

# Dive industry perspectives on the threats to coral reefs: A comparative study across four Asia-Pacific countries

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## ABSTRACT

The combined effects of climate change, marine tourism and other stressors threaten the ecological and economic sustainability of coral reefs. This study investigates dive industry stakeholder awareness of the threats to coral reefs through structured interviews with Dive Masters, company managers and marine management agencies in Vietnam, Australia, Malaysia and Indonesia. Stakeholders from all locations have observed degradation of local reefs. Destructive fishing was identified as the principal threat in all regions except Australia. Most participants identified threats from climate change and marine tourism. There was a lack of awareness about ocean acidification by all participants from Maluku, Indonesia. However, ocean acidification could make coral more fragile and, therefore, vulnerable to diver-induced damage. The majority of Dive Masters across all regions provide pre-dive briefings to reduce diver impacts and participate in environmental activities to protect local reefs. Stakeholders in three regions thought there was capacity to expand the local dive industry. However, in Nha Trang Vietnam, most industry stakeholders thought they were at, or exceeded, carrying capacity, whereas marine management employees thought there was room to expand. This study highlights an opportunity to improve diver education on the vulnerability of coral to damage in acidifying oceans. This study also identifies various non-regulatory and regulatory strategies used to reduce diver impacts, emphasising the value of multi-national knowledge sharing between the dive industry and regulatory agencies for adaptive management.



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**DOI** [10.30852/sb.2023.2346](https://doi.org/10.30852/sb.2023.2346)

**RECEIVED** 24 March 2023

**PUBLISHED (HTML)** 27 October 2023

**PUBLISHED (PDF)** 27 October 2023

**CITATION** Benkendorffe, K., Ngoc, Q. T. K., Ab Lah, R., Ode, I., Dimmock, K., Trinh, D. T., ... Limmon, G. (2023). Dive industry perspectives on the threats to coral reefs: A comparative study across four Asia-Pacific countries. *APN Science Bulletin*, 13(1), 224–240. doi:10.30852/sb.2023.2346

## KEYWORDS

Coral reefs,  
 diver impacts,  
 environmental stewardship,  
 marine tourism,  
 ocean acidification

## HIGHLIGHTS

- Dive industry stakeholders are concerned about threats to coral reefs.
- Impacts from diving activities were recognised in three of four regions.
- There was great discrepancy between regions in the awareness of ocean acidification.
- Most dive industry stakeholders are engaged in marine conservation activities.
- Some marine managers and industry stakeholders had discrepant views on diver carrying capacity.

### 1. INTRODUCTION

Coral reefs provide important ecosystem services, including a tourism industry worth billions of dollars annually. High in biodiversity and aesthetic appeal, coral reefs provide the foundation of the Self Contained Underwater Breathing Apparatus (SCUBA) dive industry, which is one of the world's fastest-growing leisure activities (Ong & Musa, 2012, Schuhbauer et al., 2023). The uniqueness and abundance of marine life are important drivers of SCUBA tourism (Apps, Heagney, Ngoc, Dimmock, & Benkendorff, 2023). Recognised as a biodiverse coral hotspot, Southeast Asia has become a leading recreational SCUBA diving destination (Dimmock & Musa, 2015, Schuhbauer et al., 2023). Thus, SCUBA dive tourism is an important source of income for many regions in Southeast Asia (Tuntipisitkul & Fuchs, 2023). However, long-term sustainability of the industry depends on the effective management of healthy coral reefs.

SCUBA diving is typically considered a low-impact activity that provides an economic alternative to fishing (Tapsuwan & Asafu-Adjaye, 2008). Yet, diving can cause direct and indirect negative impacts on coral reef ecosystems by trampling, fin damage and inadvertently touching corals, causing breakage (Barker & Roberts, 2004; Sumanapala, Dimmock, & Wolf, 2023). Inexperienced divers were more likely to cause damage due to poor buoyancy

control (Toyoshima & Nadaoka, 2015) and divers carrying cameras and other equipment were more likely to impact the reef than those without (Barker & Roberts, 2004; Hammerton, 2018). The amount of broken coral on reefs has been correlated with the number of divers and intense diving activities can lead to compositional changes (Au, Zhang, Chung, & Qiu, 2014) or phase shifts in coral reef communities (Giglio, Luiz, & Ferreira, 2020).

Further risk to coral reefs stem from the synergistic impacts of multiple stressors, including human activities and climate change. Ocean acidification poses a particular threat to coral reefs by reducing the concentration of carbonate ions required to build reefs (Albright et al., 2018) and increasing the risk of reef dissolution (Eyre et al., 2018). The mechanical integrity of coral reef structures is fundamentally important to coral reef ecosystem services, including the strength of the reef substrate (Madin, Dell, Madin, & Nash, 2012). Exposure to elevated CO<sub>2</sub>-induced acidified waters can increase the skeletal porosity and reduce the bulk density of corals (Fantazzini et al., 2015), which reduces their mechanical strength and increases susceptibility to damage. Intense diving activity could drive coral reefs towards their tipping point, leading to a phase shift in community structure and potential functional collapse (Hoegh-Guldberg et al., 2007). Serious socio-economic consequences for coastal protection and regional communities that

are dependent on coral reefs for their livelihoods, including marine tourism industries, would occur.

The combined effects of acidification and SCUBA diving on increasingly sensitive coral reefs require effective management to ensure the protection of ecological, cultural and economic values. The sustainable management of dive tourism requires stakeholder engagement to account for divers' environmental awareness and willingness to contribute to marine conservation (Apps et al., 2023; Hillmer-Pegram, 2014). Sustainable marine tourism requires consideration of social, environmental and economic factors, and therefore, a systems approach to consider the views of all stakeholder groups is preferred over narrow, linear approaches (Dimmock & Musa, 2015). Recently an online survey has been undertaken on SCUBA divers to gauge the level of awareness of threats to coral reefs from ocean acidification and diver impacts (Apps et al., 2023). Here, we build on this to gain insight into the environmental awareness of Dive Company Managers and Dive Masters working at the forefront of the SCUBA dive industry.

Southeast Asia is one of the world's leading recreational SCUBA diving destinations (Dimmock & Musa, 2015) and ocean acidification-induced damage to coral reefs will disproportionately impact developing countries that rely on marine-related economic activities (Cooley, Kite-Powell, & Doney, 2009). This study investigates knowledge of ocean acidification, awareness of the risk from diver-induced damage and other perceived threats to coral reefs from the perspective of stakeholders in the SCUBA dive industry across four areas within the Asia-Pacific region. Interview sessions were also held with staff from marine management agencies from two regions. We hope to empower stakeholders with a greater sense of environmental stewardship by providing information to support effective education and leadership with "future-oriented thinking" (Dimmock & Musa, 2015) necessary for sustainable marine tourism in a changing world.

## 2. METHODOLOGY

### 2.1. Study locations

Four locations were selected as case studies to conduct interviews with the SCUBA dive industry: (a) Solitary Islands and Cape Byron Marine Parks on the mid-north to north coast of New South Wales (NSW), Australia, (b) Nha Trang Bay Marine Protected Area, Nha Trang, Vietnam, (c) Ambon and Banda Islands, Maluku Archipelago, Indonesia, and (d) Tioman Island, East Peninsula, Malaysia. North NSW provides a case study with relatively few dive operators and high government regulation within marine parks. The reefs in this area contain a high proportion of soft coral and a high diversity of Scleractinian corals (Harriott, Smith, & Harrison, 1994), with previous reports of diver-induced damage (Hammerton & Bucher, 2015). Nha Trang Bay Marine Protected Area has rapidly grown as a popular dive spot in the last decade, with a burgeoning local and foreign tourist industry in Nha Trang and evidence of degradation of coral reefs in this area (Long & Vo, 2013). The Maluku Province has been identified as a high priority for biodiversity conservation (Asaad, Lundquist, Erdmann, & Costello, 2018) and provides a relatively untapped biodiversity hotspot for dive tourism, with an amazing diversity of coral in shallow waters (Edinger, Kolasa, & Risk, 2000). The Malaysia Islands of East Peninsula, Malaysia, are coral hotspots that have experienced rapid marine tourism growth over the last two decades. Increasing reports of diver damage and coral bleaching in the area resulted in the closure of 12 islands in 2012 (Saleh & Hasan, 2014). A Reef Check program has since been implemented in Malaysia to facilitate marine parks management and diver education (Lau et al., 2019).

### 2.2. Data collection

In June 2019, a preliminary survey was conducted in Nha Trang, Vietnam, using face-to-face interviews with four SCUBA Dive Company Managers and five Dive Masters. Subsequently, in November 2019, a workshop was held on the Gold Coast, Australia, involving a focus group of 13 researchers and divers across four countries to refine the ques-

tions. The final survey consisted of structured face-to-face interviews involving 15 questions delivered consecutively to Dive Masters (Supplementary Table S1). A different questionnaire was used for Dive Company Managers to obtain more information on local dive operations (Supplementary Table S2). The interviews were undertaken from 2020–2022 by researchers from the local region and translated into local language where necessary. Primary data collection included: demographics; knowledge of risks to coral reefs; familiarity with ocean acidification and diver-induced damage to coral; environmental stewardship and mechanisms for communicating impacts; and opinions on a carrying capacity for the local reefs. In tourism, ‘carrying capacity’ refers to the maximum number of people who can use a site without unacceptable deterioration of the physical environment or decline in the quality of the experience by the visitors (Cooper, 2016).

Marine management agencies are also important stakeholders for the ecologically sustainable use and protection of coral reefs. Therefore, additional interviews were undertaken with employees in the Nha Trang Bay Management Authority (NTBMA), Vietnam, due to rapid growth in the local dive industry and the Maluku Natural Resource Conservation Centre (MNRCC) in Ambon Indonesia, which has a relatively new tourism industry and potential for future growth (Supplementary Table S3).

### 2.3. Data analysis

A mixed-method approach was adopted using a combination of qualitative and quantitative techniques for both data collection and analysis. The structured interviews used a combination of binomial (yes or no), selective (multiple unranked options) and open-ended questions (reflections). Data was collated across the four countries using descriptive statistics and frequency tables. Open-ended responses were content analysed to identify themes of similar meaning, with each theme tested for reliability among two coders until a consensus was reached (McGrath, 2010). Themes were then reviewed in terms of how frequently participants

mentioned them. Representative quotes from participants were included to illustrate themes, highlight particular findings and help provide transparency in the interpretation of qualitative data (Eldh, Årestedt, & Berterö, 2020).

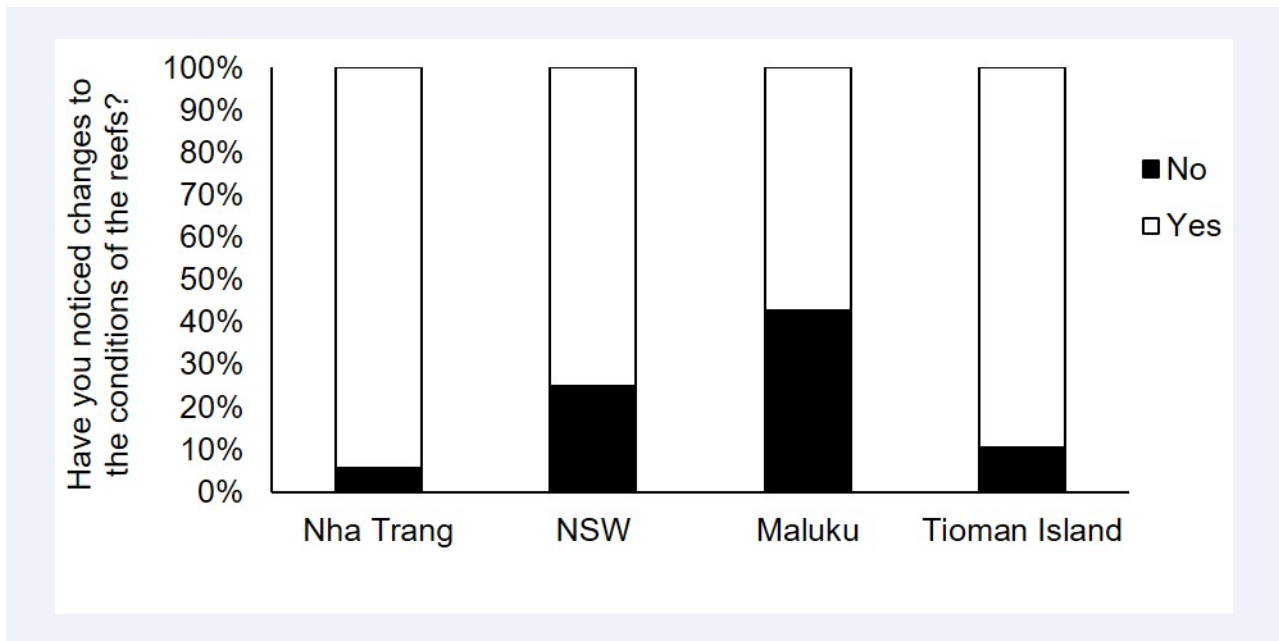
## 3. RESULTS AND DISCUSSION

### 3.1. SCUBA Dive Master and company manager demographics

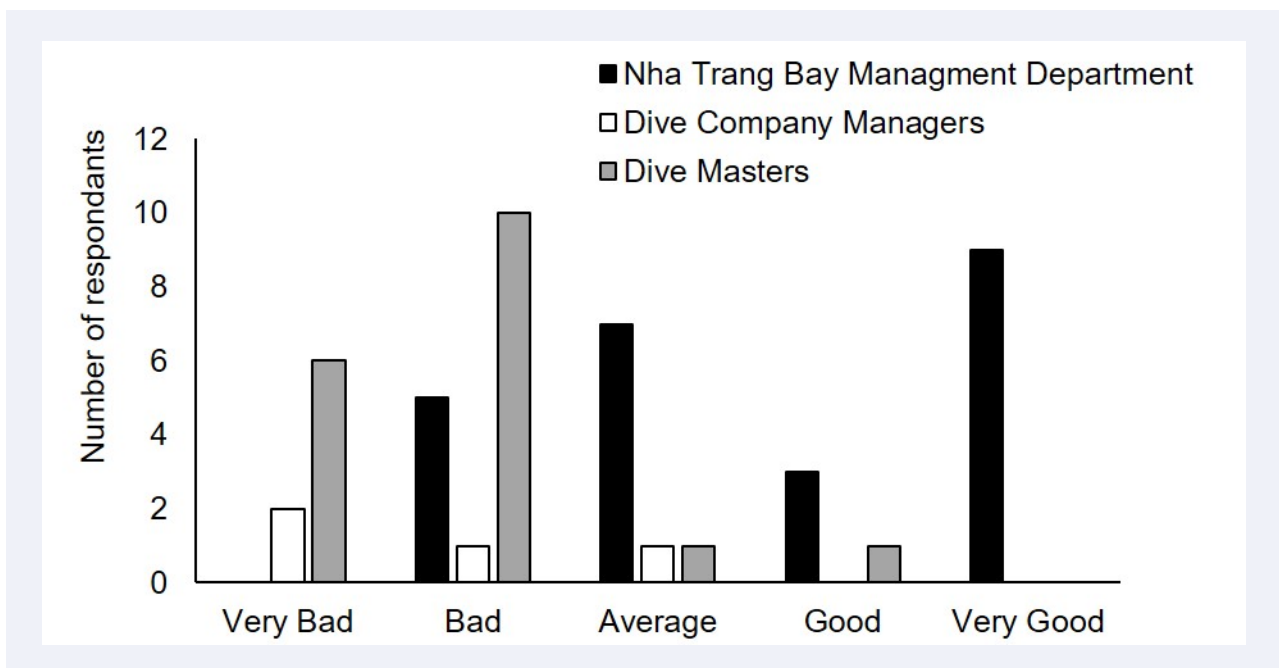
A total of 53 Dive Masters and 24 SCUBA Dive Company Managers were interviewed across the four regions (Supplementary Table S4). The majority of the Dive Masters surveyed in Vietnam (74%), and NSW (50%) had extensive experience in the dive industry, being employed for over ten years. In Tioman Island, only 32% had over ten years of experience, but 68% had over five years of experience, whereas none of the Dive Masters from Maluku had over ten years of experience, and less than 50% had over five years in the industry (Table S4b). Dive Companies have been in operation for less than one year to over 40 years across the regions, with a tendency towards more established companies in NSW and Tioman Island (Table S4b). The majority of Dive Masters were local residents and the Dive Company Managers confirmed they provide training for locals to become Dive Masters (Table S4). Findings confirm that the dive tourism industry supports local economies in these four Asia-Pacific regions, e.g. Ngoc (2019).

### 3.2. Stakeholder perspectives on the state of coral reefs

The majority of Dive Masters indicated they had noticed degradation or decline in local coral reefs since they commenced (Figure 1). Comments indicated the reefs are “getting worse all the time”, “more bleaching, muck smothering coral”, “Coral reefs are fractured, broken more and more”, and in Nha Trang, they indicated that the net area of coral reefs is increasingly reduced. This is supported by recent studies in Nha Trang Bay that have confirmed the coral reefs are in a declining condition due to various anthropogenic and biotic stressors (Tkachenko, Britayev, Huan, Pereladov, &



**FIGURE 1.** The proportion of Dive Masters that have noticed changes to the condition of local coral reefs since they have been diving.



**FIGURE 2.** Frequency histogram comparing different stakeholders' perspectives of the condition of coral reefs in Nha Trang Bay and Hon Mun Island, Vietnam.

Latypov, 2016; Tkachenko, Huan, Thanh, & Britayev, 2021). The majority of Dive Company Managers and Dive Masters in Nha Trang rated the reefs as being in bad or very bad condition, with only one Dive Master indicating they were in good condition (Figure 2). In contrast, 47% of employees from the

NTBMD thought the coral condition in Nha Trang Bay was normal or average, and 20% rated it as good, whereas only 33% indicated it was in a bad condition (Figure 2). The MNRCC considered the quality of coral reefs in Maluku province to be relatively good, but with damage in some places, which was

generally consistent with the Dive Masters and Dive Company Managers from that region. In the absence of longitudinal studies documenting the actual decline of coral reefs, long-term observations from experienced divers can provide some insight into potential “shifting baselines” that could otherwise be regarded as normal.

### 3.3. Main anthropogenic impacts on coral reefs in the region

The predominant threats to coral reefs identified by Dive Masters were anthropogenic stressors (Table 1). Various impacts associated with fishing and boating were identified in Nha Trang, Maluku and Tioman Island, whereas these activities were not identified as major threats in mid-north NSW. In Tioman Island, one Dive Master commented on “more and more illegal fishermen”, and a number of others referred to ghost nets breaking the coral. Abandoned fishing nets have been identified as a global problem causing considerable ecological and socioeconomic challenges (Do & Armstrong, 2023). Concerns regarding the use of explosives or dynamite were raised by three Dive Masters in Maluku and seven in Nha Trang, whereas one from Tioman Island highlighted both dynamite and cyanide fishing. Despite being illegal in Indonesia since 1984, dynamite fishing remains a widespread threat to coral reefs in the region (Praveena, Siraj, & Aris, 2012; Razak, Boström-Einarsson, Alisa, Vida, & Lamont, 2022). Cyanide fishing is also recognised as a most destructive technique for collecting fish from coral reefs; despite widespread laws banning the practice in most source countries, cyanide is still widely used in some Asia-Pacific regions (Calado et al., 2014). One Maluku Dive Master noted, “For coral reefs to be maintained, there must be supervision from government for fishing activities with explosives”. Given that these practices are more common in socio-economically disadvantaged countries, legislation implementation approaches to deter the import of fish caught using these methods are important (Calado et al., 2014).

The major threats to coral reefs in Maluku and Nha Trang identified by the management agency employees, the NTBMD and MNRCC, included destructive fishing practices like the use of explosives and Bameti shell collecting (Table 1). The MNRCC indicated that almost all conservation areas have been degraded by human activities, and changes in the local reefs include coral death due to explosives. The steps to mitigate threats to coral reefs by the MNRCC were identified as: (a) Socialisation and community empowerment; and (b) Development of a village supporting the conservation area. When asked about ways to reduce the main threats to coral reefs in Nha Trang, 80% of the surveyed staff from the NTBMD said that all three of the following actions should be taken: (a) Socialisation and community empowerment; (b) Propagating and educating the community’s awareness; (c) Increase surveillance and patrol activities at sea. All agreed there should be regulations/policies to protect coral reefs in Nha Trang. However, some Dive Masters indicated that management of NTBMD is not good or effective, complaining that there are illegal fishing activities on the coral reefs, the staff lack expertise and there is corruption. One Dive Master claimed that “night diving is not safe due to dynamite fishermen (who pay thankyou money)”.

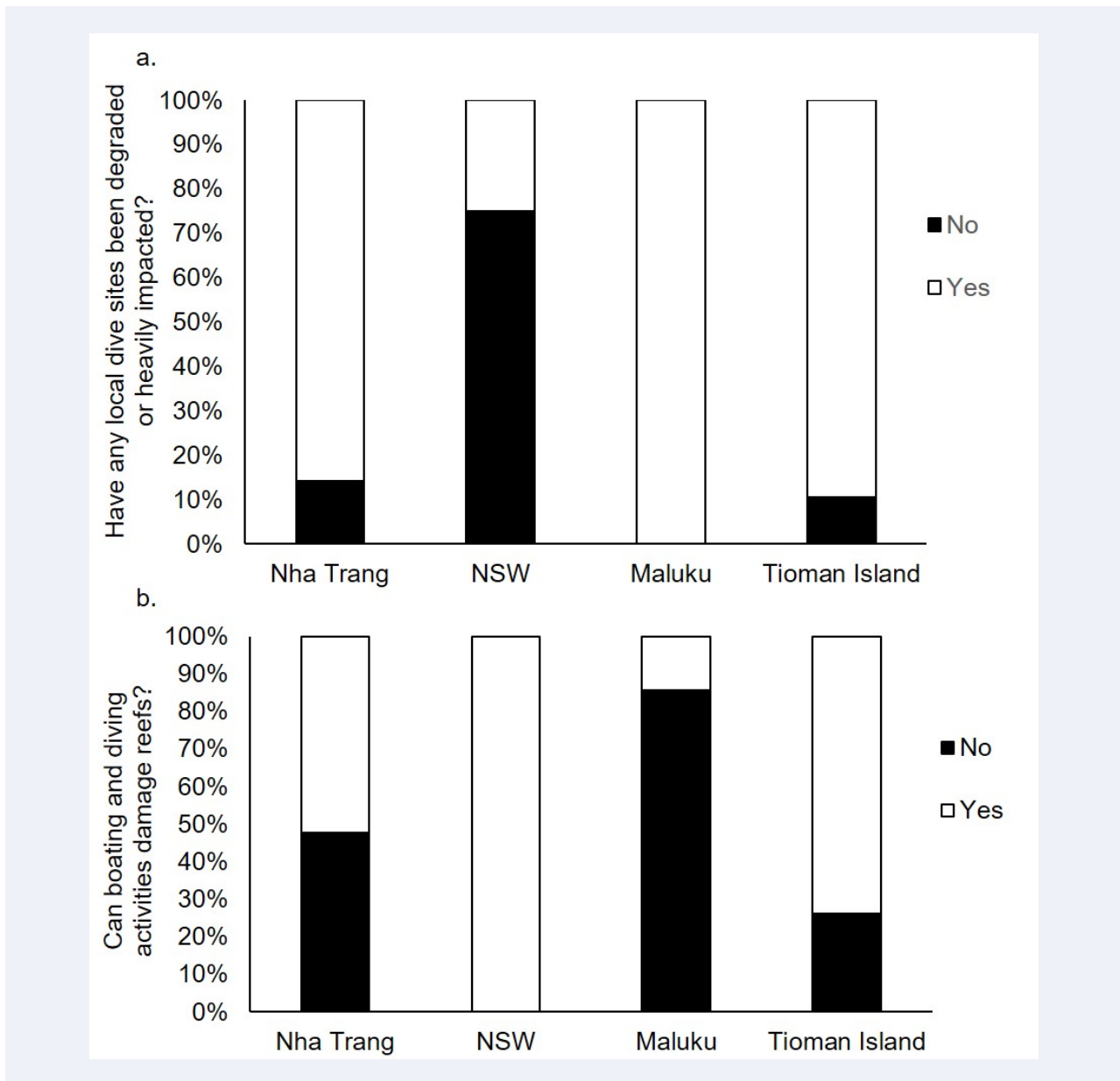
Knowledge about the scope of reef degradation caused by recreational diving and other stressors is crucial for the sustainable management of marine tourism industries (Giglio et al., 2020). The majority of Dive Masters agreed that some local dive sites had been degraded or heavily impacted by human activities (Figure 3a), except in NSW, where only one indicated there had been mild damage at one site. Diving and other tourism activities were only identified as threats by a few Dive Masters in Nha Trang, NSW and Tioman Island, but not by any participant from Maluku (Table 1). Similarly, in a previous review of threats to coral reefs in Malaysia, diving was not identified and tourism was only regarded as a minor threat in some locations (Praveena et al., 2012). In Nha Trang, one Dive Master noted “boats tying off to coral heads” and anchoring blocks being “pulled out, turned over and dragged across

Type of Impact	Threat	Nha Trang N = 24 (15)	Coffs Harbour N = 4	Maluku N = 7 (1)	Tioman Island N = 19
Anthropogenic fishing	Human impacts broadly	5 (15)		1 (1)	1
	Ghost nets / Fishing nets/ illegal nets			1	6
	Overfishing /unsustainable fishing				4
	Destructive fishing practices dynamite/cyanide, explosives	7 (15)		3 (1 main threat)	1
	Fishing line			1	1
	Bameti activities (shell hunting) that damage corals	3 (15)		1 (1)	
	Collecting coral/ornamental fish			1	1
Boating/shipping	Anchors, ships anchors, ships parked on reefs	1		3	
Tourism/diving	Other divers/lack of environmental awareness	1	2		3
	Poor diver training				1
	Tourists/island tours	2 (1)			1
Pollution	Littering/trash/rubbish/ plastic	4	1	4	1
	Oil contamination				1
	River run-off/nutrients, pesticides etc.	2 (2)	2		
	Fish feeding	1			
Habitat disturbance	Coral mining/extraction of building materials				2
	Development				2
Biotic stressors	Crown of Thorn	5 (15)		(1)	1
	Coral Bleaching	6 (15)		2 (1)	
Abiotic stressors	Climate change	1	2		1
	Global warming	1 (1)	1		1
	Ocean acidification		2		
	Intensified storms		1		1
	Weather	2			1

**TABLE 1.** Frequency of major threats to coral reefs identified by Dive Masters (and employees from the Nha Trang Bay Management Department and Maluku Natural Resource Conservation Centre).

reefs”. Whilst not denying the economic benefits of the SCUBA diving industry, 80% of staff from the NTBMD agreed that recreational activities such

as boating and diving can cause damage to coral reefs in Nha Trang. Conversely, the Maluku Natural Resource Conservation Centre indicated, “Boating



**FIGURE 3.** Percent of Dive Masters interviewed in four Asia-Pacific Regions who (a) have observed degradation of coral reefs, and (b) agreed that boating and diving activities can impact coral reefs.

does not damage the reef. If the diving activity involves a diving guide, it might not damage the coral reef”.

The ecological impacts from diving are well documented (Giglio et al., 2020; Sumanapala et al., 2023). When asked directly whether recreational activities like diving and boating could cause damage to coral reefs, 58% of Dive Masters across the four regions agreed (Figure 3b). However, understanding of impacts from diving ranged from 100% in NSW to only 14% (1/7) in Maluku (Figure 3b). Comments from experienced Dive Masters in Nha Trang in-

cluded “improper dive practices and the same dive spots regularly over-used, tea-bagging” (tethering several inexperienced divers together in a line), “many tourists stand on corals”, “need to regulate bad activity, poor standard of instruction ... some companies even take people who cannot swim. ...others overweight to keep them on the bottom”. Some dive services available in Nha Trang include “Sea Walking” and “Try Dive” for non-certified divers. Conversely, a less experienced Dive Master suggested that “Dive Masters and Instructors take care and don’t allow anyone to touch or take any-



thing”. Dive Masters in Tioman Island noticed “up-rooting”, “broken corals”, “coral damage (people keep touching while diving)”, “assault by tourists (touching)” and “some dive sites are losing corals probably after being stepped on”. One Dive Master from NSW highlighted the need to monitor for diver impacts. Previous studies on diver impacts in the Solitary Islands Marine Park have reported high levels of damage, with SCUBA tanks, cameras, divers knees and untethered equipment contributing to severe impacts (Hammerton, 2018).

Rubbish, litter and trash were identified as threats across all four regions, but more frequently in Nha Trang and Maluku (Table 1). One Dive Master from Maluku commented that they “need a government program to reduce plastic waste at sea”; another noted they need training to clean up rubbish. Some other forms of pollution identified as threats included oil contamination in Tioman Island and terrestrial run-off in NSW and Nha Trang. This is consistent with previous research on marine ecosystem impacts in these areas (Jamal, Reichelt-Brushett, & Benkendorff, 2022; Laicher et al., 2022; Tkachenko et al., 2016). Habitat disturbance from coral mining and development was identified as a threat by four Dive Masters on Tioman Island. Coral mining was previously identified as a risk to coral reefs in East Malaysia, but not on the east coast peninsular (Praveena et al., 2012), and there is no coral mining currently on Tioman Island.

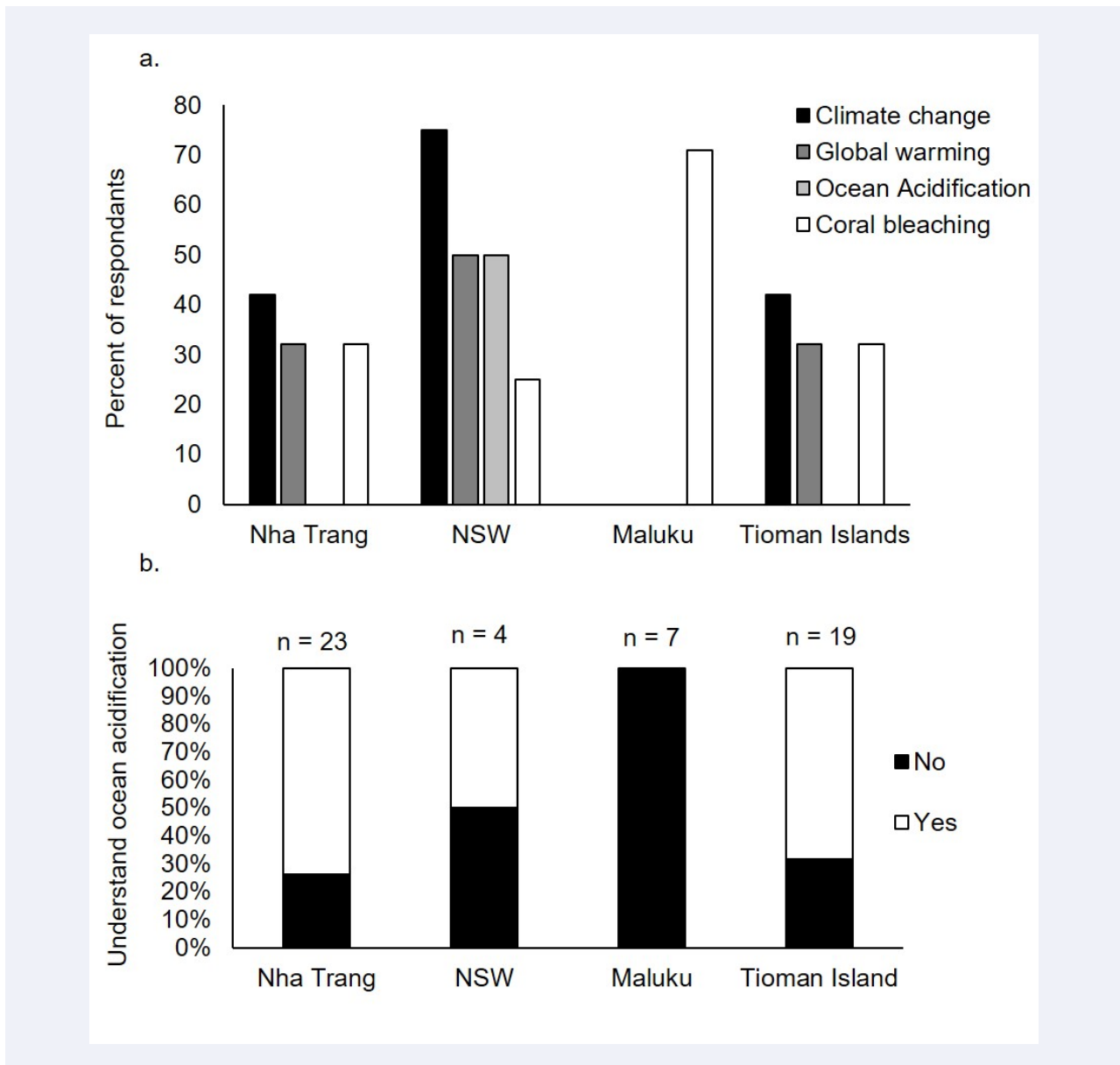
### 3.4. Awareness of climate change and ocean acidification

Abiotic stressors associated with climate change and weather events were identified as threats in Nha Trang, NSW and Tioman Island (Figure 4), but not by Dive Masters in Maluku. These climate-related stressors were identified by 75% of NSW Dive Masters, compared to 9% in Nha Trang and 42% in Tioman Island (Table 1). Yet, coral bleaching was identified by six Dive Masters in Nha Trang and two in Maluku (Table 1). Bleaching was mentioned by 16 Dive Masters across all regions in response to the question of whether any dive sites have degraded. The susceptibility of corals to heat stress

and bleaching has previously been documented for the Solitary Islands (Dalton & Carroll, 2011), Nha Trang (Tkachenko et al., 2016) and Tioman Island (Guest et al., 2012). The highest severity of coral disease and compromised health was linked to areas with greater coastal development and tourism activities on Tioman Island (Akmal & Shahbudin, 2020).

Across all regions, only two Dive Masters from NSW identified ocean acidification as a major threat to coral reefs when asked an open question (Table 1, Figure 4b). One had studied a course on Ocean Change Biology, and the other had “Heard about it and talked to a lot of people who are concerned about it”. Another Dive Master from Coffs Harbour indicated they “Haven’t heard of OA and want to understand it more”. No Dive Masters from other locations identified ocean acidification as a specific threat, compared to 42% identifying “climate change” and global warming as threats in Nha Trang and Tioman Island (Table 1, Figure 4a). Nevertheless, when asked specifically if they had heard about ocean acidification and the problems it could cause for coral reefs, 74% and 68%, respectively, agreed they had in those two regions (Figure 4b). In Nha Trang, one Dive Master indicated they had heard of it “But what could be done about it?”.

Similar to Dive Masters and Company Managers in Nha Trang, the majority of employees from the NTBMD were aware of ocean acidification (93%) but did not identify it as a specific threat to coral reefs. Conversely, MNRCC employees had never heard of ocean acidification, no Dive Masters or Company Managers from Maluku were previously aware of ocean acidification, and none identified climate change as a threat. However, 71% had observed coral bleaching as a change since they have been diving on local coral reefs (Figure 4). These findings align with findings from surveys of divers (Apps et al., 2023; Buckley et al., 2017), which found divers less aware of ocean acidification than other coral reef impacts. Given that ocean acidification is likely to make coral more fragile and, therefore, more vulnerable to diver impacts, this highlights the need to raise public



**FIGURE 4.** Percent of Dive Masters interviewed in four Asia-Pacific countries who (a) identified factors associated with ocean climate change as a major threat or factor associated with degradation at dive sites in the region and (b) indicated that they understand what ocean acidification is and the consequences for coral reefs.

awareness. To support the SCUBA dive industry in this endeavour, we have produced an information brochure that is available for free download and display (<https://www.apn-gcr.org/publication/protect-coral-reefs-under-climate-change-how-you-can-help/>).

### 3.5. Environmental education and stewardship in the SCUBA Dive industry

The impacts of diving on coral reefs are typically managed with non-regulatory strategies implemented by dive companies, such as education,

improving dive techniques and pre-dive briefing (Sumanapala et al., 2023). Three dive companies on Tioman Island are certified members of Green Fins (<https://greenfins.net/>), which provides environmental guidelines to promote a sustainable diving industry. Green Fins has been implemented internationally by the Reef-World Foundation and the UN Environment Programme to provide an independent assessment system of digital or certified membership (in active countries) for sustainable marine tourism operators. The program aims to empower

Question	Nha Trang N = 23	NSW N = 4	Maluku N = 19	Tioman Island N = 7
Do you provide training to alert and educate divers (e.g. buoyancy control, fin damage, not holding coral)?	87	100	100	100
Participation in marine-based community environmental activities	61	100	71	100
Do you communicate concerns about reef health or potential diver-induced damage?	78	100	86	100
Do you have a choice of dive sites with different quality reef health where you take divers?	83	100	100	100
Are inexperienced divers taken to particular dive sites – already damaged sites vs. fragile sites?	61	100	0	84
Does local culture influence the choice of dive sites (e.g. protected areas, no diving during coral spawning)?	87	0	0	32
Do you think the capacity has been reached?	78	33	0	11

**TABLE 2a.** Environmental stewardship in the SCUBA dive industry (a) the percent of Dive Masters responding positively to questions relating to environmental stewardship and strategies to reduce diver impacts on coral reefs.

Dive Guides to positively influence diver behaviour and effectively manage divers to prevent them from causing damage to coral and other marine life. No other region in our study participates in this program, although several Dive Company Managers mentioned a code of practice. Furthermore, all Dive Company Managers in NSW and Tioman Island and several in Nha Trang ensure their Dive Masters provide a thorough pre-dive briefing with education around fin damage and buoyancy control (Table 51b). Consistent with this, all Dive Masters in NSW and Tioman Island, as well as Maluku, indicated they provide training to divers to limit coral reef damage, whereas a minority in Nha Trang did not (Table 2a). The majority of Dive Masters said that diving in Nha Trang is an indispensable part of Nha Trang tourism but highlighted that some diving companies operate for profit and neglect the protection of marine natural resources; they recruit amateur or unqualified divers to cope but do not have adequate knowledge of environmental protection.

Targeted interventions, including pre-dive briefing and direct underwater reinforcement at the time of first contact, were effective in significantly reducing the impact of divers (Hammerton

& Bucher, 2015). While most Dive Masters provide dive briefings on site, reminding divers to stay off the bottom, maintain buoyancy, watch fins and not touch the coral, only a couple of the Company Managers from NSW indicated their Dive Masters are trained to intervene/intercept when required. One Dive Master from NSW confirmed, “If they are unsure of weights or buoyancy, I do a surface check. I have more on me to give them..”. Another indicated, “If I see poor buoyancy underwater, I go up and let them know”. One Dive Master in Nha Trang “Evaluates all groups to find out the weakest and strongest link...” and “Trains divers to use lungs instead of buoyancy vests...”. These are all useful strategies for improving diver awareness and skills, thereby reducing likely diver contact with coral (Hammerton & Bucher, 2015).

Experienced SCUBA divers generally have good environmental ethics (agree they have a responsibility to protect the marine environment) and show a preference for operators that promote coral reef conservation (Apps et al., 2023). Involvement in diver awareness, marine education programs or marine conservation training was mentioned by three Dive Company Managers in Tioman Island, two in

Number involved in environmental activities	Nha Trang		NSW		Maluku		Tioman Island	
	DM	DCM	DM	DCM	DM	DCM	DM	DCM
Rubbish removal	4	3	4	2	4		19	9
Ghost net removal							2	3
Crown of thorns removal	2	1						3
Habitat rehabilitation			1	1			2	2
Reef Check							2	1
Other (fish recovery and turtle conservation)			1	1				1

**TABLE 2b.** Environmental stewardship in the SCUBA dive industry (b) the number of Dive Masters participating in different environmental activities.

Nha Trang and one from NSW. All Dive Company Managers interviewed from Nha Trang and Tioman Island indicated their companies participate in some sort of environmental programmes, along with two from NSW and one from Maluku. Consistent with this, all Dive Masters in Tioman Island and NSW and over 60% in Maluku and Nha Trang indicated they participate in marine environmental activities (Table 2a). However, not all Dive Masters or managers specified what these activities were in Maluku or Nha Trang (Table 2b). The activities primarily included rubbish collection, informally or as part of Project Aware clean-ups and crown of thorns removal (Table 2b). Other environmental programs include coral planting, ghost net removal, and turtle conservation. A survey of divers has confirmed they enjoy learning about the environment whilst on holidays and generally agreed that dive operators have a responsibility to protect the environment at their dive sites and support marine conservation and education (Apps et al., 2023).

Sharing information with government managers and their diving clients is important to improve awareness of factors contributing to coral reef degradation (Giglio et al., 2020). The majority of Dive Masters across all four regions communicated concerns about reef health and/or potential diver-induced damage (Table 2a). Nearly half of the Dive Masters in Nha Trang indicated they notified the NTBMD when they observed deterioration or reef damage. However, others have the opinion

that when they announce any broken coral reefs, their company or NTBMD always opposes them and claims the coral reefs are in good condition. Conversely, 14 of 15 NTBMD employees interviewed acknowledged changes in coral reef health in Nha Trang, including reduced coral reef area and more and more broken coral. This is noteworthy because it indicates a lack of trust between the Dive industry and management agencies in the region. However, 87% of employees surveyed from NTBMD believe they have close cooperation with the SCUBA diving industry.

The Maluku Natural Resource Conservation Centre indicated they do not work closely with the SCUBA dive industry, although they ask for help from the diving community for activities like coral reef transplants. In other regions, most Dive Managers communicated concerns about coral health, but the responses focused on educating customers on dive charters. Both non-regulatory and regulatory management strategies are required to facilitate an ecologically sustainable SCUBA dive industry (Giglio et al., 2020; Sumanapala et al., 2023).

### 3.6. Regulatory strategies for management of coral reefs

Regulatory strategies to manage diver impacts on coral reefs can be self-imposed by the Dive Industry or Company Managers or formally regulated by the government. Spatial or temporal

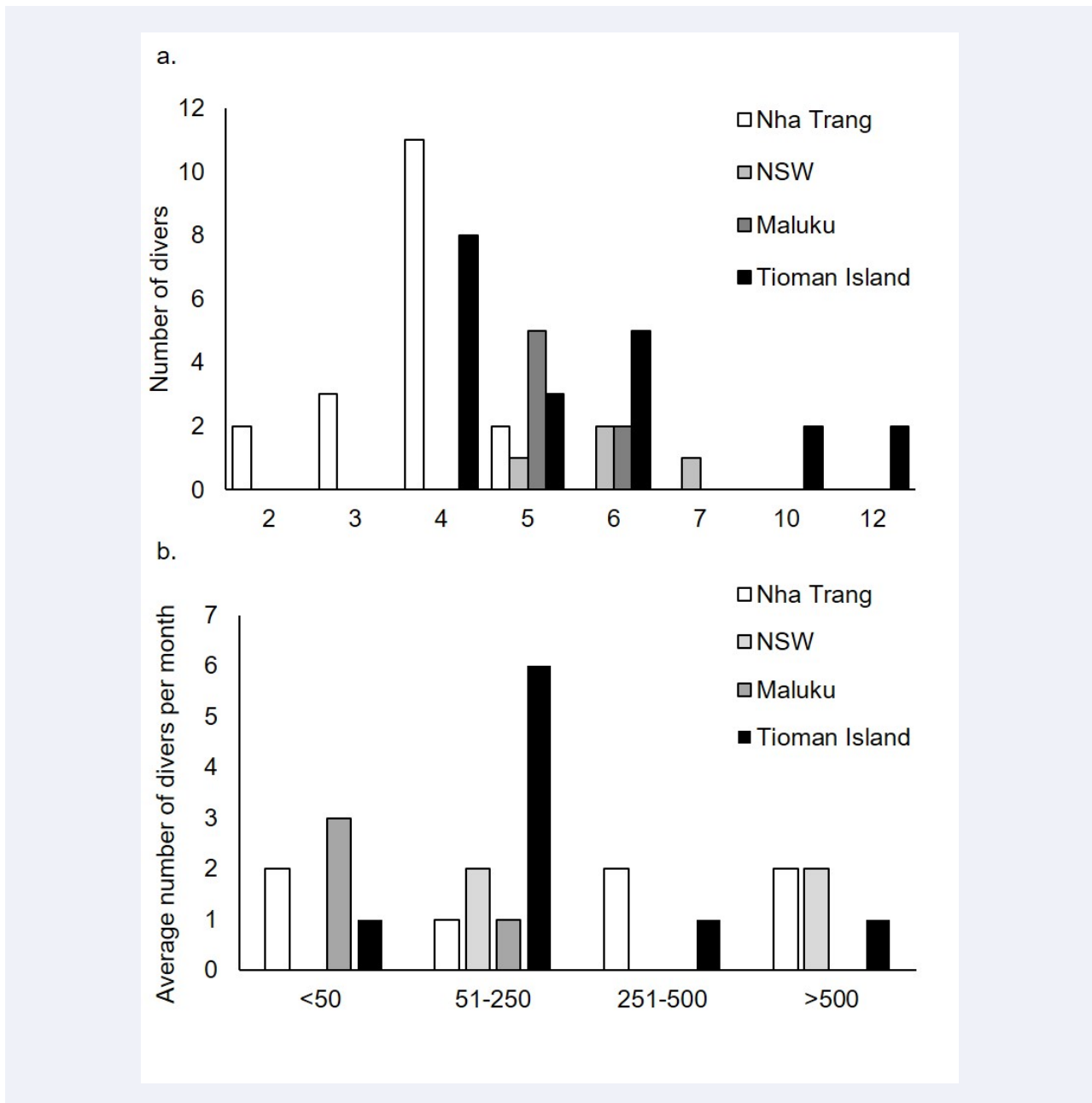
zoning (Giglio et al., 2020) can limit the overall number of sites accessible to divers or times of year in which diving can occur (Sumanapala et al., 2023). Temporal zoning typically occurs in response to seasonal weather patterns that influence safety. On Tioman Island, most Dive Company Managers indicated that it is a closed season, with diving restricted to 7–8 months per year. A few Dive Masters in Tioman Island and the majority in Nha Trang indicated that some protected areas are not accessible for diving (Table 2a). In NSW, SCUBA diving is not excluded from sanctuary zones in multi-use marine parks. However, NSW Dive Companies must report the number of dive charters annually to the Marine Parks Authority. Regulation can be further achieved by introducing a permit system or charges (Sumanapala et al., 2023). In Nha Trang, all Dive Charters pay a fee for each diver to access Nha Trang Bay Marine Park. However, one Dive Company Manager noted that “many cheat even though it is cheap (they claim less on board)”, and they have “no idea if marine park fees are going back to the marine park for management”.

Another mechanism for regulating diver impacts could involve limiting access to diving sites depending on the experience level of divers (Sumanapala et al., 2023). Many studies found no direct correlation between diver experience and damage to corals, yet introductory-level divers can have poor buoyancy control and are likely to cause damage at the start of the dive (Giglio et al., 2020). The majority of Dive Masters indicated they access a range of dive sites with different reef health. All Dive Masters in NSW and the majority on Tioman Island use different sites according to diver experience (Table 2a). This was less frequently the case in Nha Trang, although several indicated they only take more experienced divers to deeper dive sites, and many indicated inexperienced divers would be taken to specific dive sites (already damaged or less damaged). No Dive Masters in Maluku indicated that they discriminated between inexperienced and experienced divers in the choice of dive sites (Table 2a). In Tioman Island, Dive Masters indicated, “We check out divers at the shore on a sandy area

to evaluate diving skills before they get on the boat. From there, we decide on the type of sites to suit them” and “I will make sure they have sufficient training or lesson on a sandy bottom area before heading to the coral area”. Another commented, “It depends on the diver’s technique rather than experience”.

Restricting the number of divers through maximum group size, number of boats and/or establishing a reef carrying capacity are other options for regulating diving impacts (Zhang, Chung, & Qiu, 2016). The size of the dive groups varied from two up to 12 across all four regions (Figure 5). The modal group size was four in both Tioman Island and Nha Trang, where a larger number of Dive Masters participated in the survey. However, Nha Trang has a smaller frequency distribution with a maximum of five divers. One Dive Master responded, “It was based on international standards or the diving group was often divided according to the experience of the guests, but the maximum was still four people/diving group”. Few Dive Company Managers mentioned restricting the dive group size. Small group size, minimal number of boats at the dive sites and high-quality coral with minimal disturbance are important features of the dive experience (Apps et al., 2023) and could be promoted by dive operators aiming to attract environmentally conscious divers, willing to pay for marine conservation (Wielgus, Balmford, Lewis, Mora, & Gerber, 2010).

Responses to the question of whether a carrying capacity for diving on local reefs had been reached were highly variable (Table 2a). In Maluku, all Dive Masters indicated the carrying capacity had not been reached and there was room for expansion. One indicated they need “support from provincial government and local communities to develop the diving industry”. Consistent with this, the MNRCC agency employees indicated there is room for expansion of the SCUBA dive industry in Maluku. They are optimistic about the potential for attracting more SCUBA dive tourism due to the unique marine life and diverse coral ecosystems in the area. The MNRCC agreed there should be a carrying capacity but highlighted there had been no study on this,



**FIGURE 5.** Frequency histogram of the (a) maximum size of dive groups taken out by Dive Masters and (b) average number of SCUBA clients per month for dive companies interviewed in four Asia-Pacific regions.

although they thought it had not been reached yet. In Tioman Island, the majority of Dive Masters thought there was room for expansion, although several indicated with the proviso that it is well regulated and there was an emphasis on training and environmental education. One suggested, “It’s better to increase the quality of the dive/divers rather than the quantity”. Several Dive Company Managers in Tioman Island indicated that the government needed to enforce a carrying capacity to

limit the number of divers, and there should be stricter requirements for all SCUBA operators to enhance diver education and improve the quality of dive instructors.

In Nha Trang, responses about the carrying capacity of the local reefs were divergent, with the majority indicating the reefs were at or above capacity for diving, although several still thought there was room for expansion (Table 2a). A couple of Dive Masters indicated they were over capacity

at specific sites and “need to change the mentality and prevent so many divers at one spot. “Need more moorings to spread out around the island. Boat captains all park together to drink beer and chat - need rules such as max three boats per spot”. This suggests that regulatory support may be required to initiate behavioural change in some sectors of the industry to protect coral in diving hotspots. The NTBMD employees indicated they feel optimistic about the SCUBA industry in Nha Trang (93.3%), but only 53.3% of employees believe there is room for expansion, with 33.3% of employees indicating it might be possible to expand the diving area to another place, but this would not be easy. Nevertheless, 93.3% of NTBMD employees indicated the current number of divers was less than the carrying capacity of the environment and only 6.7% of employees think the number of divers is greater than the capacity. This is in contrast to the Dive Masters from Nha Trang, in which 73% think the carrying capacity has been reached (Table 2a).

#### 4. CONCLUSION

To minimise the impact of snorkelling and diving on coral reefs, it is crucial that tourism is planned and a framework developed which is within the context of sustainable development principles. For example, the UN sustainable development goal 14: Conserve and sustainably use the oceans, seas and marine resources, recognises the need to minimise the impacts of ocean acidification and sustainably manage and protect marine ecosystems to avoid adverse impacts. It is not possible to eliminate all threats to coral reefs, including impacts of SCUBA diving. However, regulations can set controls on dive operator activity, such as establishing a carrying capacity, limiting diver numbers at one site at one time and licensing for well-qualified dive operators who are willing to take responsibility for stewardship of the environment. Non-regulatory management strategies include establishing clear guidelines for pre-dive briefings, assessing diver skills and selecting dive sites accordingly, and empowering Dive Masters to intervene on-site when they witness poor diving practice. Expansion of the

active Green Fins approach into more Asia-Pacific regions could be one way to promote sustainable diving practices for the protection of coral reefs. Dive Masters and Company Managers have extensive experience of their local environment, along with a vested interest in protecting the reefs, which could provide a resource to government marine management agencies. Building stakeholder trust and collaboration should be part of the management strategies to facilitate ongoing monitoring and raise awareness of the health of coral reefs.

#### 5. ACKNOWLEDGEMENTS

This research was funded by the Asia-Pacific Network for Global Change Research grant number CRRP2019-05MY-Benkendorff. This research was supported by the Southern Cross University Human Ethics Committee (Ethics Approval Numbers 2020/024 and 2019/198). The authors are grateful to the dive industry and management agency participants who willingly gave their time and knowledge during the interviews undertaken in this study. We are grateful to Mr Alvin Chelliah for facilitating interviews on Tioman Island and all project collaborators who participated in a 2019 project workshop to refine the interview questions: Prof Stephen Smith, Dr Dang Thuy Binh, Dr Si Vo Tuan, Dr Razak Zachariah, Mr Simon Hartley, Dr Elizabeth Heagney, Prof. Peter Harrison, Mr Van Hai Dam, Ms Kate Bradshaw, Ms Jaime Kruusmaa and Dr Rajendra Khanal.

#### 6. APPENDICES

Appendices are available online at <https://doi.org/10.30852/sb.2023.2346>

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