REHABILITATING INDONESIA'S REEFS: CORAL RESTORATION IN THE HEART OF GLOBAL MARINE BIODIVERSITY

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DISSERTATION

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1. Suppressed recovery of functionally important branching *Acropora* drives coral community composition changes following mass bleaching in Indonesia. *Coral Reefs*, 2022. https://doi.org/10.1007/s00338-022-02275-2
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3. Survival rates of branching *Acropora* morphologies on coral rubble stabilization structures. *Restoration Ecology*, 2024. Accepted.

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Summary

Indonesia is a nation that will be crucial to coral reef restoration efforts as the effects of human-induced climate change intensify. It has the most coral restoration projects running of any country worldwide and is situated at the heart of the world's most biodiverse marine area in the Coral Triangle. At the same time, restoration efforts remain disparate and diverse in nature. The creation of a formal network of reef restoration practitioners to develop and implement a national restoration roadmap could be effective in consolidating and focusing reef restoration efforts. Such a network can help to build on past successes and extant networks, authorities, and programmes. This dissertation will not only explore the possibilities for the creation of a national reef restoration network in Indonesia, but also look at the potential to create transferrable actions for the wider Coral Triangle region. One major aspect of coral reef restoration globally is the use of fast-growing but vulnerable branching *Acropora* species transplanted or outplanted in degraded reef areas using techniques formulated under the concept of "coral gardening", now more commonly referred to as active reef restoration. With the importance of branching *Acropora* in mind, the dissertation presents a major warning sign for the Indo-Pacific region: the suppressed recovery of branching *Acropora* in Indonesia's Wakatobi Marine National Park (WMNP) following a mass bleaching event in 2010. It will go on to explore the varied survival rates exhibited by expansive and compact branching *Acropora* morphologies attached to sediment stabilisation structures on shifting rubble slopes in the WMNP. It will also look at the benefits of incorporating a modular mid-water floating nursery phase into restoration efforts, in order to create a closed nursery cycle that can function as a biomass production system. The findings of the dissertation suggest the need for greater quantification of Indonesian reef restoration

efforts; the preservation and restoration of functionally important, structurally complex branching *Acropora* corals, which have been a historically dominant component of Indonesian reefs; and further investigation into the morphologies of branching *Acropora* being used in reef restoration, as well as the efficacy of outplanting fragments in single-species aggregations to mimic the historical presence of expansive single-species thickets on mid-depth reef slopes across Indonesia.

Acknowledgements

Comparing myself today to the person I was at the start of this journey, and the world in which I found myself, I find it hard to put my thoughts and emotions into words. The lead-up to, commencement, and completion of this PhD have spanned six years and the full spectrum of experiences. Years spent living remotely on an island in the Wakatobi Marine National Park with no running water, generator-powered electricity for just a few hours a day, and months of relative isolation interspersed with periods of intense activity were followed by the outbreak of the Covid-19 pandemic and the need for my partner and I to make a hurried and enforced evacuation of the research site. A highly stressful journey out of Indonesia saw last minute flight cancellations, and a forced separation to return to South Africa and France, our countries of citizenship. Seven months of successive lockdowns followed, alongside the realisation that we would not, as we first thought, be able to return to Indonesia. Not only did we have to rethink our lives, but I also had to restructure the entire focus of the PhD.

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Abbreviations

Abbreviation	Meaning
AICc	Corrected Akaike Information Criterion
AICcWt	AICc weight
ANOVA	analysis of variance
AR	artificial reef
BA	branching *Acropora*
BPS	biomass production system
BPSPL	Balai Pengelolaan Sumberdaya Pesisir dan Laut (Coastal and Marine Resources Management Center)
BRIN	Badan Riset dan Inovasi Nasional (National Research & Innovation Agency)
BRSDM KP	Badan Riset dan Sumber Daya Manusia Kelautan dan Perikanan (Maritime and Fisheries Research and Human Resources Agency)
CBP	current best practice
CBRM	community-based resource management
CCA	crustose coralline algae
CCAGs	climate change adaptation goals
CCMRS	Centre for Coastal and Marine Resources Studies
CoPs	corals of opportunity
COREMAP	Coral Reef Rehabilitation and Management Project
CRC	Coral Reef Consortium
CRRTF	Coral Reef Restoration Task Force
CT	Coral Triangle
CTC	Coral Triangle Centre
CTI-CFF	Coral Triangle Initiative on Coral Reefs, Fisheries, and Food Security
CTMPAS	Coral Triangle MPA System Framework and Action Plan
CTSP	Coral Triangle Support Partnership
DHW	degree heating week
EAFM	ecosystem approach to fisheries management
ER	ecological restoration

GBP	goal-based performance
GBR	Great Barrier Reef
GLMM	generalised linear mixed model
GPR	generalised poisson regression
GVFB	Global Village Foundation Bali
HC	hard coral
IBF	Indonesia Biru Foundation
ICRG	Indonesia Coral Reef Garden
ICRI	International Coral Reef Initiative
IPB	Institut Pertanian Bogor (Bogor Agricultural Institute)
KDS	Kaledupa Double Spur
KKP	Kementerian Kelautan dan Perikanan (Ministry of Marine Affairs and Fisheries)
LCC	live coral cover
LIPI	Indonesian Institute of Sciences
LMMA	locally managed marine area
LOESS	locally estimated scatterplot smoothing
LPI	line point intercept
MARRS	Mars Assisted Reef Restoration System
MMAF	Ministry of Marine Affairs and Fisheries
MPA	marine protected area
MSS	Mars Sustainable Solutions
NBRC	North Bali Reef Conservation
NDRF	Nusa Dua Reef Foundation
NGO	non-governmental organisation
NKS	Nino Konis Santana Marine Park
NMS	non-metric multidimensional scaling
NOAA	National Oceanic and Atmospheric Administration
NPO	non-profit organisation
NPOA	national plan of action
OBC	other branching corals

Opwall	Operation Wallacea
PNG	Papua New Guinea
Pokmaswas	community surveillance group
PSKP	Penguatan Sumberdaya, Kerjasama dan Pengembangan (Strengthening Resources, Cooperation and Development)
Pulau	island
R&D	research and development
RAP	Restoration Action Plan
RISTEK	Indonesian Ministry of Research and Technology
SCORES	School of Coral Reef Restoration
SDB	social desirability bias
SER	Standards for Ecological Restoration
SIMCA	Sugud Islands Marine Conservation Area
SMART	specific, measurable, achievable, relevant, timebound
SSME	Sulu Sulawesi Marine Ecoregion
TP	time period
UN	United Nations
USAID	US Agency for International Development
WMNP	Wakatobi Marine National Park
WWF	World Wide Fund for Nature

Chapter 1: Introduction

The aims of this dissertation are twofold. Firstly, it seeks to advance the understanding of and approaches to coral reef restoration in Indonesia, because of the country's pivotal placement at the forefront of international coral reef rehabilitation and restoration efforts. Secondly, it provides a specific focus on branching *Acropora* as a functionally important and historically dominant component in the make-up of Indonesian coral reefs, within the context of the impacts of mass bleaching events on the genus, as well as its ongoing value for reef restoration efforts despite (and indeed, because of) its vulnerability to external stressors.

The work done here is also expanded on to discuss potential transferrable actions for the wider Coral Triangle (CT) region. The CT has long been acknowledged as a priority area for coral conservation and restoration because of its exceptional biodiversity and the ongoing presence of some of the most severe anthropogenic threats worldwide (Williams et al. 2019).

It is not always straightforward to distinguish between what should be considered as "rehabilitation" or "restoration", especially where specific scientific aims or goals are absent from coral reef rehabilitation and/or restoration efforts. This should not detract from the majority of analyses, as regardless of the ultimate aims of active management interventions, considerations and protocols that will maximise the success of a project are usually the same (Edwards 2010). The primary focus of this dissertation encompasses the reversal of coral reef ecosystem degradation, regardless of the specific aims (elucidated or not) of any particular project. For this reason, the terms "rehabilitation" and "restoration" are mostly treated as interchangeable.

The countries of the CT contain the largest repository for marine biodiversity on the planet, and Indonesia specifically is – by number of projects – the largest coral restoration nation worldwide, meaning that it has the potential to become a major force in international restoration efforts. To do so, however, will require a concerted effort to consolidate the wide variety of projects across this expansive archipelago and make sure that government officials, park authorities, restoration practitioners, and local communities are all reading from the same script and pulling in the same direction. In this way, all stakeholders can benefit from the advantages restoration can provide – not only in ecological terms, but also in relation to socio-economic upliftment, community sustainability, the protection of cultural values, and the ongoing health of ecosystems and human populations.

This Introduction provides an overview of coral reef restoration in the CT leading up to the Covid-19 pandemic outbreak in March 2020, to provide context for the main body of the dissertation. Chapter 2 reviews the status of Indonesian coral reef restoration post-pandemic, compared to international current best practice (CBP) and standards for ecological restoration (SER). Suggestions are provided for the creation of a formal network of reef restoration practitioners to develop and implement a national restoration roadmap with an increased focus on climate change adaptation goals (CCAGs), including a tiered system to standardise project planning, monitoring, and reporting. Chapter 3 analyses a long-term data set to examine how the suppressed recovery of branching *Acropora* has driven coral community composition changes in the Wakatobi Marine National Park (WMNP) following a mass bleaching event in 2010. This illustrates the importance of further studies on branching *Acropora* recovery trajectories post-bleaching, due to the critical implications for this functionally important and vulnerable taxon. Chapter 4 looks at varied survival rates of branching *Acropora* morphologies within a restoration context and offers further evidence of the efficacy of using floating mid-water coral nurseries as systems to produce higher volumes of coral for outplanting in reef restoration. Chapter 5 presents a general discussion and conclusion on the dissertation findings, and recommendations for the future, including potential transferrable actions for the CT region.

1.1. Geographic and biological characteristics of the Coral Triangle

Ecologically, the CT centres on the geographical area formerly known as the Indo-Malay Archipelago, which spans all or part of Indonesia, Malaysia, Papua New Guinea (PNG), the Philippines, the Solomon Islands, and Timor-Leste (Burke et al. 2012). Spread along the equator between the Indian and Pacific Oceans, this core zone, or hotspot, (Fig. 1.1) is the world centre for marine biodiversity, encompassing roughly one-third of the world's coral reef areas (Burke et al. 2012). The CT harbours 76% of all identified scleractinian corals. Of its 605 species of zooxanthellate corals, 66% are common to all CT ecoregions and over 80% are found in at least 12 of 16 ecoregions. By way of comparison, Australia's Great Barrier Reef (GBR) is home to fewer than 500 species, and the Caribbean Sea only 61 species (Veron et al. 2009, 2015). The CT also boasts a higher number of coral reef fish species (2,228) than any comparable marine area (Allen 2007) and is the centre of diversity for the vital mangrove and seagrass associated shallow coastal ecosystems (Polidoro et al. 2010; Short et al. 2011).

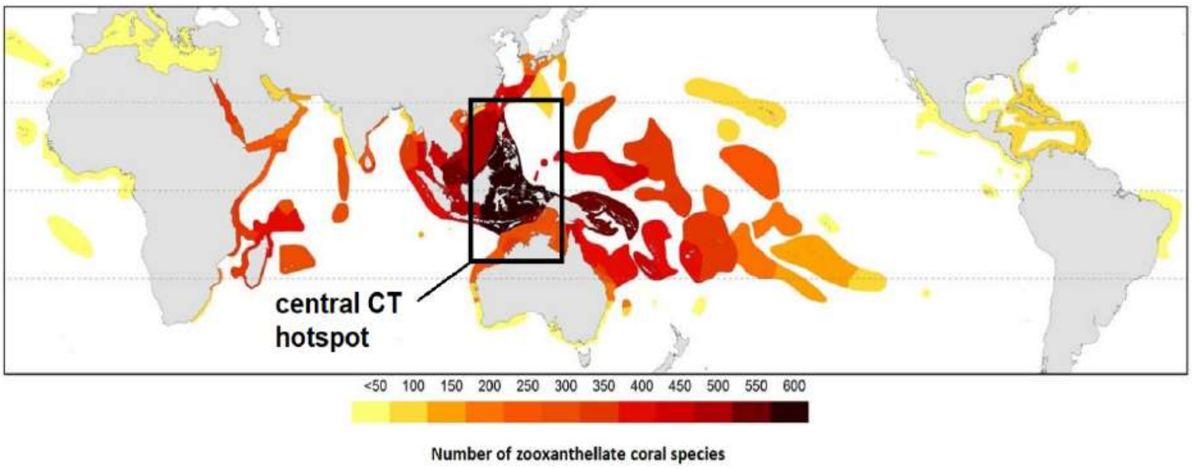

Figure 1.1 Contours of zooxanthellate coral species diversity. The clearly defined global hotspot for coral biodiversity rests in the central regions of the Coral Triangle in the heart of the Indo-Pacific, predominantly comprising central and eastern Indonesia and the Philippines.

This marine biodiversity is threatened not only by global climate change, but also by local anthropogenic influences including growing populations, marine resource overexploitation, destructive fishing practices, coastal development, pollution, and increased disease (Bruno and Selig 2007; Burke et al. 2012; Williams et al. 2017, 2019), while the most recent regional surveys rate over 90% of CT reefs as threatened – significantly higher than the 75% global average (Walton et al. 2014). Over 85% of CT reefs are threatened by local anthropogenic stressors, also well above the global average of 60% (Burke et al. 2012), further highlighting the pressing importance of conserving, managing, and restoring the region's marine ecosystems, particularly in light of the increasingly immediate global threat of climate change.

In the more populous nations, Indonesia and the Philippines, growing coastal populations and associated pollution and marine plastics pollution are significant threats. Singapore faces major challenges from land reclamation and sedimentation caused by the dredging of shipping channels. Indonesia, Malaysia, and Brunei have major offshore oil and gas operations with the potential to cause extensive marine ecosystem damage. Reefs in PNG, the Solomon Islands, and Timor-Leste are threatened by runoff and sedimentation from forest clearing for the oil palm industry, logging and mining operations, and conversion of forest to agricultural land respectively. The two former nations also have a long history of substantial live coral harvesting activities for lime production. Across the CT, overfishing and the prevalence of blast fishing remain the most immediate localised threats, affecting over 85% of reefs, although intensity varies with local cultural values and practices (Burke et al. 2012).

1.2. Historical conservation and restoration efforts in the CT

The economic and ecological importance of coral reefs within the Coral Triangle has been well-established (e.g. Burke et al. 2012; Williams et al. 2017): roughly one-third of populations in the CT live within 30 km of the coast (Burke et al. 2012), while at least 120 million people in the region rely on the natural resources produced by coral reefs (Hoegh-Guldberg et al. 2009; Green et al. 2012; Foale et al. 2013; Cruz-Trinidad et al. 2014), in line with the norm for developing countries worldwide (de Groot et al. 2012).

Formed in 2009, the Coral Triangle Initiative on Coral Reefs, Fisheries, and Food Security (CTI-CFF) has been central to CT marine conservation and the interaction between coastal populations and the marine environment (Wilkinson 2010), as a mechanism to conserve key ecological and economic components of the region (Veron et al. 2009). This political agreement is perhaps the most ambitious international marine resource management and conservation project to date (Clifton and Foale 2017), and includes the adjacent nations of Brunei Darussalam and Singapore (Burke et al. 2012). Its ratification came with the specific focus of securing the immense economic and social value of coral reef resources in signatory countries for many millions of people into the future; it represents a unique model of collaboration amongst developing countries and is of paramount significance to regional conservation efforts (Wilkinson 2010). Initial goals included designating priority seascapes, establishing a marine protected area (MPA) system, protecting threatened species, facilitating coordinated action on climate adaptation, and implementing an ecosystem approach to fisheries management, with much being accomplished since its establishment (Weeks et al. 2014). For example, the CTI-CFF produced the CT MPA System Framework and Action Plan in 2013, as a major cross-regional programme laying out minimum standards for national reporting on MPA status and a common set of indicators for tracking progress and evaluating management effectiveness. The regional framework allows countries to compare progress and generates healthy ‘peer pressure’ and incentives to improve national MPA budget allocations, and many regional programmes also exist within the CTI-CFF framework (Wells et al. 2016).

In 2011, Indonesia, Malaysia, and the Philippines set up the Sulu Sulawesi Marine Ecoregion (SSME), an ambitious cross-border agreement for a seascape management plan of action in the highly diverse Sulu-Sulawesi Seas region (Ambo-Rappe and Moore 2019). Timor-Leste also committed to seven national MPA establishment actions, including the declaration and zoning of the Nino Konis Santana (NKS) Marine Park (Edyvane et al. 2012).

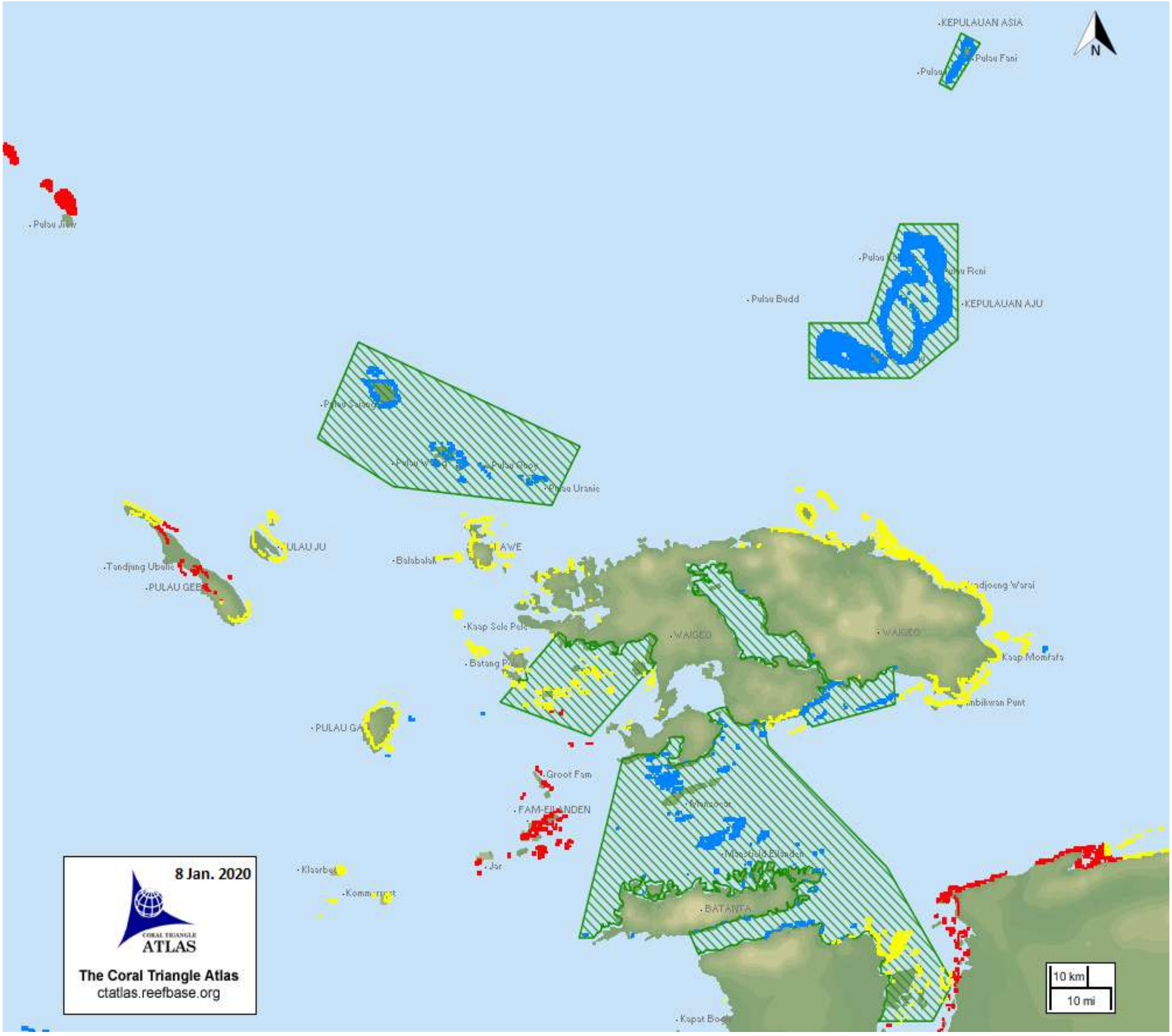

Figure 1.2 Effectiveness of the Raja Ampat Marine Protected Area (MPA), represented by green polygons. The reduction in overfishing and destructive fishing in the MPA is illustrated by Low to Medium Threat ratings (blue and yellow areas) prevalent within its boundaries, compared to High Threat (red) areas in neighbouring waters.

** Note: All maps created on the CT Atlas represent data based on the World Resources Institute's 2011 global report, Reefs at Risk Revisited, supplemented with more recent and detailed data for the Coral Triangle region.*

Another conservation success story is Indonesia's first legally established co-management system and effectively managed MPA network in the Southwest Papuan Bird's Head Seascape. This encompasses the Raja Ampat islands and boasts the country's highest MPA management effectiveness scores, averaging 73% (Fischborn and Levitina 2018). MPA patrol teams have reduced destructive fishing practices to less than 1% of fishers within Raja Ampat MPAs (Fig. 1.2), while illegal overfishing from outside poachers has been reduced by over 90%. Live coral cover across MPAs has been ~12% since their establishment and the average increase in fish biomass across MPAs is ~114%. Combined with a government ban on shark and ray fishing and mining, this has resulted in an average annual tourism growth rate of 30%. The CTI-CFF, supported by the US Agency for International Development (USAID), regularly runs regional and national workshops to increase transferable knowledge on sustainable fisheries and other topics. In Sabah, Malaysia, for example, the Department of Fisheries incorporates elements of the Ecosystem Approach to Fisheries Management (EAFM) into planning and policies, aiming for a more inclusive approach to encompass diverse stakeholders in fisheries management and evaluating the long-term effect of different methods on the sustainability of fish populations (USAID, CTSP 2013).

More than 1,900 MPAs have been listed or established across the six main signatories of the CTI (Walton et al. 2014; White et al. 2014), although just 920 of these were listed in the CT Atlas at the time (Cros et al. 2014). This number subsequently rose to 1,202 (CT Atlas 2018). The number of MPAs within the region is likely even higher now, with the Philippine MPA Database alone having concurrently listed 1,800 MPAs (Cabral et al. 2014) and the CT Atlas listing 1,268 MPAs at the end of 2023 (CT Atlas 2023).

A wide range of different types of protected areas with different management approaches and dynamics are represented across the region (White et al. 2014). Indonesia is notable for establishing mostly large MPAs (Walton et al. 2014), while in the Philippines, there has been a substantial focus on creating a variety of different MPAs managed by both national and local government entities, with the primary objectives being biodiversity conservation, fisheries sustainability, and tourism (Cabral and Geronimo 2018).

In PNG and the Solomon Islands, there is a proliferation of community-based resource management (CBRM) and/or locally managed marine areas (LMMAs), the successes of which are reported in several studies (Mills et al. 2010; Cohen et al. 2012; Sulu et al. 2014; Walton et al. 2014; White et al. 2014; Rutherford 2015; Sukulu et al. 2016; Jupiter et al. 2019). The approach to restoration activities throughout the CT has been similarly diverse.

One of the precursors to the CTI-CFF was the Coral Reef Rehabilitation and Management Project: Coral Triangle Initiative (COREMAP–CTI) in Indonesia, aiming to manage coral reef resources, associated ecosystems, and biodiversity in a sustainable manner to increase incomes for coastal communities (CTI-CFF 2013). Phase I ran from 1998 to 2004 (with investment of US$7 million) and Phase II from 2004 to 2011 (with investment of US$36 million), piloting a viable national coral reef management system framework before successfully strengthening national institutions and policies to increase the capacity for coral reef management.

A second restructuring phase began in March 2019, with the general aim of strengthening institutional capacity for coastal ecosystems monitoring and research, to inform and improve the effectiveness of coastal ecosystem management (BAPPENAS 2019). However, the effectiveness and sustainability of alternative livelihoods, so critical for establishing effective MPA management (CTI-CFF 2013) and support for restoration initiatives, is yet to be fully attained.

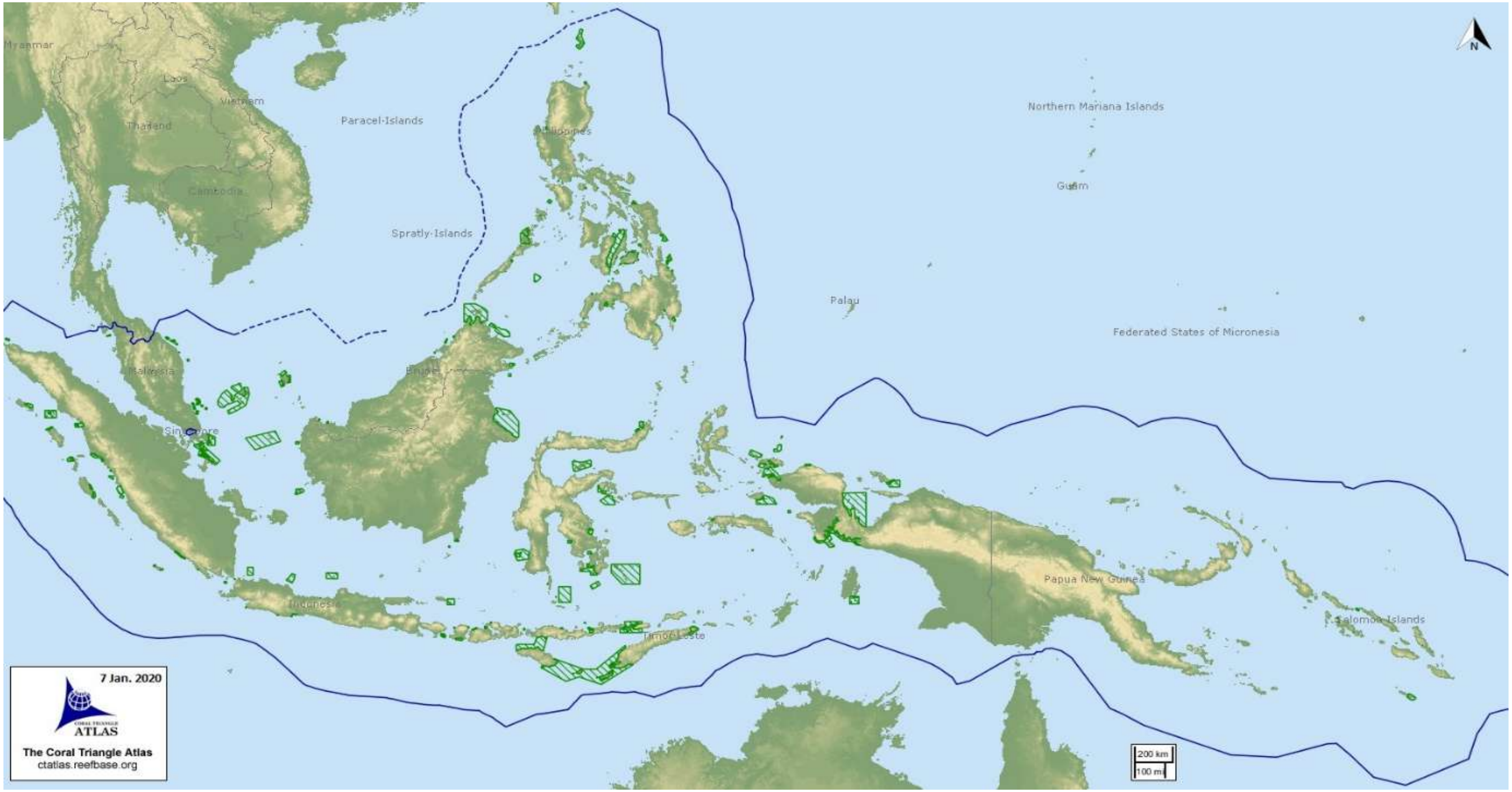

Figure 1.3 MPAs in the Coral Triangle Initiative on Coral Reefs, Fisheries, and Food Security (CTI-CFF) implementation area. Marine Protected Areas (green polygons) covered almost 18% of the CTI-CFF implementation area (blue bordering line) pre-pandemic.

Prior to the outbreak of Covid-19, MPAs covered over 200,000 km^2 of marine area within the CT (Fig. 1.3), including 7,757 km^2 of coral reef habitat, representing 17.8% of the regional total (Cros et al. 2014). The six primary signatory countries endorsed the Coral Triangle MPA System Framework and Action Plan (CTMPAS) supported by scientific data (White et al. 2014), which set a target for 20% of critical habitats to be inside some form of MPA by 2020 (CTI-CFF 2013). Superficially, the almost 18% of CT coral reefs already protected in 2014 (the latest updated data from the region available pre-pandemic, including from the Coral Triangle Atlas) would seem to indicate that this goal had already nearly been achieved six years ahead of schedule.

There are differing views on the level of success achieved, however. Only about 1% of the reef area in the Philippines was deemed to be under truly effective protection just two years earlier in 2012, while it has been claimed that many MPAs are not achieving their management objectives, and “no-take marine reserves” (with a regional target of 10%), make up only a small proportion of protected areas (Burke et al. 2012). Numerous studies highlight the prevalence of ‘paper parks’ – theoretically but not practically protected – particularly in the developing world (e.g. Saporiti 2006; Tam 2015; Arias 2016; Bender 2018), where countries receive on average less than 30% of the estimated funding needed for basic conservation management (Saporiti 2006). These countries may consequently find it difficult to bridge the gap between regional planning and local implementation (Mills et al. 2010). Primary considerations for the effective implementation of both protected areas and coral restoration initiatives within the CTI-CFF framework are the enormous geographic extent of the region and its complex social, political, and ecological structures (Fidelman et al. 2012; Treml et al. 2015). These considerations will have various levels of influence over the long-term success of any attempted restoration projects or wider-ranging programmes.

The numerous factors that can hamper protection enforcement usually lead to increased non-compliance with and/or non-enforcement of protection rules (Pieraccini et al. 2016). Failure to involve local communities in decision-making processes usually results in a lack of support for conservation efforts due to feelings of disenfranchisement, marginalisation and/or resentment at having restrictions on traditional resources imposed by outsiders (Ferse et al. 2010). Tensions over different understandings among stakeholders (e.g. fishers, dive operators, and conservationists) about MPA goals may also undermine their success (Fabinyi 2008), so incorporating stakeholders into the goal setting process early on is crucial (Barber et al. 2008). This is equally true for coral restoration projects, as discussed in Chapter 2.

Within the CT, several case studies highlight issues with the active implementation of conservation strategies and management, which tend to reflect the situation in many areas (Tam 2015; Mudge 2018). Now more than ever, protection and restoration efforts should follow a holistic, rights-based approach that integrates ecological, economic, social, and political considerations (Bender 2018) without promoting certain considerations to the detriment of others (e.g. conservation over food security). There are already a number of successful protected areas across the region, particularly linked to work done by the USAID-funded Coral Triangle Support Partnership (CTSP), including the Raja Ampat MPA network in Indonesia, the Tun Mustapha Park in Malaysian Borneo, the work of WWF-Philippines and Conservation International alongside local governments and communities in the Philippines (e.g. Palawan), and the running of LMMAs in PNG (e.g. Milne Bay and Mane Province) and the Solomon Islands (e.g. Gizo Island) (Read, 2014). Funding from CTSP also supported drafting and implementation of the Timor-Leste National Plan of Action (NPOA). Working with three coastal communities in NKS, the country's first and only national park, established in 2007, this community-based process led to communities and government establishing MPAs, passing local regulations to guide management and enforcement, and agreeing to jointly manage marine and coastal areas in NKS (Read 2014). This should bode well for the future establishment of restoration initiatives if and when required, with the groundwork for marine conservation already having been established with stakeholders.

Private management can be an effective way to conserve biodiversity in MPAs and facilitate the implementation of restoration initiatives, and may well succeed regionally in suitable scenarios. Situated 80 km northwest of the mainland town of Sandakan in north-eastern Sabah, Malaysia, the Sugud Islands Marine Conservation Area (SIMCA) covers roughly 467 km^2 in the Sulu Sea, encompassing three islands: Lankayan, Billean, and Tegapil. SIMCA has seen positive results from private investment and management by the organisation Reef Guardian, with sustainable financing generated by visitor conservation fees, and funds reinvested into training and surveillance technology. Threats such as illegal fishing and turtle egg poaching have been reduced, and coral reefs and seagrass rehabilitated (Teh at al. 2008). The success of private ventures can usually partly be attributed to stakeholders receiving monetary incentives to protect environmental resources. This sometimes means that they are more motivated and adept than governments at handling the economics of running a specific protected area (Wilkinson et al. 2006). Donor funding represents an alternative setup, but is usually short-term (McClanahan 1999) and consequently fails to provide the long-term funding necessary to support ongoing operations (Depondt and Green 2006; Subade 2007). These commercial initiatives represent one useful mechanism for delivering restoration in the CT.

An increasing focus on the region’s importance as a repository for coral biodiversity, the rise of ecotourism and popularity of recreational SCUBA diving, and a growing understanding amongst the general public about the importance of coral reefs have the potential to support this model in the future. However, it is imperative to ensure long-term sustainability of these types of ventures, with the key usually being cross-sector cooperation and cultivating a sense of ownership in local communities, rather than simple monetary incentives (Bottema and Bush 2012; Westoby et al. 2020). Marrying the diverse agendas of wide-ranging ecosystem services, varied stakeholders, and the centrality of the region to international trade networks is a singularly complex and constantly changing difficulty, particularly in light of the vast size of the CT (Fidelman et al. 2012). While there has been significant progress, very real challenges still face marine conservation and restoration in the region. Increasing MPA effectiveness (White et al. 2014) and solving the multi-faceted complexity of multi-national fisheries and marine commons throughout the CT are vital to ensuring the effectiveness of coral reef restoration efforts. Furthermore, these efforts need to be supported by the removal of local stressors to marine and associated ecosystems.

1.3. References

Allen GR (2007) Conservation hotspots of biodiversity and endemism for Indo-Pacific coral reef fishes. *Aquatic Conservation: Marine and Freshwater Ecosystems* 18:541-556

Ambo-Rappe R, Moore AM (2019) Sulawesi Seas, Indonesia. In: *World Seas: An Environmental Evaluation* 559-581

Arias A (2016) Avoiding and reversing “paper parks”: integrating fishers’ compliance into marine conservation efforts. *Doctoral dissertation,* James Cook University

BAPPENAS (Indonesian Institute of Science & Ministry of National Development Planning/ National Development Planning Agency, Government of Indonesia) (2019) Coral Reef Rehabilitation and Management Program – Coral Triangle Initiative Environmental and Social Safeguard Framework (COREMAP CTI-ESSF), Second Restructuring Phase. Jakarta, Indonesia 99pp.

Barber T, Krumholz J, Walch J, Jadot C, Harris L, Beggs L, Van Der Buik M, Young W (2008) A step-by-step guide for grassroots efforts to reef rehabilitation, poster presentation material. *Proc. 11th International Coral Reef Symposium* Ft. Lauderdale, Florida 7-11

Bender M (2018) As nature evolves, so too does MPA management need to evolve. *Biodiversity* 19:131-136

Bottema MJ, Bush SR (2012) The durability of private sector-led marine conservation: a case study of two entrepreneurial marine protected areas in Indonesia. *Ocean & Coastal Management* 61:38-48

Bruno JF, Selig ER (2007) Regional decline of coral cover in the Indo-Pacific: timing, extent, and subregional comparisons. *PloS One* 2:e711

Burke L, Reytar K, Spalding M, Perry A (2012) Reefs at Risk Revisited in the Coral Triangle. *Defenders* 74:130

Cabral RB, Aliño PM, Balingit ACM, Geronimo RC, MSN Partners (2014) The Philippine marine protected area (MPA) database. *Philippine Science Letters* 7(2):300-308

Cabral RB, Geronimo RC (2018) How important are coral reefs to food security in the Philippines? Diving deeper than national aggregates and averages. *Marine Policy* 91:136-141

Clifton J, Foale S (2017) Extracting ideology from policy: analysing the social construction of conservation priorities in the Coral Triangle region. *Marine Policy* 82:189-196

Cohen PJ, Evans LS, Mills M (2012) Social networks supporting governance of coastal ecosystems in Solomon Islands. *Conservation Letters* 5:376-386

Cros A, Fatan NA, White A, Teoh SJ, Tan S, Handayani C, Huang C, Peterson N, Li RV, Siry HY, Fitriana R (2014) The Coral Triangle Atlas: an integrated online spatial database system for improving coral reef management. *PloS One* 9(6):e96332

Cruz-Trinidad A, Aliño PM, Geronimo RC, Cabral RB (2014) Linking Food Security with Coral Reefs and Fisheries in the Coral Triangle. *Coastal Management* 42:160-182

CTI-CFF (2013) Proposed loan and administration of grant INO: Coral reef rehabilitation and management: Coral Triangle Initiative Project (co-financed by the Global Environment Facility). *Concept paper: Asian Development Bank* Project Number:46421

CT Atlas (2018) The Coral Triangle Atlas: providing information to decision makers (online). Available at: https://www.ctatlas.reefbase.org (Accessed 20 Dec 2018)

CT Atlas (2023) The Coral Triangle Atlas: providing information to decision makers (online). Available at: https://ctatlas.coraltriangleinitiative.org/MPA (Accessed 29 Dec 2023)

de Groot R, Brander L, van der Ploeg S, Costanza R, Bernard F, Braat L, Christie M, Crossman N, Ghermandi A, Hein L, Hussain S, Kumar P, McVittie A, Portela R, Rodriguez LC, ten Brink

P, van Beukering P (2012) Global estimates of the value of ecosystems and their services in monetary units. *Ecosystem Services* 1:50-61

Depondt F, Green E (2006) Diving user fees and the financial sustainability of marine protected areas: opportunities and impediments. *Ocean & Coastal Management* 49:188-202

Edwards AJ (ed.) (2010) Reef rehabilitation manual. Coral Reef Targeted Research & Capacity Building for Management Program. St Lucia, Australia: ii + 166pp.

Edyvane K, de Carvalho N, Penny S, Fernandes A, de Cunha C, Amaral A, Mendes M, Pinto P (2012) Conservation values, issues and planning in the Nino Konis Santana Marine Park, Timor-Leste – Final Report

Fabinyi M (2008) Dive tourism, fishing and marine protected areas in the Calamianes Islands, Philippines. *Marine Policy* 32:898-904

Ferse SCA, Máñez Costa M, Mez KS, Adhuri DS, Glaser M (2010) Allies, not aliens: increasing the role of local communities in marine protected area implementation. *Environmental Conservation* 37:23-34

Fidelman P, Evans L, Fabinyi M, Foale S, Cinner J, Rosen F (2012) Governing large-scale marine commons: contextual challenges in the Coral Triangle. *Marine Policy* 36:42-53

Fischborn M, Levitina Z (eds.) (2018) Solutions in focus: community-led successes in marine conservation

Foale S, Adhuri D, Aliño PM, Allison EH, Andrew N, Cohen P, Evans L, Fabinyi M, Fidelman P, Gregory C, Stacey N, Tanzer J, Weeratunge N (2013) Food security and the Coral Triangle Initiative. *Marine Policy* 38:174-183

Green A, White A, Tanzer J (2012) Integrating fisheries, biodiversity, and climate change objectives into marine protected area network design in the Coral Triangle. Report prepared by The Nature Conservancy for the Coral Triangle Support Partnership: 105pp.

Hoegh-Guldberg O, Hoegh-Guldberg H, Veron JEN, Green A, Gomez ED, Lough JM, King M, Ambariyanto, Hansen L, Cinner J, Dews G, Russ G, Schuttenberg HZ, Peñaflor EL, Eakin CM, Christensen TRL, Abbey M, Areki F, Kosaka RA, Tewfik A, Oliver J (2009) The Coral Triangle and climate change: ecosystems, people and societies at risk. WWF Australia, Brisbane: 276pp.

Jupiter S, McCarter J, Albert S, Hughes A, Grinham A (2019) Solomon Islands: coastal and marine ecosystems. *In: World Seas: An Environmental Evaluation* 855-874

McClanahan TR (1999) Is there a future for coral reef parks in poor tropical countries? *Coral Reefs* 18:321-325

Mills M, Pressey RL, Weeks R, Foale S, Ban NC (2010) A mismatch of scales: challenges in planning for implementation of marine protected areas in the Coral Triangle. *Conservation Letters* 3:291-303

Mudge L (2018) Use of community perceptions to evaluate and adapt coastal resource management practices in the Philippines. *Ocean & Coastal Management* 163:304-322

Pieraccini M, Coppa S, De Lucia GA (2016) Beyond marine paper parks? Regulation theory to assess and address environmental non-compliance. *Aquatic Conservation: Marine and Freshwater Ecosystems* 27:177-196

Polidoro BA, Carpenter KE, Collins L, Duke NC, Ellison AM, Ellison JC, Farnsworth EJ, Fernando ES, Kathiresan K, Koedam NE, Livingstone SR, Miyagi T, Moore GE, Ngoc Nam V, Ong JE, Primavera JH, Salmo SG, Sanciangco JC, Sukardjo S, Wang Y, Yong JWH (2010) The loss of species: mangrove extinction risk and geographic areas of global concern. *PloS One* 5(4)

Read T (2014) Stewarding biodiversity and food security in the Coral Triangle: achievements, challenges, and lessons learned. Report produced by the Coral Triangle Support Partnership (CTSP) for USAID R.D.M.A. Project Number: GCP LWA Award # LAG-A-00-99-00048-00

Rutherford J (2015) Western Province Ridges to Reef: integrated planning for natural resources, communities, and biodiversity, CEPF Final Project Completion Report, WWF Solomon Islands: 20pp.

Saporiti N (2006) Managing national parks: how public-private partnerships can aid conservation. *Journal of Public Policy:* 4pp.

Short FT, Polidoro B, Livingstone SR, Carpenter KE, Bandeira S, Bujang JS, Calumpong HP, Carruthers TJB, Coles RG, Dennison WC, Erftemeijer PLA, Fortes MD, Freeman AS, Jagtap TG, Kamal AHM, Kendrick GA, Judson Kenworthy W, La Nafie YA, Nasution IM, Orth RJ, Prathep A, Sanciangco JC, van Tussenbroek B, Vergara SG, Waycott M, Zieman JC (2011) Extinction risk assessment of the world's seagrass species. *Biological Conservation* 144:1961-1971

Subade RF (2007) Mechanisms to capture economic values of marine biodiversity: the case of Tubbataha Reefs UNESCO World Heritage Site, Philippines. *Marine Policy* 31:135-142

Sukulu M, Orirana G, Oduagalo D, Waleilia B, Sulu R, Schwarz A, van der Ploeg J, Eriksson H (2016) “Management over ownership”: modern community cooperation in Langalanga Lagoon, Solomon Islands. *SPC Traditional Marine Resource Management and Knowledge Information Bulletin* 37:13-21

Sulu R, Boso D, Vave-Karamui A, Wini-Simeon L (2014) State of the Coral Triangle: Solomon Islands. Asian Development Bank. Mandaluyong City, Philippines

Tam CL (2015) Timing exclusion and communicating time: a spatial analysis of participation failure in an Indonesian MPA. *Marine Policy* 54:122-129

Teh LCL, Teh LSL, Chung FC (2008) A private management approach to coral reef conservation in Sabah, Malaysia. *Biodiversity and Conservation* 17:3061-3077

Treml EA, Fidelman PIJ, Kininmonth S, Ekstrom JA, Bodin Ö (2015) Analyzing the (mis)fit between the institutional and ecological networks of the Indo-West Pacific. *Global Environmental Change* 31:263-271

USAID, CT Support Partnership (2013) Malaysia Success Stories. (online) http://www.coraltriangleinitiative.org/sites/default/files/resources/13_Malaysia%20Success%20Stories.pdf (Accessed 14 Jan 2024)

Veron JEN, DeVantier LM, Turak E, Green AL, Kininmonth S, Stafford-Smith M, Peterson N (2009) Delineating the Coral Triangle. *Galaxea, Journal of Coral Reef Studies* 11:91–100

Veron J, Stafford-Smith M, DeVantier L, Turak E (2015) Overview of distribution patterns of zooxanthellate Scleractinia. *Frontiers in Marine Science* 1:81. Maps available online at: http://www.coralsoftheworld.org/page/distributions/ (Accessed 14 Jan 2024)

Walton A, White AT, Tighe S, Aliño PM, Laroya L, Dermawan A, Kasasiah A, Hamid SA, Vave-Karamui A, Genia V, De Jesus Martins L, Green AL (2014) Establishing a functional region-wide Coral Triangle Marine Protected Area system. *Coastal Management* 42:107–127

Weeks R, Aliño PM, Atkinson S, Beldia P, Binson A, Campos WL, Djohani R, Green AL, Hamilton R, Horigue V, Jumin R, Kalim K, Kasasiah A, Kereseka J, Klein C, Laroya L, Magupin S, Masike B, Mohan C, Da Silva Pinto RM, Vave-Karamui A, Villanoy C, Welly M, White AT (2014) Developing marine protected area networks in the Coral Triangle: good practices for expanding the Coral Triangle marine protected area system. *Coastal Management* 42:183-205

Wells S, Ray GC, Gjerde KM, White AT, Muthiga N, Bezaury Creel JE, Causey BD, McCormick-Ray J, Salm R, Gubbay S, Kelleher G, Reti J (2016) Building the future of MPAs – lessons from history. *Aquatic Conservation: Marine and Freshwater Ecosystems* 26:101-125

Westoby R, Becken S, Laria AP (2020) Perspectives on the human dimensions of coral restoration. *Regional Environmental Change* 20:1-3

White AT, Aliño PM, Cros A, Fatan NA, Green AL, Teoh SJ, Laroya L, Peterson N, Tan S, Tighe S, Venegas-Li R, Walton A, Wen W (2014) Marine protected areas in the Coral Triangle: progress, issues, and options. *Coastal Management* 42:87-106

Wilkinson C, Caillaud A, DeVantier L, South R (2006) Strategies to reverse the decline in valuable and diverse coral reefs, mangroves and fisheries: the bottom of the J-Curve in Southeast Asia? *Ocean & Coastal Management* 49(9-10):764-778

Wilkinson C (2010) Foreword in: Clifton J, Unsworth RK, Smith DJ (eds.) *Marine research and conservation in the Coral Triangle – The Wakatobi National Park.* Nova Science, i-ii

Williams SL, Ambo-Rappe R, Sur C, Abbott JM, Limbong SR (2017) Species richness accelerates marine ecosystem restoration in the Coral Triangle. *PNAS* 114:11986-11991

Williams SL, Sur C, Janetski N, Hollarsmith JA, Rapi S, Barron L, Heatwole SJ, Yusuf AM, Yusuf S, Jompa J, Mars F (2019) Large-scale coral reef rehabilitation after blast fishing in Indonesia. *Restoration Ecology* 27:447-456

Chapter 2: Coral reef restoration in Indonesia: lessons learnt from the world's largest coral restoration nation

This chapter is a more extensive and revised version of the study originally published by Springer Nature as:

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Abstract

Indonesia is the global coral reef restoration leader by number of projects, yet these remain diverse and disparate. This chapter reviews the status of Indonesian coral reef restoration within a framework of international common best practice (CBP) that incorporates internationally recognised standards for ecological restoration (SER). This framework is used to formulate recommendations for a formal network of reef restoration practitioners with the purview to develop and implement a national restoration roadmap. Forty-five projects were surveyed to determine how projects have been planned and implemented. This was compared with recommendations from CBP. There is particular scope to increase quantitative data collection, reinforce community involvement, improve ecological data collection, and standardise monitoring protocols. While 84% of projects reported quantifiable goals, 64% did not quantify goals during planning and 61% did not incorporate climate-smart design features. Quantitative reef monitoring surveys were absent in 22% of projects. The majority of projects did not quantify important ecological metrics like coral community composition/diversity (96%), coral health/bleaching (89%), benthic community (62%), and coral survival (62%). Indonesia has the capacity, regulations, and networks to position itself as a driver of reef restoration in the Coral Triangle region, but this will require increased coordination, alignment, and quantification of restoration. A structured, collaborative, and

iterative national network of various stakeholders would facilitate the development of a national restoration roadmap based on adaptive management strategies. This would in turn aid in standardising project planning, monitoring, and reporting. Efforts to develop restoration efforts should include an increased focus on climate change adaptation goals.

2.1. Introduction

The economic and ecological importance of coral reefs in the Coral Triangle (CT) is well established; the region is recognised as the world centre for marine biodiversity and one of the primary biodiversity storehouses on the planet (Burke et al. 2012; Williams et al. 2017). Indonesia harbours more than 39,500 km^2 of coral reef area (16% of the global total), including the world's most biologically rich coral reefs in eastern Indonesia. At the heart of the CT, these reefs are home to approximately 590 of the region's 605 recorded hard coral species and 2,200 reef fish species (Burke et al. 2012). Indonesia also has the world's largest reef-associated population: around 60 million people (26% of the population) live within 30 km of a reef (Burke et al. 2012). The nation is among the top five global reef product exporters; more than one million fishers depend on reef fisheries for their livelihood. Tourism revenue is closely linked to reefs, while the annual net economic benefits of the shoreline protection reefs provide are estimated at US$387 million (Burke et al. 2012). The country's reefs are, however, under severe pressure.

While efforts have been made to increase marine conservation awareness, Indonesia is rated in the highest category of vulnerability to coral reef degradation and loss globally. Over 90% of its coral reefs have been impacted by various local activities (Burke et al. 2012). A more recent report on the status of Indonesian coral reefs surveyed 1,153 sites across the country. Only 6.4% of reefs were in an excellent state (>75% healthy hard coral) and 71.2% had less than 50% healthy hard coral (Hadi et al. 2020). Widespread Marine Protected Area (MPA) implementation and restrictions on reef ecosystem utilisation have not been enough to halt ongoing reef degradation in the face of persistent threats.

Ongoing overfishing (Larsen et al. 2018) and blast fishing (Saragih and Trencher 2020; Veloria et al. 2021) remain two of the most immediate localised threats. Destructive fishing is widespread (e.g. Simmons and Fielding 2019; Shafira and Anwar 2021); this is partly due to ineffective enforcement of legislation banning illegal practices (Gorris 2016) and mild penalties for those prosecuted (Renggong et al. 2021). The combination of high biodiversity and high prevalence of localised threats means that effective coral reef restoration is widely perceived as valuable and important. Ongoing attempts to support, improve, and scale up active coral reef restoration efforts are therefore imperative (Lamont et al. 2022). The assertion that Indonesia is one of the most important countries for coral reef conservation and restoration is supported by the "50 Reefs Initiative". This identified an optimum portfolio of 50 areas within which reefs have a higher potential to survive climate change impacts and the ability to repopulate neighbouring reefs over time – almost one quarter of these are located in Indonesia (Beyer et al. 2018).

Indonesian coral reef restoration has a long history: the first artificial reefs (ARs) were deployed in 1979 (Sukarno 1988). ARs and coral transplantation are popular techniques, although restoration projects incorporate diverse materials and methods. These include piles of volcanic rocks, custom-designed concrete structures, branching ceramic modules, electrolytic deposits on shaped wire mesh templates, hexagonal steel structures, and direct attachment of coral fragments to consolidated ocean substrate (Razak et al. 2022). Many different sectors are involved in coral reef restoration; prominent stakeholders include national and local government, local and international non-governmental and non-profit organisations (NGOs and NPOs), the private sector, and coastal communities.

Indonesia's coral reef restoration regulations promote wide community participation; local governments are encouraged to share ownership and responsibility with local communities living near and benefiting from reefs. There are 17 Indonesian reef restoration policies and regulations: four national laws, three government regulations, two presidential regulations, and eight ministerial regulations (Razak et al. 2022). There have also been various long-term regional and national initiatives focused on coral reef health and other marine conservation priorities.

The Coral Triangle Initiative on Coral Reefs, Fisheries, and Food (CTI-CFF) has been a significant regional mechanism for collaborative marine resource management and conserving key ecological and economic components (Veron et al. 2009). A precursor to this was Indonesia's Coral Reef Rehabilitation and Management: Coral Triangle Initiative Project (COREMAP–CTI). This was aimed at sustainably managing coral reef resources, associated ecosystems, and biodiversity to increase coastal community incomes. The CTI-CFF and COREMAP have achieved some major conservation successes. Southwest Papua's Raja Ampat MPA network, for example, has significantly reduced destructive and illegal fishing and improved live coral cover and fish biomass. Communities catch more fish, traditional practices are being revitalised, and new livelihood opportunities are appearing in the growing tourism sector (Fischborn and Levitina 2018). Despite individual success stories, however, there remains a need to bolster passive conservation efforts with active ecological restoration (ER) interventions.

Effective and sustainable ER should not only focus on protecting biodiversity, but also on addressing socioeconomic concerns and supporting climate change mitigation, resilience, and adaptation (Gann et al. 2019). Restoration is a complex undertaking requiring substantial time, resources, and expertise; despite the best intentions, restoration projects regularly underperform (Gann et al. 2019). International standards for ecological restoration (SER) provide a foundation on which to build well-designed, planned, and implemented restoration projects. These standards recognise the need for appropriate knowledge and resources, an understanding of different contexts and risks, ongoing stakeholder involvement, and monitoring programmes that allow for adaptive management. Applying clear and carefully considered SER principles can therefore lead to improved outcomes from high-quality initiatives amenable to monitoring and assessment (Gann et al. 2019).

The sheer number of projects and diversity of organisations involved in Indonesian coral reef restoration presents various challenges for standardisation: mismatches between programme objectives and the metrics used to assess their effectiveness hamper current efforts (Hein et al. 2020b). While COREMAP has previously introduced a set of standardised practices for reef managers, these focused primarily on passive conservation efforts centred around the creation of MPAs, rather than providing a specific focus for active restoration efforts. There remains a widespread lack of effective ecological monitoring and consistent reporting in Indonesia's coral reef restoration efforts: only 16% of projects since 1990 have incorporated a post-installation monitoring programme to gauge ecological responses to restoration (Razak et al. 2022). Standardised approaches to and monitoring of restoration activities would greatly benefit Indonesia's efforts to protect its valuable coral reef resources. Meaningful comparisons between sites across the country and evaluations informing the direction of conservation and restoration efforts would enable Indonesia to maximise its substantial coral restoration footprint.

This chapter reviews the planning stages of coral reef restoration projects in Indonesia. It identifies how project planning corresponds with international CBP (Goergen et al. 2020; Shaver et al. 2020) and restoration projects (e.g. Boström-Einarsson et al. 2020; Ferse et al.

2021), and the SER underpinning coral reef restoration CBP (McDonald et al. 2016; Gann et al. 2019). These principles inform recommendations on how Indonesia can further adopt and adapt international CBP based on SER to minimise inappropriate, unbalanced, and/or ineffective interventions and scale up coral restoration nationwide.

Sharing practical and scientific knowledge is key to implementing restoration efficiently and effectively, and to achieving restoration at scale. The creation of a national network of reef restoration managers, policymakers, and researchers is recommended; this aligns with recommendations to develop and promote bilateral and multilateral cooperation among and within countries (Gann et al. 2019). Primary goals include to coordinate more projects with wider, integrated networks of diverse stakeholders and to develop a roadmap for Indonesia's reef restoration efforts. This can help to realise Indonesia's substantial potential, cement its leading role in global coral reef conservation and restoration efforts, and inform reef restoration in the CT.

2.2. Methods

2.2.1. International CBP and SER frameworks

While efforts have previously been made under COREMAP to develop CBP approaches for coral reef rehabilitation in Indonesia, these have focused predominantly on public awareness, surveillance and enforcement of conservation efforts, and social development aspects (Kuehnast 2001), rather than how to plan and sustain active restoration projects.

CBP for coral restoration is underpinned by eight general principles for ecological restoration: ER (1) engages stakeholders; (2) draws on many types of knowledge; (3) is informed by native reference ecosystems, while considering environmental change; (4) supports ecosystem recovery processes; (5) is assessed against clear goals and objectives, using measurable indicators; (6) seeks the highest level of recovery attainable; (7) gains cumulative value when applied at large scales; and (8) is part of a continuum of restorative activities (Gann et al. 2019).

With these principles in mind, Shaver et al. (2020) propose a six-step iterative planning cycle for coral reef restoration projects, including multiple entry points to which managers can refer. This facilitates integration into existing projects regardless of whether or not planning has previously been undertaken. Responses relevant to the planning cycle, restoration principles underpinning its various stages, and other considerations are detailed in the results. The first four stages focus purely on planning, while the final two stages encompass implementing and evaluating active restoration:

1. *Set goal and geographic focus.*
2. *Identify, prioritise and select sites:* Create a framework for prioritising sites and involving stakeholders in the planning and selection process.
3. *Identify, design, and select interventions:* Identify diverse intervention options, apply climate-smart design considerations, and engage stakeholders to design and select applicable approaches.
4. *Develop Restoration Action Plan (RAP):* Define SMART (specific, measurable, achievable, relevant, timebound) objectives (Table 2.1); develop a restoration timeline and strategic plan.
5. *Implement restoration*: Ensure long-term project sustainability; identify control sites against which to evaluate restoration and measure successes and shortcomings.
6. *Monitor and evaluate progress alongside restoration implementation*: Analysing monitoring data enables progress evaluations. Over time, short-term assessments of restoration interventions should switch to examining reef-scale effects over longer timeframes.

Table 2.1 Attributes and examples of the SMART Goals and Objectives to be considered by coral reef restoration projects [Adapted from Shaver et al. (2020) and CMP (2020)].

Attribute	Description (adapted from CMP 2020)	Examples (adapted from Shaver et al. 2020)
Specific	Clearly defined so all involved share an understanding of what the objective means	Identifies restoration site, species, or techniques for restoration
Measurable	Can be defined relative to a standard scale (e.g. numeric or all/nothing states)	Identifies size of area for restoration / number of outplants / survival rate compared to a baseline
Achievable	Practical and appropriate in light of project site, political, social, and financial context	Considers feasible numbers of corals / measurable outcomes within project scope; local/climatic threats to restoration activities
Relevant	Ensures the significance of the outcome within regional or local management context	Coral species selected for specific resilience, ecological importance, or conservation status
Timebound	Achievable within a specific time period (usually 10-20 years for goals; 1-10 years for objectives)	Identifies deadlines considering biological and ecological parameters

Monitoring and evaluation can incorporate universal and goal-based performance (GBP) metrics that quantify change to address goals identified during planning (Goergen et al. 2020). Universal metrics are assessed at reef-scale, population, and colony levels. They provide a basic, standardised description of restoration size, composition, and status that is accessible to practitioners – regardless of expertise or resources. This facilitates meaningful comparisons between sites: what and how much was restored, and the progress of restored sites over time (Goergen et al. 2020). GBP metrics should focus particularly on diverse ER categories. These should encompass coral population enhancement; community and habitat enhancement, including invertebrate and reef fish communities; reef structure and complexity; and habitat quality. Other categories for GBP include various ecological, socioeconomic, event-driven, climate change adaptation, and research metrics.

2.2.2. Data Collection

Using Google, Google Scholar, Ecosia, and YouTube search engines, extensive Boolean searches were conducted to identify active coral restoration projects in Indonesia. The terms “reef rehabilitation” and “reef restoration” were treated as interchangeable. Keywords and phrases acted as operators to narrow down or broaden search results, such as “active AND/OR coral AND/OR reef restoration”, “coral nursery/ies”, “coral conservation” and “coral transplantation”, in conjunction with “Indonesia”, and/or “Coral Triangle”, “Indo-Pacific”, “NGO”, “NPO”, “university”, “government”, and “dive centre OR center”. When compiling the final list of projects reviewed, those identified in online searches who were contactable were added to projects sourced from extant networks of coral reef restoration practitioners within Indonesia, including the School of Coral Reef Restoration (SCORES), the national Indonesia Coral Reef Garden (ICRG) project, and the International Coral Reef Initiative (ICRI) online restoration database.

A survey template was developed based on the planning cycle recommended in international CBP (Shaver et al 2020). Social desirability bias (SDB) was considered as a potential skewing factor on survey responses. This is the tendency to present oneself and one’s social context in a way perceived to be socially acceptable, but not wholly reflective of one’s reality (Bergen and Labonté 2020). In some situations, people may tend to portray themselves in a more favourable light (Podsakoff et al. 2003). There is evidence, though, to suggest it plays a relatively minor role in environmental psychology research (Vesely and Klöckner 2020). As this review is not concerned directly with environmental psychology, SDB was not deemed to be a significant confounding factor; measuring potential discrepancies was considered beyond the scope of the review. Nevertheless, measures were taken to minimise SDB. A combination of approaches was used to source data through various channels: online media; project documentation and webinars; written survey responses; and/or conducting face-to-face interviews (online) whenever feasible to allow additional questioning and clarifications (Mooney et al. 2018). An introductory discussion established rapport, put participants at ease, and conveyed appropriate respect for the high standing of academics and government officials. This increased the likelihood of honest responses. It also allowed interviewers to contextualise their own involvement in Indonesian marine research and explain the review's focus, purpose, and how data would be used. This aimed to reassure respondents that accurate responses would not cast them in a negative light (Bergen and Labonté 2020). Respondents were also informed that responses would remain anonymous to remove significant motivations for SDB, such as the potential for subsequent social sanctioning (Vesely and Klöckner 2020). Information provided in interviews was corroborated where possible by documented information and formal presentations.

Data were recorded using publicly available information, webinars, follow-up interviews, and/or email correspondence. Interviews were conducted in English, or in Bahasa Indonesia and translated into English. Data were extracted from 19 videos (25:20 hours) on 29 projects from the School of Coral Reef Restoration (SCORES) coral reef restoration knowledge-sharing platform's webinar series hosted by IPB University and supported by the World Wide Fund for Nature (WWF) CT Programme. This included 20:25 hours in Bahasa Indonesia and 4:55 hours in English. Twenty-six respondents were interviewed directly in September and October 2022 (22 in English and four in Bahasa Indonesian) for a total of 15:45 hours (13:00 in English and 02:45 in Bahasa Indonesia) and 13 of these projects also provided further information by email. Between September 2022 and January 2023, 17 projects returned completed survey forms to provide responses, nine of which were in addition to data extracted from the webinars, and eight as the sole form of data provided. One project that delivered a webinar declined to provide further data to inform the review. All data collected related to different aspects of project planning and implementation. Analysis was also conducted on projects surveyed for this review as well as the database of Indonesian coral reef restoration projects (1990–2020) compiled by Razak et al. (2022), to examine geographical project distribution and regional variations in the type of leadership for restoration initiatives.

2.3. Results

2.3.1. Data collected from surveyed projects

Data from 45 respondents were analysed to examine planning, implementation, and monitoring stages of coral reef restoration projects, to make comparisons with international CBP and recommendations for monitoring and assessing restoration.

2.3.1.1. Set goal and geographic focus

Survey respondents defined a primary goal (Fig. 2.1a) best describing project aims, in line with eight global primary restoration goals (Boström-Einarsson et al. 2020). Thirty-one percent of respondents selected “reestablish a self-sustaining, functioning reef ecosystem”, followed by “promote coral reef conservation stewardship” (22%), and “accelerate reef recovery post-disturbance” (16%).

The eighth principle of ecological restoration advocates a holistic approach as part of a continuum of restorative activities. This encapsulates four major approaches: reducing societal impacts, rehabilitating degraded areas, ecological restoration, and (where applicable) remediating contaminated or polluted sites (Fig. 2.1b). Goals related to reducing societal impacts were the most widely and frequently reported (71 citations of six goals across 82% of projects) followed by the rehabilitation of degraded areas (39 citations of two goals across 87% of projects). Four ecological restoration goals were cited 42 times across 78% of projects. The most frequently reported goal encompassed rehabilitating degraded reef areas and/or accelerating recovery post-disturbance (69% of projects). This was followed by reestablishing a self-sustaining, functioning reef ecosystem (62%); promoting reef conservation stewardship (60%); and developing alternative livelihoods and/or tourism (60%).

Due to its limited specificity, remediation was excluded when looking at the extent to which projects approached restoration holistically. Twenty-seven projects (60%) included goals relating to all three of the other major approaches; nine projects (20%) included goals for reducing societal impacts and degraded reef rehabilitation; five (11%) had goals for rehabilitation and ecological restoration; three (7%) had only restoration goals; and one (2%) had only rehabilitation goals.

In terms of measurable indicators, 84% of projects reported diverse medium- to long-term quantifiable and relevant objectives they aimed to achieve on a timescale of up to 10 years. These included increasing biodiversity; attracting fish to support local fisheries and reduce fishing pressure on other reef areas; mitigating beach erosion; developing tourism; promoting coral reef conservation; and protecting shores from wave damage. During the planning phase, 36% of projects quantified at least one specific goal relevant to their overall objectives. These included identifying the size of reef area to rehabilitate; delivering a set number of coral restoration scholarships within a specified timeframe; setting timeframes within which to monitor and analyse success; and allocating 10% of farmed corals to restoration.

Setting a geographic focus area involves identifying a broad area where conducting restoration interventions would be most appropriate or relevant to achieving the project's goal, within which final site selection takes place. All projects bar one (which provided no response) followed this step. Appointing a technical advisory team is recommended for the goal-setting stage, including any experts or scientists that may be needed to complete any of the steps (Shaver et al 2020). This was done by 89% of projects.

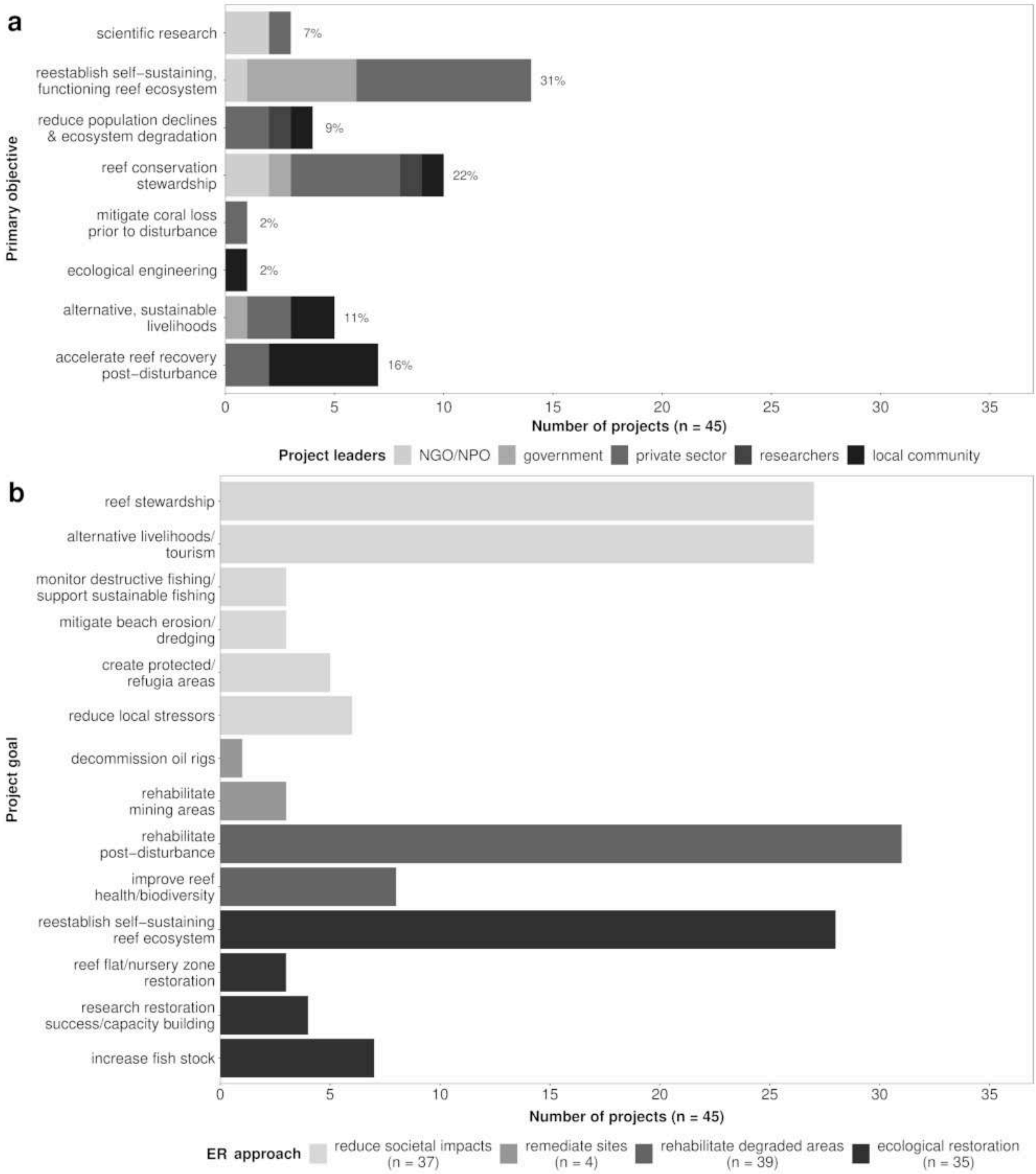

Figure 2.1 Primary restoration objectives and goals related to ecological restoration (ER) principles. (a) ER was the most common primary objective identified by projects, followed by reef conservation stewardship. (b) Of the four major ER approaches applied in coral restoration, goals relating to societal impact reduction were most widely and frequently cited (71 mentions of six goals across 37 projects). The two goals focusing on degraded area rehabilitation were cited by the most projects (39) and four ER goals were cited across 35 projects. Rehabilitating degraded reef areas post-disturbance was the most commonly cited goal, followed by reestablishing a self-sustaining, functioning reef ecosystem.

2.3.1.2. Identify, prioritise, and select sites

A documented site selection process that considered the potential to improve restoration site condition was described by 89% of projects. Criteria followed for identifying, prioritising, and selecting sites within geographical focus areas were grouped into six broad categories (Fig. 2.2a). Ecological considerations were most common, cited by 91% of projects. Other considerations were a site's tourism value (64%); pragmatic considerations such as logistics, finances, and accessibility (58%); climate-smart design considerations, including potential temperature changes, storm intensity, and interactions with local stressors (38%); improving local fish stocks or sustaining fisheries (27%); and compliance with legislation that mandated the restoration of areas degraded by mining activities (7%).

Ecological surveys were incorporated into site selection by 78% of projects; 16% also conducted reef user satisfaction and other socioeconomic surveys. Socioeconomic data were absent from projects where no ecological data were collected (Fig. 2.2b). Local expert knowledge was incorporated into site selection by 84% of projects. Sixty-one percent of projects ranked site importance to prioritise where to start restoration, while 68% discussed potential sites with local stakeholders before finalising selection. Two projects (4%) did not involve communities in planning.

2.3.1.3. Identify, design, and select interventions

Eighty-nine percent of projects implemented an evaluation process for determining restoration intervention type; 84% considered different restoration techniques during planning. Restoration techniques varied, and 80% of projects incorporated multiple approaches. When analysing projects' restoration techniques, a distinction was made between substrate stabilisation methods and ARs. The former often include artificial structures similar to ARs but focus specifically on stabilising loose, shifting coral rubble in addition to increasing habitat complexity. Coral fragment transplantation was the most commonly cited approach (84%), followed by ARs (58%); 16% of projects relied solely on natural larval recruitment on ARs. One bioacoustics study did not involve growing corals.

Already-broken fragments, or corals of opportunity (CoPs), were the main source for fragments for projects actively sourcing corals. CoPs were used in 73% (n = 37) of projects and were the sole fragment source in 41%. Nursery or commercially grown fragments augmented or replaced CoPs in 41% of these projects; 11% exclusively used commercially farmed corals. Twenty-seven percent of these projects fragmented wild colonies alongside other fragment sources; 8% relied exclusively on wild donor colonies. This resembles international findings that CoPs are the most frequent source of fragments for transplantation projects (58%, n = 50); although a higher proportion (46%) of global projects also sourced fragments from wild colonies (Ferse et al. 2021).

Thirty-eight percent of projects in the current study (n = 37) utilised a natural mix of local coral species in restoration, and 46% chose local corals based on specific factors, chiefly:

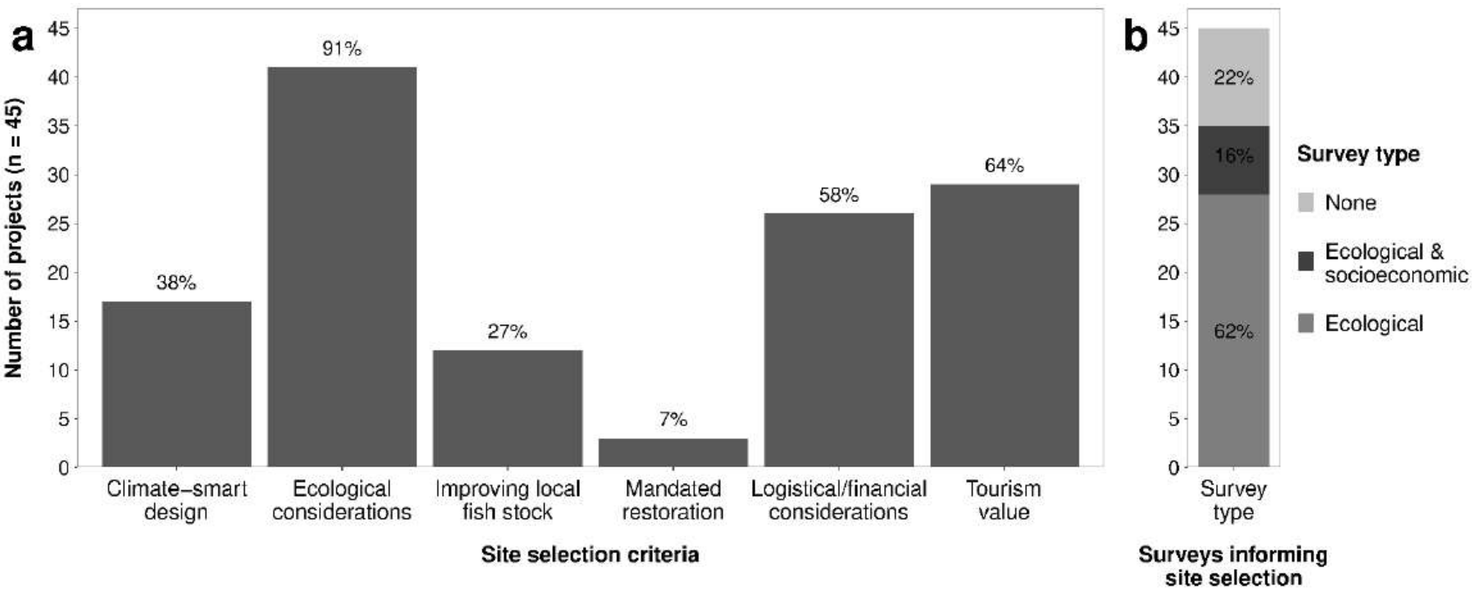

Figure 2.2 (a) Criteria followed for identifying, prioritising, and selecting sites within geographical focus areas were grouped into six broad categories. Ecological considerations were the most commonly cited, followed by the site's tourism value. (b) Ecological and/or socioeconomic surveys were incorporated into site selection by 78% of projects.

fast-growing corals, especially branching and mainly *Acropora* (24%); variety of ecological function (11%); and thermal resilience (8%). International reviews variously reported one-third of projects incorporating *Acropora* and more than three-quarters of projects using branching corals (Boström-Einarsson et al. 2020), and the use of fast-growing, branching corals in 96% of transplantation projects (Ferse et al. 2021). There was no mention in these reviews of the investigation or incorporation of coral thermal resilience in coral selection.

2.3.1.4. Develop Restoration Action Plan (RAP)

Project responses were used to categorise the SMART features of their goals and objectives (Fig. 2.3). Timebound goals were the most lacking, with 51% of projects specifically outlining objectives within a contextualised timeframe (Fig. 2.3a). Fifty-one percent met the criteria for all SMART features and 80% met at least four of five criteria (Fig. 2.3b). Of the nine projects that met three or fewer SMART objectives, seven were small-scale or once-off projects driven by local communities, private resorts, or local NGOs. The other two projects were managed by local government authorities. Seven of these projects were not partnered with researchers; the other two were small-scale community projects driven by a local NGO and a city government authority respectively.

Projects listed all measurable restoration objectives, with 18 reported across five broad categories (Fig. 2.4). Ecology/restoration success was the most common objective (54% of 127 responses), ahead of alternative livelihoods/ tourism (18%), and local stewardship (12%). The most common metric, quantitative reef monitoring, was listed by 78% of projects, while semi-quantitative and qualitative reef monitoring surveys were used by 9 and 11% respectively. Post-impact change was measured by 38% of projects and 31% quantified local stewardship/community buy-in. The extent of alternative livelihoods provided was quantified by 27% of projects and 16% conducted socio-economic or reef user satisfaction surveys.

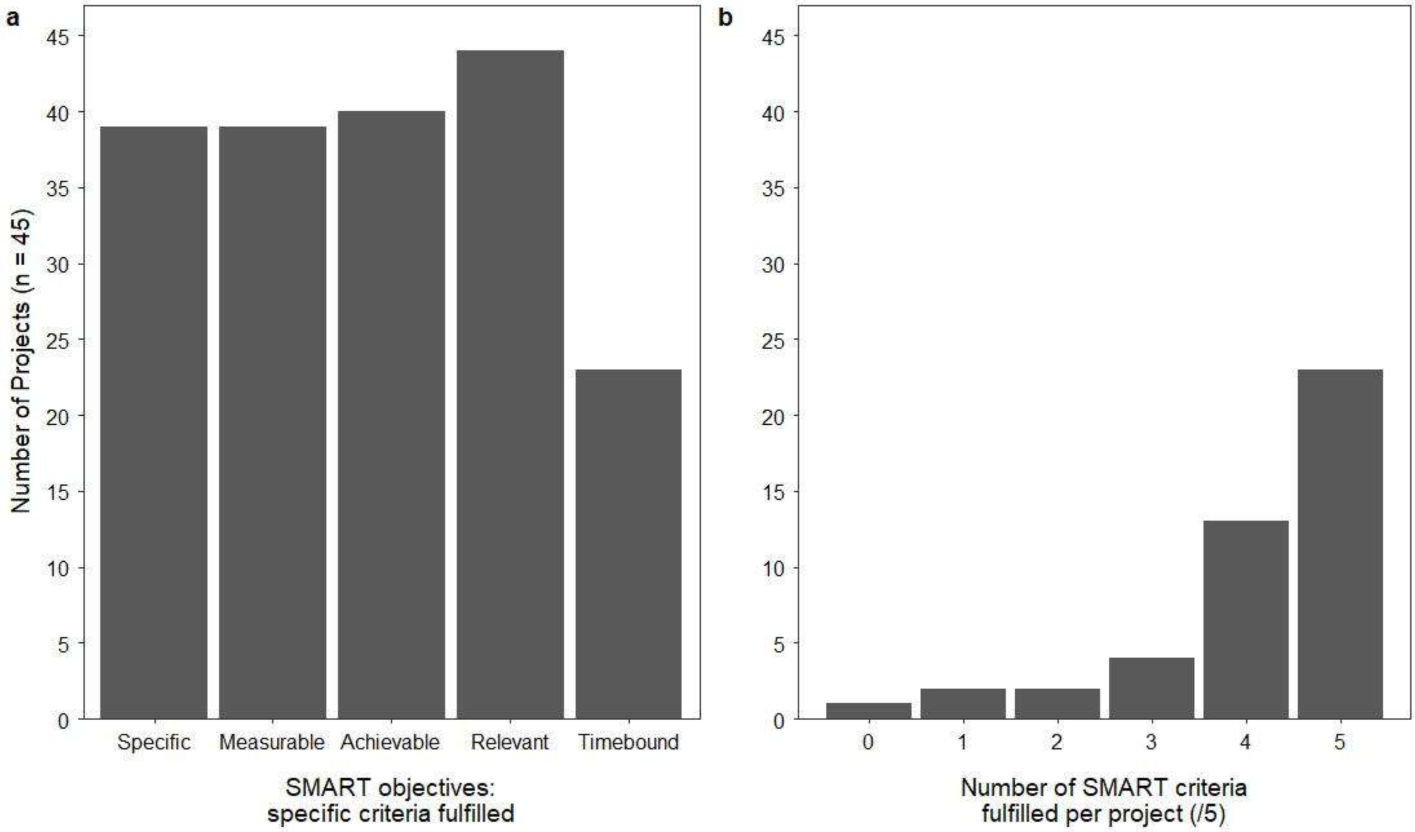

Figure 2.3 (a) The number of projects meeting SMART objectives for coral reef restoration planning. The biggest deficiency in project planning was the lack of timebound objectives in 49% of projects. (b) The number of the five SMART criteria fulfilled by each project. At least four of five criteria were met by 80% of projects.

2.3.1.5. Implement restoration

Shaver et al. (2020) propose five components for the RAP developed in Stage 4. Of these, a formal action plan was implemented by 55% of projects (n=44); 41% had an annual work plan; 50% had an operational plan; and a monitoring plan and restoration timeline were both present in 68% (Fig. 2.5a). While 36% of all projects implemented all five components, 36% implemented two or fewer, and 16% implemented none (Fig. 2.5b). The bioacoustics study was excluded due to the absence of long-term planning requirements.

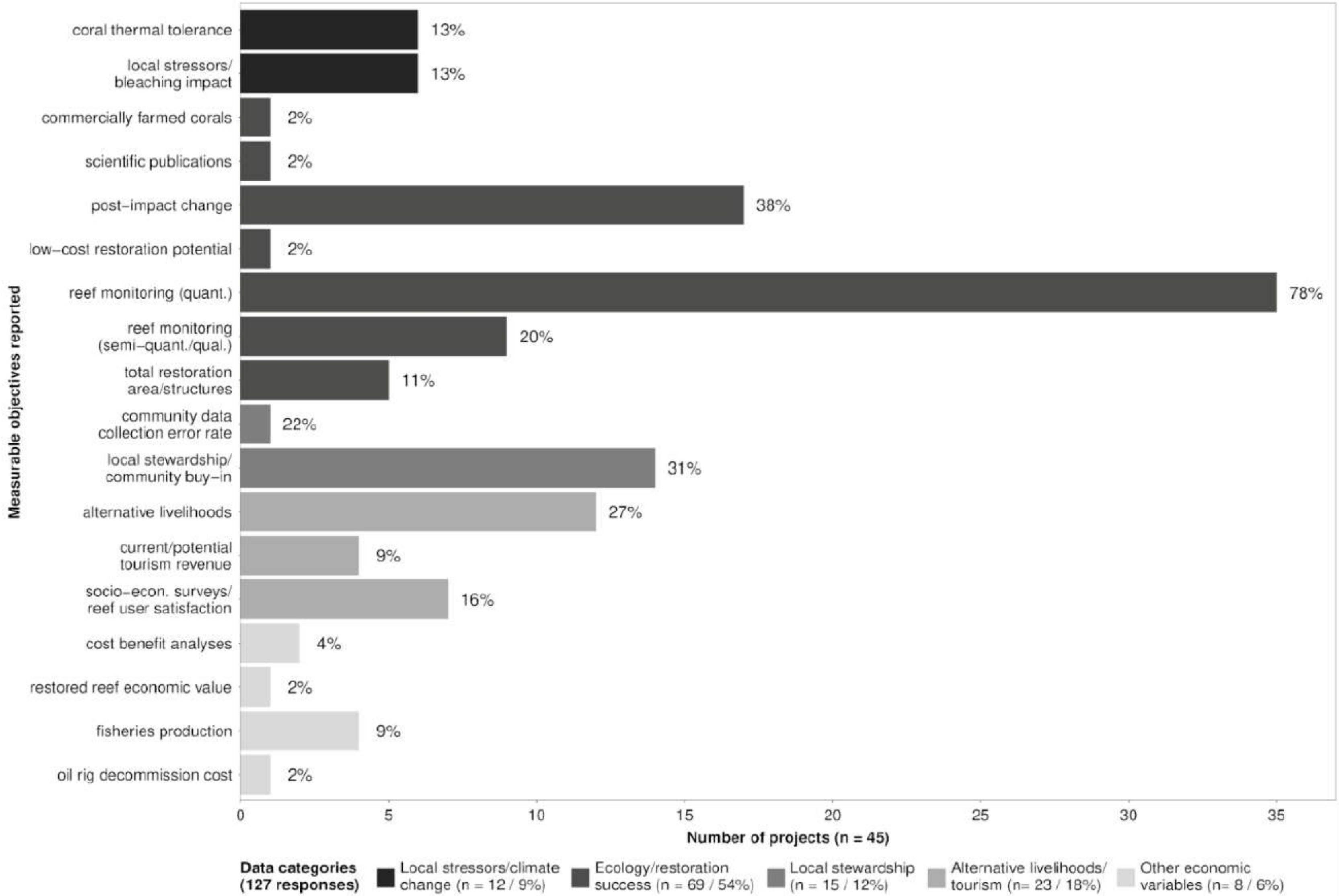

Figure 2.4 Measurable objectives reported by projects. Most data were gathered on ecological/restoration success (54%, n = 127), followed by alternative livelihoods and/or tourism (18%). Reef monitoring programmes were run by 78% of projects and were the most common form of data collection, ahead of post-impact change (38%).

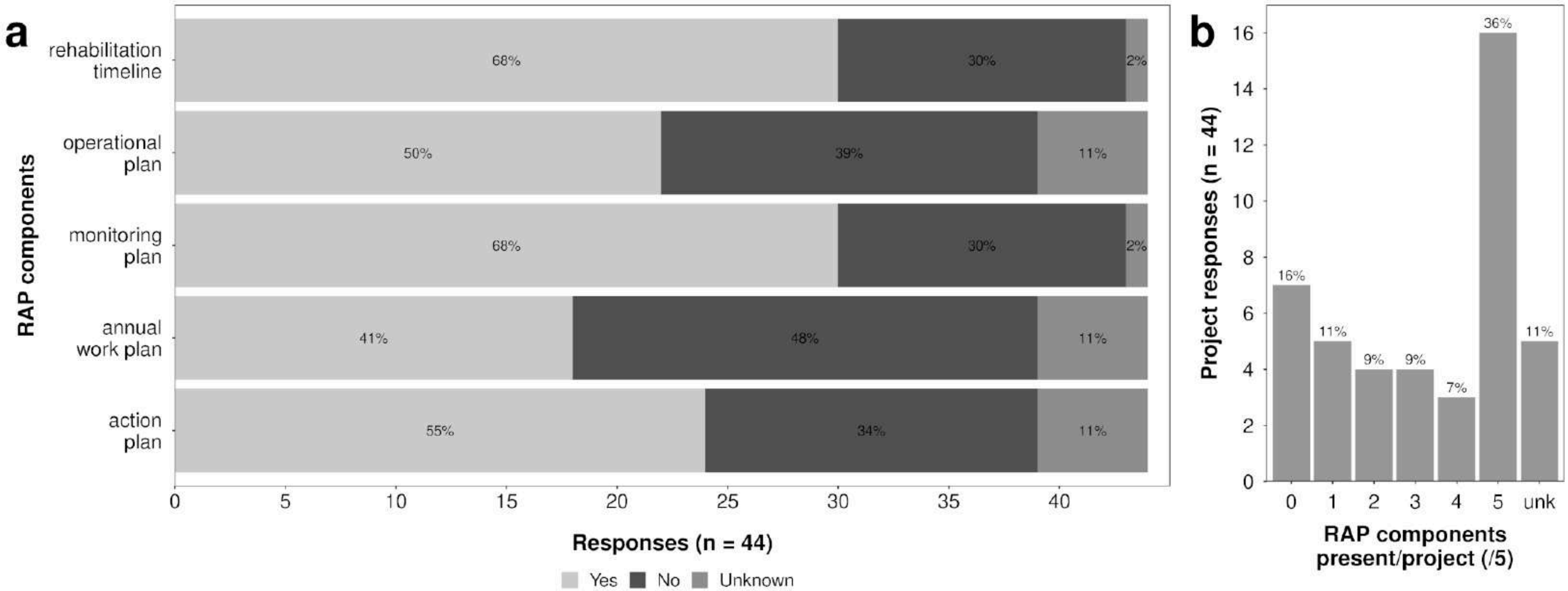

Figure 2.5 (a) The number of projects to implement each of the five Restoration Action Plan (RAP) elements. (b) The number of RAP components implemented per project.

Of 15 projects with no action plan, 67% were run on a local scale (one site location) by NGOs, local communities, the private sector, or (in one case) a once-off research intervention. Local projects also accounted for 47% (n = 17) of projects with no operational plan, 54% (n = 13) with no rehabilitation timeline, and 57% (n = 21) with no annual work plan. Of the 13 projects with no monitoring plan, 38% gauged success by visual observation and 8% by counting artificial structures without measuring coral cover or growth. The remaining 54% ran reef monitoring surveys with no formal monitoring plan. At two projects, outside researchers conducted surveys, and may have had monitoring plans that they did not share with partners.

Forty-two percent of projects were local, 40% were regional (more than one location in the same area), and 18% were multi-regional or national programmes with multiple locations and/or projects (Fig. 2.6a). Projects involved varying degrees of cross-sector cooperation at different scales. Formal partnerships with local communities were present in 72% of projects not led by communities themselves (n = 43). NGO/NPO-driven (86%) and government-driven (82%) projects in particular secured partnerships with local communities. The private sector (17%) generally worked alongside, but did not partner with, communities (Fig. 2.6b).

2.3.1.6. Monitor and evaluate progress

Ecological monitoring data were collected by 84% of projects, compared to 80% of international coral transplantation projects (Ferse et al. 2021). Less than half the projects collected event-driven (49%), economic (44%), or socio-cultural (42%) data, and 36% collected climate change adaptation goal (CCAG) data (Fig. 2.7a). In terms of specific CCAG metrics, 16% of projects measured coral thermal tolerance, including growth and restoration success at different temperatures and depths; 16% monitored coral recovery post-bleaching (disturbance response); 7% monitored bleaching frequency and severity; and 13% monitored water temperature and/or quality (Fig. 2.7b).

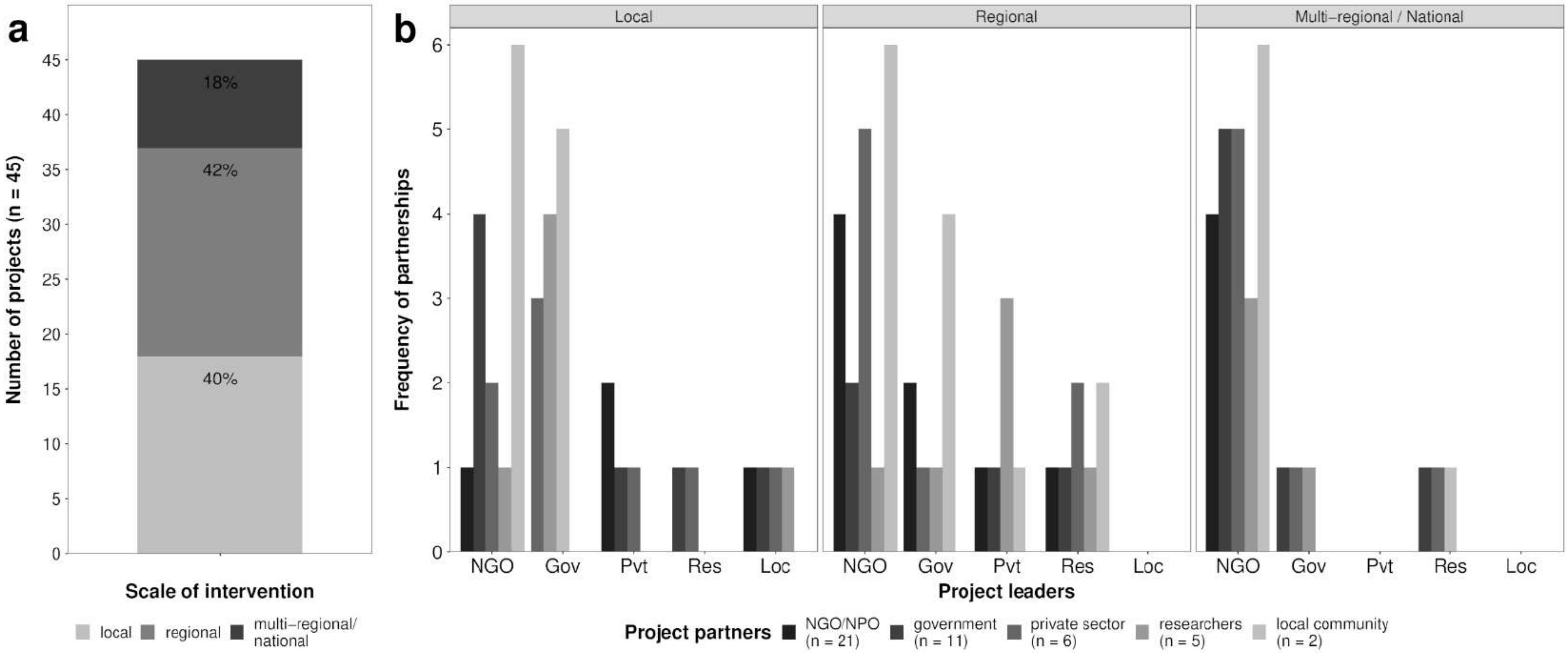

Figure 2.6 Scale of restoration interventions and degrees of cross-sector cooperation at different scales. (a) Local and regional projects were more common than larger scale multi-regional and national programmes. (b) NGOs/NPOs frequently cooperated with other sectors (particularly local communities) at all scales. Government projects frequently cooperated with communities at local and regional scales.

Not all universal metrics recommended by international monitoring CBP (Goergen et al. 2020) were ascertained. Where possible, however, specific metrics were examined (Fig. 2.8a). Reef-level restored area was quantified by 27% of projects. Colony-level and population-level metrics were each quantified by 64% of projects; a further 11 and 9% respectively used visual observation to estimate these metrics. Only two projects (4%) specifically mentioned collecting water temperature measurements (the universal environmental metric), while the extent to which genetic and genotypic diversity were monitored was not ascertained. The prevalence of GBP metrics from international CBP was assessed by looking at whether metrics collected related to the types of goals specified by projects (Fig. 2.8b). The majority of projects that specified CCAGs (93%, n=14); event-driven goals (89%, n=37); and ecological goals (73%, n=45) collected metrics related to those goals. Roughly half the projects that specified economic (54%, n=26) and sociocultural (52%, n=33) goals collected goal-related metrics.

Quantitative reef monitoring surveys were the main tool used to collect ecological data (76%); 9% of projects collected semi-quantitative reef monitoring data and 11% relied on qualitative visual observations (Fig. 2.9a). Coral cover/growth was the most commonly collected ecological metric and was measured in 64% of projects. Fish community data were collected by 51% of projects, while 38% collected benthic community/associated biota or coral survival data. Coral community composition/diversity data were only collected by 4% of projects, quantitative coral health/bleaching data by 11%, data on water quality/temperature by 18%, and data on recruits/juveniles by 20% (Fig. 2.9b).

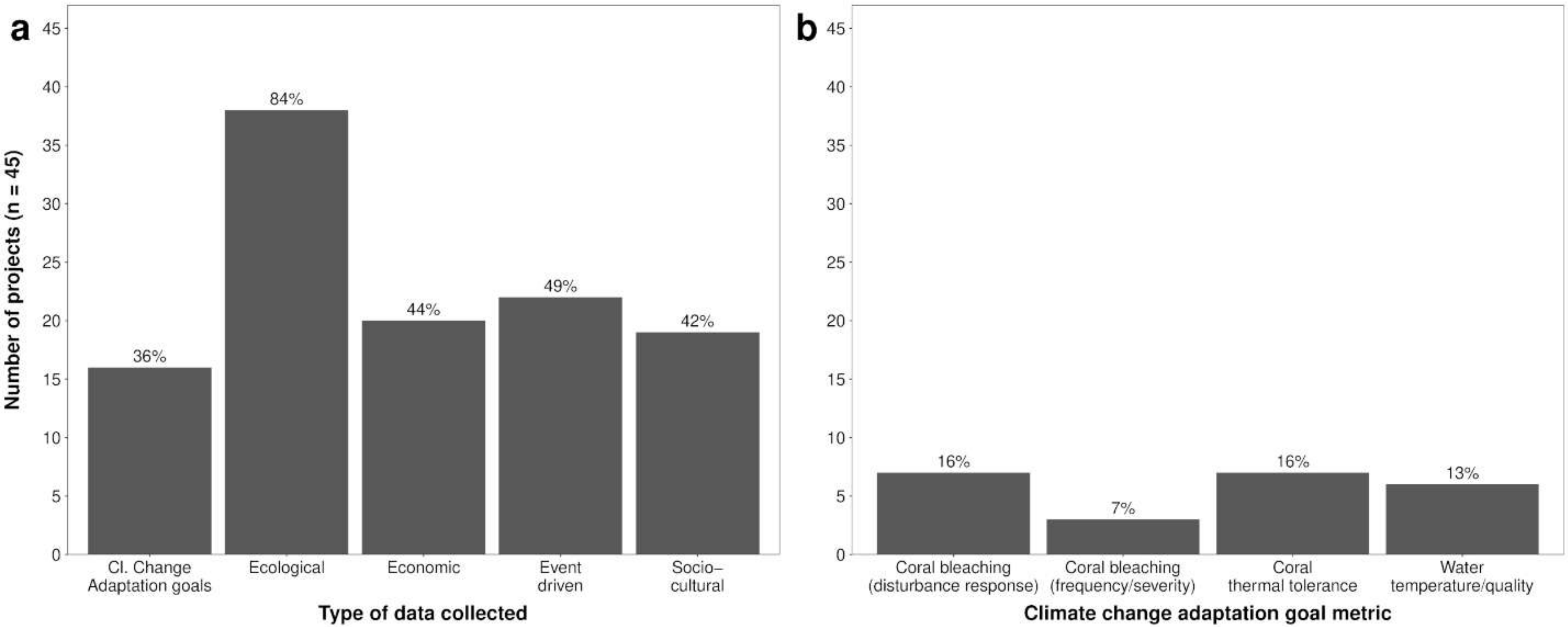

Figure 2.7 Types of data and climate change adaptation goal (CCAG) metrics collected by coral restoration projects in Indonesia. (a) Ecological data were the most commonly represented metric, followed by event-driven data. Data on CCAGs were the most lacking. (b) In the 16 projects that reported specific CCAG metrics, the thermal tolerance of restored corals and their response following bleaching disturbances were the most common metrics.

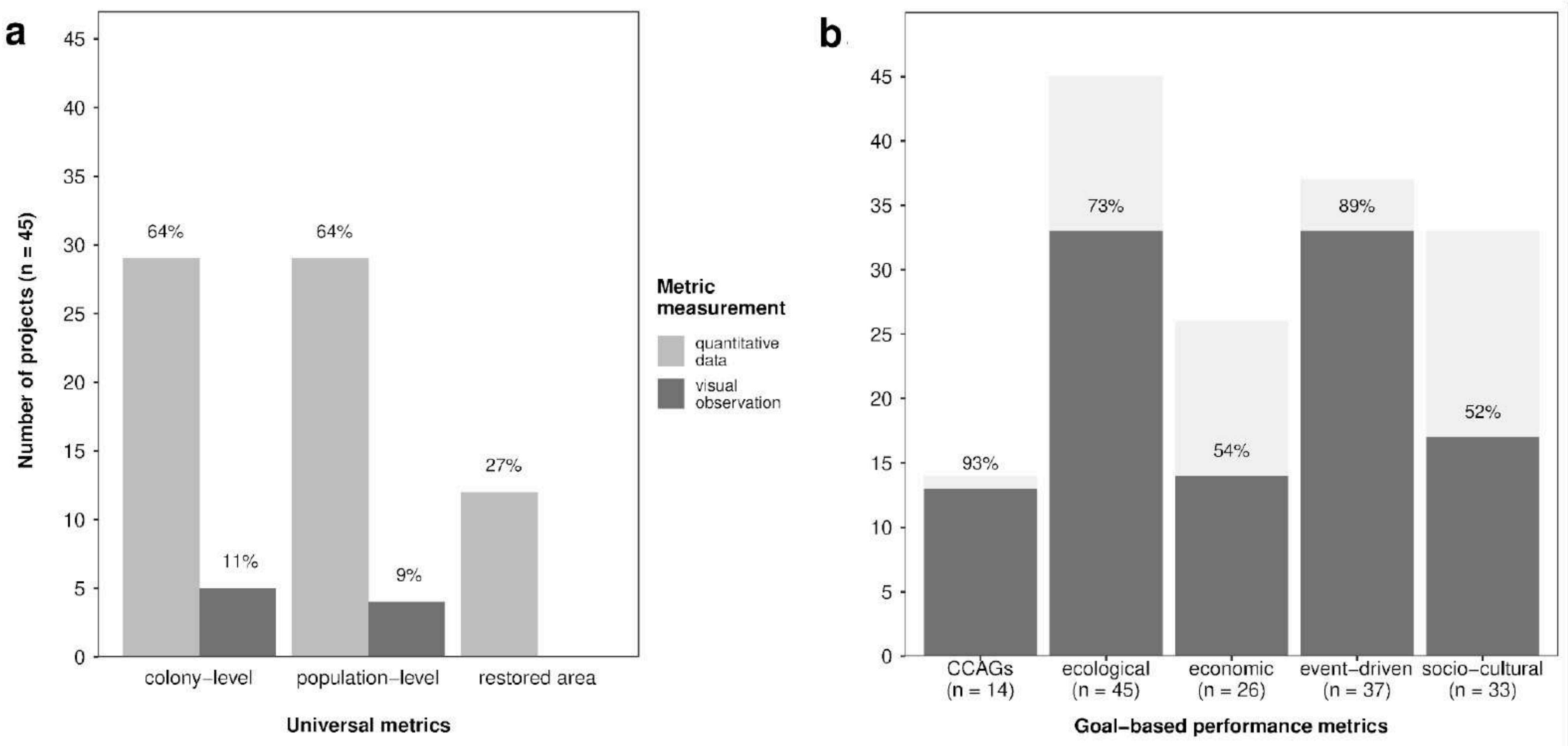

Figure 2. Error! Use the Home tab to apply 0 to the text that you want to appear here. Projects incorporating universal and goal-based performance metrics from international monitoring CBP. (a) Colony-level and population-level metrics were each quantified by 64% of projects; 11% and 9% monitored these respective metrics via visual observation. Restored area was quantified by 27% of projects. (b) The majority of projects that specified CCAGs collected goal-related data (93%). The same was

true for event-driven goals (89%) and ecological goals (73%). Roughly half the projects that specified economic (54%) and sociocultural (52%) goals collected goal-related data.

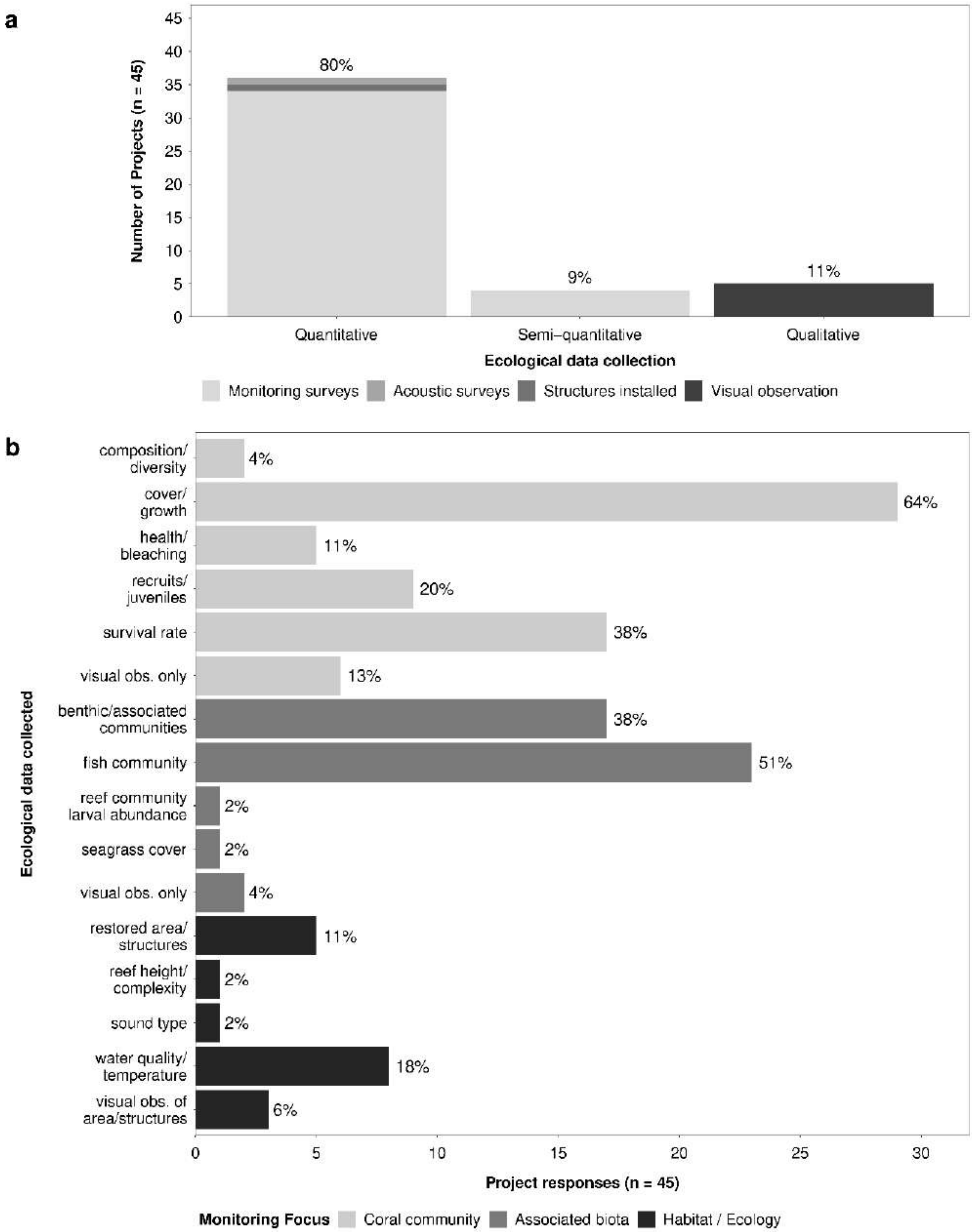

Figure 2.9 Types of ecological data collected in restoration projects. (a) 80% of projects collected quantitative ecological data, mostly in monitoring surveys. (b) Coral cover/growth was the most commonly monitored ecological metric, with more effort put into monitoring the coral community than associated biota, habitats, or other ecological factors.

2.3.2. Regional distribution of Indonesian coral reef restoration projects

2.3.2.1. Regional distribution of surveyed projects

In total, 76% of the projects surveyed in this review were located in Central Indonesia (n = 45). Nine percent were located in West Indonesia and 7% in East Indonesia, 7% had sites in all regions, and one project had sites in both Central and East Indonesia. Central Indonesia was the location for the majority of projects across all sectors, including both of the community-led projects, five of six private sector-led projects (83%), nine of 11 government-led projects (82%), and three of five researcher-led projects (60%). Of the 21 NGO-led projects surveyed, 15 (71%) were located in Central Indonesia, two were in East Indonesia, and one was in West Indonesia; one had locations in both the central and eastern regions, and two were present in all regions (Fig. 2.10).

2.3.2.2. Regional distribution of Indonesian coral reef restoration efforts (1990–2020)

Of 533 coral reef restoration projects recorded in Indonesia between 1990 and 2020 (Razak et al. 2022), 257 were located in West Indonesia (48%), 242 in Central Indonesia (45%), and 34 in East Indonesia (6%). Thirty-eight percent of these 533 projects were led by the Indonesian government, 22% by the private sector, 17% by researchers and/or university students, 13% by NGOs, and 10% by local communities. One percent were spearheaded primarily by foreign governments / international aid programmes.

Government, private sector, and research projects were particularly weighted towards West and Central Indonesia (Fig. 2.11). Over half (53%) of the government projects and 60% of research projects were conducted in West Indonesia, while 54% of private sector projects were located in Central Indonesia, which includes high-profile tourist spots and SCUBA diving destinations such as Bali (including Nusa Penida, Nusa Lembongan, and other smaller islands), West Nusa Tenggara (including Lombok, the Gili Islands, and Sumbawa), East Nusa Tenggara (including Flores, Alor, and Komodo National Park), and Manado in North Sulawesi.

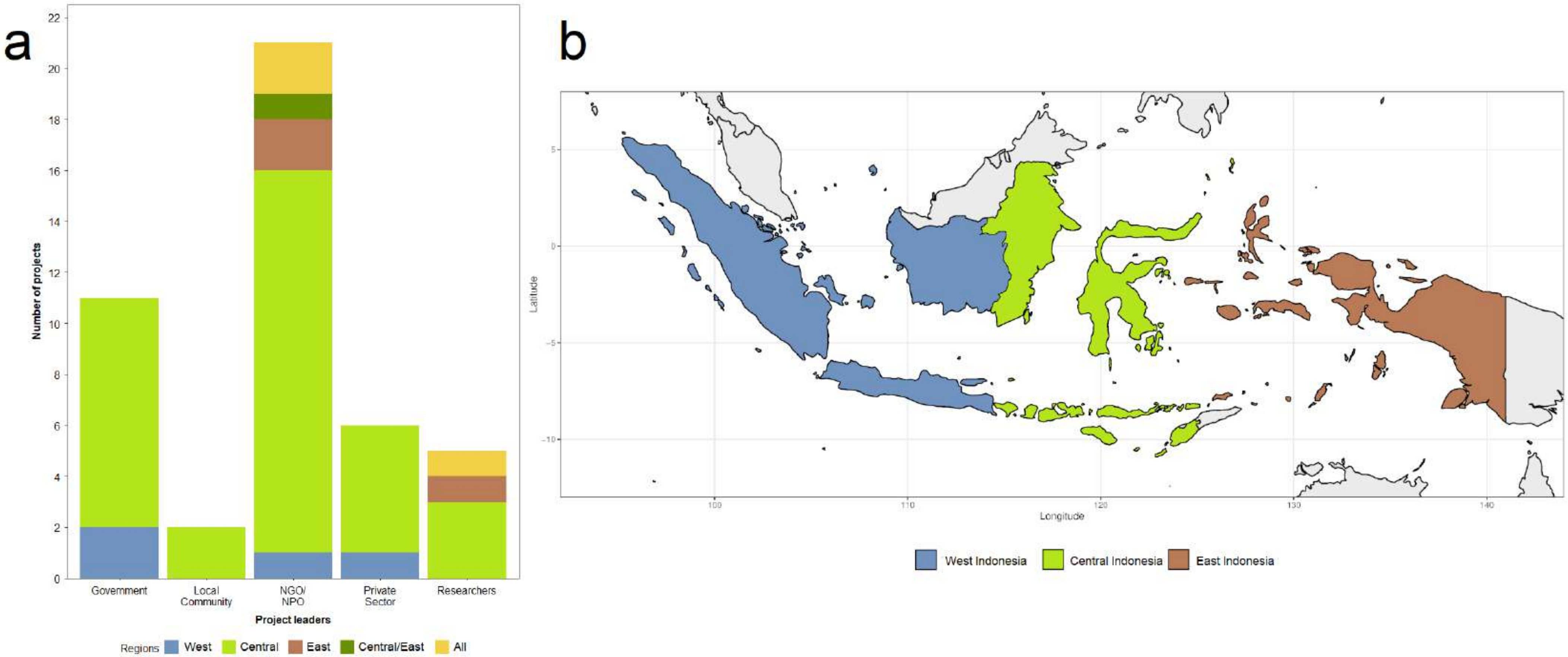

Figure Error! Use the Home tab to apply 0 to the text that you want to appear here. Distribution of projects surveyed in the current study. (a) The distribution of surveyed projects by project leader/sector across Western, Central, and Eastern Indonesia as delineated in (b) a map of the country. The majority of projects were located in Central Indonesia, made up predominantly of Sulawesi; the islands of East and West Nusa Tenggara; and North, East, and South Kalimantan.

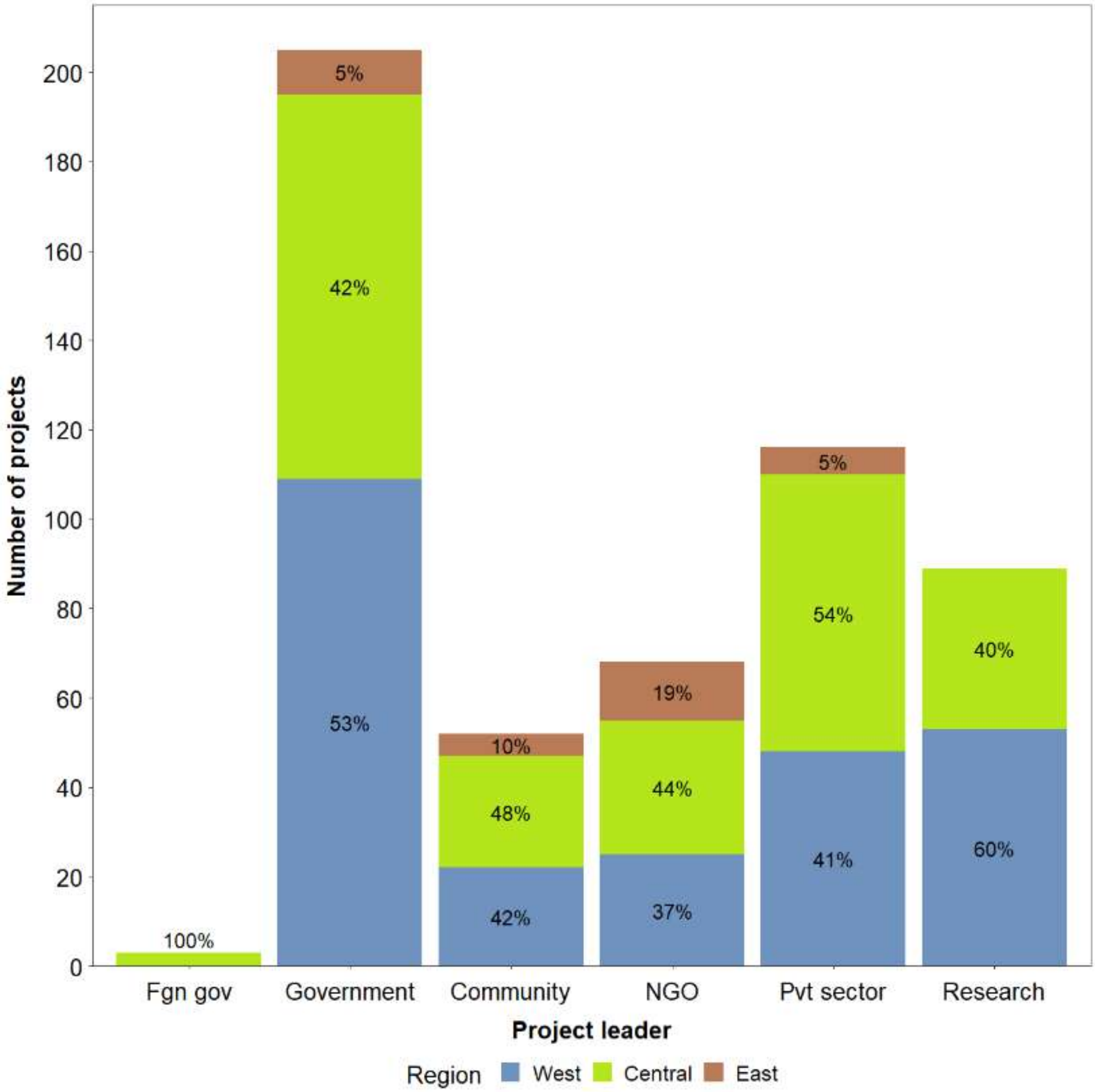

Figure 2.11 An analysis of 533 Indonesian coral reef restoration projects recorded by Razak et al. (2022) from 1990–2020. Government and research projects in particular were conducted predominantly in West Indonesia, while over half the private sector projects were located in Central Indonesia. NGO-run projects had less variable distribution across the regions than other sectors.

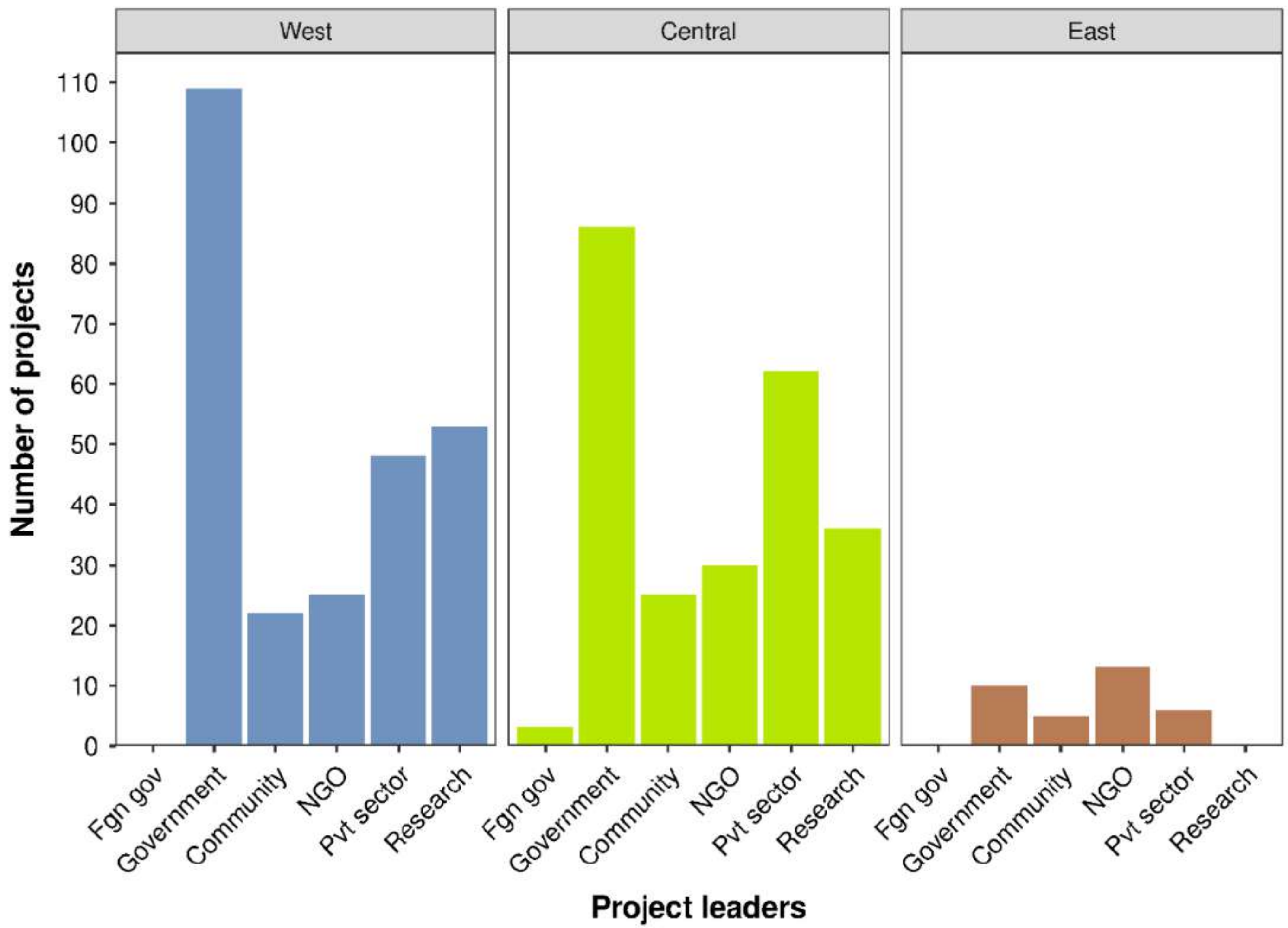

Figure 2. Error! Use the Home tab to apply 0 to the text that you want to appear here. An analysis of sectors/stakeholders driving coral restoration for all recorded projects from 1990–2020 (Razak et al. 2022). Most projects in West and Central Indonesia were led by the Indonesian government (42%

and 36% respectively), followed by researchers in the West (21%) and the private sector in Central Indonesia (26%). Project leader sectors in East Indonesia were more evenly distributed, with NGOs leading the way.

The government led 42% of projects in West Indonesia (n = 257), researchers accounted for 21%, and the private sector for 19%. In Central Indonesia, the government also led the most projects, accounting for 36% (n = 242), followed by the private sector with 26% (Fig. 2.12). Conversely, the majority of East Indonesia's 34 projects were led by NGOs (38%), followed by government (29%) and the private sector (18%). Excluding projects driven by foreign governments and/or aid organisations – and apart from the fact that no research projects were found in East Indonesia – projects run by local communities were the most underrepresented in all three regions, accounting for 9, 10, and 15% of projects in West, Central, and East Indonesia respectively (Fig. 2.12).

Twenty-nine individual provinces accommodated at least one coral reef restoration project between 1990 and 2020. Projects were recorded in 13 West Indonesian, 12 Central Indonesian, and four East Indonesian provinces (Fig. 2.13a). There was a particularly high concentration of projects in Java and the Lesser Sunda Islands (Bali, West Nusa Tenggara, and East Nusa Tenggara), as well as in some provinces on Sulawesi. Bali had the highest concentration of projects for any province (14%, n = 533), followed by East Java (12%), Jakarta (10%), West Nusa Tenggara (6%), North Sulawesi (6%), and South Sulawesi (5%) (Fig. 2.13b).

No records were found from four West Indonesian provinces: Riau, Jambi, and South Sumatra in Sumatra, as well as the Special Region of Yogyakarta in Java. In East Indonesia, projects in Indonesian Papua were grouped into the two provinces that were extant when restoration projects were started (namely, West Papua and Papua). These provinces were subsequently split into six new provinces in 2022. West Papua became West Papua and Southwest Papua, while Papua was split into four new provinces: Papua, South Papua, Central Papua, and Highland Papua.

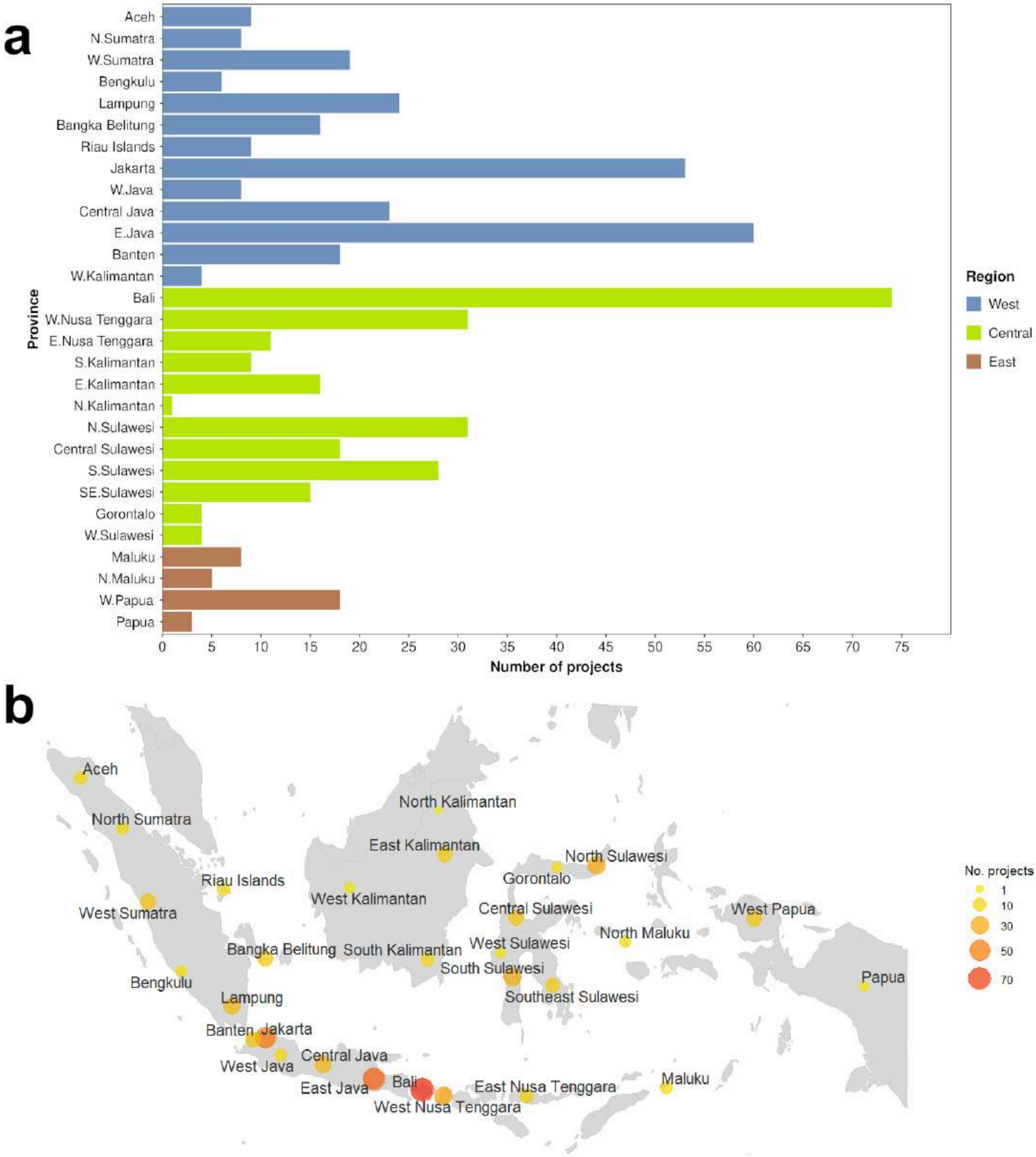

Figure 2.13 Regional and provincial distribution of Indonesian coral restoration projects, 1990–2020. (a) Bali (74), East Java (64), and Jakarta (53) were the three provinces with the highest number of restoration projects recorded. (b) A particularly high concentration of projects was found in proximity to the main hubs of Jakarta and Bali, as well as in North and South Sulawesi. Lower concentrations of projects were found in many of the more remote provinces.

2.4. Discussion

This review chapter encompasses approximately 28% of documented extant Indonesian coral reef restoration projects (n = 159). This was estimated by excluding 374 projects from a database of 533 historical projects up to 2020 (Razak et al. 2022). The projects excluded comprised concluded projects, once-off installations, defunct restoration methods (e.g. tyre reefs), localised projects within the purview of wider-ranging projects or programmes in the current study, and time-specific academic projects, studies, and theses. Results highlight a number of important considerations, which are unpacked as they relate specifically to the six-step planning cycle laid out in Shaver et al. (2020). Other general considerations are also examined, such as the early and continued engagement of all stakeholders, with a particular focus on local communities.

2.4.1. Set goal and geographic focus

The fifth principle of ecological restoration (ER) states that it should be assessed against clear goals and objectives, using measurable indicators (Gann et al. 2019). International monitoring protocols for coral restoration support this; the first step in developing a restoration monitoring plan is to clearly define goals and objectives aligned to the project's capacity and restoration abilities (Goergen et al. 2020). This underpins the first phase in the six-step planning cycle.

- The prominence of restoring the reef ecosystem, as a primary goal reported by surveyed projects, aligned with the sixth principle of ER: to seek the highest level of recovery attainable. As in this study, ecosystem restoration was the primary consideration identified by reef restoration practitioners interviewed during development of international guidelines for GBP metrics (Goergen et al. 2020). Reestablishing the reef ecosystem; accelerating recovery post-disturbance; reducing population declines and ecosystem degradation; and ecological engineering accounted for the primary aim of a combined 58% of projects. This aligned with the fourth ER principle: that it supports ecosystem recovery processes (Gann et al. 2019).

- A focus on reef ecosystem restoration implies an understanding that restoration must take a holistic approach that encompasses the reef community. Goals relating to reducing societal impacts (82% of projects), rehabilitating degraded areas (85%), and ecological restoration (78%) were defined by the majority of projects. Sixty percent of projects defined goals from all three of these aspects of a holistic approach.
- The number of projects identifying goals related to alternative livelihoods and reef stewardship (each present in 60% of projects) compared well with a review of 12 restoration projects in Latin America, which reported 15 and 13% of projects with goals relating respectively to alternative livelihoods and reef stewardship. Australia, on the other hand, reports the involvement of local communities and traditional owners in all 19 restoration efforts on the GBR (McLeod et al. 2020). The quantification of socioeconomic goals is still lacking; this will be discussed further regarding RAP development.
- Indonesian projects should do more to set quantifiable goals during initial planning phases; these were totally absent from 64% of projects. A set of simple standards could be applied for determining desired aspects, including the size of area to be rehabilitated, coral cover and biodiversity increases, and socio-economic project functions. This could additionally be informed by universal and GBP metrics (Goergen et al. 2020).
- Technical advisory groups were present in most projects. Although the exact composition of these groups was not always verifiable, projects should follow the ecological principles within international CBP in utilising all available scientific, practical, traditional, and local knowledge. This may include stakeholders from various sectors: local leaders and other

community members, scientists, engineers, the private sector, and national and local governments (Shaver et al. 2020). In Pemuteran, Bali, for example, the pivotal role played by community leaders in bridging the gap between global science and local awareness has previously been highlighted (Trialfhianty and Suadi 2017).

2.4.2. Identify, prioritise, and select sites

Improper site selection is one of the most commonly cited failures of coral reef restoration projects. Areas should be selected where stressors can be minimised; long-term survival of reefs can be achieved; and stakeholders, policies, and legislation support restoration (Hein et al. 2020a). Site identification and selection should also be done to meet goals specified within an agreed prioritisation framework. This should emphasise the site's relevance to goals; restoration's potential to improve site condition; and short- and long-term coral survivorship, encompassing vulnerability to climate change and other stressors. Selection should also be informed by the collection of various quantitative or semi-quantitative data depending on specified goals (Shaver et al. 2020). The first principle of ER stresses the genuine and active engagement of local communities and other stakeholders at the conceptual phase or prior to project initiation (Gann et al. 2019). Prioritising restoration sites can be significantly aided by local knowledge, and some of the most important takeaways from the analysis of Indonesian projects are as follows:

- The utilisation of local knowledge in initial site selection could be better extended through the planning phases to include further discussions with local stakeholders prior to final site selection. This step was lacking in one-third of projects.
- One in ten projects did not consider the potential to improve site condition during planning, and just under a quarter of projects did not employ ecological or social surveys to aid site selection. The absence of quantitative data collection largely reflected logistical

and/or budgetary priorities or constraints (cited by over half the projects); limitations in scientific training; and a reliance on local knowledge of the reefs, degraded areas, and pre-disturbance conditions.

- There is a pressing need for greater emphasis on the future vulnerability of reefs: 62% of projects did not incorporate climate-smart design considerations into site selection. Prioritising restoration sites by considering their potential to withstand future climate change is increasingly crucial, yet 39% of current projects did not rank sites by order of importance in any way. This is, however, understandable when one considers everyday practicalities: 58% of projects cited logistical, financial, and accessibility considerations as important criteria for site selection.
- While ecological considerations were by far the main driver of site selection, scientific standardisation of primary ecological data for site selection would help to improve success at a national scale. This should be informed by international CBP and universal monitoring metrics, potentially including metrics such as water circulation, natural recruitment levels, health of associated habitats, and the prevalence of local environmental stressors.
- The absence in 22% of projects of any form of ecological surveys informing site selection – along with the ad-hoc nature of many smaller projects – suggests that a substantial number of projects are not comparing restoration efforts with baseline controls or reference sites.

There are further opportunities to refine restoration site selection. Logistical, financial, and site accessibility considerations will remain critical, including minimising maintenance and long-term monitoring costs. It is worth considering the development and implementation of a national training element encompassing not only how to select areas for restoration, but also other elements of project design and implementation. A standardised and more structured approach to assessing and prioritising sites, as per international CBP, can help to bolster holistic restoration that includes ecological, operational, and societal aspects. Other important aspects of site selection that can be improved via standardised protocols include more widespread evaluation of socio-economic benefits related to restoring a particular site, the incorporation of marine spatial planning principles (Viehman et al. 2023), and measurable assessments of the potential for local community buy-in and long-term ownership. ER standards adopted in international CBP stress the importance of reference sites representing approximate reef conditions in the absence of degradation (Gann et al. 2019). The standards highlight six key elements for selecting a reference site: absence of threats, physical conditions, species composition, structural diversity, ecosystem function, and external biotic and abiotic exchanges. The inclusion of reference sites would be greatly improved by standardised planning within a science-based framework.

2.4.3. Identify, design, and select interventions

Lamont et al. (2022) offer insights from Indonesian case studies to inform reef restoration management and policy interventions, recommending multi-dimensional approaches that include ecological, social, and economic processes. This aligns with CBP recommendations for a holistic approach to restoration. In the current study:

- The majority of projects aligned with CBP recommendations to select a limited combination of priority interventions following an evaluation of potential choices (Shaver et al. 2020). However, climate-smart design considerations require more attention for a truly holistic approach; only 38% of projects included these in intervention design.
- The use of ARs was almost three times higher than in international coral restoration projects (Boström-Einarsson et al. 2020). This may partly reflect the widespread structural degradation on Indonesian reefs (Burke et al. 2012; Razak et al. 2022).

- Coral transplantation was the most common restoration approach. This was substantially more common than international restoration projects involving coral fragmentation or transplantation (84% versus 68%) (Boström-Einarsson et al. 2020). Twenty-four percent of Indonesian projects focused primarily on fast-growing branching species, compared with 59% of international restoration projects (Boström-Einarsson et al. 2020) and 96% of transplantation projects (Ferse et al. 2021).
- Indonesian projects have done well in reducing pressure on natural reefs when sourcing coral fragments. Only 8% of projects relied exclusively on wild donor colonies; 27% fragmented wild colonies alongside other fragment sources, compared to 46% of international coral transplantation projects (Ferse et al. 2021). Corals of opportunity (CoPs) were replaced or augmented by nursery-reared and/or commercially farmed corals in 41% of projects.
- Just 16% of Indonesian projects focused on a single coral species, compared to 28% of international projects (Boström-Einarsson et al. 2020). This aligns with holistic approaches and universal metrics for achieving reef-scale restoration.
- When selecting coral species, more projects should factor in thermal resilience and other climate-smart considerations like resistance to bleaching (Rinkevich 2019).

The use of a nursery phase to grow corals for outplanting (‘coral gardening’) has been gaining in popularity across Indonesia for a number of years. Coral gardening principles have been developed and tested in a wide variety of studies over more than two decades (e.g. Epstein et al. 2001; Rinkevich 2006; Shaish et al. 2008; dela Cruz et al. 2015). Today, coral gardening is more commonly referred to as active reef restoration. Nevertheless, it remains one of the most popular approaches in Indonesia as well as in international coral restoration interventions (Rinkevich 2019).

A more structured evaluation of coral restoration techniques and approaches in Indonesia could be beneficial to identify and prioritise a list of broadly standardised interventions. There is scope to increase the use of coral nurseries to produce additional coral biomass for outplanting and reduce reliance on CoPs and parent colonies on the reef (Boström-Einarsson et al. 2020).

The use of a closed cycle of nursery-reared fragments following an initial collection phase is one approach that has potential for wider implementation, with these corals supplemented or replaced in certain areas by corals sourced from commercial farms. This approach will be examined in more detail in Chapter 4, where it is suggested that the term “biomass production system” can be used to distinguish the approach from other types of coral nurseries.

The selection of groups of corals with varying ecological functions can better align restoration projects with international CBP for reestablishing a fully functioning reef community, and this should incorporate climate-smart design considerations. The use of ARs relying solely on natural recruitment, meanwhile, would benefit from standardised site assessment protocols including scientific analyses of natural larval supply and recruitment levels.

2.4.4. Develop RAP

Specific, measurable, achievable, relevant, and timebound (SMART) objectives provide a framework within which to assess progress and apply adaptive management principles to improve coral restoration interventions. Project design should facilitate decision-making that involves a number of diverse stakeholders and be transparent about decisions made on interventions (Shaver et al. 2020).

- The reasons for projects failing to meet SMART objectives are multi-faceted. Indonesian policy encourages diverse practitioners to implement reef restoration (Razak et al. 2022), so, for example, ad-hoc projects undertaken in isolation could benefit from coordination with other restoration practitioners and scientists. A failure to set timeframes for specific quantifiable goals reflects varied approaches to project monitoring and evaluations. Historically, monitoring schedules have ranged from one month to 16 years (Razak et al. 2022). Respondents in the current study highlighted financial and logistical constraints as challenges for conducting regular monitoring activities. As reef restoration is increasingly placed on government agendas worldwide, there may be further avenues for sustainable funding to improve restoration efficacy (Ferse et al. 2021) which could be augmented by national, regional, and international networks.
- The preponderance of reef monitoring surveys – alongside the relative dearth of social, economic, climate change adaptation, and local stressor metrics – suggests more focus is needed on holistic approaches beyond basic measurements of coral cover, growth, and survival (Razak et al. 2022).
- There remains a need to better incorporate explicit objectives during planning (Razak et al. 2022). The varied objectives reported exemplify the diversity of projects, thus further standardisation of ecological monitoring metrics would facilitate more effective evaluation of successes and failures and guide management decisions in different contexts (Vardi et al. 2021; Razak et al. 2022).
- Long-term objectives can be consolidated by increasing the focus on the most pressing needs and aligning with ER goals identified in international CBP. Local stressors need to be reduced; restoration objectives should incorporate and evaluate socio-economic and cultural concerns; and restoration should be resilient to future climate change, as well as

produce quantified outcomes to inform and evolve best practice. Strengthening ties between reef restoration projects and regulators may help to address ongoing stressors (Ferse et al. 2021) and deliver large-scale restoration.

2.4.5. Implement restoration

A complete RAP includes descriptions of project scope, vision, and targets (restoration timeline); an analysis of project situation (work plan); and action, monitoring, and operational plans (Shaver et al. 2020). It is a highly effective way of planning, implementing, and assessing restoration progress. Many projects without a formal plan may informally adhere to aspects of a RAP, but this minimises accountability and the ability to meaningfully assess progress. Furthermore, ER principles emphasise the full utilisation of available scientific, traditional, and local knowledge (Gann et al. 2019), including CBP frameworks like RAPs.

- The fact that over one third of projects used two or fewer RAP components may reflect the ad-hoc nature and small scale of many interventions. Concerns were raised by smaller-scale projects regarding the added logistical workload of putting together and maintaining detailed documentation. Another point raised was the reliance on and uncertain availability of donor funding; in some instances, projects planned interventions as and when funds were received, rather than laying out a detailed annual work plan or operational plan.
- The absence of a monitoring plan can be linked to various factors. These include a lack of sustainable funding or technical expertise, and a reliance on visual observation or other qualitative monitoring. The absence of various RAP elements from project planning emphasises the importance of promoting a simplified framework for implementing restoration. This would help to make effective restoration accessible to as wide a range of projects as possible, while still utilising a standardised framework.

- Nearly three quarters of projects had formal partnerships in place with local communities. The private sector in particular, however, tended to work alongside local communities rather than with them as equal partners. Merely involving the community does not guarantee an effective collaboration: focus group discussions and agreements with local community leaders are important in laying groundwork, as is ongoing community participation. It is also essential that communities recognise and understand the potential benefits of participation.
- There is an opportunity to increase the focus on and assessment of local community involvement by standardising the quantification of sociocultural/socioeconomic metrics. This is illustrated by the low incidence of reporting and quantification of alternative livelihoods and local stewardship objectives compared to ecological and/or restoration success.

Consistent minimum standards of accountability and monitoring for reef restoration projects can be highly beneficial (Ferse et al. 2021). Existing regulations seek to open up restoration to local communities – bolstering these regulations with complementary mechanisms based on international CBP would help to achieve this aim and improve overall project efficacy and sustainability. Standardisation would increase the potential to collate data from multiple projects and facilitate meaningful contributions from small-scale projects nationwide. Achieving meaningful community engagement and buy-in should be seen as imperative; this should ideally start prior to project commencement and seek to foster a sense of community ownership over restoration efforts.

2.4.6. Monitor and evaluate progress

Monitoring and evaluation of restoration are critical components of the adaptive management of restoration efforts (Gann et al. 2019). The variable quality of monitoring programmes worldwide is one multi-faceted challenge that complicates attempts to characterise restoration effectiveness and quantify efforts on regional and national scales. Clearly defined indicators linked to specific objectives and the properties of the entire reef community are needed, as are appropriate timeframes; it is also critical to integrate ecological indicators with sociocultural, economic, and governance considerations (Hein et al. 2017). International CBP for monitoring programme implementation emphasises the need for quantifiable universal metrics as a minimum requirement for any restoration project, regardless of goals and objectives. Monitoring should happen simultaneously with restoration implementation and should shift over time from short-term effects of interventions to examining reef-scale effects over longer timeframes (Shaver et al. 2020). Measurable performance metrics should include SMART objectives identified in Planning Stage 3 and consider socioeconomic elements, as well as encompass climate-smart design considerations and CCAGs (Shaver et al. 2020; Goergen et al. 2020).

- Ongoing monitoring of restoration efforts was varied: 76% of projects conducted quantitative reef monitoring surveys, with 64% quantifying coral cover or growth. Both of these metrics are able to provide simple and informative standardisable data on restoration successes. Data on the wider reef ecosystem were under-represented: 51% of projects collected fish community data, 38% monitored the benthic community and/or associated biota, and 4% quantified coral community composition/diversity.
- Qualitative visual observations were conducted by 13% of projects. With some expert input, the adoption of simplified monitoring metrics, and/or an effective monitoring plan, the majority of these projects could likely achieve quantifiable outputs with minimal difficulty.

- Quantitative measurements of bleaching, coral health, coral thermal tolerance, and/or changes in restoration success relating to temperature and depth were also underrepresented. CCAG metrics are an imperative focus point, as fewer than 20% of projects quantified any of these metrics.
- There is a decisive opportunity to better integrate climate-smart design considerations and CCAGs to increase meaningful and impactful long-term outcomes. To achieve this will likely require legislative updates, increased funding for scientific studies, standardised planning structures, and the adoption of innovative climate-smart reef restoration efforts (Camp et al. 2018a, 2018b; van Oppen et al. 2017). This will be especially pertinent if significant local threats persist. Accurate reporting of restored area in particular was underrepresented and the extent to which projects consider genetic/genotypic diversity warrants further investigation. While the extent of water temperature monitoring was unsubstantiated, this should be a standard approach as an entry point to climate-smart design and the integration of CCAGs.
- Indonesia can play a significant international role in identifying reef degradation causes and using environmental assessments to inform reef restoration efforts. For comparison, a survey of coral transplantation projects mostly from the Caribbean and Indo-Pacific found that the majority of projects did not conduct environmental assessments prior to transplantation, no project reported an assessment of coral recruitment, and two-thirds of projects failed to assess initial causes of reef degradation. The researchers further noted that a lack of monitoring standards and guidelines has impeded measurements of social and ecological success (Ferse et al. 2021).

- The ongoing use of standardised socio-economic and reef user satisfaction surveys can help to inform interactions with community leaders and other stakeholders and help to improve relations in an adaptive approach.

There are readily available ER tools developed for international CBP. The Coral Reef Consortium (CRC) Restoration Evaluation Tool, for example, has developed standardised guidelines for reporting progress in projects with varying expertise levels and goals (Goergen et al. 2020). The Five-Star System and Ecological Recovery Wheel (McDonald et al. 2016) have been increasingly adapted and utilised by practitioners and scientists in a wide variety of ecosystems globally, including coral reefs (Gann et al. 2019). Both tools offer potential standardised approaches for evaluating restoration effectiveness and applying adaptive management principles, which could add significant value to restoration efforts in Indonesia.

2.4.7. Distribution of coral reef restoration projects

The historic distribution of projects across the country shows that the restoration activities led by different sectors have been weighted towards certain regions. For example, if one excludes the Special Region of Yogyakarta – which has had no recorded coral reef restoration activities – the Special Capital Region of Jakarta (664 km^2) and Bali (5,780 km^2) are Indonesia's two smallest provinces (BPS Statistics Indonesia 2024), yet have the third highest and highest provincial concentrations of restoration projects respectively. In Central Indonesia, the high percentage of projects run by the private sector and NGOs reflects the drawcard of Bali and the other Lesser Sunda Islands – as well as Manado in North Sulawesi and various locations in South and Southeast Sulawesi – for divers and other tourists. The same is true of the former province of West Papua, where the Raja Ampat archipelago (now in Southwest Papua) has a reputation as one of the world's premier diving destinations. NGOs and the Indonesian government are particularly active in the former West Papua province compared to the rest of East Indonesia.

After Jakarta, the busiest regional hubs in Indonesia are Denpasar (Bali), Surabaya (East Java), and Makassar (South Sulawesi). The regions comprising East Indonesia in this review represent the most remote parts of the country from central government in Jakarta, as well as these travel hubs; this may go a long way to explaining the underrepresentation of coral reef restoration activities in these areas compared to central and western provinces. It may, however, simultaneously be true that not as much restoration is needed in these areas due to lower anthropogenic pressures, including sparser human populations and – in Raja Ampat in particular – the success of passive conservation efforts and reduction of local stressors (Fischborn and Levitina 2018).

Furthermore, the high concentration of projects in Java's provinces, especially Jakarta – alongside the high proportion of government projects in West Indonesia – may reflect an imbalance in government funding and/or attention towards areas close to the capital, similar to the lack of attention paid by national government to problems in regional MPA management in the provinces and regencies (Jompa et al. 2023). This may, however, be partly representative of higher levels of reef degradation in or near more densely populated areas, combined with the presence of cities larger than those in the more remote parts of the Indonesian archipelago (Baum et al. 2015; Riegl and Glynn 2020). It should be noted, however, that studies have also shown increased degradation of reef areas in more remote areas of Indonesia due to a lack of effective enforcement in reducing local stressors like destructive fishing (Ceccarelli et al. 2022).

2.4.8. Major challenges faced by Indonesian reef restoration practitioners

A passage from the CTI-CFF State of the Coral Triangle: Indonesia country report (ADB 2014) – although it refers to MPA management – is nevertheless particularly instructive regarding the challenges facing coral reef restoration in the country:

> *"Lack of capacity at the national, regional, and local levels has been identified as one of the main bottlenecks for marine and coastal sustainable development in Indonesia. The issues include (i) shortage of qualified staff, (ii) limited resources and time for training activities, (iii) uncoordinated sector efforts, (iv) limited understanding of coastal biodiversity and links to development planning and management, and (v) weak and fragmented communication channels among the various stakeholders. Furthermore, there is a systemic lack of marine conservation education because of practitioners' limited access to appropriate guidance and training in addressing local problems. Often, training is provided on an ad hoc basis without follow-up assistance or mentoring. Such training has used nonstandard modules; and, in many cases, curricula are duplicated or overlapped, target the same people, or omit basic competencies. Systematic and well-designed capacity development approaches are needed."*

2.4.8.1 Engaging stakeholders

A failure to include communities and other stakeholders in decision-making processes usually leads to a lack of support for conservation (Ferse et al. 2010). Definitions of community buy-in encompass a spectrum of interactions and participation levels. Direct buy-in can be monitored by gauging community satisfaction with the project (Hein et al. 2017), which in turn is tied to the community's degree of involvement, sense of ownership, and perceptions of success (Westoby et al. 2020). Some responses received in the study reflect community integration challenges. Minimal community buy-in at one project likely arose from a disconnect between terrestrial farmers and marine environmental issues, as well as productivity and efficiency concerns regarding the removal of pesticide use (c.f. Coggan et al 2021). Another mandated mining remediation project failed to establish long-term community support because of negative reactions to the mining company's previous destructive activities, while ongoing destructive fishing practices at a third project reflected a gap in understanding about the sustainable use of coral reefs, despite attempts at community education and awareness campaigns.

Amongst the challenges to be overcome when dealing with local communities is finding the best way to accommodate cultural norms to enrich collaboration. Failure to do this can cause divergent experiences of participation, a mismatch between efforts to involve the community and the true integration and representation of its needs, and gaps in understanding between communities and conservation authorities (Tam 2015). Establishing and maintaining trust is also a complex issue requiring more than simply "providing" alternative livelihoods. An increased focus on the potential for improving local fish stocks and sustaining local fisheries, for example, can be a significant driver for community support; however, restoration practitioners must respect, integrate, and actively encourage local customs such as traditional rules on access to certain fishing grounds (Bottema and Bush 2012).

Sociopolitical factors also present challenges in a country as culturally and ethnically diverse as Indonesia. Marginalised ethnic groups such as the Bajau, for example, have commonly been associated with destructive fishing practices and overexploitation of resources (Pet-Soede and Erdmann 1998; Exton et al. 2019). In Southeast Sulawesi, value and belief systems of this traditionally nomadic ethnic group contrast with conservation aims, as the enforced sedentarisation of Bajau communities has led to intensified fishing effort, accelerating the impacts of their fishing practices (Crabbe and Smith 2005). Destructive fishing is often prevalent in more remote areas where alternative employment opportunities are low. In South Sulawesi, other complex societal issues perpetuate the problem. Here, fishers are economically dependent on patrons embedded in a complex governance network. These patrons supply fishing technologies like boats, bombs, and cyanide to reinforce their positions of power over socially marginalised and excluded individuals (Grydehøj and Nurdin 2016).

One vehicle for community involvement with potential for wider implementation is the creation of community surveillance groups ("pokmaswas"). As part of the CTI, MPA authorities in Nusa Penida and the Gili Islands consulted with stakeholders and drafted seven standard operating procedures to promulgate these groups, with resounding success. Community members reportedly benefit from employment, education, stewardship, recreation, satisfaction, and other social and cultural benefits (ADB 2022), although the report does not quantify successes or cover challenges faced by the surveillance groups.

In a government-led programme in Gorontalo province, pokmaswas members were positive about the effectiveness of decision-making structures, chain of command, and available human resources. Some members, however, raised concerns about physical and psychological well-being, and a lack of support and facilities. The study noted that the group lacked written plans and could benefit from better organisational structures (Rohyani et al. 2023).

In Banten province, the main obstacles to a formal pokmaswas programme included conflicting interests across different provincial sectors; a lack of understanding of the reasons to create the programme; the ability to enforce pokmaswas authority; and the need to improve understanding and perception of environmentally friendly fishing gear (Wicaksono et al. 2019).

Despite these challenges, progress has been made in a number of areas. Lamont et al. (2022), for example, highlight several multi-dimensional community engagement success stories across the country, including:

- the incorporation of threat reduction involving local communities into restoration initiatives in Raja Ampat by two NGOs;
- strategic project placement in Bali to aid job creation in tourist areas heavily affected by the Covid-19 pandemic; and
- site selection guided by a mix of ecological and social factors, allowing efficient scale-up of restoration efforts in areas of the Spermonde Archipelago where future success was most likely.

Projects in north Bali surveyed during the current review, led by former cyanide and dynamite fishermen, have been exemplars of engaging diverse local community participants. The youth-driven nature of initiatives formulated by these projects have also made them particularly impactful in achieving societal change.

Restoration at Gili Trawangan island, meanwhile, involves a collaboration of foreign businesses, academics, NGOs, and local government. Local leadership is maintained through the institutionalisation of traditional customary laws for regulating marine activities, which all stakeholders work together to uphold and implement, and the ongoing success of this particular venture highlights the prioritisation of within-community leadership as a key enabling principle of scalable restoration success.

2.4.8.2. Funding

A lack of sustainable funding is an ongoing challenge for coral reef restoration practitioners. Internationally, 60% of projects reported that funding received was associated with specific monitoring requirements (Hein and Staub 2021). Funding is essential for effective long-term monitoring programmes, yet funding timelines are predominantly between one and three years, which is inadequate for long-term planning, monitoring, and management (Hein and Staub 2021).

Not only is donor funding usually short-term, but it often relies on monetary incentives for community buy-in (Depondt and Green 2006; Wilkinson et al. 2006), while any long-term funding that projects do manage to secure also has inherent dangers linked to its continued availability (Browne et al. 2022). Practitioners' concerns include the linking of funding to specific outplanting requirements, rather than long-term goals associated with restoration success; and a disconnect between funders' expectations of coral reef restoration and practical project realities (Hein and Staub 2021). Bearing these funding considerations in mind, detailed work plans and budgets are essential to gauge what is realistically possible and achievable under budgetary and capacity constraints. Cross-sector cooperation is usually key, to ensure that the interests of all stakeholders in the reef and its resources are being considered and met (Bottema and Bush 2012).

Indonesia is an attractive location for international funding, NGOs, eco-tourism, and scientific study. Projects should aim to be self-sustainable, but should also focus on creating detailed, goal-oriented planning documents and regular reports on quantitative monitoring data. This will greatly improve their chances of securing and retaining meaningful external funds to supplement restoration activities. This is especially true as interest and support for coral reef restoration continues to grow in the United Nations (UN) Decade on Ecosystem Restoration (Hein and Staub 2021).

2.4.8.3. Ongoing reef degradation

Despite the widespread implementation of MPAs and restrictions on reef resource use, the degradation of Indonesia's reefs continues (Hadi et al. 2020) and many local stressors remain. Some of this is attributable to a lack of effective MPA and coral reef management. Less than 3% of existing MPAs worldwide are rated as effectively managed (Marine Protection Atlas 2022), while 65% of MPAs around the world have insufficient budget to cover management needs and over 90% lack staff capacity (Gill et al. 2017).

A recent nationwide evaluation of Indonesian MPAs found an unequal distribution of staff, with provincial MPAs having fewer staff despite covering twice as much overall area as national MPAs. Less than one-third of 36 MPAs met minimum staffing requirements, and the study emphasised the need for collaborations with local stakeholders and NGOs to bridge resource gaps (Capriati et al. 2024). However, these collaborations raise their own challenges: divergent interests and understanding of MPA goals among diverse stakeholders, for example, is another factor that may undermine MPA success (Fabinyi 2008), once again reinforcing the need for effective cross-sector cooperation.

The Indonesian government has focused on developing marine and coastal tourism to drive economic growth, and associated tourist pressure is another contributor to reef degradation across the nation. Small islands in particular are vulnerable to tourism pressures, and integrated small island management policies are essential (Kurniawan et al. 2016). On the other hand, tourism growth also increases opportunities for tourism-based restoration. This can create associated livelihoods, foster a sense of community stewardship, and aid economic security founded on reef health and restoration. ARs can help to ease diver pressure and reduce damage on natural reef areas, serving as tourist attractions in their own right and helping to control the number of divers and snorkellers on natural reefs (Piskurek 2001; Fadli et al. 2012).

The fundamental challenge facing widespread coral reef restoration success and the ongoing future maintenance of reef health comes from global human-induced climate change. As mass bleaching events become increasingly common and severe, a better understanding of which corals will survive best in particular areas and conditions will be vital to successful restoration, as will the prioritisation of environmentally buffered core refugia zones. These considerations can be addressed by more stringent scientific selection of viable sites and by adopting innovative management approaches that incorporate restoration in lower light conditions, focus on more resilient corals, and/or experiment with assisted evolution, hybridisation, and other potential solutions (van Oppen et al. 2015, 2017; Camp et al. 2018b; Chan et al. 2018). Proactive integration of emerging technologies – in an adaptive process of research and development (R&D), learning, consultation, risk management, and staged implementation (Anthony et al. 2017) – should also be fostered and encouraged. This will likely require financial backing and scientific training from national and/or international partners.

2.4.9. Creating a consolidated coral reef restoration network

While Indonesia’s legislative frameworks are in place and there is an abundance of coral reef restoration activity, the lack of standardised implementation and institutional arrangements has likely contributed to some of Indonesia's current problems with reef restoration effectiveness (Razak et al. 2024). There is now a need to bring these efforts together and consolidate efforts across the country within a solid framework of ER principles and CBP to deliver meaningful restoration at scale. The shortcomings in nationwide reef restoration efforts that require attention do, however, also provide opportunities to learn, consolidate, and create a lasting legacy of sustainable coral reef restoration projects on a national scale. Greater efficacy in meeting target-driven outcomes, consistency in ecological monitoring, and intentionality in global knowledge exchange can help to reposition Indonesia’s restoration projects as a transformative resource for the region and an example for the world to follow (Razak et al. 2022).

According to SER, sharing practical and scientific knowledge is key to implementing restoration efficiently and effectively, and to achieving restoration at scale. An important way to advance the science and practice of large-scale ecological restoration is hence to develop and promote forward-thinking cooperative networks. The Indonesian government has established a commendable framework for coral reef restoration, with legislation specifically requiring, for example, that local communities and stakeholders be directly involved in both the planning and implementation of restoration activities (Razak et al. 2022). The legislature contains a prevailing sentiment of community-driven restoration management and the management of fisheries resources. Razak et al. (2022) highlight Presidential Regulation No. 121/2012 Article 12.1 (“*Rehabilitation can be conducted through cooperation between government, regional government, person or community*”) and Article 15.1 (“*Community or persons can participate in the implementation and maintenance of rehabilitation voluntarily*”), as well as Ministry of Marine Affairs and Fisheries (MMAF) Ministerial Regulation No. 26/2021, Article 67.1 (“*Each person can participate in the rehabilitation of fisheries resources and their environment*”).

Centralised training hubs can substantially accelerate the establishment and scaling up of successful projects through knowledge sharing (Lamont et al. 2022). A formal national network of practitioners, experts, and decision-makers would add significant value and create accountability. This should seek to consolidate and build on existing networks and knowledge sharing being forged by initiatives like IPB University's School of Coral Reef Restoration (SCORES), the Coordinating Ministry for Maritime Affairs and Investment's Indonesia Coral Reef Garden (ICRG) programme, the Coral Triangle Centre's Coral Reef Restoration Task Force (CTC-CRRTF), the National Park authority-aligned Mars Sustainable Solutions (MSS) training programme, and the CTI-CFF and COREMAP programmes. It will also be important to foster connections with those outside the field of coral restoration. The socioecological resilience of coral reef restoration, for example, can be improved by diversified community-based management governance, better coordination and planning between fisheries and MPAs, fostering sustainable tourism, and planning for future conditions (Tranter et al. 2022).

There is significant potential to standardise quantifiable, iterative goals (Hobbs and Harris 2001) integral to adaptive restoration management. Greater efficacy in meeting target-driven outcomes, consistency in ecological monitoring, and intentionality in global knowledge exchange can help to reposition Indonesia's restoration projects as a transformative resource for the region and an example for the world to follow (Razak et al. 2022). Efforts should be consolidated at a national scale to deliver more efficient and effective collective actions that provide balanced benefits to reefs and communities.

A potential vehicle for improved project outcome reporting within a consolidated reef restoration network is the creation of a national database of reef restoration projects or similar platform (Fig. 2.14). Reports and project-specific data could be submitted and stored in such a repository, facilitating the evaluation of reef restoration progress, successes, and failures at a national scale. Any such repository would require a coalition or network of projects willing and able to ascribe to a set of CBP requirements encompassing project management, scientific monitoring, and outcome reporting. Within such a framework, centralised skills and knowledge sharing from leading experts could be made available, helping to decrease the gap in disparate levels of project funding and logistical resources. Pooling nationwide data would facilitate more accurate national assessments of reef restoration, which would aid researchers and decision-makers to evolve restoration approaches and policies over time, with data informing scientific research and adaptive management strategies. This network could help projects meet logistical, financial, administrative, scientific, and reporting standards via training, support, and skills transfer. Feedback from experts within the network would enable a tiered system of project design and implementation; in line with adaptive management principles, projects could thus iteratively increase their efficacy over several years of implementation.

Various guidelines and document templates from Shaver et al. (2020) and other resources could be used as a starting point to develop standardised documentation and protocols at different expertise levels (e.g. “Standard”, “Expert”, and “Multi-Dimensional”). Putting checks in place to monitor the extent to which guidelines are being followed would improve accountability. This should include:

- forming and implementing reporting requirements for projects;
- providing feedback to projects from restoration network members or a central board; and
- creating procedures and channels for submitting project documentation to a central repository.

This would also facilitate periodic assessments and the identification of projects in need of additional training and/or administrative assistance to improve intervention efficacy via adaptive management.

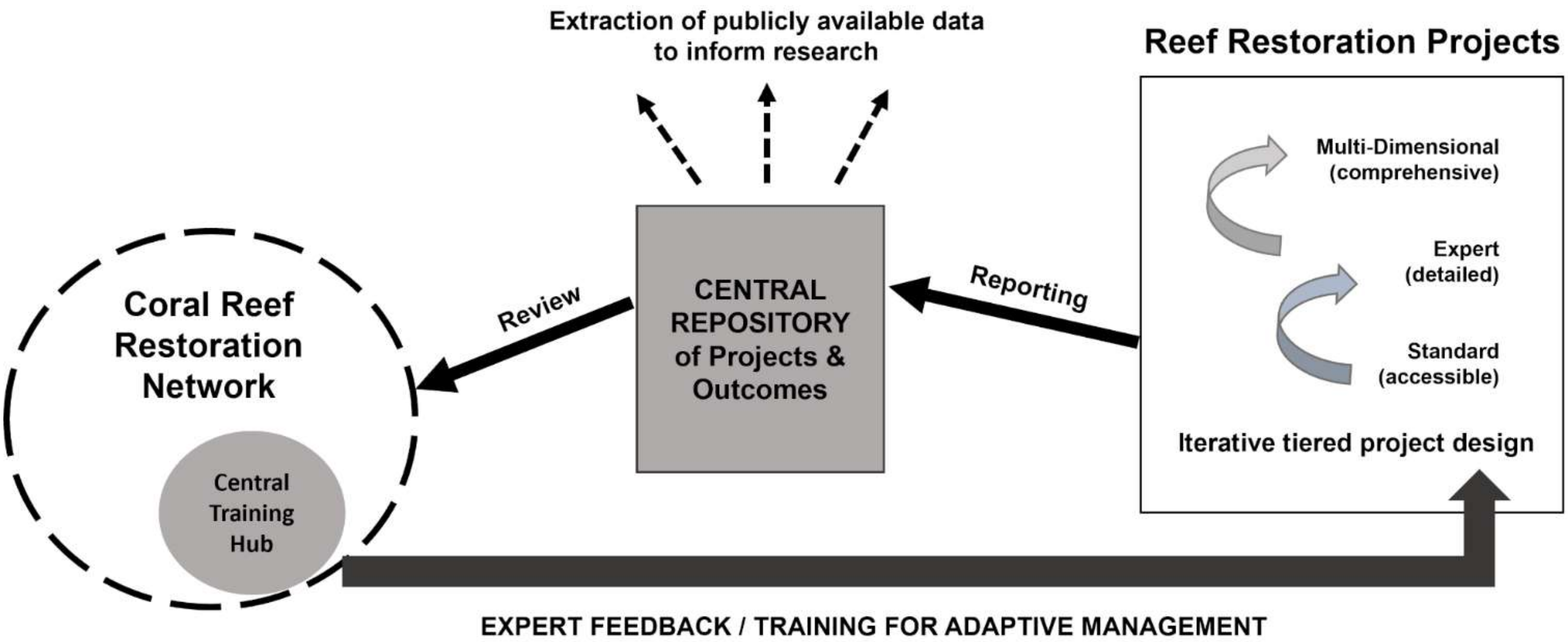

Figure 2.14 Potential functions and processes of a formalised coral reef restoration network in Indonesia. A formal network of coral reef restoration managers and decision-makers supported by centralised training hubs and data repositories can facilitate an iterative process of reef restoration project design and implementation. In line with ER principles of adaptive management, a tiered project design system can help to better implement a national reef restoration roadmap developed by this network. This roadmap should be based on knowledge sharing and the alignment of overarching national goals and objectives for coral reef restoration.

The creation of a fully inclusive national network comprising all stakeholders would be a highly complex undertaking. If done well, however, it could increase the effectiveness, accountability, and longevity of restoration projects and develop increased funding opportunities for projects by creating links between restoration practitioners and the corporate sector; international, national, regional, and local NGOs; government agencies; research institutions; and regional programmes like the CTI-CFF. This would help to channel funding into supporting the restoration and protection of prioritised reefs nationwide to maintain Indonesia’s status as a hotspot for global marine biodiversity.

2.4.10. Developing a national roadmap for restoration

One of the primary objectives of a consolidated restoration network would be to cooperatively develop an iterative roadmap for coral reef restoration based on CBP principles (Table 2.2). The length and complexity of international CBP may be off-putting for projects, especially in countries where English is not the first language; there are, however, distilled resources available (e.g. Hein et al. 2020a, 2020c; Vardi et al. 2021). It is also recommended that authorities across the world aim to produce and disseminate resources in their countries’ official language(s) to aid practitioners. By becoming part of the network, new and extant projects with diverse goals and approaches would gain access to knowledge and skills transfer from a pool of experts. These experts could form part of project-specific technical advisory groups to assist practitioners in implementing the key objectives of the national roadmap. In this capacity, leaders in the field of coral restoration could provide consultation, feedback, and guidance on various processes, including adaptive management, project administration, monitoring, reporting, and community engagement.

The national roadmap should include as a minimum requirement actions that: (a) assess the causes of reef degradation and whether environmental conditions are conducive to restoration; (b) quantify and evaluate ongoing community engagement; (c) integrate climate-smart design and CCAG metrics; (d) agree on high priority restoration areas; (e) standardise long-term reef monitoring protocols and project evaluation strategies; and (f) apply adaptive management principles.

2.5. Conclusion

While no single management objective is sufficient for coral reef ecological restoration (Williams et al. 2019), identifying certain policies, actions, and approaches can strengthen nationwide efforts, reducing the need for projects to “reinvent the restoration wheel” when dealing with complex reef ecosystems across varying conditions and levels of resource utilisation. Simple, standardised scientific methodologies can help Indonesia to play a leading role as a natural laboratory in which to make further advances in coral reef restoration methods and techniques. A well-developed network of knowledge sharing would allow scientific institutions to iteratively feed positive research outcomes into best practice to include CCAGs and other advances, such as (to give one example) the use of midwater nurseries to take advantage of enhanced reef function metrics (Baer et al. 2023).

Coral reef restoration projects regularly commence with little by way of planning or framework. As noted by one NGO, “Project planning is evolving. With each site, the process is formalised more.” The adoption of international CBP approaches that incorporate SER, and adaptive management strategies within an iterative, tiered roadmap designed specifically for the Indonesian context should be a priority for the country’s authorities and restoration practitioners. This will enable effective, efficient, and successful restoration efforts with the potential for replication, adaptation, and upscaling. This roadmap can position Indonesia as a regional leader in coral restoration best practice and serve as a framework for the CT by taking country-specific and regional challenges into account.

Table 2.2 Proposed Indonesian coral reef restoration roadmap elements. These include actions to be taken by a consolidated network of practitioners, scientists, regulatory authorities, and decision-makers; actions to be taken by individual projects within the network; and important considerations to inform these actions.

Project stage	Network actions	Project actions	Considerations
Set goal and geographic focus	- Define overarching restoration goals. - Consolidate, homogenise, and expand participation in existing networks. - Emphasise CCAGs. - Identify refugia for coral diversity, including thermally resistant coral survivors of mass bleaching events. - Refine priority geographical areas based on existing restoration successes, sustainability, and potential for futureproofing. - Ensure and assist technical advisory groups; develop availability of technical expertise. - Establish skills and knowledge transfer for stakeholders and assist projects to follow SER.	- Incorporate: • SMART characteristics • standardised goals and objectives • climate-smart design considerations • specific social contexts/risks - Focus on ecologically significant areas; identify priority areas linked to goals. - Utilise tiered project planning and development. - Maintain formal administrative standards. - Include any scientific, practical, traditional, and local knowledge available. - Promote community ownership and active, ongoing engagement in planning.	- Remove local stressors. - Ecosystem-level restoration. - Provide socio-economic benefits. - Accessible documentation for varying expertise levels: • use distilled international CBP where necessary • develop resources in Bahasa Indonesia - Establish functionality/benefits of restoration: • management challenges and likelihood of success • biophysical context • unique opportunities of areas identified - Build on the "50 Reefs" Initiative to identify coral reef refugia and increase focus on coral thermal resilience.
Identify, prioritise, and select sites	- Identify priority areas conducive to natural recovery within MPAs. - Develop standards, strategies, and evaluation protocols for site selection.	- Link site selection to restoration goals. - Follow a framework for prioritising sites for selection; base selection on standardised data collection.	- Include CCAGs in site selection. - Evaluate natural recovery areas (lack of local stressors; larval supply; consolidated substrate).

		- Identify control/ reference sites.	- Ensure effective community engagement actions and stakeholder integration in planning.
Identify, design, and select interventions	- Develop list of complementary potential interventions to promote on regional and national scales. - Facilitate project access to expert advice; strengthen knowledge/ skills sharing networks.	- Consider roadmap objectives within individual context to select applicable intervention(s) including: • sociocultural context • budgetary constraints	- Foster consultation with restoration experts to avoid duplication of effort/ reliance on trial and error. - Promote coral biomass production in active restoration projects to reduce pressure on wild donor colonies.
Develop RAP	- Develop detailed and standardised RAP for projects based on international CBP. - Implement pilot phase assessments as standard practice. - Provide technical/ scientific guidance via representation in technical advisory teams.	- Fully utilise all available knowledge and resources provided by the network. - Focus on primary goals; include SMART objectives. Use as a framework for funding applications/ stakeholder interactions. - Establish contextualised timeframe for goals.	- Train community members in monitoring protocols. - Design plans to facilitate future upscaling. - Ensure transparency with stakeholders and the opportunity for input and feedback.
Implement restoration	- Encourage projects to utilise standardised RAP as a framework for restoration interventions. - Oversee minimum requirements for restoration projects, informed by international CBP. - Offer training, support, knowledge sharing, and skills transfer.	- Quantify successes and shortcomings compared to control sites. - Implement adaptive management strategies to improve restoration efficacy over time. - Follow an achievable plan for ongoing community involvement.	- Maintain accounting diligence using standardised RAP. - Ensure transparency, feedback, and standardisation within the network to engender accountability. - Potential for project inspection and assessments by regional network representatives.

Monitor and evaluate progress	- Develop differentiated assessment and monitoring protocols; establish minimum monitoring requirements based on CBP universal monitoring metrics; oversee project monitoring to produce comparable results. - Integrate CBP principles/tools (CRC Restoration Evaluation Tool; Five-Star System and Ecological Recovery Wheel).	- Clearly define metrics for success linked to ecological, social, and economic outcomes. - Prioritise quantifiable GBP metrics depending on available objectives, expertise, and resources.	- Regular meetings to keep stakeholders abreast of progress. - Quantify alternative livelihoods, local stewardship, and other socioeconomic objectives to enable adaptive management of community relations. - Organise regional and/or site-specific training workshops to elevate scientific monitoring standards.
Scale up interventions	- Work towards establishing a multi-dimensional and increasingly holistic approach in all projects.	- Incorporate monitoring of CCAG metrics and evaluate climate-smart design objectives. - Increase GBP metrics monitored based on available expertise.	- Develop evaluations to scale up over time from short-term assessments to long-term reef-scale effects. - Link with restoration in associated ecosystems.
Utilise ongoing adaptive management strategies	- Foster local, regional, national, and/or international reef restoration networks. - Promote reciprocity for continual improvement and upscaling.	- Assess potential to scale up training/involvement of community members and/or other stakeholders. - Utilise expertise offered by knowledge sharing; supply data to the central repository.	- Regular assessments/feedback to improve outputs. - Adapt approaches that fall short of expectations.

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2.7. References

ADB (2014) State of the Coral Triangle: Indonesia. Asian Development Bank (ADB). https://www.adb.org/sites/default/files/publication/42409/state-coral-triangle-indonesia.pdf (Accessed 5 Mar 2024)

ADB (2022) Indonesia: Coral Reef Rehabilitation and Management Program – Coral Triangle Initiative Project. Project Number 46421-001. Asian Development Bank (ADB). https://www.adb.org/projects/46421-001/main (Accessed 14 Jan 2024)

Anthony K, Bay LK, Costanza R, Firn J, Gunn J, Harrison P, Heyward A, Lundgren P, Mead D, Moore T, Mumby PJ (2017) New interventions are needed to save coral reefs. *Nature Ecology and Evolution* 1:1420-1422

Baer JL, Carilli J, Chadwick B, Hatay M, van der Geer A, Scholten Y, Barnes W, Aquino J, Ballard A, Little M, Brzenski J (2023) Coral Reef Arks: An in situ mesocosm and toolkit for assembling reef communities. *Journal of Visualized Experiments (JoVE)* 191:e64778

Baum G, Januar HI, Ferse SCA, Kunzmann A (2015) Local and regional impacts of pollution on coral reefs along the Thousand Islands north of the megacity Jakarta, Indonesia. *PloS One* 10(9):e0138271

Bayraktarov E, Banaszak AT, Montoya Maya P, Kleypas J, Arias-González JE, Blanco M et al. (2020) Coral reef restoration efforts in Latin American countries and territories. *PloS One* 15(8):e0228477

Bergen N, Labonté R (2020) "Everything is perfect, and we have no problems": detecting and limiting social desirability bias in qualitative research. *Qualitative Health Research* 30(5):783-792

Beyer HL, Kennedy EV, Beger M, Chen CA, Cinner JE, Darling ES, Eakin CM, Gates RD, Heron SF, Knowlton N, Obura DO (2018) Risk-sensitive planning for conserving coral reefs under rapid climate change. *Conservation Letters* 11(6):e12587

Boström-Einarsson L, Babcock RC, Bayraktarov E, Ceccarelli D, Cook N, Ferse SCA, Hancock B, Harrison P, Hein M, Shaver E, Smith A, Suggett D, Stewart-Sinclair PJ, Vardi T, McLeod IM (2020) Coral restoration – A systematic review of current methods, successes, failures and future directions. Dryad, Dataset. https://doi.org/10.5061/dryad.p6r3816 (Accessed 14 Jan 2024)

Bottema MJ, Bush SR (2012) The durability of private sector-led marine conservation: A case study of two entrepreneurial marine protected areas in Indonesia. *Ocean & Coastal Management* 61:38-48

BPS Statistics Indonesia (2024) Luas Daerah dan Jumlah Pulau Menurut Provinsi (Total Area and Number of Islands by Province), 2002-2016. https://www.bps.go.id/id/statistics-table/1/MTM2NiMx/luas-daerah-dan-jumlah-pulau-menurut-provinsi--2002-2016.html (Accessed 06 Mar 2024)

Browne K, Katz L, Agrawal A (2022) Futures of conservation funding: Can Indonesia sustain financing of the Bird's Head Seascape? *World Development Perspectives* 26:100418

Burke L, Reytar K, Spalding M, Perry A (2012) Reefs at Risk Revisited in the Coral Triangle. WRI: World Resources Institute. USA https://policycommons.net/artifacts/1360491/reefs-at-risk-revisited-in-the-coral-triangle/1974017/ (Accessed 14 Jan 2024)

Camp EF, Schoepf V, Mumby PJ, Hardtke LA, Rodolfo-Metalpa R, Smith DJ, Suggett DJ (2018a) The future of coral reefs subject to rapid climate change: Lessons from natural extreme environments. *Frontiers in Marine Science* 5:1-21

Camp EF, Schoepf V, Suggett DJ (2018b) How can "Super Corals" facilitate global coral reef survival under rapid environmental and climatic change? *Global Change Biology* 24:2755-2757

Capriati A, Widodo H, van de Leemput I, Hakim A, Timotius S et al. (2024 – preprint) Beyond Numbers: Assessing Staff Capacity and Competency to Improve Marine Protected Areas (MPAs) Management in Indonesia. Available at SSRN: https://ssrn.com/abstract=4769600 or http://dx.doi.org/10.2139/ssrn.4769600

Ceccarelli DM, Lestari AP, White AT (2022) Emerging marine protected areas of eastern Indonesia: Coral reef trends and priorities for management. *Marine Policy* 141:105091

Chan WY, Peplow LM, Menéndez P, Hoffmann AA, van Oppen MJ (2018) Interspecific hybridization may provide novel opportunities for coral reef restoration. *Frontiers in Marine Science* 5:160

CMP (2020). The Open Standards for the Practice of Conservation, v 4.0. Conservation Measures Partnership. https://conservationstandards.org/wp-content/uploads/sites/3/2020/10/CMP-Open-Standards-for-the-Practice-of-Conservation-v4.0.pdf (Accessed 14 Jan 2024)

Coggan A, Thorburn P, Fielke S, Hay R, Smart JC (2021) Motivators and barriers to adoption of Improved Land Management Practices. A focus on practice change for water quality improvement in Great Barrier Reef catchments. *Marine Pollution Bulletin* 170:112628

Crabbe MJC, Smith DJ (2005) Sediment impacts on growth rates of Acropora and Porites corals from fringing reefs of Sulawesi, Indonesia. *Coral Reefs* 24(3):437-441

dela Cruz DW, Rinkevich B, Gomez ED, Yap HT (2015) Assessing an abridged nursery phase for slow growing corals used in coral restoration. *Ecological Engineering* 84:408-415

Depondt F, Green E (2006) Diving user fees and the financial sustainability of marine protected areas: opportunities and impediments. *Ocean & Coastal Management* 49:188-202

Epstein N, Bak RP, Rinkevich B (2001) Strategies for gardening denuded coral reef areas: the applicability of using different types of coral material for reef restoration. *Restoration Ecology* 9(4):432-442

Exton DA, Ahmadia GN, Cullen-Unsworth LC, Jompa J, May D, Rice J, Simonin PW, Unsworth RK, Smith DJ (2019) Artisanal fish fences pose broad and unexpected threats to the tropical coastal seascape. *Nature Communications* 10(1):1-9

Fabinyi M (2008) Dive tourism, fishing and marine protected areas in the Calamianes Islands, Philippines. *Marine Policy* 32:898–904

Fadli N, Campbell SJ, Ferguson K, Keyse J, Rudi E, Riedel A, Baird AH (2012) The role of habitat creation in coral reef conservation: a case study from Aceh, Indonesia. *Oryx* 46(4):501-507

Ferse SCA, Máñez Costa M, Mez KS, Adhuri DS, Glaser M (2010) Allies, not aliens: Increasing the role of local communities in marine protected area implementation. *Environmental Conservation* 37:23-34

Ferse SC, Hein MY, Rölfer L (2021) A survey of current trends and suggested future directions in coral transplantation for reef restoration. *PloS One* 16(5):e0249966

Fischborn M, Levitina Z (Eds.) (2018) Solutions in focus: Community-led successes in marine conservation. International Union for Conservation of Nature (IUCN). https://panorama.solutions/sites/default/files/mediathek/solutions_in_focus_community-led_successes_in_marine_conservation.pdf (Accessed 14 Jan 2024)

Gann GD, McDonald T, Walder B, Aronson J, Nelson CR, Jonson J, Hallett JG et al. (2019) International principles and standards for the practice of ecological restoration. *Restoration Ecology* 27(1):1-46

Gill DA, Mascia MB, Ahmadia GN, Glew L et al. (2017) Capacity shortfalls hinder the performance of marine protected areas globally. *Nature* 543(7647):665-669

Goergen EA, Schopmeyer S, Moulding AL, Moura A, Kramer P, Viehman TS (2020) Coral reef restoration monitoring guide: Methods to evaluate restoration success from local to ecosystem scales. NOAA Technical Memorandum NOS NCCOS 279: 145pp.

Gorris P (2016) Deconstructing the reality of community-based management of marine resources in a small island context in Indonesia. *Frontiers in Marine Science* 3:120

Grydehøj A, Nurdin N (2016) Politics of technology in the informal governance of destructive fishing in Spermonde, Indonesia. *GeoJournal* 81(2):281-92

Hadi TA, Abrar M, Giyanto, Prayudha B, Johan O, Budiyanto A, Dzumalek AR, Alifatri LO, Sulha S, Suharsono (2020) The status of Indonesian coral reefs 2019. Research Center for Oceanography – Indonesian Institute of Sciences, Jakarta 1-88. https://www.researchgate.net/publication/342663285_The_Status_of_Indonesian_Coral_Reefs_2019 (Accessed 14 Jan 2024)

Hein MY, Willis BL, Beeden R, Birtles A (2017) The need for broader ecological and socioeconomic tools to evaluate the effectiveness of coral restoration programs. *Restoration Ecology* 25(6):873-883

Hein M, Mcleod E, Razak T, Fox H (2020a) Meeting 30 by 30: The role of coral reef restoration. International Coral Reefs Initiative (ICRI) Vibrant Oceans Initiative Whitepaper 1-17. https://icriforum.org/wp-content/uploads/2022/12/Hein-McLeod-et-al.-2022-Reef-Restoration-White-Paper.pdf (Accessed 4 Mar 2024)

Hein MY, McLeod IM, Shaver EC, Vardi T, Pioch S, Boström-Einarsson L, Ahmed M, Grimsditch G (2020b) Coral Reef Restoration as a strategy to improve ecosystem services – A guide to coral restoration methods. United Nations Environment Program, Nairobi, Kenya. https://wedocs.unep.org/20.500.11822/34810 (Accessed 4 Mar 2024)

Hein MY, McLeod IM, Shaver EC, Vardi T, Pioch S, Boström-Einarsson L, Ahmed M, Grimsditch G (2020c) Coral Reef Restoration as a strategy to improve ecosystem services – Policy Brief. United Nations Environment Program, Nairobi, Kenya. https://wedocs.unep.org/bitstream/handle/20.500.11822/34811/CRRPB.pdf (Accessed 4 Mar 2024)

Hein MY, Staub F (2021) Mapping the global funding landscape for coral reef restoration. International Coral Reef Initiative 23pp. https://icriforum.org (Accessed 4 Mar 2024)

Hobbs RJ, Harris JA (2001) Restoration ecology: repairing the earth's ecosystems in the new millennium. *Restoration Ecology* 9(2):239-246

Kuehnast K (2001) Protection, participation, and public awareness: Indonesia coral reef rehabilitation and management project. Social Development Notes; No. 57. World Bank, Washington, DC. http://hdl.handle.net/10986/11395 (Accessed 8 Mar 2024)

Kurniawan F, Adrianto L, Bengen DG, Prasetyo LB (2016) Vulnerability assessment of small islands to tourism: The case of the Marine Tourism Park of the Gili Matra Islands, Indonesia. *Global Ecology and Conservation* 6:308-326

Lamont TA, Razak TB, Djohani R, Janetski N, Rapi S, Mars F, Smith DJ (2022) Multi-dimensional approaches to scaling up coral reef restoration. *Marine Policy* 143:105199

Larsen SN, Leisher C, Mangubhai S, Muljadi A, Tapilatu RF (2018) Fisher perceptions of threats and fisheries decline in the heart of the Coral Triangle. *Indo Pacific Journal of Ocean Life* 2(2):41-46

Marine Protection Atlas, The (2022) Announcing the MPA Guide: a framework to achieve global goals for the ocean. Marine Conversation Institute, Seattle, Washington

McDonald T, Jonson J, Dixon KW (2016) National standards for the practice of ecological restoration in Australia. *Restoration Ecology* 2(24):S6-S32

McLeod IM, Hein MY, Babcock R, Bay L, Bourne DG, Cook N, Doropoulos C, Gibbs M, Harrison P, Lockie S, van Oppen MJ et al. (2022) Coral restoration and adaptation in Australia: The first five years. *Plos One* 17(11):e0273325

Mooney AC, Campbell CK, Ratlhagana MJ, Grignon JS, Mazibuko S, Agnew E, Gilmore H, Barnhart S, Puren A, Shade SB, Liegler T (2018) Beyond social desirability bias: Investigating inconsistencies in self-reported HIV testing and treatment behaviors among HIV-positive adults in North West province, South Africa. *AIDS and Behavior* 22(7):2368-2379

Pet-Soede L, Erdmann MV (1998) Blast Fishing in Southwest Sulawesi, Indonesia. *Naga, the ICLARM Quarterly* 21(2):4-9

Piskurek N (2001) Dive tourism in coral reefs-impacts and conditions for sustainability: a case study from Desa Pemuteran (Bali/ Indonesia). ACP-EU Fisheries Research Report 10:57-65. https://aquadocs.org/bitstream/handle/1834/293/acp_10_proceedings_en.pdf (Accessed 22 Feb 2024)

Podsakoff PM, MacKenzie SB, Lee J-Y, Podsakoff NP (2003) Common method biases in behavioral research: A critical review of the literature and recommended remedies. *Journal of Applied Psychology* 88(5):879-903

Razak TB, Boström-Einarsson L, Alisa CAG, Vida RT, Lamont TA (2022) Coral reef restoration in Indonesia: A review of policies and projects. *Marine Policy* 137:104940

Razak TB, Lamont TA, Hukom FD, Alisa CA, Asri AR, Ferse SC (2024) A review of the legal framework for coral reef restoration in Indonesia. *Ocean & Coastal Management* 248:106944

Renggong R, Hamid AH, Yulia Y (2021) Investigating law enforcement for coral reef conservation of the Spermonde Archipelago, Indonesia. https://repository.unibos.ac.id/xmlui/handle/123456789/861 (Accessed 14 Jan 2024)

Riegl BM, Glynn PW (2020) Population dynamics of the reef crisis: consequences of the growing human population. *Advances in Marine Biology* 87(1):1-30

Rinkevich B (2006) The coral gardening concept and the use of underwater nurseries: lessons learned from silvics and silviculture. *Coral Reef Restoration Handbook* 1:291-301

Rinkevich B (2019) The active reef restoration toolbox is a vehicle for coral resilience and adaptation in a changing world. *Journal of Marine Science and Engineering* 7(7):201

Rohyani V, Baruadi AS, Husain R (2023) Institutional Effectiveness of Community Supervisory Group (Pokmaswas) in Supervision of Illegal Fishing and Destructive Fishing in Gorontalo Province. *Central Asian Journal of Social Sciences and History* 4(12):186-92

Saragih RF, Trencher G (2020) Blast fishing activity and coping strategies in Indonesia (South Nias and Pohuwato Regency). *Jurnal Ilmiah Administrasi Publik* 6(1):127-138

Shafira M, Anwar M (2021) Destructive fishing treatment policy based on community supervision in Lampung Province. In I-COFFEES 2019: *Proc. 2nd International Conference on Fundamental Rights, Bandar Lampung, Indonesia*: p56. European Alliance for Innovation

Shaish L, Levy G, Gomez E, Rinkevich B (2008) Fixed and suspended coral nurseries in the Philippines: Establishing the first step in the "gardening concept" of reef restoration. *Journal of Experimental Marine Biology and Ecology* 358(1):86-97

Shaver E, Courtney C, West J, Maynard J, Hein M, Wagner C, Philibotte J, MacGowan P, McLeod I, Böstrom-Einarsson L, Bucchianeri K (2020) A manager's guide to coral reef restoration planning and design. NOAA Coral Reef Conservation Program. *NOAA Technical Memorandum CRCP* 36:120pp.

Simmons EC, Fielding KS (2019) Psychological predictors of fishing and waste management intentions in Indonesian coastal communities. *Journal of Environmental Psychology* 65:101324

Sukarno (1988) Terumbu karang buatan sebagai sarana untuk meningkatkan produktivitas perikanan di Perairan Jepara (Artificial coral reefs as a means to increase fisheries productivity in Jepara waters). *Jurnal Perairan Indonesia Biologi Budidaya, Kualitas Lingkungan, Oseanografi* 87-91

Tam CL (2015) Timing exclusion and communicating time: A spatial analysis of participation failure in an Indonesian MPA. *Marine Policy* 54:122-129

Tranter SN, Ahmadia GN, Andradi-Brown DA, Muenzel D, Agung F, Ford AK, Habibi A, Handayani CN, Iqbal M, Krueck NC, Lazuardi ME (2022) The inclusion of fisheries and tourism in marine protected areas to support conservation in Indonesia. *Marine Policy* 146:105301

Trialfhianty TI, Suadi (2017) The role of the community in supporting coral reef restoration in Pemuteran, Bali, Indonesia. *Journal of Coastal Conservation* 21:873-882

van Oppen MJ, Oliver JK, Putnam HM, Gates RD (2015) Building coral reef resilience through assisted evolution. *PNAS* 112(8):2307-2313 van Oppen MJH, Gates RD, Blackall LL, Cantin N, Chakravarti LJ, Chan WY, Cormick C, Crean A, Damjanovic K, Epstein H, Harrison PL (2017) Shifting paradigms in restoration of the world's coral reefs. *Global Change Biology* 23:3437-3448

Vardi T, Hoot WC, Levy J, Shaver E, Winters RS, Banaszak AT, Baums IB, Chamberland VF, Cook N, Gulko D, Hein MY (2021) Six priorities to advance the science and practice of coral reef restoration worldwide. *Restoration Ecology* 29(8):e13498

Veloria AI, Hernandez DT, Tapang GA, Aragones LV (2021) Characterization of Open Water Explosions from Confiscated Explosives in the Philippines – Possible Implications to Local Marine Mammals. *Science Diliman* 33(1)

Veron JE, Devantier LM, Turak E, Green AL, Kininmonth S, Stafford-Smith M, Peterson N (2009) Delineating the Coral Triangle. *Galaxea, Journal of Coral Reef Studies* 11:91-100

Vesely S, Klöckner CA (2020) Social desirability in environmental psychology research: Three meta-analyses. *Frontiers in Psychology* 24(11):545057

Viehman TS, Reguero BG, Lenihan HS, Rosman JH, Storlazzi CD, Goergen EA, Canals Silander MF et al. (2023) Coral restoration for coastal resilience: Integrating ecology, hydrodynamics, and engineering at multiple scales. *Ecosphere* 14(5):e4517

Westoby R, Becken S, Laria AP (2020) Perspectives on the human dimensions of coral restoration. *Regional Environmental Change* 20:1-3

Wicaksono AW, Abdul KM, Haerudin (2019) Empowerment strategy for Community Surveillance Groups (POKMASWAS) in marine and fisheries resource surveillance activities to prevent illegal and destructive fishing activities through Interpretive Structural Modeling (ISM). *International Journal of Applied Environmental Science* 14(4):307-324

Wilkinson C, Caillaud A, DeVantier L, South R (2006) Strategies to reverse the decline in valuable and diverse coral reefs, mangroves and fisheries: The bottom of the J-Curve in Southeast Asia? *Ocean & Coastal Management* 49(9-10):764-778

Williams SL, Ambo-Rappe R, Sur C, Abbott JM, Limbong SR (2017) Species richness accelerates marine ecosystem restoration in the Coral Triangle. *PNAS* 114(45):11986-11991

Williams SL, Sur C, Janetski N, Hollarsmith JA, Rapi S, Barron L, Heatwole SJ, Yusuf AM, Yusuf S, Jompa J, Mars F (2019) Large-scale coral reef rehabilitation after blast fishing in Indonesia. *Restoration Ecology* 27:447-456

2.8. Supplementary Material

Table S2.1 Indonesian coral reef restoration projects surveyed

Project Leader	Project	Sector	Contact	Position	Location(s)	Region	Project Size	Start
Coral Triangle Initiative	Coral Reef Rehabilitation & Management	Gov	RA Saputra	IBF (project partner), marine biologist	Nusa Penida NP, Gili Matra NP & Gili Balu NP (W.Nusa Tenggara)	Central	Regional	2020
Indonesia Biru Foundation (IBF)	Community Restoration & Coral Laboratory	NGO	RA Saputra	Founder & director, marine biologist	Lombok Utara (W.Nusa Tenggara)	Central	Regional	2008
Gili Eco Trust	Biorock, Reef Restoration & Protection	NGO	D Robbe	Co-founder/ coordinator, project manager	Gili Islands (W.Nusa Tenggara)	Central	Local	2019
Yayasan Terumbu Rumpa	ARTificial Reef Art for Corals	NGO	AH Arifin	Chairperson	Lombok (W.Nusa Tenggara); Wangi Wangi - Wakatobi (SE.Sulawesi); Seribu Archipelago (Jakarta); Bangka - Manado (N.Sulawesi), Ternate (N.Maluku), Banyuwangi (E.Java)	West, Central, & East	Multi-regional	2014
Yayasan Terangi	Restoration of Indonesian Coral Reefs	NGO	Idris Idris	Terangi coral reef management division	Seribu Archipelago (Jakarta); Gili Matra NP (W. Nusa Tenggara); Tunda (Banten); Raja Ampat (SW.Papua); Belitung District (Sumatra)	West, Central, & East	Multi-regional	2010
BPSPL Denpasar	Community-based coral reef restoration in Lombok	Gov	M Barmawi	Marine and coastal ecosystem manager	Pandanan NP - Lombok Utara (W.Nusa Tenggara)	Central	Local	2019

WWF Indonesia	Rock piles as an effort to rehabilitate Indonesian coral reefs	NGO	ME Lazuardi	National coordinator: marine science & knowledge management	P. Kangge & P. Buaya - Alor Islands MPA (E.Nusa Tenggara); Derawan Islands MPA (E.Kalimantan); Jembrana Regency - Bali (W.Nusa Tenggara)	Central	Multi-regional	2013
Fish Resources Recovery Research Institute	Bio-Transplants	Gov	Mujiyanto	BRSDM KP – KKP expert researcher	Tunda Island - Serang (Banten)	West	Local	2019
Khairun University, Ternate	Restoration of coral reefs around mining area	Res	N Wahidin	Lecturer & researcher, Khairun University	Central Halmahera Regency (N.Maluku)	East	Regional	2019
Oceanara	Initiating coral transplant growth	NGO	FR Hakim	Oceanara founder, marine biologist & environmental scientist	Kelapa Dua Island - Seribu Archipelago (Jakarta)	West	Local	2006
IPB Centre for Coastal and Marine Resources Studies	Coral Reef Rehabilitation	Res	N Rikardi	IPB CCMRS researcher	Seribu Archipelago (Jakarta); Indramayu (W.Java); Nyamuk, Madura, & Mandangin Island (E.Java); Kampung Yensawai - Raja Ampat (SW.Papua); Anambas Islands	West, Central, & East	Multi-regional	2018
Anambas Foundation	Reef Restoration Programme	NGO	R Muharam	AF marine conservation programme manager	Yellit, Kaleg, Batbitim, Daram & Kelinci Island - Misool, Raja Ampat (SW.Papua)	East	Regional	2017
Kapoposang Aquatic Tourism Park Authority (TWP)	Reef restoration in Kapoposang National Park	Gov	I Mahmuda	Kapoposang TWP management team coordinator	Kapoposang National Park (S.Sulawesi)	Central	Regional	2014

Coordinating Ministry for Maritime Affairs and Investment	Indonesia Coral Reef Garden (ICRG)	Gov	M Abrar	National Research & Innovation Agency (BRIN) Research Center for Oceanography senior researcher	Buleleng, Sanur, Serangan, Nusa Dua & Pandawa - Bali (W.Nusa Tenggara)	Central	Regional	2014
Yayasan LINI	National Reef Restoration Programme	NGO	RD Astuti	LINI research and education manager	7 sites in Bali (W.Nusa Tenggara); Banggai (Central Sulawesi); Selayar (S.Sulawesi); Banda Islands (Maluku)	Central & East	Multi-Regional	2010
PT Timah Tbk Mining	Marine Reclamation	Pvt Sector	IA Syar'i	Bangka Belitung University lecturer	Bangka Island – Manado (N.Sulawesi)	West	Regional	2018
Lancaster Uni bioacoustics research	Applying bioacoustic techniques to coral reef restoration	Res	Dr. T Lamont	Lancaster Environment Centre marine biologist	Spermonde Archipelago (S.Sulawesi)	Central	Regional	2018
PT Lombok Samudera Abadi	Rehabilitation in ornamental coral farming industry	Pvt Sector	Z Arifin	East Lombok Regency Agriculture and Livestock Service	Pantai Pandanan, Pulau Moyo - Sumbawa (W.Nusa Tenggara)	Central	Regional	2014
Candidasa Local Government	Mendira Beach Reef Restoration	Gov	Dr. R Prasetyo	Dean of Health Sciences, Science & Technology, Dhyana Pura University	Mendira Beach, Candidasa - Bali (W.Nusa Tenggara)	Central	Local	2024
Kuta Public Works Regional River Office	Kuta Coral Reef Restoration Work	Gov	Dr. R Prasetyo	Ibid.	Kuta - Bali (W.Nusa Tenggara)	Central	Local	2003
Benoa Harbour Authority	Coral restoration in harbour dredging plot	Gov	Dr. R Prasetyo	Ibid.	Benoa Harbour - Bali (W.Nusa Tenggara)	Central	Local	2022

Bukti & Bondalem Community Groups	Community-based Artificial Reef project	Local Comm	N Sugiarta	Bondalem pokmaswas	Bukti / Bondalem Village - Bali (W.Nusa Tenggara)	Central	Local	2015
IndoOcean Project	The Indo CorAlliance: A Social-Ecological Response to the Effects of Covid-19	NGO	P Sebastian	IOP scientific director and lead marine biologist	Prapat, Bodong, Sental - Nusa Penida (W.Nusa Tenggara)	Central	Regional	2015
Gili Matra Bursama / Coral Catch	Internship program / Empowering women in coral restoration	NGO	E Putri	Coral Catch Superwoman; co-founder of Lombok Hidden Trip	Gili Air, Lombok (W.Nusa Tenggara)	Central	Regional	2021
Coral Triangle Centre / MSS	Coral Reef Restoration Task Force (CRRTF)	NGO	M Welly	CTC marine conservation advisor	Bontosoa & Takabonerate - Selayar (S.Sulawesi); Wakatobi NP (SE.Sulawesi); Bunaken NP (N.Sulawesi); Bali, Nusa Penida & Nusa Lembongan (W.Nusa Tenggara)	Central	Multi-regional	2017-21
Ocean Gardener	Restoration Programme & Courses	NGO	V Chalias	Ocean Gardener Bali / coral mariculturalist	Gili Islands, Bali, Nusa Penida (W.Nusa Tenggara); Manado & Bangka (N.Sulawesi); Bira (S.Sulawesi)	Central	Multi-regional	2015
Reef Check Indonesia	Coral Restoration alongside LMMA Development	NGO	D Prabuning	RCI chairperson	Buleleng and Karangasem – Bali (W.Nusa Tenggara)	Central	Regional	2017
Baubau city gov. / Ministry of Environment	Coral reef restoration and fisheries programme	Gov	H Maswar	Rock'n'Roll Divers (partner organisation)	BauBau - Buton (SE.Sulawesi)	Central	Regional	2018

Coral Guardian / Yayasan Waka Eling Semeton	Restoring Coral Reefs through Sustainable Financing	NGO	F Jacob	Coral Guardian field and scientific project manager	Hatamin Island, off Seraya Besar (E.Nusa Tenggara)	Central	Local	2015
Livingseas Asia	Padang Bai Reef Restoration	NGO	L Boey	Coral conservation programme leader	Padang Bai - Bali (W.Nusa Tenggara)	Central	Local	2009
Mars Sustainable Solutions (MSS)	Mars Assisted Reef Restoration System (MARRS) - stabilising coral rubble	NGO	P Mansell	MSS R&D project manager	Spermonde Archipelago (S.Sulawesi)	Central	Regional	2013
CV Tumbak Island Cottages	Rehabilitation of reefs on a private resort island	Pvt Sector	Y Parizot	Marine biologist, owner CV Tumbak Island Cottages	Tumbak Island (N.Sulawesi)	Central	Local	2016
Loe Village Community	Using local mountain rocks as new reef structure	Local Comm	S Garvin	Togean Conservation Foundation	Togean Islands (Central Sulawesi)	Central	Local	2020
Fish in Air Tulamben & Heart of Ocean	Transplantation of nursery-raised corals	Pvt Sector	D Daxhelet	Fish in Air founder	Tulamben - Bali (W.Nusa Tenggara)	Central	Local	2020
Global Village Foundation Bali	Kalanganyar Village Coral Reef Restoration Project	NGO	A Bracey	GVFB founder	Kalanganyar - Bali (W.Nusa Tenggara)	Central	Local	2020
Nusa Dua Reef Foundation	Artificial Reefs, Coral Transplantation & Local Management Interventions	NGO	P Hutasoit	NDRF director/co-founder	Nusa Dua - Bali (W.Nusa Tenggara)	Central	Local	2016

Provincial gov. & Thalassa Dive Resort	Single intervention, then successful natural recruitment	Res	Dr. KA Roeroe	Sam Ratulangi University associate professor	Manado (N.Sulawesi)	Central	Local	2020
North Bali Reef Conservation	Reef Restoration in Tianyar Village	NGO	Dr. Z Boakes	NBRC co-founder, marine biologist	Tianyar - Bali (W.Nusa Tenggara)	Central	Local	2011
Blue Corner Dive Centre	Rehabilitating a key tourist reef	Pvt Sector	A Taylor	Co-founder, marine biologist	Sental Reef - Nusa Penida (W.Nusa Tenggara)	Central	Local	2010
Government, with support from South Korean gov.	Rigs-to-Reefs Programme	Gov	A Rizal	Dept of Environmental Science, Indonesia International Institute for Life-Sciences	Bontang (E.Kalimantan)	Central	National	2019
Mataram University	Developing a Reef Restoration Roadmap for Uni Marine Dept	Res	MR Himawan	Dept of Fisheries and Marine Science, lecturer	Lombok Utara (W.Nusa Tenggara)	Central	Regional	2022
Coral Reef Care	Coral Restoration Amed CRC-P3A	NGO	Dr. R Voorhuis	CRC chairperson	Jemeluk Bay & Lipah Beach, Amed - Bali (W.Nusa Tenggara)	Central	Regional	2021
MMAF	Rubble area restoration with local communities	Gov	Dr. O Johan	BRIN Research Group of Coral Reef Ecosystem Conservation	Seribu Islands (Jakarta)	West	Regional	2004
The SEA People	"Yaf Keru" (coral garden)	NGO	A Brival	SEA People director, marine biologist	Rajah Ampat (SW.Papua)	East	Regional	2016 (pilot)
PT Amman Mineral Nusa Tenggara	Reefball programme	Pvt Sector	W Prayogo / A Setianto	PT Amman Mineral NT - Environmental Department	Benete, Kenawa & Lawar Bay - Batu Hijau, W.Sumbawa (W.Nusa Tenggara)	Central	Regional	2004