initiatives as a viable starting point (to reduce the required resources and build on existing momentum), (ii) that the network should be tailored to the unique needs and challenges of the Southeast Asian region, and most crucially, (iii) the need for the network to be 'owned' by the region, with active participation and leadership from Southeast Asian countries driving its direction and activities.

A Renewed Focus on Research

Addressing critical research gaps is fundamental to ensure the success of coral reef restoration efforts in Southeast Asia. Identified as essential prerequisites for effective restoration initiatives, these research gaps represent areas where further investigation and scientific inquiry are urgently needed. By elucidating and sharing these

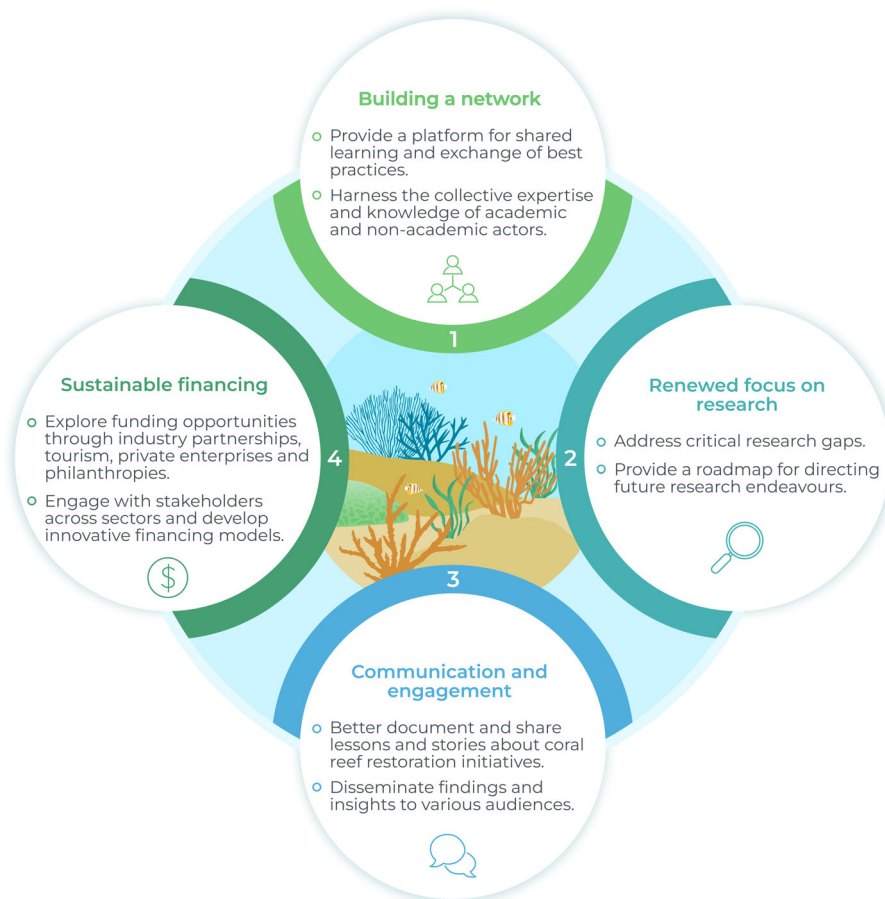


Figure 1. Visual representation of the four focal areas that emerged through dialogues as the priorities for improving coral reef restoration practices in Southeast Asia.

gaps, this section aims to provide a roadmap for directing future research endeavours towards maximizing the efficacy and sustainability of coral reef restoration in the region. Importantly, these discussions noted that ‘more of the same’ research will not adequately support coral reef restoration practices and efforts in the region and that research on restoration methods and techniques is only a small part of the puzzle. Rather, delegates and deliberations noted that a renewed research focus is needed.

Documenting and sharing of knowledge

Firstly, the delegates noted a significant gap in the documenting and reporting of knowledge regarding coral reef restoration efforts and practices in Southeast Asia. Accelerated investment and innovation in reef restoration research has led to a flood of newly documented innovative practices and strategies in some parts of the world such as the Great Barrier Reef (McLeod *et al.* 2022; Suggett *et al.* 2023). Despite a longer history of restoration efforts in Southeast Asia, a lack of documentation and reporting on locally led practices and their efficacy hampers the integration of existing knowledge into a sustainable restoration strategy for the region. For example, recent work by Razak *et al.* (2024) did undertake a review of Indonesian restoration efforts, considering both the academic and non-peer-reviewed literature, revealing the extent of restoration occurring in Indonesia (>120,483 units of artificial reef installed). This work highlighted that work often has limited coordination, and only 16% had post-installation monitoring, challenging our understanding of effectiveness. Such work by Razak *et al.* (2024) does, however, demonstrate the value of collating national knowledge, which would ultimately be required to support the regional coordinated restoration approach proposed here. For the other nations, it will be necessary to undertake a systematic review of both published studies and non-peer-reviewed documents, as well as targeted on-ground dialogue to capture insights from restoration practitioners and implementing agencies whose

methodologies may not be formally documented in conventional publications. Synthesizing existing knowledge and identified gaps in understanding will provide a foundation of evidence-based approaches to advance coral reef conservation and restoration in the region that aligns with a global response to perpetual reef decline.

Trial coral reef restoration sites

Another critical research need is establishing standardized trial coral reef restoration sites in all partner countries. These sites should serve as vital demonstrations of the feasibility and efficacy of coral reef restoration techniques (Cook *et al.* 2022), providing tangible proof of concept to garner support from local communities, governments and other stakeholders. Alongside the establishment of these trial sites, there is a pressing need for the development and implementation of a shared and coherent monitoring programme (Goergen *et al.* 2020). This programme would facilitate the systematic comparison of restoration outcomes across sites and countries, enabling researchers to evaluate the effectiveness of different restoration approaches. Standardizing monitoring protocols and data collection methodologies will ensure consistency and enable robust assessments of restoration progress.

Governance arrangements

The discussions identified that many of the critical research questions relate to social science, particularly governance and community engagement in coral reef restoration efforts. Participants emphasized the importance of understanding how best to govern and manage coral reef restoration areas, recognizing that effective governance is essential for the success of restoration initiatives. As part of the governance process, consultation with stakeholders on the social licence of different types of restoration actions is also something that will need to be considered. For example, different interventions carry different levels of risk (ecological, financial and societal), and considering these risks relative to potential return is ongoing and requires

clear processes for consultation and ultimate decision-making (Camp 2022).

As with all other development interventions, coral restoration is not just a technical intervention and its long-term sustainability is ultimately dependent on its capacity to be integrated into complex social and economic systems (Kittinger *et al.* 2016; Hein *et al.* 2019), and to be supported by enabling mechanisms from government (Matorres *et al.* 2023; Razak *et al.* 2024). Inadequate governance structures can undermine restoration efforts and hinder progress towards conservation goals. Therefore, there is a pressing need to identify appropriate governance arrangements, including transboundary governance mechanisms, to facilitate coordinated and collaborative management of coral reef restoration areas across borders in Southeast Asia. In this context, it is particularly important to recognize the importance of working across multiple scales and with different stakeholders—from the community level where legitimacy is required for effectiveness and where restoration needs to deliver social and economic benefits; to the local government level which has jurisdiction over much of the coral reefs of decentralized states such as Indonesia and the Philippines; to the national level that can provide greater resources; and to the regional level, where there are several existing conservation and marine governance partnerships that can be built on (Pomeroy *et al.* 2019; Fortnam *et al.* 2022). Across all these levels, better recognition of, and ways to, address complex trade-offs between diverse interests will also be needed (Fortnam *et al.* 2023). Similarly, there is a need to understand the authority division between central/national and local government on marine and conservation management across Southeast Asia.

Community participation and engagement

Successful restoration relies on community engagement and meaningful co-design from the onset (i.e. as a very first step when designing restoration efforts). In this regard, we use the term *engagement* to describe traditional and linear modes of communication (i.e. consultative

approaches), and *participation* to refer to higher order engagement where research stakeholders, for example, inform the development of research questions and contribute to the setting of research agendas (i.e. partnership approaches; Arnstein 1969; Reed *et al.* 2017), in acknowledgement of the spectrum of approaches that comprise participatory research as detailed in Cvitanovic *et al.* (2019). Coral reefs are socio-ecological systems, and thus it is crucial to ensure both the societal and ecological aspects are accounted for when undertaking restoration initiatives (Kittinger *et al.* 2012, 2016; Suggett *et al.* 2023). In Indonesia for example, regulations around coral restoration encourage community engagement, with responsibility and ownership shared between both local communities and government (Razak *et al.* 2022). Participants highlighted examples of successful coral restoration that were community led (e.g., in Australia; Suggett *et al.* 2023 and Indonesia; Razak *et al.* 2022). In these examples, coral restoration was found to provide broad benefits that included upskilling local communities, increased social licence for coral protection, and local economic support. The latter was particularly evident during COVID-19 when the abrupt downturn in tourism left many without work. In Bali, many of the workforce were re-purposed to support coral restoration endeavours, achieving an impressive restoration of 74.3 hectares of coral, using ca. 96,000 units of artificial reef, and employing ca. 10,000 people under the governments COVID-19 economic relief package (Razak *et al.* 2022); a similar scheme was also undertaken in Australia (Suggett *et al.* 2023) demonstrating how coral restoration can support both ecological and societal resilience in an increasingly uncertain world.

From a practical standpoint, community local site knowledge is crucial to understand how sites have changed and to support decisions on where and what to restore. The delegates agreed there was a need for more research (drawing heavily on the social sciences and the field of Science and Technology Studies, which seeks to understand the creation, development and impacts of science and technology in

their historical, cultural and social contexts, as reviewed in Jasanoff 2015) to better understand how to engage with communities effectively and inclusively, including Indigenous Peoples and women (Clifton & Majors 2012; Pauwelussen & Verschoor 2017), ensuring that their voices are heard, and their interests are incorporated into decision-making processes. The lessons learnt from the previous COREMAP project (World Bank supported project, <https://projects.worldbank.org/en/projects-operations/project-detail/P036048>) in Indonesia can provide reference on designing the inclusive/participatory process. This will become increasingly important as reefs globally decline, and new interventions that carry higher risk, but potentially greater reward, are considered as part of the restoration toolbox (Lubchenco *et al.* 2023). Ultimately, if countries are to meet their international agreements on protecting marine systems, such as the 2021 United Nations Human Rights Council resolution to recognize access to a clean, healthy and sustainable environment as an important human right or those associated with the United Nations Ocean Decade to reverse the decline of ocean health, local communities must be engaged in a proactive and meaningful way (Lubchenco *et al.* 2023).

Leveraging livelihood and economic opportunities

The potential to leverage livelihood opportunities from nature-based tourism and ecotourism can be a key motivator for communities to engage in restoration initiatives (Blanco-Pimentel *et al.* 2022; Matorres *et al.* 2023). This stems from a long-standing recognition of the potential for tourism to coexist with, and generate support for, marine conservation (Ceballos-Lascurain 1991; Agardy 1993; Diedrich 2007). However, the achievement of equitable and sustainable livelihood benefits from the strategic development of tourism alongside coral restoration must be underpinned by participatory research that elicits a nuanced understanding of the local socioeconomic and cultural context (Brugère *et al.* 2008; Diedrich *et al.* 2022; Fabinyi *et al.* 2022). Well-planned tourism has significant

potential to generate economic benefits for coral reef communities. Moreover, it can support restoration initiatives by generating local support for, and engagement in, conservation (Diedrich 2007; Mangubhai *et al.* 2020) and creating a business case for protecting ecosystem services (Blanco-Pimentel *et al.* 2022). Conversely, tourism development that does not align with local culture, needs and priorities can lead to adverse socioeconomic and ecological impacts (Fabinyi *et al.* 2022). As such, the implementation of locally engaged research and monitoring of the economic, social and ecological dimensions of tourism is an important priority for restoration initiatives that seek to align with this key coastal sector (Matorres *et al.* 2023).

Technical and natural science

Finally, participants identified a range of natural science research needs critical for advancing coral reef restoration efforts in Southeast Asia. This includes the need to better understand the dispersal patterns of coral larvae across geographic regions and countries. Effective restoration requires knowledge of larval connectivity between coral reef habitats to inform the design and placement of restoration sites, ensuring the connectivity and resilience of coral populations (e.g. King *et al.* 2023). Additionally, there is a need to enhance understanding of how to scale-up restoration efforts to achieve meaningful and sustainable impacts at regional and global scales. This will entail investigating scalable restoration techniques and strategies, as well as assessing the ecological and socioeconomic implications of scaling up restoration initiatives (Lamont *et al.* 2022).

Delegates emphasized the importance of ensuring that the right functional groups of corals and associated species (e.g. herbivorous fishes) return to restored coral sites to ensure their long-term sustainability. With increasing frequency of disturbance, functional trait diversity is at risk of being increasingly lost on coral reefs (McWilliam *et al.* 2020). Reef restoration efforts must counteract this loss by being built on an approach that stimulates functional species assemblages and

dependencies of trophic interactions that define a thriving reef ecosystem (Kollmann *et al.* 2016). Fundamental research is widely needed into the processes that govern the recruitment of biodiverse coral assemblages and the associated trophic cascades on Southeast Asian reefs. Innovative restoration practices will then be needed to promote recruitment and growth of key coral species that perpetuate biodiversity to deliver functionally restored reefs, and by effect, promotes a more resilient and sustainable reef system under ever-growing pressures and pace of disturbance. The identification and specification of such species, however, was beyond the remit of our deliberations. Instead, delegates noted that this should be informed by subsequent placed-based ecological studies across the region.

Communication and Engagement

Improving communication and engagement was also identified as critical for the success of coral reef restoration efforts in Southeast Asia, with delegates noting that practical efforts in this regard must be informed by the research outlined in “Community participation and engagement” section. In particular, discussions identified the need to better document and share lessons and stories about coral reef restoration initiatives in the region which can, in turn, identify enablers of success (e.g. following Karcher *et al.* 2022, 2023). While it was noted that the sharing of results through peer-reviewed publications is important, especially for building credibility and legitimacy of coral restoration practices among decision-makers, this alone was insufficient. It was noted that it is also critical to engage directly with communities living adjacent to coral reefs and the broader public. Effective communication strategies tailored to local contexts was considered essential for conveying the importance of coral reef restoration and its potential benefits to communities and must be undertaken through culturally-appropriate communication tools which may include community workshops and storytelling. Participatory research approaches that

actively engage community members in restoration efforts were also considered important, given their touted benefits for fostering meaningful dialogue and collaboration with communities, building public support for coral reef restoration initiatives and building local stewardship (reviewed by Ison *et al.* 2024).

Finally, throughout deliberations the importance of engaging policymakers was consistently raised as fundamental for garnering support and facilitating the integration of coral reef restoration into policy and governance frameworks, however, workshop discussions did not go so far as to identify existing and expected frameworks in this regard. It was noted, however, that engagement with policymakers and other decision-makers must be focused on two-way knowledge exchange between those undertaking reef restoration efforts and policymakers. One approach that shows promise in this regard is the notion of co-production, which involves collaborating with policymakers (and all non-academic partners including Indigenous groups) to identify research priorities, co-design research projects and jointly interpret and apply research findings to inform decision-making processes (Norström *et al.* 2020). Through such collaborative approaches, researchers can ensure that their work addresses policymakers’ needs and concerns, leading to more relevant and actionable insights for decision-making (Cvitanovic *et al.* 2015). It is important, however, to note that co-production can take many forms, each with their own goals, strengths and weaknesses (Chambers *et al.* 2021). As such, while knowledge co-production has become a modern day buzz-word in the research community and is increasing called for, we stress the importance of critical reflection during its design and implementation to ensure that it does not reinforce power imbalances, such as the privileging of western knowledge over Indigenous and cultural knowledges (Chambers *et al.* 2022; Muhl *et al.* 2023). We also emphasize the importance of building trust-based relationships among all academic and non-academic partners to ensure the success of co-production processes (following key trust-building

principles outlined in Cvitanovic *et al.* 2021, 2024).

Sustainable Financing

Finally, the critical importance of identifying and developing long-term and sustainable financing mechanisms for coral reef restoration efforts in Southeast Asia was emphasized. Sustainable finance means that there are adequate financing vehicles or mechanisms to achieve the long-term environmental outcomes for the reefs and their restoration (Sumaila *et al.* 2021). Having adequate financing mechanisms is important because substantial financial investments are required to undertake restoration activities at the necessary scale and with the required technologies. Reef restoration investments are often (but not always) ongoing in that restoration efforts need updating and maintenance in the medium and longer term. This time dimension to restoration means that it should be ‘sustainable’ (i.e. not rely on one-off investment opportunities) or where possible financially self-sustaining. To address this challenge, delegates indicated the need for innovative financing mechanisms and to explore opportunities for private enterprise funding through partnerships with various industries that could develop a commercial interest in reef restoration, such as tourism and aquaculture. For instance, potential collaborations could involve the harvesting and sale of coral produced through restoration efforts to the aquarium trade, providing a sustainable source of revenue to support ongoing restoration initiatives or leveraging income and exploring the potential for commercial interest from tourism to support restoration activities.

Generally, reef restoration activities need to have the necessary sustained operational and financial strategies in place to achieve long-term goals (Ando & Mallory 2012). By engaging with stakeholders across private and public sectors and developing innovative financing models, delegates sought to secure sustainable funding solutions to ensure the long-term success and resilience of coral reef restoration efforts in the region. However, further work is needed to identify diverse

finance portfolios and suitable options (Hoegh-Guldberg *et al.* 2018; Suggett *et al.* 2023) to underpin sustained coral reef restoration operations.

Conclusion

In this paper, we have drawn on our combined experiential and technical knowledge to outline a roadmap for improving collective efforts in coral reef restoration practices in Southeast Asia. In doing so, we note that the four strategies are not mutually exclusive and must be considered and implemented in parallel to ensure the benefits are realized. While global partnerships are necessary to deliver the roadmap (especially in terms of securing long-term funding mechanisms), we conclude by re-emphasizing that all efforts must ultimately be 'owned' by the region, with active participation and leadership from Southeast Asian countries driving its direction and activities.

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Conflict of Interest

None.

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