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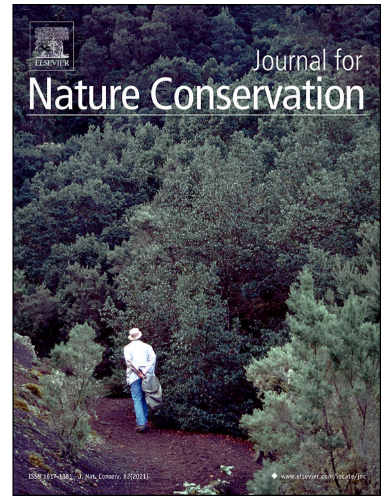

Review

Coral reef conservation in Bali in light of international best practice, a literature review

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Coral reef conservation in Bali in light of international best practice, a literature review.

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Abstract:

Bali, Indonesia sits within the coral triangle and is internationally recognised for its high coral reef diversity. The health of Bali's marine ecosystems has declined in recent decades, and this is thought to be due to threats from climate change, destructive fishing practices, pollution, outbreaks coral eating invertebrates, coral disease and unsustainable tourism. As a response, multiple conservation strategies have been introduced by the island's communities, non-government organisations and governments, with the aim of preventing further decline, as well as restoring already degraded coral reefs. This literature review provides an in-depth analysis of the tools used to conserve Bali's coral reefs, and compares them to those used in other countries. In light of international 'best practice' in coral reef conservation, this review makes suggestions on how Bali could better conserve its coral reef ecosystems. These include (1) increasing its designation of official Marine Protected Areas (MPAS) and strengthening management of existing ones, (2) creating an MPA network, (3) substantially reducing marine plastic pollution, (4) continuing artificial reef construction in degraded habitats, (5) continuing to develop Bali as an ecotourism destination, (6) increasing engagement in global science to inform marine conservation decision-making, and (7) developing more marine monitoring programmes.

Key words: Coral Reef Restoration, Marine Conservation, Indonesia, Artificial Reefs, Ecotourism

1. Introduction

1.1. Coral reefs: a global perspective

Coral reefs, large underwater habitats of calcium carbonate skeletons produced over time by coral polyps, are critically important to tropical coastlines (Hoegh-Guldberg et al. 2017). Often referred to as 'rainforests of the sea', coral reefs occupy less than 0.1% of the ocean floor, yet host 25% of the world's marine species (Fisher et al. 2015). They provide ecosystem services estimated at a value of over US $1 Trillion globally (Costanza et al. 2014) through food provision, shoreline protection, biogeochemical cycling and tourism (Moberg and Folke 1999, Principe et al. 2012). The provision of these ecosystem services is under threat (Bell et al. 2006) as anthropogenic activities have caused a worldwide long-term decline in coral reef biodiversity, abundance and habitat structure (Pandolfi et al. 2011, Hughes et al. 2018). The cumulative effect of this damage has resulted in declines of associated nearshore tropical biodiversity (Pratchett et al. 2014), altering ecosystem functioning and processes (Richardson et al. 2018).

The first United Nations Educational, Scientific and Cultural Organization (UNESCO) assessment of global coral reef decline predicts that all 29 coral-containing World Heritage sites will no longer be functioning coral reef ecosystems by 2100 under a business-as-usual emissions scenario, due to coral bleaching mostly associated with ocean warming and acidification (Heron et al. 2017). The same study indicates that climate-related losses of reef ecosystem services will total approximately US $500 billion by 2100, with the greatest of these impacts experienced by people who rely upon reef services for day-to-day subsistence Under these scenarios, it is predicted that reefs previously dominated by hard and soft corals, will experience regime shifts, changing the ecosystem to one that is instead dominated by algae (Vercelloni et al. 2020). Alongside aggressive and immediate global-scale interventions to reduce greenhouse gas emissions and their impact on coral reefs (as highlighted by Pörtner et al. (2014) by the International Panel for Climate Change (IPCC) 'Ocean Systems' report), various other local scale options may be considered to offset the decline of coral reef biodiversity, abundance and habitat structure.

1.2. Introduction to Indonesia's / Bali's coral reefs

Indonesia makes up 12.5 % of the world's total coral reef area (Susiloningtyas et al. 2018). It sits within the Coral Triangle, an area recognised as the global centre of marine biodiversity (Allen 2008) which is of global conservation importance (Briggs 2005). Bali is a province of Indonesia (Figure 1), and has the second highest documented reef fish species richness in the Asia-pacific (Mustika and Ratha 2013), with at least 805 documented fish species (Allen and Erdmann 2013).

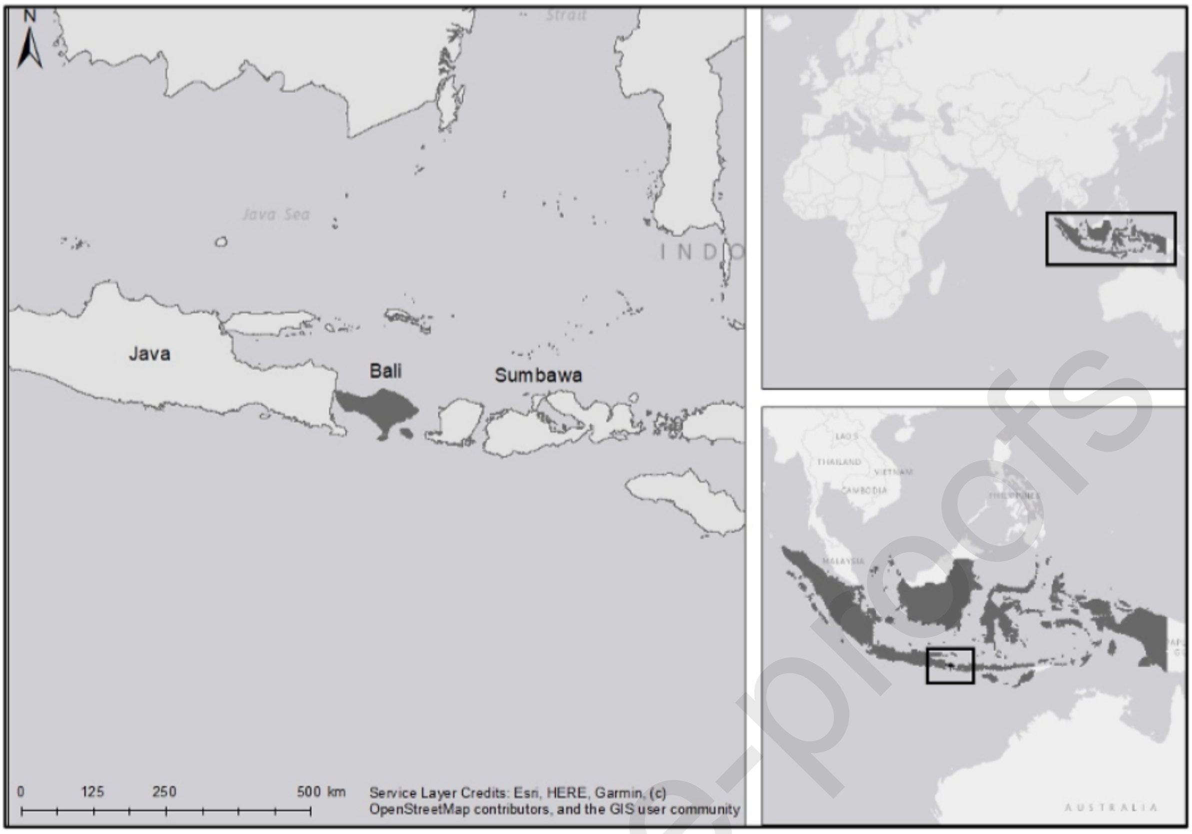

Figure 1: Location of Bali within Indonesia *(Created using ArcGIS OpenStreetMap powered by Esri).*

Research suggests that 86% of Indonesia's coral reefs face medium or high levels of threat (Burke et al. 2012). Studies on Bali's reef in 2011, collected from the 27 reefs across the island, showed that its corals were generally in good condition (Lazuardi et al. 2013). More recent data from 2017 has highlighted similar results, suggesting that 50% of its corals are in good health, whilst 20% are declining and 30% are poor (Marine and Fisheries Office 2017 data, as cited by Wicaksana (2020). Reefs in Bali are exposed to multiple threats, that combined together, make the ecosystems less resilient rising sea temperatures (Salm 2005). Resilience can be defined as "the capacity of a system to resist and recover from disturbance and undergo change while still retaining essentially the same function, structure and integrity" (GBRMPA 2018). A reduction in coral reef resilience through combined threats can result in coral mortality and regime shifts, where the reef will become dominated by algae instead of coral, as reported in reefs across Bali (Tito and Ampou 2020). This alternative algal state is generally viewed as less desirable in terms of the provision of ecosystem services and it is unlikely, especially with rising temperatures, that a coral reef will recover to its original state after a regime shift (Selgrath et al. 2017).

1.3. This Literature Review

As discussed by Ridley (2012), a literature review is "in itself a research study, using the literature as data to be coded, analyzed and synthesized to reach overall conclusions". This literature is aiming to identify good practice and areas for improvement for marine conservation in Bali and wider Indonesia, compared to typical and best practice internationally. It will start by identifying the main threats to the coral reefs of Bali, then main tools for conservation in Bali will be discussed and analysed. This review will end by making suggestions for marine conservation in Bali, informed by internationally recognised 'best practice'.

2. Methods

The purpose of this study was to provide a comprehensive review of marine conservation issues in Bali, acknowledging that much of the relevant literature would not be present in peer reviewed papers or published in English. We therefore used Google Scholar as the main search engine. Key themes related to the research title were selected and within each theme key discussion points chosen. For example, the within the theme 'Coral Reef Threats', the key points included: 'Bleaching', 'Nutrient Enrichment', 'Damaging SCUBA practices', 'Coral Disease', 'Crown of Thorns Starfish', 'Plastic Pollution' and 'Destructive Fishing Practices' (see also subheadings below for full list). Following the methods of Lison et al. (2020), each theme and key point was then systematically searched for in relation to Bali, for example 'Destructive Fishing Practices Bali'. The use of Google Scholar was key here as the term Destructive Fishing Practices AND Bali returned only two references in Web of Science, whereas over 16,000 results were returned from Google Scholar. Relevant papers were selected, normally from the first three pages of results sorted by relevance, based on the examination of the paper title and abstract. Additional grey literature was obtained through local knowledge of many of the authors, as well as contacts with local government departments and NGOs.

3. Results/ Discussion

The most substantial threats to the reefs of Bali are listed and discussed below:

3.1.1. Coral bleaching

Anthropogenic greenhouse gas emissions have led to an increase in atmospheric carbon and average global temperatures (Clark et al. 2020). As a consequence, ocean surface temperatures are thought to have increased by approximately 0.4 - 0.5°C since the 1980s (Pörtner et al. 2014). The ocean has also absorbed approximately half of the anthropogenic atmospheric CO2 emissions in the past 200 years (Raven et al. 2005) and this has reduced the ocean surface pH by more than 0.1 (Pörtner et al. 2014). The increase in ocean temperatures, alongside the reduction in ocean pH has been attributed with worldwide coral bleaching (Heron et al. 2017).

Coral bleaching occurs as a stress response to changes in temperature, and results in a loss of the coral's endosymbiotic dinoflagellates (Lesser 2011), which leads to a decrease in growth rate and fertility and can result in mortalities (Sully et al. 2019; Ampou et al. 2020). Corals have a limited temperature threshold which they are able to tolerate, and localised increases of 1-2 °C can result in severe bleaching events (Ampou 2020). These events are predicted to increase in frequency in the future, and consequently, it is thought that 90% of global coral reefs may be at risk of long-term degradation (Grottoli et al. 2014). After a bleaching event it is possible for a coral reef to recover, but in these situations they are under greater stress and are more subject to mortality from other threats (Normile 2016). If a reef is resilient, it may be able return to its original state after a disturbance (Salm 2005, Ampou et al. 2020), although resilience varies between coral species, with some being more vulnerable to threats than others (Roche et al. 2018). This can be further explained by the research of Foden et al. (2013) which highlighted that 15-32% of coral species have high sensitivity and low adaptive capacity to climate change, and are therefore most vulnerable to climate change. As a result of this, studies have highlighted the loss of the most vulnerable coral species on a reef, resulting a loss heterogeneity and ecosystem function (Strychar et al. 2005).

Coral bleaching has been documented on multiple coral reefs in Bali, including southern reefs in Sanur, Nusa Dua and Serangan (Wicaksana 2020), northern reefs in Buleleng (Suparno et al. 2019, Tito et al. 2019) and the reefs of Nusa Penida and Nusa Lembogan (Prasetia et al. 2017). It is one of the most substantial threats to the reefs of Bali and has been attributed with a loss of live coral cover of 44.4% in North West Bali (Suparno et al. 2019). Coral bleaching is linked with increasing sea temperatures, which in Bali, were on average two degrees warmer in 2016 compared with 2012 (Susiloningtyas et al. 2018), peaking in the January 2016 El Niño event at 32.2°C (Suparno et al. 2019), one of the strongest in history (Lian et al. 2017).

Most recent data has highlighted the occurrence of a bleaching event in May 2020, caused by a significant increase in sea surface temperature, widespread across all of Bali's coasts (Ampou 2020). During this time, South Bali was categorised with a National Oceanographic and Atmospheric Administration (NOAA) bleaching alert of 2, whilst North Bali was categorised with alert 1-2 (Ampou 2020). By NOAA definition, significant bleaching is likely with alert level 1, and severe bleaching and significant mortality is likely for alert level 2. The magnitude of mortalities caused by this bleaching event is currently unknown, but *Scleractinia* (Bourne, 1900) hard corals were documented to have been bleached on the reefs in Les Village, North Bali (Ampou 2020).

3.1.2. Destructive fishing practices

Destructive fishing practices (DFPs) are any method used by fishers that causes direct damage to the surrounding habitat (Bacalso and Wolff 2014). DFPs known to be used in Indonesia include blast (dynamite) and cyanide fishing, inshore trawling and muroami nets (Erdmann et al. 2000). Cesar et al. (1996) discussed that DFPs not only result in exploitation of a local fishery, but also cause substantial physical damage to the surrounding habitat structure (usually hard substrata like corals) on which commercial species depend. Despite being illegal, the use of DFPs is thought to be widespread across Indonesia (Pet-Soede and Erdmann 1998). Estimates suggest that up to 80% of the country's coral reefs have been targeted by DFPs, which are used more frequently in poorer regions, often by communities that are experiencing poverty and/or insufficient fish catches from standard, less destructive techniques (Erdmann et al. 2000). There is limited available information on current use of DFPs in Bali, although it is thought that dynamite fishing, which uses an explosive blast that instantly kills the fish (as well as destroying the surrounding habitat), was still in use in some regions in 2013 (Doherty et al. 2013). Additionally, cyanide fishing, which increases mortality of target and nearby non target species (Madeira et al. 2020), was made illegal under Indonesian law in 1985 (Fisheries Regulation Act, 1985; Halim (2002)). It was previously a widespread method used by ornamental fishers across the island (Frey and Berkes 2014) and was still thought to be in use in 2013 (Doherty et al. 2013). Since experiencing a decline in the health of their coral reefs as a result of cyanide and dynamite fishing, some communities in Bali have replaced their use with more sustainable harvesting methods (Frey 2013).

3.1.3. Plastic Pollution

Worldwide plastic production is thought to have increased from approximately 1.5 million tonnes in 1950 to 322 million tonnes in 2015 (Villarrubia-Gómez et al. 2018). This exponential rise in the global production of plastics, as well as a mismanagement of its disposal, is estimated to have led to between 4.8 and 12.7 million tonnes of plastic entering the oceans per year (Jambeck et al. 2015). The occurrence of plastic debris has now been documented across coastlines worldwide (Barnes et al. 2009). Plastic entering the sea is of global concern due to its persistence in marine environment and its impact on wildlife and potentially humans (Barnes et al. 2009). Marine plastic pollution has also been shown to attract persistent organic pollutants (POPs), and has been linked with the ingestion of these pollutants by marine megafauna (Clukey et al. 2018). Despite these threats, the extent to which plastic pollution is harmful to marine environment is debatable, especially when compared to other threats from climate change and overfishing (Stafford and Jones 2019).

Increased demand for single use plastics (Sur et al. 2018), alongside a lack of expenditure in its waste management (Glaser et al. 2010), has led to Indonesia becoming the world's second largest plastic polluter (Shuker and Cadman 2018). Unsurprisingly, plastic pollution is therefore a substantial issue in Bali (Turak and Devantier 2013, Giesler 2018, Brooijmans et al. 2019). Much of the islands plastic is disposed of by being dumped in rivers or the sea (posing serious direct marine pollution threats (Lestari and Trihadiningrum 2019)) or by being burnt (releasing organic aerosols thought to pose serious risks to human health and the environment (Velis and Cook 2020)). Most recent data on plastic pollution in Benoa Bay, South Bali indicates that microplastics are abundant in Bali's marine environment, being detected in the surface waters of all four research stations (Suteja et al. 2021).

There is currently limited literature which assesses the impacts of plastic pollution on coral reefs in Bali, and it can be assumed that the issues highlighted above can be applied to the situation in Bali. Germanov et al. (2019) used boat trawls in Bali and its neighbouring island of Java, and concluded that plastic abundance in these marine environments ranged from 20,000 – 449,000 pieces km–2, with higher estimates in the wet season due to increased land run off. The same study suggested that reef manta rays (*Mobula alfredi;* Krefft 1868), which are listed as vulnerable on the International Union for Conservation of Nature (IUCN) red list (Marshall et al. 2019), may ingest between 110 and 980g of plastic for every kg of plankton. The bio accumulative ingestion of plastics by manta rays and other mega faunal filter feeders has been shown to cause endocrine disruption, as well as altering reproductive fitness and potentially offloading toxicity from a mother to her offspring (Germanov et al. 2018). Despite the limited literature available, it is clear that that marine plastic pollution is a substantial issue to the marine ecosystems of Bali. More research is required to quantify the extent of this threat.

3.1.4. Crown of Thorns Starfish

Outbreaks of the Crown of thorns starfish (CoTS; *Acanthaster planci;* Linnaeus, 1758), are a substantial threat to coral reef ecosystems (Deaker et al. 2020). CoTS are coral eating invertebrates native to the Indo-pacific. They are not considered a substantial threat in 'normal' reef populations, however their numbers can increase dramatically due to an increase nutrient supply (Brodie et al. 2005). This is thought to occur because nutrient loading increases phytoplankton abundance, which provides a reliable food source for CoTS larvae (Fabricius et al. 2010). Brodie et al. (2005) showed that when phytoplankton concentrations double, CoTS' chance of survival to adulthood can increase almost ten-fold.

CoTS outbreaks have resulted in a 50% loss of coral cover on some reefs in Indonesia (Plass-Johnson et al. 2015). Multiple studies have highlighted the threat of CoTS within North West Bali. Suparno et al. (2019) documented CoTS populations within Bali Barat National Park (BBNP) in North West Bali in 2016 and suggested that their presence may be due to effluent from a local shrimp farm. Doherty et al. (2013) discussed how outbreaks of CoTS, as well as the coral eating drupella snail (D*rupella cornus;* Röding 1798) which are known to cause similar impacts (Al-Horani et al. 2011), have resulted in mass deaths of corals around Menjangan Island, in North West Bali. A more recent study of Menjangan Island, has shown that CoTS outbreaks are predicted to occur during Bali's wet season due to increased nutrient loading (Pradisty et al. 2020). There are multiple community projects and Non-Government Organisations (NGOs) that work to remove CoTS in Bali. Some of this is documented within literature, such as the 1997 programme in BBNP, which removed more than 700,000 CoTS individuals (Boekschoten et al. 2000).

3.1.5. Coral disease

Outbreaks of coral diseases have caused devastating mortalities to reefs around the globe (Walton et al. 2018) and are increasing with frequency and severity (Maynard et al. 2015). 'White Syndromes' (WS) are described as the most destructive and widespread group of worldwide coral diseases (Bruno et al. 2007, Hobbs and Frisch 2010), and have been associated with mortalities as high as 96% of *Acropora* (Oken, 1815) plate corals on some coral reefs (Hobbs and Frisch 2010). Coral diseases are associated with mortalities of corals in reefs on the Great Barrier Reef, Red Sea, Caribbean, Philippines (Williams and Miller 2005, Aronson and Precht 2006, Hobbs and Frisch 2010).

Coral diseases also appear to also be widespread across reefs in Indonesia's national marine parks and on its most diverse reefs (Johan et al. 2015, Ampou et al. 2020). They are documented in Bali, on reefs in Buleleng (Karim 2019, Suparno et al. 2019) and Nusa Penida (Ampou 2018), although research on this is relatively limited. Most literature on coral disease in Bali/ Indonesia appears to have been undertaken in the past two decades. This is likely because coral disease is thought to be a relatively recent issue, perhaps because it is linked with rising sea temperatures (Aeby et al. 2020, Ampou et al. 2020), which has also gained more research attention in recent decades (Pörtner et al. 2014). The link between coral diseases and thermal stress has been further studied by Bruno et al. (2007), who found a highly significant relationship between rising sea temperature and increased emergence of coral disease outbreaks. Current literature suggests that coral diseases, alongside bleaching, are one of the greatest threats to some of Indonesia's coral reefs (Subhan et al. 2020). More research is required to identify the causes of coral disease outbreaks, as well as quantifying their overall threats and outlining potential management methods.

3.1.6. Damaging SCUBA practices

The tourism sector makes up approximately 68% (in 2014) of Bali's GDP (Antara and Sumarniasih 2017). According to Gerungan and Chia (2020), Bali has some of the best SCUBA diving sites in South East Asia, which are an important source of income for coastal communities (Tapsuwan and Rongrongmuang 2015). For example, one of Bali's most famous dive locations, Tulamben in North East Bali, has 14 dive centres that generate income for a village (in the poorest region of Bali) that was previously almost entirely reliant on subsistence fishing (De Brauwer et al. 2017).

Dive tourism, however, has been associated with environmental consequences when there is a lack of management (Haddock-Fraser and Hampton 2012). One of the most substantial ecological impacts of dive tourism is the physical damage to corals caused by divers who lack experience or respect environmentallyconscious dive practices (Davenport and Davenport 2006). Divers swimming too close to the sea floor can stir up benthic sediments, which smothers the corals (Abidin and Mohamed 2014). Coral skeletons may also be broken if divers step on or accidentally collide with them (Mastny 2001). In both cases, this is thought to negatively affect the coral's biological processes, including growth and sexual reproduction (Davenport and Davenport 2006). Another environmental impact of dive tourism is overfishing/exploitation of a local fishery, as the demand for fish increases in tourist restaurants (Tompkins 2003).

There is existing literature that assesses the impact of dive tourism on the coral reefs of Bali. Suparno et al. (2019) discussed how SCUBA diving activities across the island have been correlated with structural damage of coral reefs. A substantial increase in broken and upturned corals between 2002 – 2011 was observed in Bali Barat National Park dive sites by Doherty et al. (2013), who attributed this to diving boats having inadequate access to mooring buoys, and instead using anchors which destroy the corals. Gerugan and Chia (2020) highlighted how scuba dive tourism at one of Bali's most famous dive sites, 'Manta Bay', in Nusa Penida is poorly managed by dive centres, and consequently frequently reported stepping on or colliding with corals. The same study interviewed local people, who agreed that dive tourism has contributed towards the degradation of the 'Manta Bay' coral reef.

Despite tourism being associated with the degradation of corals, it is thought that it may be helping to protect the charismatic species that gives 'Manta Bay' its name. Manta rays (*Mobula alfredi;* Krefft 1868) are heavily fished in some parts of Indonesia (Lewis et al. 2015). There is also a large international demand for non-consumptive manta ray dive tourism, which is calculated to have an industry value of USD $140 million per year worldwide (O'Malley et al. 2013). It is thought that manta rays may be worth up to $1 million when they are alive (through the tourism income they generate), compared to $500 when they're fished (Hani et al. 2019). In sites like 'Manta Bay', dive tourism (and the income generated from it) provides a compelling reason to protect *Mobula alfredi* (Krefft 1868), and is the main driver of strict regulations which prohibit all extractive activities. Hani et al. (2019) commented that sustainable manta ray dive tourism at 'Manta Bay' and other sites in Indonesia requires strict governance, adequate regulations/enforcement and collaborative management.

A study by Piskurek (2001) assessed the sustainability of dive tourism in Pemutaran, North West Bali. The study concluded that divers cause very little damage to the Pemutaran reef, especially when compared to the threats caused by pollution and overfishing. The contrasting results of this study may be due to the stricter diving regulations limiting the number of divers permitted on the reef, as well as mooring buoys to stop boats anchoring and rest stations for tired divers and snorkellers (to reduce stepping on corals). This case study provides a promising example amongst many negative ones, that the ecological consequences of dive tourism can be reduced with adequate management.

3.1.7. Nutrient Enrichment

A decline in coral reef health is frequently linked to nutrient enrichment (Szmant 2002, D'Angelo and Wiedenmann 2014). Although the in-situ effects are mostly non-lethal and modest (Koop et al. 2001), research has shown that the increase of nutrients level can lead to coral diseases (Bruno et al. 2003, Voss and Richardson 2006, Vega Thurber et al. 2014, Lapointe et al. 2019), coral bleaching (D'Angelo and Wiedenmann 2014, Vega Thurber et al. 2014, Lapointe et al. 2019), outbreaks of CoTS (Fabricius et al. 2010), a decrease of coral growth (Ferrier-Pagès et al. 2000, Loya et al. 2004, Lapointe et al. 2019) and phase shifts to algae dominated reefs (Baum et al. 2016, Adam et al. 2021). Nutrient enrichment has been highlighted as an issue in Bali, due to high concentrations of nitrates and phosphates from river discharge; however there have only been a few studies in Indonesia which explore the link between nutrients enrichment and coral decline (e.g. Baum et al. 2015, 2016; Faizal et al. 2020), and no such studies are known in Bali. More research in Bali is required to quantify water quality, and study its link to coral health.

3.2. Threats to Bali's reefs: an island perspective

It must be noted that the threats to Bali's reefs vary spatially across the island, and also vary in terms of their severity/associated consequences. For example, CoTS outbreaks have only been documented in the reefs in North West Bali (Doherty et al. 2013) and there is no other literature to suggest that they threaten reefs in other regions of the island. Similarly, SCUBA diving activity is limited to a few dive sites. It is not known to occur on a large proportion of the islands reefs and is therefore of limited threat to the islands total coral reef biodiversity.

Half of Bali's corals are thought to remain unbleached (Wickasana 2020), and it appears that the severity of bleaching may be far worse in other countries. Coral bleaching is now generally accepted as the primary threat to coral reefs globally (Boström-Einarsson et al. 2020) and has been linked with severe coral mortalities on world heritage listed reefs around the world (Heron et al. 2017). The great barrier reef (GBR) in Australia may be most affected by bleaching in terms of total coral losses (Lewis and Mallela 2018). It is of importance to mention this, and to highlight how the total bleaching of Bali's reefs appears to be relatively low compared to other parts of the world.

3.3. Marine restoration and conservation

'Ecological restoration' is defined as "the process of assisting the recovery of an ecosystem that has been degraded, damaged, or destroyed" (SER 2004). In comparison, 'ecological conservation' is a slightly broader term, which incorporates preservation and protection, as well as restoration (Parsons et al. 2017). So far, this literature review has discussed some of the main threats to Bali's coral reefs. The remainder of this review will now focus on the restoration and conservation of coral reefs, whilst specifically looking at what has been undertaken, both past and present, globally and in Bali. We discuss methods used, and evaluate their overall successes and failures.

3.3.1. Climate change mitigation

As previously highlighted, coral bleaching is generally regarded as the greatest global threat to coral reefs (Boström-Einarsson et al. 2020). Therefore, effective coral reef conservation should include a global mitigation of climate change through aggressive and large reductions in greenhouse gas emissions (Ben-Romdhane et al. 2020). The 2015 Paris Agreement is the most recent international treaty to address climate change, and includes an agreement, signed by 196 countries, which aims to limit global warming to well below 2 degrees compared to pre-industrial levels (Schurer et al. 2018). As highlighted by the IPCC, climate change mitigation will require global efforts to reduce net emissions from energy supply, transport, buildings, industry, agriculture and land/ natural resource use (Edenhofer et al. 2014).
The 2020 European Commission report on global greenhouse gas (GHG) emissions ranks Indonesia's as the 9th highest greenhouse gas emitter compared to the rest of the world (Crippa et al. 2020). The same report highlighted how Indonesia's total GHG emissions are still 58x lower than China's and 18x lower than the US'. Indonesia is one of the world's largest producers and exporters of coal (Dwiki 2018) and it is deforesting its rainforests faster than any other nation (Tacconi et al. 2019). Whilst it is out of the scope of this review to provide an in-depth assessment of Indonesia's climate change contributions and mitigations, it must be noted that Indonesia has joined the Paris Agreement, and alongside other newly developed countries, it aims to reduce emissions by 29% by 2030, compared to a business-as-usual scenario (Wijaya et al. 2017). Indonesia has recently declared it aims to reach net-zero emissions by 2070 (van Soest et al. 2021), a target which has been criticised as unambitious by activities and other governments.

3.3.2. Coral reef conservation initiatives

Global initiatives are not just limited to climate change, they also exist to directly protect the world's coral reefs. Previous examples include the 1992 convention on Biological Diversity (Bell 1992) and the 2000 International Coral Reef Network (ICRAN) (Ben-Romdhane et al. 2020). A more recent initiative is the 'Aichi Targets', a strategic plan to conserve international coral reef biodiversity developed at the 2011 – 2020 Convention of Biological Diversity (Leadley et al. 2014).

As well as global greenhouse gas emission reductions and international coral conservation initiatives, multiple small/medium scale tools may be considered to conserve, restore and increase the resilience of coral reefs. These methods may include coral transplantation (Endo et al. 2008, Onaka et al. 2013, Barton et al. 2017, Baria-Rodriguez et al. 2019), building coral nurseries with coral species that are resistant to bleaching (Camp et al. 2017, Morikawa and Palumbi 2019), community development and education (Sigit et al. 2019), marine protected area establishment (Edgar et al. 2014, Zhao et al. 2020), genetically modifying reef building corals

(Cleves et al. 2018), constructing artificial reefs (ARs) (Bohnsack and Sutherland 1985, Baine 2001, Keller et al. 2017) and coral microbiome manipulation (Rosado et al. 2019). Whilst these methods may be unable to conserve large-scale ecosystem function and processes (Pörtner et al. 2014), they have been shown to provide some degree of protection at a localised level and in some cases, restore ecosystem services in areas which have lost reefs. Each method varies in terms of its overall effectiveness, implementation feasibility and how well researched it is. The remainder of this review will discuss what is being done to restore and conserve Bali's reefs, and how this relates to what is being undertaken on a global scale.

3.3.3. Marine Protected Areas

Marine Protected Areas (MPAs) impose regulations on marine areas as a natural conservation and social management tool to enhance the ecological resilience of a marine area (Costello 2014). The designation of MPAs is increasing worldwide (Edgar et al. 2014) and the IUCN has recently called for the 'full protection' of 30% of the worlds oceans by 2030 (Zhao et al. 2020), due to their global importance in protecting marine ecosystems from the effects of human exploitation and activities (Perez et al., 2017; Marcos et al. 2021). 'Full protection' MPAs are areas which are completely closed off to all extractive and potentially harmful activities, and as highlighted by Perez et al. (2017) provide three main benefits: (1) preserving of biological diversity at a regional level, (2) allowing the natural variability of the system to be differentiated from the effects of regulation and to be integrated in to sampling schemes as controls, and (3) maintaining the natural size and age structure of natural populations and therefore maximizing potential fecundity. However, MPAs may fail to reach their targets, with Marcos et al. (2021) discussing how many existing MPAs are mere "paper parks", where legislation is not enforced, necessary enforcement does not exist and management planning is lacking.

Indonesia's Ministry of Marine Affairs and Fisheries has established marine reserves which aim to protect marine biodiversity, whilst supporting sustainable fisheries and tourism (Ruchimat et al. 2013). However, it is thought that less than 15% of the country's MPAs are functionally meeting their management objectives (Burke et al. 2012). Marine reserves in Bali have undergone multiple successes and failures since their inception in the 1970s (Polunin et al. 1983). Some of the first reserves such as BBNP in West Bali (Polunin et al. 1983), as well as Ambon reserve at Pombo Island in North East Indonesia (Sumadhiharga 1977) were unsuccessful in achieving their aims. In situations like these, DFPs and other ecologically-harmful activities continue unregulated within the reserve, as seen with multiple examples in Indonesia (Robinson et al. 1981).

Table 1: Summary of Bali's three officially designated marine protected areas.

Location	Size	Details	Ecological successes / failures	Community perception
Bali Barat National Park, North Bali	34 km^2 (Mahmud et al. 2016)	This was Bali's first MPA, which was established in the early 1970s (Polunin et al. 1983). The MPA uses a zoning system, which includes core zones, marine protected zones, utilisation zones and traditional zones (Mahmud et al. 2016).	Suparno et al. (2019) showed that between 2011 - 2016 fish biomass had doubled on average across the MPA. However, in some areas of the reserve, regulations were poorly enforced and the use of DFPs continued to occur (Doherty et al. 2013). Suparno et al. (2019) discussed that the unclear boundaries in the MPA has resulted in non-compliance with regulations. Suparno et al. (2019) also revealed that between the same dates, the reserve had lost 44.4% of its living coral cover. This coral mortality was primarily associated with the 2016 global bleaching event.	The majority of local fishers believe the health of the reef ecosystem within the MPA had worsened since 2010 (Pedju 2018), likely due to coral bleaching (Suparno et al. 2019) and stakeholder noncompliance (Doherty et al. 2013).
Pemutaran, North Bali	*Unknown*	The Pemutaran village notake-zone was established by a community conservation organisation in 2003, and was given official MPA status in 2014 (Pedju 2018). The MPA's regulations were established and are enforced by the community (Bottema and Bush 2012).	The MPA is part of an integrated local conservation initiative, which includes other projects, including a turtle hatchling conservation centre (Suparno et al. 2019) and the Biorock TM artificial reef programme (Hilbertz and Goreau 1996). This community work has received multiple UN coastal management awards (Trialfhianty 2017) and has resulted in a substantial increase in Pemutaran's marine biodiversity (Jamison 2009). This example highlighted the potential role of the private sector within Bali's marine reserves (Bottema and Bush 2012).	The majority of local fishers believe the health of reef ecosystem within the MPA had improved since 2010 (Pedju 2018).
Nusa Penida Island, East Bali	20 km_2 (Yunitawati and Clifton 2019)	Established in 2010 (Daulat et al. 2019), the marine reserve protects15 km^2 of coral reefs and hosts charismatic marine megafauna which attracts over 200,000 tourists per year (Ruchimat et al. 2013). The Nusa Penida marine reserve uses a five-tier zoning system, which	Ruchimat el al. (2013) criticised the lack of clear zone boundaries within the MPA, and commented that this has led to certain stakeholders not complying with the regulations. Despite this, initial surveys of the MPA recorded a doubling of fish biomass between 2010 – 2012 (unpublished data, discussed by Yunita and Clifton (2019)). Since then, there has been a lack of follow up surveys, so it is difficult to draw further conclusions. Yunita and Clifton (2019) also discussed how coral cover within the reserve has remained stable at around	The majority of local fishers believe the health of reef ecosystem within the MPA had improved since 2010 (Pedju 2018).
		includes a core zone, marine tourism zone, special tourism zone, harbour zone, sustainable fisheries zone, seaweed farming zone and a holy zone (Ruchimat et al. 2013).	70% between 2011 – 2016, which would be considered 'excellent' condition by Indonesia's standards (Zamani and Madduppa 2011). Weeks et al. (2014) commented that other progress within the reserve includes the development of a longterm management plan, strict enforcement through regular patrols and the establishment of a multi stakeholder task force. The reserve also has a designated learning site which offers training on MPA principles, zone planning, financing and general management.	

Table 1 outlines the successes and failures of Bali's three official MPAs. Despite challenges associated with lack of clear zonation and user non-compliance, it is evident that the three MPAs within Bali have contributed towards the conservation of the marine environment, although some have been more successful than others.

3.3.4. Artificial reefs

ARs are structures built of natural or man-made materials which are designed to protect, enhance, or restore components of marine ecosystems (Baine 2001). Once placed on the sea floor, ARs can restore a previously degraded and/or unproductive ecosystem by providing previously unavailable resources for both juvenile and adult species (Becker et al. 2017, Israel et al. 2017). It is of general agreement that ARs are effective at attracting fish and thus, can be important within fisheries management (Bohnsack and Sutherland 1985). However the 'attraction versus production' debate (Pickering and Whitmarsh, 1997) remains topical within current AR literature (Roa-Ureta et al. 2019). The debate is centred on whether ARs actually increase net production of a site, or whether they merely cause attraction and redistribution of already existing individuals (Brickhill et al. 2005).

Baine et al. (2001), discussed that as well as restoration and conservation, ARs have multiple other purposes in coastal management. Some of these include increasing fisheries yield (Bohnsack and Sutherland 1985, Keller et al. 2017), boosting dive tourism (Kirkbride-Smith et al. 2016, Bideci and Cater 2019), coastal protection (Harris 2009) and preventing bottom trawling (Fabi and Spagnolo 2011). Literature has demonstrated the potential of ARs to mitigate habitat loss (Baine 2001), increase larval and juvenile recruitment, survival, and growth (Bohnsack and Sutherland 1985) and maintain biodiversity in marine systems (Becker et al. 2017).

3.3.4.1. Artificial reefs in in Bali

The first officially reported instalment of ARs in Indonesia was the 1989 deployment of 60,000 units in Jakarta Bay (Azis 2010, cited by Puspasari et al. (2020)). AR deployment in Bali's marine environment is now widespread, from the coastal seas of Bali's largest tourism hubs, such as Nusa Dua, to some of Bali's poorest regions like Buleleng and Karangasem (Puspasari et al. 2020). The materials used to build Bali's AR structures vary greatly, with some of the most common including concrete substrate blocks, reef balls and Biorock (Global Coral Reef Alliance, Cambridge, MA). Multiple organisations are responsible for the deployment of ARs in Bali, including international NGOs, community groups, village governments and the central government. The use of ARs as a habitat enhancement tool is becoming widespread within Indonesia. A restoration programme in Buleleng, North Bali, extending across 6 villages, built and deployed 13,000 AR structures in 2020 (LINI 2021).

The current Indonesian government is committed to protecting its coral reefs, and will invest 1.5 trillion IDR (Approximately 105 million USD) in labour intensive coral reef restoration activities like artificial reef deployment and coral monitoring (Karunia 2021). From this fund, 111.2 billion IDR (Approximately 8 million USD) will be spent on coral reef restoration in Bali, in areas including Sanur, Serangan, Pandawa and Buleleng (Wicaksana 2020). It is thought that this investment will employ 11,000 workers in Bali.

The ecological success of ARs can be categorised by benthic species and mobile species, and factors which can impact this success are highlighted in table 2. With regard to benthic species, studies in Bali and wider Indonesia showed mixed results in terms of ARs potential to increase abundance and diversity. For example, in Seribu Islands, close to Jakarta, Azis (2010), as cited by Puspasari et al. (2020), showed that coral cover only increased 6% from the initial condition after 10 years of AR instalment. In contrast, ARs in Jemeluk Bay, Karangasem, Bali, increased coral cover by 59% over 15 years (Hartati 2017). With regard to mobile species, ARs in Bali have demonstrated potential to significantly increase abundance and diversity. The ARs of Jemeluk Bay, North East Bali, displayed a 3.2x increase in number of fish species and a 25.6x increase in fish abundance 10 years after deployment (Puspasari et al. 2020). Similarly, Syam et al. (2017) showed that the ARs of Lebah, North East Bali, attracted 267 fish species over a 10 year period.

Table 2: Factors which impact diversity and abundance of benthic and mobile species on artificial reefs, based on both Indonesian and international literature.

Factor	Impacting diversity and abundance of:	Explanation	'Best practice' suggestion for creating the artificial reef
Angle of the substrata	Benthic species	Perkol-Finkel et al. (2006) discussed how coral recruitment on AR is usually higher on vertical or inclined surfaces. This is because horizontal ARs are thought to have higher sedimentation levels (as sand can more easily settle on a flat surface), making it more difficult for coral larvae to attach themselves (Clark and Edwards 1999).	Create ARs with vertical or inclined surfaces (PerkolFinkel et al. 2006).
Structural complexity	Benthic species	Coral larvae more successfully settle on complex AR surfaces that are easier to grip and become attached to (Carleton and Sammarco 1987).	Create ARs with high structural complexity (Perkol-Finkel et al. 2006, Herbert et al. 2017).
	Mobile species	ARs are more likely to attract mobile species if they are designed with structural features that mimic those of natural reefs (Komyakova et al. 2019). These structural features commonly include hiding spaces, more than one exit, shadow against light, high surface area and hollow interior spaces (Baine 2001). ARs that are created with these features will increase colonisation of juvenile fish (that require protective space), as well as attracting spawning adults (that require a textured surface to lay eggs) (Perkol-Finkel et al. 2006, Herbert et al. 2017).	
Composition of AR	Benthic species	The composition of surface substrata, in terms of chemistry and toxicity is thought to affect coral settlement (Baine 2001). For example, the use of rubber tyres as ARs has been associated with the leaching of heavy metals, which are toxic to benthic invertebrates (Collins et al. 2002).	Create ARs with nontoxic materials. Concrete is generally the most favoured building material (Baine 2001).

Age of AR	Benthic species Mobile species	Coral cover on ARs will increase as the corals grow over time (Wenker and Stevens 2020). ARs may take up to one century to mimic natural reefs in terms of coral cover (Perkol-Finkel et al. 2005). Unpublished data from The Indonesian Nature Foundation (as discussed by Puspasari et al. (2020)), showed that 15 month old ARs had four times higher coral recruitment than 7 month old ARs. These ARs were deployed in Buleleng, North Bali. Colonisation rate of mobile species onto artificial reefs is generally greatest within the first few months after deployment, and decreases with time (BaileyBrock 1989, Pickering and Whitmarsh 1997, Arney et al. 2017).	Allow time for colonisation of the AR. Regularly monitor the programmes ecological success and change methods/ objectives if necessary (Boström and Einarsson et al. 2020).
Location of AR	Benthic and mobile species	Shortly after development, it is expected that species from other reefs will colonise the AR (Koeck et al. 2011). Komyakova et al. (2019) suggests if the ARs are spatially isolated from other reefs, then they may be undetected by species looking for new habitats, and this will limit colonisation. This applies to benthic and mobile species at larval and adult life stages. Location is also an important factor, as the environmental conditions (e.g. wave action, temperature, depth and water quality) of a particular area may influence the ecological success of the AR (Baine 2001).	Create ARs that are close to natural reefs and/or built with corridors to allow species to move between reefs (Relini et al. 1994). Monitor the AR to ensure that deployment area is suitable (Baine 2001).
Fishing pressure	Mobile species	ARs are likely to reach their full potential (in terms of increasing diversity and abundance) when they are not subject to fishing pressure (Addis et al. 2016). Syam et al. (2017) described how most ARs within Bali are regularly fished, and target commercial species are therefore frequently missing. This can be problematic in situations where functional species are missing, such as marine mesopredators like black tip reef sharks (*Carcharhinus limbatus;* Muller and Hënle, 1839), which are thought to be overfished across Indonesia (Sembiring et al. 2015). The loss of sharks on a coral reef has been shown to alter the food chain below it, leading to potential declines in populations of herbivorous fish (Ruppert et al. 2013). Herbivorous fish are fundamental to the dynamics of reef communities as they reduce algal cover and provide corals more space to colonise benthic habitats (Estes et al. 2011), and the loss of these species on an AR may result in changes to ecosystem function and processes.	If possible, deploy the ARs within an MPA (Addis et al. 2016).

3.3.4.2. ARs and tourism related socio-economic benefits

ARs provide experiences to non-consumptive recreational marine users, such as divers, anglers and snorkellers (Stolk et al. 2005). AR marine tourism is thought to have multiple benefits, as discussed by Stolk et al. (2007):

1. Redistribution of tourists away from natural reefs. This can be help to reduce the threats associated with dive on coral reefs as discussed in section 1.5.
2. Highly valued experiences to tourists, which can be easier to access than natural reefs. ARs such as shipwrecks can provide exciting and unusual dive experiences
3. Generation of revenues which can be used to employ communities and further develop ecologically beneficial programmes.

Bali has multiple AR dive tourism sites. Pemutaran, in North West Bali, hosts an AR which is one of Bali's most popular dive sites (Trialfhianty 2017). This is a Biorock™ AR programme, which has led to Pemutaran becoming a highly popular dive tourism site and its communities have successfully used tourism income to develop multiple coral reef restoration programmes (Trialfhianty 2017). The effectiveness of this AR in attracting dive tourism was highlighted Budisetyorini and Cahyani (2016) who showed that approximately 70% of tourists primarily visit Pemutaran to see the AR structures.

3.3.5. Decentralisation policy and NGOs

The Indonesian Decentralisation Policy (Act No.33), which established in 2004, gave greater authority, political power, and financial resources directly to local regencies and municipalities (Soejoto et al. 2015) and promoted the role of NGOs in pursuing conservation objectives (Atmodjo et al. 2020). The Decentralisation Policy has enabled and encouraged support from NGOs following the identification of an emerging threat to marine diversity within Indonesia. For example, Raja Ampat, the global epicentre for coral reef biodiversity, underwent vast developments in fisheries and oil/gas extraction in the early 2000s, posing substantial threats to internationally protected marine species including sea turtles and cetaceans (Mangubhai et al. 2012). This, alongside the newly implemented Decentralisation Policy, prompted conservation efforts from international NGOs like 'Conservation International' and 'The Nature Conservancy'. A large proportion of NGO effort in Bali is focused on the plastic pollution problem. Examples of this includes 'EcoBali', which offers plastic collection services and 'BYEBYEPLASTIC' which organises beach cleans and works with communities and the government to reduce the production and consumption of plastic products (Brooijmans et al. 2019).

3.3.6. Factors that influence community engagement

Tightly knit fisher communities are a common feature of coastal villages in Bali because fisher groups frequently gather for the planning and implementation of regular community events and religious ceremonies (Ginaya 2018). The involvement of these community groups is important for the success of a sustainable coral reef management programme in Bali (Suadi 2009). There are multiple factors that contribute towards community participation in a marine conservation programme. These are described in table 3.

Table 3: Factors which can influence community engagement in a conservation programme.

Factor	Explanation	Bali/ Indonesia example
Perceived personal benefit	The level of personal benefit is thought to be a substantial factor determining communities willingness to participate in a conservation programme (Berkes 2010). *Note:* It can be problematic if support for marine conservation is driven purely by financial gain, because motivation to continue supporting the programme's objectives may reduce with a decrease in financial gain (Stem et al. 2003).	Berkes (2010) conducted interviews with fishers that participate in the 'Yayasan Alam Indonesia Lestari' (LINI) coral reef conservation NGO, based in Les Village, North Bali. From the interviews, it was clear that fishers efforts were not merely for conservation, but largely for an improvement of their livelihoods, such as increased fishing yields.
Education	Educational programmes that increase local people's knowledge of sustainable resource management have been shown to increase	Leisher et al. (2012) demonstrated that educating local communities about the ecological and socio-economic benefits of marine protected areas (MPAs) within Raja

	community participation in marine conservation projects. This is discussed by Hines et al. (1987), who highlighted that outreach programmes like these can lead to an increased individual sense of responsibility in taking care of their resources.	Ampat, Indonesia, led to a substantial increase in community compliance and active participation. The study suggests that investments in MPA education and outreach is an effective tool to engage communities in conservation objectives.
Meeting community needs	Inclusion of the community in marine conservation decision-making determines how motivated they are to participate in the programme and/or contribute towards achieving its objectives (Lundquist and Granek 2005). When local fishers feel their livelihoods are not considered within the establishment of an MPA, they are likely to ignore regulations and fish illegally (Lundquist and Granek 2005), which will undermine the project's success (Campbell et al. 2012).	Elliott et al. (2001) discussed this concept in terms of the Wakatobi Marine Park in Eastern Indonesia. In 1996, the marine park established zoning regulations and fishing restrictions which were criticised for not considering the livelihoods requirements of the local Sama-Bajo fishers. Glaser et al. (2010) discussed how MPAs in Indonesia have greater potential when they are developed and enforced by local people, with regulations that protect nature whilst considering the needs of the community.
Influence from local leaders	The success of marine resource management programmes often rely on support from influential local leaders(McLeod and Palmer 2015), which may 'bridge the gap' between local people and marine conservation objectives (Trialfhianty 2017).	Frey and Berkes (2014) concluded that local leaders, associated with the 'LINI' NGO in Les Village, North Bali, made great contributions towards encouraging local fishers to stop using cyanide. The study discussed how the widespread use of cyanide fishing bought the Les Village reef to the brink of collapse in 2006, but through the gradual phasing out of this technique, the reef was restored to relative health. It is now understood, that with the help of local leaders, fishers in Les Village have developed a sense of ownership over protecting their reef, and trust one another to not use cyanide. This case study provides a striking example of how community action, particularly with the help of local leaders, can generate positive environmental change on the reefs of North Bali.

3.3.7. Marine Ecotourism

Bali was visited by 3.5 million international tourists and 7.3 million domestic tourists in 2018 (Wardana et al. 2018). Despite the vast economic benefits tourism has bought to the Bali, it has been criticised for destroying the islands rich culture and high biodiversity (Tomomi 2010, Byczek 2011). For example, certain villages within South Bali were previously recognised for religious ceremonies and traditional music, however since the influx of tourism, these locations have been criticised for losing their cultural heritage and are now associated with westernised drinking and drug problems (Tomomi 2010). Tourism in these areas have been predominantly facilitated by large hotels and mega-resorts, which are owned by ex-patriots and provide limited benefits to local people. Mass tourism within Bali has also been associated with water pollution due to insufficient waste management, as well as water scarcity and loss of ecologically diverse and agriculturally productive land (Chong 2020).

Ecotourism can be defined as responsible travel to natural areas that conserves the environment and sustains the well-being of local people (Wall 1997). Global literature has highlighted that the influx of ecotourism can provide economic opportunities to areas with high unemployment (Garrod et al. 2003, Shani et al. 2012). For example, the coastal village of Kaikoura in New Zealand, was transformed from an economically depressed area to one with a successful ecotourism industry focused primarily around marine mammal tours (Orams 2002). Volunteer tourism is also considered a form of ecotourism which involves individuals undertaking an organised holiday that includes some form work to help the destination's local community or restore its environment (Wearing 2001). Many international volunteer organisations exist that aim to facilitate this type of work, and an example includes the 'Marine Conservation Cambodia' project, which hosts international volunteers who assist in activities aiming to conserve endangered sea horses in the area of Koh Rong in Cambodia (Kitney et al. 2018).

Table 4: Examples of ecotourism projects contributing to marine conservation in Bali.

Ecotourism Project Title	Conservation Issue:	Conservation Activity	Overall Success:
'Turtle Conservation and Education Centre' (TCEC) in Serangan Island, South Bali.	-30,000 turtles poached per year around Serangan Island (Tomomi 2010). Poaching offers high incomes to local people as turtles are highly desired for Balinese Ceremonies (McLeod and Palmer 2015). -Development of tourist resorts lead to the loss of suitable turtle nesting sites (Tomomi 2010).	-Offering educational sessions encouraging the public not to consume turtle products (Tomomi 2010). -Providing live turtles for religious ceremonies without killing them (Tomomi 2010). -Donations collected from tourists which used for activities (and employment of local people) that protect sea turtles.	-Tomomi (2010) concluded that ecotourism is expected to be the most effective way to protect turtles around Serangan Island. However (at the time of the study) incomes raised from ecotourism were insufficient in providing alternative livelihoods for turtle poachers, and ecotourism was far from preventing the illegal turtle trade.
'North Bali Reef Conservation' (NBRC) in Karangasem, North Bali.	-Widespread coral reef destruction, mostly due to the anchoring of fishing boats (NBRC 2019). - Substantial marine plastic pollution issue due to overconsumption of single use plastics and lack of waste management infrastructure (NBRC 2019).	- Developing a volunteer-tourism programme, where international volunteers worked with local fishers to: - Build and deploy over 3000 artificial reef units. - Start a community plastic recycling centre -Run ongoing plastic awareness educational school programmes (NBRC 2019).	-After approximately one year, the artificial reefs were shown to have 5-6x higher fish biodiversity compared to a nearby control site (NBRC 2019). -Successful establishment of North Bali's first community run plastic recycling centre (NBRC 2019). There is currently no data on whether this has been effective in reducing marine plastic pollution.

Pemutaran Reef Restoration	-Between 1980 – 2000, Pemutaran was thought to be one of the poorest villages in Bali. Its severe poverty contributed towards fishers use DFPs, which resulted in a widespread destruction of local reefs (Trialfhianty 2017).	-Using ecotourism to provide alternative jobs to (DFP) fishers, who were consequently able to earn much higher incomes. -Establishing ecotourism allowed the development of marine conservation projects, including a turtle hatchling conservation (and adult rehabilitation) organisation (Suparno et al. 2019) and the Biorock ™ artificial reef programme (Hilbertz and Goreau 1996).	-Marine conservation projects shown to be an important driver of ecotourism in Pemutaran (Trialfhianty 2017). These projects are also dependant on ecotourism, as it often provides their main source of funding. -Pemutaran is an example highlighting how marine conservation and ecotourism can work together synergistically to improve ecosystems and livelihoods of in Balinese coastal communities.

Ecotourism has demonstrated potential as a marine conservation tool, as highlighted with examples in Bali in table 4. Ecotourism in Bali is thought to have started in the 1980s and has become increasingly favoured by tourists in recent years (Tomomi 2010). Astarini et al. (2019) demonstrates that the tourism market in Bali is moving towards sustainable ecotourism and suggests that Karangasem, one of Bali's poorest regions, is well suited to develop this industry. Some small scale eco-tourism projects have already been established in this region, such as the Tenganan ecotourism village, which puts particular emphasis on protecting its local highly biodiverse flora and fauna (Karmini 2020), or Jasri village, which received Indonesia's 2013 Village Tourism award for its work developing tourism in a manner that preserves local Hindu culture (Amerta 2017).

Assuming it is appropriately managed so that local ecology and culture are well preserved, ecotourism has great potential in bringing some of Bali's poorest regions out of poverty (Byczek 2011) whilst providing ecological benefits such as supporting conservation and restoration (Tomomi 2010, NBRC 2019). Research has shown that in terms of attracting environmentally minded consumers, it is important for Bali's ecotourism businesses to demonstrate genuinely sustainable practices, rather than just using the word 'eco' as a meaningless marketing tool (Mahyuni et al. 2020). In 2016, the Indonesian Ministry for Tourism established Regulation No. 14/2016, which demands that all ecotourism projects advertised as 'sustainable', should accommodate local community empowerment, cultural preservation, and environmental conservation (Sugiri and Mahyuni 2019). After a recent temporary suspension of tourism in Bali due to the covid-19 pandemic, it is hoped that upon reopening, Bali transitions into more, genuinely sustainable forms of tourism (Stafford and Choe 2020).

3.3.8. What else could be done to protect Bali's reefs?

So far, this review has highlighted some of the main tools used to restore and conserve Bali's coral reefs. Ben-Romdhane et al. (2020) discussed international best practices in terms of the effective management of coral reefs, using examples like Australia (GBR), Belize, Bermuda and the Cayman Islands. When comparing marine conservation between these 'best practice' example nations and Bali, it is clear that Bali has demonstrated some level of effective coral reef management. Examples of this may include the development of effective ecotourism projects, the construction of large scale habitat enhancement projects like artificial reefs and the establishment of co-management schemes that involve communities in marine conservation decision making processes. As discussed by Goreau and Hayes (2021), urgent action (through active restoration and threat reduction) is needed to increase the resilience and uphold the world's coral reef ecosystems. In light of international coral conservation best practices (Ben-Romdhane et al. 2020), it is suggested that Bali reefs could be better protected by:

3.3.8.1. Increasing its designation of official MPAs

The previously cited literature has highlighted that well enforced MPAs are an effective tool to restore and conserve coral reefs (Costello 2014, Edgar et al. 2014). The IUCN has recently called for the full protection of 30% of the world's oceans by 2030 as an international marine conservation target (Zhao et al. 2020). At the time of the last World Database of Protected Areas report (2018), seven of the world's countries had already designated 30% of their waters as MPAs (Germany, US, France and Australia, Belgium, Jordan and New Zealand (IUCN 2018). The same report highlighted that in 2018, Indonesia's total MPAs made up only 3% of their waters, and although there is no data on this in Bali, it is thought to also be a relatively low percentage. The establishment and enforcement of MPAs is associated with multiple economic and societal challenges, especially for developing nations (Sowman and Sunde 2018). It is however, encouraging that Indonesia has recently reached its target to declare 200,000 km^2 of its territorial waters as MPAs by 2020 (Suparno et al. 2019). It is hoped that the designation of more MPAs in Indonesia, will lead to declines in illegal activities, such as the use of DFPs and the fishing of internationally protected species like reef manta rays *(Mobula alfredi;* Krefft 1868*)*.

Additionally, as previously highlighted, unclear MPA boundaries in Bali has led to user non-compliance (Suparno at al. 2019). It is suggested that precise zoning and clear boundaries are used to mark out the Bali's MPAs. Within these boundaries should be sites of key importance, such as nursery grounds, fish aggregation sites and resilient habitats (e.g. reefs that survive bleaching), and a zonation method that is agreed and approved by the local community should be in place. This will increase user compliance and lead to a more effective MPA network.

3.3.8.2. Creating an MPA network

MPAs have been shown to be more effective if they are a connected network of protected areas (Daly et al. 2018). For example, a network of MPAs in Hawaii was shown to provide greater ecological and economic outcomes than the sum of outcomes of individual MPAs of the same size (Grorud-Colvert et al. 2014). One possible reason why an MPA network is more effective is because it protects all core habitats of migratory marine species, thus more effectively conserving their populations (Daly et al. 2018). Another reason is due to the benefits arising from congruent transnational or transregional management, resulting in an overall more effective management of the MPA (Daly et al. 2018).

There are many unofficial community managed marine reserves within Bali's Buleleng and Karangasem regencies that are not recognised as government designated MPAs (Mustika and Ratha 2013). MPAs within

Bali, would experience increased socio-economic and ecological benefits if they form a collective officially designated MPA network. This concept was first introduced in Bali by Mustika and Ratha (2013), who discussed that a network would lead to better ecologically connected MPAs, with more effective management. The authors also commented that the decline in populations of migratory megafauna (including turtles, sharks and marine mammals) in Bali is an urgent conservation issue, and that migratory routes and critical habitats of these species would be better protected if a large, highly connected MPA network is established. The proposed Bali MPA network is also expected to synchronise marine management decisions through enabling the exchange of knowledge and experience between regions (Berdej and Armitage 2018). It is thought that administrative separations between regencies have resulted in different marine management decisions and policies. The island of Bali is relatively small, so ecological marine systems are particularly connected, thus a synchronisation of marine management practices between regencies would foster more effective management (Berdej and Armitage 2018).

3.3.8.3. Substantially reducing marine plastic pollution

The previously cited literature has highlighted that Indonesia is the world's second largest plastic polluter (Shuker and Cadman 2018) and this greatly threatens its marine ecosystems (Turak and Devantier 2013, Giesler 2018, Brooijmans et al. 2019). This issue is especially prevalent in Bali, which declared a state of 'garbage emergency' in 2017 (Garcia et al. 2019). Currently, Indonesia has weak legal and institutional frameworks in place to manage its plastic pollution problem (Garcia et al. 2019). Countries such as Canada, which are moving towards becoming plastic waste free (Walton et al. 2018), may be seen as a 'best practice' nation in terms of waste management. It is beyond the scope of this study to evaluate how Bali can resolve its plastic 'emergency', although some suggestions, as discussed by Garcia et al (2019) may include:

- Developing national legal frameworks and local level regulations which work with plastic producers and consumers.
- Continuing to work with religious groups, NGOs, schools and other educational bodies which encourage communities to adopt more environmentally conscious practices, such as reducing single use plastics.
- Strengthening local waste management and recycling infrastructure.

3.3.8.4. Continuing artificial reef construction, ensuring that 'best practice' recommendations are followed

The previous literature has highlighted that ARs have been used in Bali as a habitat enhancement tool to successfully restore marine biodiversity and abundance (Syam et al. 2017, Puspasari et al. 2020). ARs are continuing to be built for marine restoration in Bali (LINI 2021), and funding for these projects appears to be increasing over the coming years (Karunia 2021). In terms of achieving restoration objectives, it is important that programmes follow guidelines in light of 'best practice' for building ARs. Table 2 highlights some of the main factors which contribute towards the success of AR programmes, and makes 'best practice' suggestions for creating an AR.

3.3.8.5. Developing Bali as an ecotourism destination

The reviewed literature within table 4 has highlighted that ecotourism has contributed towards successful marine conservation in Bali (McLeod and Palmer 2015, Trialfhianty 2017, NBRC 2019). Developing ecotourism within Bali is suggested as a tool which can be used to bring some of Bali's poorest regions out of poverty whilst simultaneously contributing to environmental conservation (Byczek 2011, Astarini et al. 2019). As Bali's businesses develop this industry, it is important that they demonstrate genuinely sustainable practices (Mahyuni et al. 2020) that accommodate local community empowerment, cultural preservation, and environmental conservation (Sugiri and Mahyuni 2019).

3.3.8.6. Increasing engagement in global science to inform marine conservation decision-making

Scientific research is important in biodiversity conservation as it informs practical decision making and provides organisations with information and tools to achieve their objectives (Mair et al. 2018). Recent literature has highlighted multiple innovative methods which may be considered for coral conservation. These can include (but are not limited to) building nurseries with coral species that are resistant to bleaching (Camp et al. 2017, Morikawa and Palumbi 2019), most effective techniques for coral transplantation (Endo et al. 2008, Onaka et al. 2013), genetically modifying reef building corals (Cleves et al. 2018) and coral microbiome manipulation (Rosado et al. 2019). Furthermore, Boström-Einarsson et al. (2020) highlighted that scientific research can support coral reef conservation programmes with aspects such as developing time and spatial scales, designing restoration methods and running adequate monitoring programmes.

However, there is a known gap between scientific research and practical restoration, which is an issue persisting globally in coral reef conservation (Habel et al. 2013, Mills et al. 2020). This gap, which is often caused by the lack of communication between the scientific community and conservation managers, has led to some coral reef restoration programmes being undertaken with little scientific input, ineffective management, and ultimately resulting in the organisation not achieving its objectives (Boström-Einarsson et al. 2020). Research has highlighted that some reef conservation activities in Bali may have been unsuccessful in achieving their objectives. For example, the BBNP MPA was ineffective in enforcing fishing regulations, and consequently it resulted in limited ecological (Doherty et al. 2013) and socio-ecological benefits (Pedju 2018). In this example, a greater understanding of scientific research in MPA regulations and enforcement may have helped conservation managers to come up with solutions to stop illegal fishing. As Bali progresses with coral reef conservation, it is important that global science is used to inform conservation decision making process. It is suggested, that this engagement can be achieved through focus group discussions (FGDs) and integrated studies between researchers and marine conservation managers. Collaborations like this could lead to successful ongoing monitoring programmes, as well as more effective decision making.

3.3.8.7. Developing more marine monitoring programmes

Marine monitoring programmes are generally recognised as important because they help scientists and conservation managers to characterise and understand coastal dynamics and vulnerabilities (Bastos et al. 2016). Marine monitoring enables environmental stressors to be identified, and in some cases, reduced or removed (Nõges et al. 2016) and is said to be "urgently required" for the protection of global marine biodiversity and ecosystem functioning (Danovaro et al. 2016). Bali's coral reefs have experienced an increase in active management measures over the last few decades (for example AR deployment, ecotourism activities and MPA establishment). It is important that these programs are monitored (in terms of the improvement of ecological conditions), so that future management decisions are informed on what is and isn't successful.

The previously highlighted literature has highlighted that water quality, especially nutrient pollution, can impact coral health (Szmant 2002, D'Angelo and Wiedenmann 2014). It appears that marine monitoring programmes are relatively limited, especially with regards to water quality and it been suggested that Indonesia should develop more water quality monitoring programmes (E.E. Ampou, Personal Communication). More specifically, this should be conducted during the transitional months between Indonesia's dry and wet seasons (March/ April and September/October) to best represent average water quality. More monitoring programmes like this will be useful to understand the link between water quality and coral reef degradation in Bali, which could lead to the development of water quality control measures.

4. Conclusion

Anthropogenic activities have caused a worldwide long-term decline in coral reef biodiversity, abundance and habitat structure (Pandolfi et al. 2011, Hughes et al. 2018). The greatest threat to the world's reefs is coral bleaching, due to ocean warming and acidification (Heron et al. 2017), which is a consequence of increased atmospheric greenhouse gas emissions (Pörtner et al. 2014). This review has assessed coral reef threats in Bali/Indonesia and has highlighted that 86% of Indonesia's coral reefs face medium or high levels of threat (Burke et al. 2012). Within Bali, Wickasana (2020) has shown 50% of its corals are in good health, whilst 20% are declining and 30% are poor to multiple threats as highlighted by part 1. Coral bleaching is present on the reefs around Bali (Ampou and Tito 2019; Karim 2019; Suparno et al. 2019), but the extent of the bleaching may be less severe than other reefs around the world, especially when compared to reefs like the GBR (Lewis and Mallela 2018).

Alongside a global mitigation of climate change through aggressive and large reductions in greenhouse gas emissions (Ben-Romdhane et al. 2020), multiple small/medium scale tools may be considered to conserve, restore and increase the resilience of coral reefs. Marine conservation appears to have first started in Bali in the 1970s (Polunin et al. 1983), likely as a result of a widespread decline of the island's coral reef health. Some primary conservation tools used across Bali so far have included MPA establishment, ecotourism development and artificial reef deployment. Engagement of the local community has been shown to be important for the success of marine conservation programme (Suadi 2009), and this is often influenced by other factors, as highlighted with examples in Bali by table 3.

This review has compared marine conservation in Bali to international 'best practices'. Marine conservation projects in Bali will likely gain further momentum in coming years, especially with Bali's 111.2 billion IDR support fund for coral reef restoration in 2021 - 2022 (Karunia 2021). It has made suggestions on how marine conservation in Bali can improve by following international best practices. These include:

1. Increasing its designation of official MPAs and strengthening management of existing ones
2. Creating an MPA network
3. Substantially reducing marine plastic pollution
4. Continuing artificial reef construction, ensuring that it follows best practices
5. Developing Bali as an ecotourism destination
6. Increasing engagement in global science to inform marine conservation decision-making
7. Developing more marine monitoring programmes

Most of the literature used to review this topic has been scientific papers. Some of these papers have been written by international scientists and are published in highly regarded journals. In contrast, some of the reviewed papers were small-scale local studies, many were written in Indonesian and were not published in a journal. It is important to have include these small-scale studies within this literature review, as many provide the most thorough insight into the current situation in Bali.

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Declaration of interests

☒ The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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