

EVALUATING THE INFLUENCE OF A PRO-ENVIRONMENTAL BEHAVIOURAL BRIEFING ON
SCUBA DIVER BEHAVIOUR AND THE DEVELOPMENT OF A SCUBA DIVER-ENVIRONMENT
RELATIONSHIP MODEL AND MANAGEMENT STRATEGY: A PULAU PERHENTIAN CASE
STUDY

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DECLARATION

This work has not previously been accepted in substance for any degree and is not being concurrently submitted in candidature for any degree.

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Abstract

SCUBA divers whether experienced or beginners, have been proven a threat to coral reef health. Poor diver behaviour has been shown to lead to degraded reef health which in turn impacts upon the livelihood of local communities and contributes to the wider threats to coral reefs in the form of climate change (acidification, sea level rise and sea temperature increase) and overfishing. Negative diver impacts relate to direct, physical contact and therefore, this research assessed diver and coral reef interactions in order to assess cause and effects. Coral reef health was surveyed off the coast of the Malaysian Peninsula at two fringing coral reefs with maximum depths of 20m, data from high and low intensity dive sites in the form of video transects proved the impact of SCUBA diving on coral health and were combined with underwater diver observations to create a broad and detailed picture of the relationship between divers and coral reefs. Results showed that diver positioning, buoyancy control and finning techniques were all fundamental aspects leading to contact and as a result, a focused behavioural pre-dive briefing was developed and utilised. Its application resulted in significant reductions in observed contacts and measurable improvements in key behaviours. Subsequently, a detailed research informed model and management strategy was developed to explain and manage the relationship between SCUBA diver behaviour, coral health and the resulting impacts on the local economy specifically highlighting and predicting percentage increase of live coral cover where diver impacts are minimised through use of the briefing. A DPSIR framework analysed complexities of interactions including drivers behind SCUBA divers intentions and desires (e.g. adventure, marine life and skill development), the growing pressures on coral reefs (e.g. carrying capacities, species specific dive tours and insufficient training programs) and the state of coral reefs as a direct result of the industry (e.g. reduced resilience and rugosity) and the impact these changes have to biodiversity and society (e.g. loss of income, loss of food sources and reduced biodiversity). These elements of the DPSIR framework led to the development of a rational response, recommendations and a management strategy that key authorities in the industry can implement, training organisations, tourism operators and policy makers. Recommendations are informed by the research along with secondary data and literature for a broad and rounded response to diver impacts on coral reef and marine life and include full use of the pre-dive behavioural briefing both within training and prior to every dive, introducing rotational reef closures to allow for recovery prior to reaching a tipping point and an introduction of permits for particularly popular and high intensity dive sites.

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Acronyms

ARC – Australian Research Council

BSAC – British Sub-Aqua Club

CESD – Centre on Ecotourism and Sustainable Development

DMPM – Department of Marine Parks Malaysia

DPSIR – Drivers, Pressures, State, Impact and Response

GBRMPA – Great Barrier Reef Marine Park Authority

HCC – Hard Coral Cover

LCC – Live Coral Cover

CVT – Coral Video Transect

LIT – Line Intercept Transect

NAUI – National Association of Underwater Instructors

PADI – Professional Association of Diving Instructors

SCUBA – Self-Contained Underwater Breathing Apparatus

SSI – SCUBA School International

UN – United Nations

UNWTO – United Nations World Tourism Organisation

WWF – World Wildlife Foundation

1.0 Introduction

The continuous evolution and growth of anthropogenic activities is having an increasingly damaging impact on marine ecosystems. Managing the threats posed through activities such as fishing, tourism, coastal development, deforestation and climate change pose a significant challenge on both local and global levels (Hughes *et al.*, 2003; Linton and Warner, 2003; Pratchett *et al.*, 2008; Cruz-Trinidad *et al.*, 2014a; Anthony *et al.*, 2015). While policymakers must consider cumulative consequences of these threats, there is an urgent need for industry leaders to establish protocols and processes that reduce their impacts on marine ecosystems.

Growth of anthropogenic activities can clearly be seen in the tourism industry which has shown continuous growth since the 1950's, where global travel was limited by transport availability and access issues. In 2018, 1.4 billion people undertook some form of tourism, a significant increase from the 25 million people in the 1950's (World Tourism Organisation, 2019). Within tourism, smaller recreational activities have emerged. SCUBA diving offers a unique opportunity to view and experience marine ecosystems, and as an industry, continues to expand (PADI 2016). This growth has spawned a range of studies focused on SCUBA diving impacts on coral reefs, though studies attempting to mitigate any impacts are less readily available. Managing the threat tourism, and specifically SCUBA diving, poses to marine ecosystems represents a challenge that encompasses international collaboration, policy and human behavioural changes.

Coral reefs are widely distributed throughout the tropics (National Oceanic and Atmospheric Administration, 2000) and are often accompanied by white sandy beaches and idyllic island settings, making them popular tourist hotspots. These ecosystems are a collection of living coral that have formed a hard, limestone skeleton just below the ocean surface. While shallow

water reefs cover just 0.015% of the ocean, they support up to 25% of marine life (International Coral Reef Initiative, 1994; National Oceanic and Atmospheric Administration, 2000). The threats that face coral and coral reefs are identical as those impacting upon the ocean as a whole: climate change, acidification, tourism, pollution and fishing (Hoegh-Guldberg, 1999a; Hughes *et al.*, 2003; Sadovy *et al.*, 2003; Donner *et al.*, 2005; Newton *et al.*, 2007; Fenner, 2012a, 2012b; Movilla *et al.*, 2012). SCUBA diving has also been highlighted as a threat towards coral reefs due to direct physical contact through poor in-water behaviour (Rouphael and Inglis, 2001; Medio, Ormond and Pearson, 1997; Rouphael and Inglis, 1997; Zakai and Chadwick-Furman, 2002; Barker and Roberts, 2004; Worachananant *et al.*, 2008; Anderson and Loomis, 2011; Musa *et al.*, 2011; Ong and Musa, 2012; Chung, Au and Qiu, 2013; Zulaiha, Abidin and Mohamed, 2014; Casoli *et al.*, 2017; Hammerton, 2017; Cheng *et al.*, 2019), where contact with substrate impacts upon coral health through breakages and abrasions. Implementation of such threat management is hindered through a lack of understanding as to why divers make contact with the substrate. Prior to 2017, only a handful of studies focused SCUBA diver research on changing behaviour, and those that existed failed to address the reasons behind diver contact.

Some of the most diverse and threatened coral reef systems lie within the coral triangle: a marine area of high biodiversity in South East Asia. As well as being important for marine biodiversity, it also supports over 120 million people who depend on the reefs for their livelihood (Cruz-Trinidad *et al.*, 2014b; Spalding *et al.*, 2017a). East Malaysia (Borneo) accounts for areas within the scientific boundary of the coral triangle, and as a country, Malaysia has shown a gradual increase from 20.97million visitors in 2007 to 25.83 million in 2018, averaging 25.12 million over the whole period (Malaysia, 2018).

Many of the island chains in Malaysia have been designated as Marine Parks under the Marine Park Act (1997) and as such are afforded some protection. The study site for this research, Pulau Perhentian, is a marine park in the state of Terengganu which has seen a steady increase in visitor numbers over the last 15 years (Department Marine Parks Malaysia, 2017). Despite being protected, coral reefs are at risk in Malaysia and elsewhere (Burke *et al.*, 2011) and they remain globally vulnerable to damage through contacts (Barker and Roberts, 2004; Camp and Fraser, 2012). Development of a management strategy to mitigate diver impact is an important step in maintaining biodiversity and coral health.

1.1 Aim and Objectives

The aim of this research is to develop a diver-environment relationship model, management strategy and recommendations for policy makers, training organisations and dive operators with regards to SCUBA tourism. Five objectives were identified on the back of a thorough review of literature linked to coral health, SCUBA diver impacts and behavioural theory.

- i. Assess and compare coral reef health at high-density and low-density dive sites to determine the impact recreational diving has on a fringing coral reef environment*
- ii. Assess SCUBA diver environmental awareness and values through questionnaire surveys*
- iii. Observe and analyse SCUBA diver behaviour, contact rates and interactions with the marine benthic environment*
- iv. Determine the effectiveness of pre-dive briefings in influencing diver behaviour and impact on contact rates*
- v. Analyse primary and secondary data to develop a relationship model, management strategy and policy frameworks for the SCUBA industry*

A second review of literature was carried out to establish strong rationale and understanding to inform a methodological approach and determine baseline data. Given the global growth of the sport (PADI, 2017c), it was necessary to demonstrate an approach to behaviour management that was both effective and simple.

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1.1.1 Objectives

The rationale for the five objectives identified is detailed in this subsection.

- i. Assess and compare coral reef health at high-density and low-density dive sites to determine the impact recreational diving has on a fringing coral reef environment*

Coral reef response to high density SCUBA diving activities has been shown to be negative (Lamb *et al.*, 2014), where low use sites have a higher percent of live coral cover. Coral growth rates and ability to recover from impact has been well documented (Pearson 1981; Woodley *et al.*, 1981; Lirman, 2000; Bruckner and Bruckner, 2001) from natural and large scale disturbances, but not from low-level or localised damage such as that found from SCUBA diving. This element of the research will establish a baseline to determine the extent to which increasing numbers of SCUBA divers and tourism can damage fringing coral reefs, ultimately this will be built into the overall model and management protocols.

- ii. Assess SCUBA diver environmental awareness and values through questionnaire surveys*

Determining SCUBA diver awareness and understanding of coral reefs, as well as their

perceived behaviour while diving, was important to determine whether there was any correlation between the divers perceived behaviour and their actual behaviour. Further, identifying the level of knowledge the dive community has about coral reef health will support evolution of training methods and protocols within the SCUBA dive industry.

A questionnaire enables information related to SCUBA diver history, training levels, number of dives and basic demographic data to be collected. This data was imperative to gain a full understanding of any correlations with contact rates in order to accurately assess interventions and causes of contacts. Use of a questionnaire has been adopted by previous studies (Musa *et al.*, 2011; Camp and Fraser, 2012; Hammerton, 2017) and built upon to determine values, beliefs and satisfaction.

iii. Observe and analyse SCUBA diver behaviour, contact rates and interactions with the marine benthic environment

Following on from identifying SCUBA diver awareness and understanding, determination of any correlations with their perceived in-water behaviour and actual in-water behaviour was important. SCUBA divers have been shown to make contact with the reef numerous times during a dive (Medio, Ormond and Pearson, 1997; Roupheal and Inglis, 1997, 2001; Barker and Roberts, 2004; Worachananant *et al.*, 2008; Anderson and Loomis, 2011). As such, the third objective was to provide unique data on SCUBA diver behaviour, conducting focal sample observations of key behaviours of interest to determine the cause of contacts. Enhancing the understanding of SCUBA diver behaviour and the reason behind contacts is vital in devising management processes. Prior to the full study, a shorter pilot study was

carried out to rigorously test the methodology for coral recovery, health and diver observations.

- iv. *Determine the effectiveness of pre-dive briefings in influencing diver behaviour and impacting contact rates*

The fourth objective was devised to determine whether, as in previous literature, a targeted pre-dive behavioural briefing influenced SCUBA diver behaviour and reduced the rate of contacts. The pre-dive briefing took into account previous studies' approaches and based on the outcome of a pilot study, adapted the length to a maximum of 5 minutes. The pre-dive behavioural briefing was partly based on behaviour theories, which state that how a person values something, and believes their actions make a difference, contributes to how they behave (Stern *et al.*, 1999; Stern, 2000; Heywood, 2002; Clayton and Myers, 2009). Targeted behaviours of interest were identified based on current literature and from discussions with SCUBA dive professionals (Rouphael and Inglis, 2001; Hasler and Ott, 2008; Othman *et al.*, 2014; Toyoshima and Nadaoka, 2015). The briefing provided personal and environmental reasons to improve specific behaviour, aimed at increasing the potential that individuals would alter behaviour to benefit their own dive enjoyment.

- v. *Analyse primary and secondary data to develop a relationship model, management strategy and policy framework for the SCUBA industry*

Based on information gathered from the first four objectives, recommendations for enhanced training and pre-dive briefings were established and coral reef management frameworks and strategies developed. Creating a greater level of understanding of SCUBA diver behaviour provided data that was, to date, non-existent, will augment the management strategies and

training methods for dive centres while providing marine park authorities with information to ensure protocols are followed.

These five objectives will develop a broad and unique understanding of the relationship between SCUBA divers and marine substrate, specifically coral reef health. Data collected will be analysed and fed into a wider relationship model, framework and management strategy for the sport moving forwards. Long term, it will be essential for these to be tested and implemented globally to limit the impact of SCUBA diving on marine environments to protect biodiversity and economic reliance.

2.0 Literature Review

This chapter will consider current literature of coral reef health and threats, tourism trends, SCUBA diver training and impact theories and models. Ultimately the link between human behaviour and the environment needs to be better understood. The final Section focuses on potential interventions used to influence and alter human behaviour and impacts.

2.1 Coral and Coral Reefs

Initially it is important to consider coral biology, distribution and reef benefits as well as determine the various threats facing coral reefs globally. It is imperative to highlight why coral reefs need to be protected and how human interactions with them can, and need to be, managed effectively.

Coral are animals, and part of the same phylum as jellyfish: *Cnidaria*. They are considered a basic lifeform, with a simple stomach and single mouth that is surrounded by stinging tentacles (Kaplan and Kaplan, 1982). Coral polyps have a symbiotic relationship with zooxanthellae, single-celled marine algae, that benefit the coral through waste management and improved respiration (Stanley and Swart, 1995). They obtain energy through both their symbiotic relationship and through feeding on zooplankton, which they catch through stinging cells on their tentacles, generally at night (Sheppard *et al.*, 2009). Sheppard *et al.* (2009) state that coral can be classified as one of three groups of Cnidarian: Stony coral (hard coral) which construct a limestone skeleton and are the main reef builders; Octocoral (soft coral) primarily organic structures and Black coral or Sea Whips.

Hard coral are considered reef builders because of their ability to utilise calcium carbonate (specifically aragonite), known as coral calcification (Done, 1999; Sheppard *et al.*, 2009; Kavousi *et al.*, 2016).

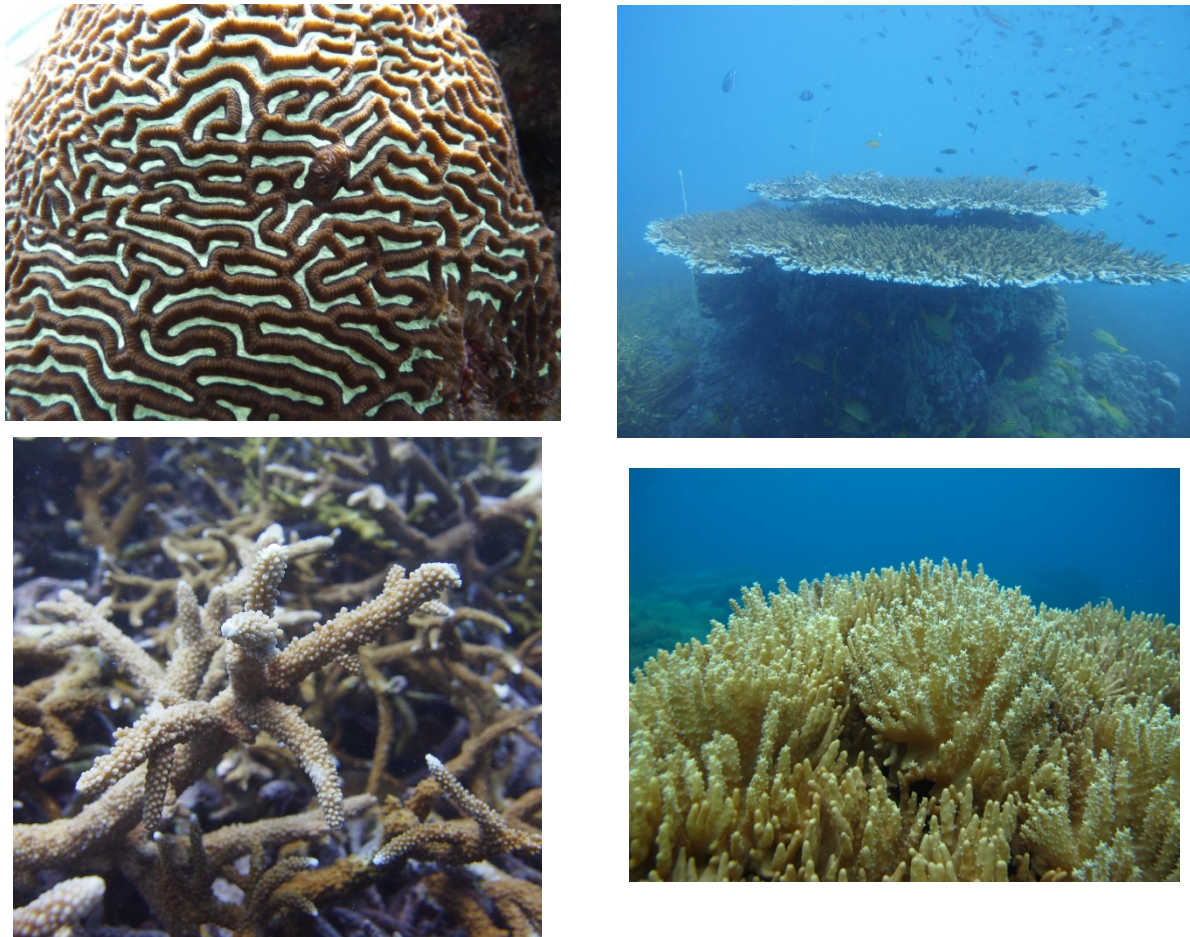


Figure 2.1: Coral structure examples (top left; massive coral, top right; plate coral, bottom left; branching coral, bottom right; soft coral ((Hinds, 2015)

Coral calcification allows coral to build limestone structures in various shapes and sizes (Figure 2.1) that contribute to the complexity and changing topography of the ocean floor (Tortolero-Langarica *et al.*, 2016). Tortolero-Langarica *et al.*, (2016) established 7 different growth forms (shapes); branching, massive (boulder shaped), encrusting, columnar, laminar, foliaceous and free-living (unattached). The variation in growth form is thought to be a result of the conditions in which the coral grows. Massive coral, with their large basal area and boulder-

like shape are considered ideal for absorbing energy from storms and physical damage (Hughes 1987). In contrast, branching or thin foliose corals are considered fragile and more prone to breakage (Hughes, 1987), while free-living coral are ideal pioneer species and can colonise areas alongside the main reef (Tortolero-Langarica *et al.*, 2016), and through experience, can regularly be found on the fringes of established reefs.

2.1.1 Growth and development

Coral growth rates and their ability to recover are areas of interest both scientifically and within conservation management. Coral growth depends on a variety of environmental factors and conditions including salinity, light, temperature, depth, turbidity, nutrients and sediment (Huston, 1985; Dullo, 2005; Sheppard *et al.*, 2009) which makes summarising or predicting growth rates difficult.

Sheppard *et al.*, (2009) considered the abiotic factors influencing growth and development of coral reefs in detail. While coral can survive varying ranges of salinity, and some have the ability to control internal water and salinity levels, sudden or extreme changes in surrounding water salinity can result in high mortality rates. The same can be said for temperature. Coral are generally bound by a minimum of 18 degrees Celsius in order to survive and develop, though Sheppard *et al.* (2009) state that ideal conditions for long term development is 21 degrees Celsius, and a key factor in global distribution. As with changes in salinity, sudden or long-term change in temperature can result in high mortality rates. Light is another major factor that influences the growth and development of coral. Stony coral relies on light penetration to enable calcification and both stony and octocoral rely on light for their symbiotic relationships with Zooxanthellae.

Light predominantly impacts the depth to which coral can survive and is strongly linked to pollution, water quality, turbidity and sedimentation. Excessive particles in the water column can reduce light penetration, affecting deeper growing coral, while sedimentation can discourage the settling of coral larvae, impacting reef structure development (Rogers, 1990). Rogers (1990) states that sedimentation can impact the ecosystem on a wider scale, through altering growth and development of species such as sea grass, sponges and mangroves, all of which contribute to water quality and coral reef health. Sheppard *et al.*, (2009) state that the growth forms discussed by Tortolero-Langarica *et al.*, (2016) can influence the impact sediment has on a reef. Branching or foliose forms are more capable of removing sediment than the massive or laminar varieties. Sheppard *et al.*, (2009) highlight that together, these factors can influence coral development and growth rates.

Different study sites have found results vary. *Acropora sp.* were found to average 6.3 cm/year (Browne, 2012) in Halifax Bay, Australia whereas colonies from the same genus in Lord Howe Island, Australia averaged 3.4 - 4.2mm per month, which equates to a maximum of 4.98 cm/year (Anderson, Pratchett and Baird, 2012). Brown (2012) concludes that there is evidence to suggest coral in Halifax Bay has adapted to the environmental conditions allowing similar growth rates to coral at comparable depths, but suggests that the highest growth rates (up to 8cm/year) were found in the shallowest waters, suggesting light penetration played a significant role in linear extension. Dullo (2005) completed a review of coral growth research between 1966 and 1989 and found further variations between growth rates of *Acropora* species (4.5 – 18 cm/year). While in Jamaica, growth rates between 1.4 and 10mm/year were found (Huston, 1985), the range here explained by light availability and depth. Huston (1985) states that although coral have the capability to continue to grow in extremely low light conditions, growth rates are drastically reduced.

Coral growth in the Indo-Pacific region showed rates between 130mm and 165mm annually, which is considerably higher than the rates found in Halifax Bay and Lord Howe Island (Huston, 1985; Dullo, 2005; Anderson, Pratchett and Baird, 2012; Browne, 2012). Anderson, Pratchett and Baird (2012) suggest that *Acropora* sp. show a positive correlation with temperature increase, enabling faster growth during summer months, particularly in sub-tropic areas. This can result in rapid recovery after damage as well as increased reef resilience.

Coral recovery can be defined as either recolonization (new larvae settlement and growth) or regeneration (regrowth of existing colonies after damage) (Pearson, 1981) and coral reef recovery is often studied after damage from major incidences such as storms or ship groundings (Woodley *et al.*, 1981; Lirman, 2000; Bruckner and Bruckner, 2001). The ability for a coral reef to recover can be determined by 5 factors: disturbance characteristics, reef characteristics, reef connectivity, ecological characteristics and anthropogenic influences (Graham, Nash and Kool, 2011). Disturbance and reef characteristics refer to the type of damage sustained by the reef. Graham, Nash and Kool (2011) state that where skeleton structure or live coral remain, the rate of recovery will be greater in comparison to an incident that results in skeleton removal or covering with sediment. Reef connectivity refers to the presence of other reefs nearby; due to the ability for new coral larvae to reach the reef from nearby healthy reefs. Ecological characteristics refer to the biodiversity of the site, and where grazing fish population is high, there is a greater chance for rapid recovery as algal growth is controlled. Anthropogenic disturbances can be both positive and negative. Where a reef is in close proximity to a human settlement, a slower rate of recovery is predicted due to increased run-off, pollution and sedimentation, while a protected area or managed site may benefit from sustainable approaches enabling faster recovery (Graham, Nash and Kool, 2011). Pearson (1981) states that disturbances caused as a result of anthropogenic action result in

damage recovering at a much slower rate, if at all, however, Pearson (1981) discusses major impacts such as dredging, pollution and blasting, rather than localised impacts such as SCUBA diver damage. The study site for this research is a small Marine Park island chain, Pulau Perhentian, 9.1 miles from the mainland with a single community of approximately 2,300 people, relying predominantly on tourism for sustenance. Such proximity to the mainland, combined with heavy tourism use and annual monsoon results in a variety of pressures facing the coral reefs in Perhentian, all impacting the ability for damaged coral to recover.

2.1.2 Reproduction

Coral reproduces both sexually and asexually. Some (approximately a quarter) species are hermaphrodites, both male and female, and release bundles of sperm and egg together. The remaining species are either male or female and release sperm or eggs accordingly and are known as 'broad cast feeders' (Sheppard *et al.*, 2009). To increase the chance of fertilisation and success, many coral species time the release of egg and sperm to a single night, with the result being a mass spawning event (Sheppard *et al.*, 2009; National Oceanic and Atmospheric Administration, 2018a). Once the sperm and egg join together, they form coral larvae, which float, with limited direction, in the water column until they find a site suitable for colonising, which, as stated in subsection 2.1.1, requires suitable light, temperature and substrate.

Asexual reproduction, or fragmentation, is most common within branching *Acropora sp.* (Sheppard *et al.*, 2009) due to the fragility of the growth structure. Asexual reproduction can happen as a result of both natural and human action, though as with sexual reproduction, requires specific environments to be successful. Fragments of coral that have been broken from the main colony are able to survive and grow into new colonies, depending primarily on

the type of substrate they land on. Lirman (2000) found fragments that landed on live coral showed the highest rates of survival, whereas fragments that landed on sand were subject to an increased rate of tissue loss (71% after four months). Lirman (2000) found that fragments that landed on rubble also showed high survivorship rates, and where tissue loss is particularly high, the development of a new substrata (rubble) would lead to an increase in new growth in future fragmentation events . Understanding the process of asexual reproduction is important when considering impacts human action can have on a reef as it will not always be negative.

2.1.3 Distribution

As discussed in Section 2.1.1, abiotic factors influencing coral growth are numerous and directly contribute to their global distribution. Coral and coral reefs are widely found both in deep, cold waters as well as shallow, tropical waters. Temperature is thought to be the leading factor influencing coral reef location (Sheppard *et al.*, 2009), resulting in most stony corals being found between 30 degrees north and 30 degrees south of the equator. Figure 2.2 displays a representation of the global distribution of coral reefs.

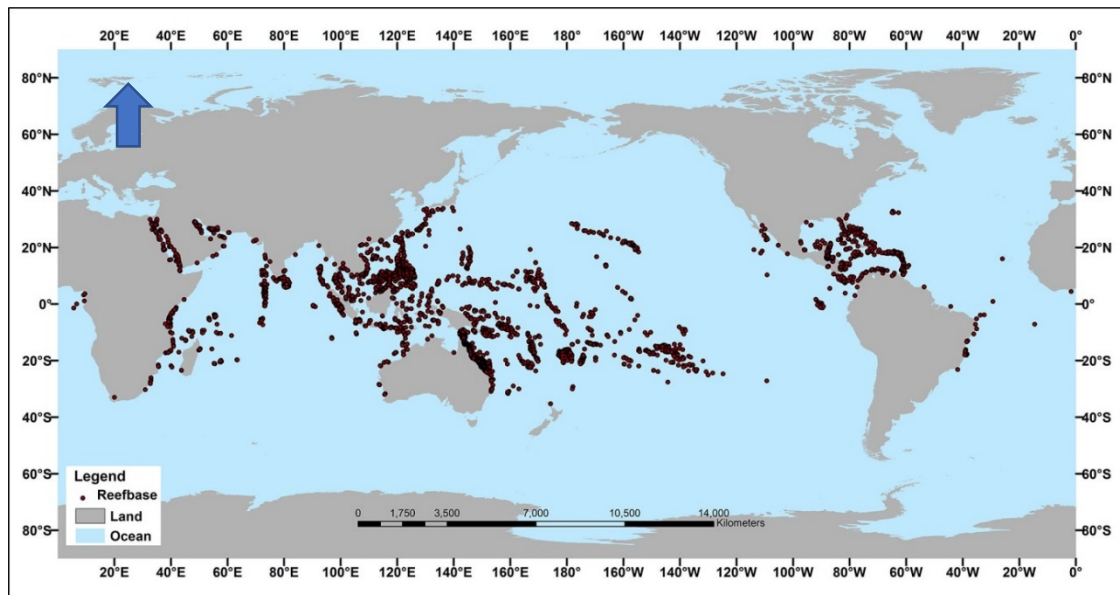


Figure 2.2 Global distribution map for coral reefs (National Oceanic and Atmospheric Administration, 2017)

There are clear clusters and groupings of coral reefs where conditions are suitable for growth. Eastern coastlines of the Atlantic and Pacific Oceans are both relatively devoid of large clusters or reefs. South East Asia and Australasia represent the largest concentrations. Based on factors that influence coral growth, this suggests these areas have ideal environments established through clear, warm waters, and generally low levels of pollution and sedimentation. The high concentration of coral reefs in South East Asia and Australasia, also known as the coral triangle, is one of the reasons the study site in Malaysia was chosen.

Malaysia's coral reefs cover approximately 4,000 square kilometres (ICRI, 2020), the majority of which are found in Eastern Malaysia, on the island of Borneo. Peninsula Malaysia accounts for 10% of the country's coral reefs and in total, approximately 540 species of hard coral and at least 925 species of fish have been found on Malaysian coral reefs (Burke *et al.*, 2012).

2.1.4 Benefits of coral reefs

Coral reefs represent some of the most biodiverse ecosystems on the planet. It is estimated that of the 34 animal phyla, 32 of them can be found living within coral reefs (Sheppard *et al.*, 2009). Burke *et al.* (2011) state that 4,000 species of coral-associated fish and over 800 species of coral have been identified to date, while the importance of shallow coral reefs as nursery grounds for juvenile fish has been acknowledged (Nagelkerken *et al.*, 2000). They highlight that larger fish tend to be located in deeper, more open water, while juveniles are found in shallow reef, seagrass and mangrove areas. This nursery role feeds directly into the fishing industry and in turn contributes protein and nutrition to millions of people globally (International Coral Reef Initiative, 1994; Burke *et al.*, 2011). Approximately 850 million people world-wide live within 100km of a coral reef or are beneficiaries of ecosystem services provided. Two hundred and fifty million people live within 10km of the coastline and within 30km of a coral reef and are considered to have a high dependency on that environment (Burke *et al.* 2011). In terms of the study area, it is estimated that between 114 million and 130 million people are living within the coral triangle region and are therefore dependent on coral reef resources for food, income and livelihoods (Burke *et al.*, 2011; Cruz-Trinidad *et al.*, 2014a). Coral reefs also contribute to nutrition and food on a global scale. According to Cruz-Trinidad *et al.* (2014), 11.3% of global fishery catch is supplied through aquaculture and capture fisheries, further highlighting the importance and reliance on coral reefs and their ability to replenish fish stocks through nursery creation.

Coral reefs also offer a first line of defence for coastlines, acting as natural barriers and absorbing wave energy before it reaches the shore (Burke *et al.*, 2011; Ferrario *et al.*, 2014; Elliff and Silva, 2017). Ferrario *et al.* (2014) determined that, when combined, the reef crest

and reef flat dissipated wave energy by 97%. The ability of coral reefs to protect coastlines, is particularly important in island communities and low-lying landscapes where there is a high risk of flooding and damage during storms. For example in the Pulau Perhentian island chain in Malaysia (study site), annual monsoons bring strong winds and waves that pose a direct threat to the local community. The presence of coral reefs near some of the beaches lessens this impact, however from personal experience, it is not uncommon for areas of the village, which no longer have a coral reef protecting it, to face flooding and wave damage. It is for this reason that coastal defences have been built along the shore adjacent to the village.

Understandably, as a natural defence from wave energy, coral reefs undergo erosion, creating sand that in turn leads to the creation and maintenance of beaches throughout the region and contributing to another benefit coral reefs provide to the human population: tourism. Coral reefs contribute towards tourism both directly, through in-water activities such as snorkelling, SCUBA diving and fishing; and indirectly, through white-sandy beaches, views and food (Burke *et al.*, 2011; Spalding *et al.*, 2017b). The Great Barrier Reef of Australia is both the largest natural structure on Earth, and perhaps the most famous and well-known coral reef (National Oceanic and Atmospheric Administration, 2018b). As a tourist attraction, it contributes between \$700 million and \$1.6 billion USD annually, and attracts an estimated 2 million people each year. These visitors spend between \$350 and \$800 USD per visit, slightly higher than reefs valued in Belize (valued at \$367 USD per visitor) (Carr and Mendelsohn, 2003). Nevertheless, globally, coral reefs are estimated to be valued at \$36 billion USD, or 9% of global coastal tourism in countries where coral reefs exist (Spalding *et al.*, 2017b).

2.1.5 Coral Reef Health

The health of a coral reef can be determined in a variety of ways. Fish species present on a reef can act as indicators for coral health, as well as highlighting the presence or (or lack of) over-fishing in an area (Linton and Warner, 2003; Pratchett *et al.*, 2008; Reef Check Malaysia, 2016). Both Linton & Warner (2003) and Reef Check state that butterfly fish (*Chaetodontid*) are valuable bioindicators of reef health as they feed on live coral polyps. As such, it is suggested that high numbers of butterfly fish would only be found on healthy coral reefs. However, an argument against this, as also highlighted by Reef Check Malaysia (2016) is the value of butterfly fish for the aquarium trade, meaning there would be unsustainable removal of butterfly fish, so surveying them for health may be inaccurate. Another fish species used as a bioindicator on coral reefs are Parrotfish (*Scaridae*), which graze on algae that would otherwise compete with coral for space (Reef Check Malaysia, 2016). Monitoring the number of parrotfish present can provide a better correlation with reef health.

The most common method of determining coral reef health is through the observation of hard coral cover (HCC) (Bruno and Selig, 2007; Reef Check Malaysia, 2015, 2016; Shidqi *et al.*, 2018). This is achieved through running transects along a reef at any given depth and conducting a survey allowing an estimated HCC percentage (Line Intercept Transect, LIT); where 0-24.99% HCC is considered poor health, 25-49.9% is fair health, 50-74.9% is considered good and above 75% is considered excellent (English, Wilkinson and Baker, 1997; Reef Check Malaysia, 2015). This method of coral health surveying is not perfect as a transect will only give a snapshot of the reef, which may have areas that differ greatly within itself.

An alternative method to the standard utilised by Reef Check is the use of coral video transects (CVT), where a diver would swim slowly along a transect at a constant distance from

the reef and video the substrate. This method requires less time in the water, but considerably more in laboratory analysis and some authors have found no significant difference in HCC (Safuan *et al.*, 2015). However, Safuan *et al* (2015) found that the LIT approach tended to result in a slightly higher percentage of HCC than the CVT method. In a comparison of 6 different methods of coral cover, CVT was found to be the fastest in-water approach and three other methods were slower to analyse in the lab (Leujak and Ormond, 2007). The same study found that all 6 methods produced different results meaning that picking one as the most accurate is difficult. However, they provide a table whereby they rank the 6 methods and found that CVT is the second most accurate (compared to LIT being the 5th) and the fastest method. Further, CVT provides a permanent record of the data, however it cannot be accurately repeated and does produce indeterminable substrate and requires the most expensive equipment. Safuan *et al* (2015) also found time constraints existed for LIT in the field, though added that CVT accuracy would vary depending on the quality of the equipment and distance to the reef. They state that an ideal distance would be 0.5m, as it requires less frame analysis than 0.2m, but a greater level of detail than 1m distance, meaning more accuracy. As with all scientific methods, there are always limitations.

Coral health in Malaysia is surveyed annually by Reef Check Malaysia (RCM) with the assistance of Reef Check trained volunteers. RCM annually survey 242 coral reefs throughout Malaysia, 84 of which are on Peninsula Malaysia, with the remaining 158 in East Malaysia. In 2015, RCM found an average HCC of 41.89%, down from 44.12% in 2014, potentially explained by the addition of 84 new sites, rather than worsening health (Reef Check Malaysia, 2015, 2016). RCM (2016) state that the site for this study, Pulau Perhentian, was found to have an average HCC of 48.06%, higher than the national average but lower than the average for sites surveyed within the South East Asian Sunda Shelf region.

Coral health has been studied from a variety of approaches: coral reef resilience looks at a reef from a broad view, taking it not just coral health, but the ability to sustain and recover after incidents as well as their reaction to stressors (Anthony *et al.*, 2015). Anthony *et al.* (2015) developed a systems diagram that helps to develop management plans and includes: influencing drivers or activities, reducing stressors and supporting resilience. When considered alongside SCUBA diving activities, the first aspect here is influencing diver behaviour, which in turn reduces stressors and leads to supporting resilience. Likewise, closing a coral reef to anthropogenic activities on a seasonal basis would provide an opportunity for ecosystem recovery, improving ecosystem conditions and therefore the long-term social-economic conditions.

The systems diagram highlights a circular link, highlighting the relationship between ecosystem conditions and social-economic conditions, which then feeds back into the anthropogenic activities. This highlights, as will be discussed in Section 2.3, that human activities are affected by social and economic conditions, as well as the ecosystem conditions (a higher quality reef with high biodiversity is more attractive to divers).

2.1.6 Coral reef threats

As stated in subsection 2.1.1, coral reefs thrive when certain abiotic factors are right (salinity, temperature, light, sedimentation, nutrient content). However, with the growth of human population, the demand for resources and climate change, pressures facing coral reefs are growing. Some threats, such as climate change affect coral on a chemical and biological level; increased levels of CO₂ absorption, leading to accelerated acidification, is inhibiting the ability for stony coral to accrete aragonite as calcium carbonate (Hoegh-Guldberg *et al.*, 2007;

Movilla *et al.*, 2012; Allison *et al.*, 2018). This will ultimately hinder growth in established coral as well as reduce the ability for development and expansion of new coral reefs. Allison *et al.* (2018) state that when reared in a lower pH environment, some colonies of coral saw their calcification rate reduced when compared to colonies reared in controlled conditions. Movilla *et al.* (2012) state that while a small number of species have the capability to adapt and survive in changing conditions, the threat of climate change is very real.

A second threat as a result of climate change is coral bleaching which is predominantly a result of increasing sea temperatures (Donner *et al.*, 2005; Hoegh-Guldberg *et al.*, 2007). Coral bleaching is a process whereby the zooxanthellae are expelled from a coral colony, leaving it colourless (white) and removing the productive symbiotic relationship between the two, thereby limiting the coral's ability to survive. An example of a major coral bleaching event was seen in Australia's Great Barrier Reef, where increased sea temperatures, caused by El Nino and climate change, resulted in an estimated 29% loss of shallow-water coral. A further bleaching event in 2017 has resulted in a 93% decrease in the of replenishment of coral (ARC Centre of Excellence for Coral Reef Studies, 2019; GBRMPA, 2019). Coral are able to recover from bleaching if conditions return to pre-bleaching state and it has also been suggested that if coral are able to integrate a more heat-resistant variety of zooxanthellae they increase their chances of survival (Brown, 1997; Hoegh-Guldberg, 1999b). However, it is thought not all coral are capable of changing their zooxanthellae (Goulet, 2006) and the ability to do so relies on a variety of other factors that all contribute to coral resilience.

Another anthropogenic-related threat facing coral reefs is that of unsustainable fishing practices. One of the benefits of coral reefs is their biodiversity and ability to act as a nursery for fish species (S.2.1.4). However, unsustainable fishing practices, on both an industrial scale

and smaller artisanal scale, threaten coral reefs physically and biologically. Over-exploitation of coral reef fisheries can result in loss of macro-fauna (Sadovy *et al.*, 2003; Fenner, 2012b, 2012a) as a minimum and a complete collapse of the fishery at worst (Newton *et al.*, 2007). Fenner (2012a; 2012b) postulates that rare sightings of large species and apex predators is now seen as normal within the science community, but argues that when compared with pristine coral reefs, such absence is uncharacteristically low in areas where humans are present. The paper gives an example in Fiji, where Bumphead Parrotfish (*Bolbometopon muricatum*) were seen throughout the markets after the introduction of night spearfishing and as a result this species has become extinct from some islands in Fiji. The increased demand globally through population growth and locally through tourism (Burke *et al.*, 2012) has seen the largest species decline dramatically, leaving only the smaller and juvenile species for fisheries. Burke *et al.* (2012) go on to say that overfishing and destructive (blast or poison) fishing practices threaten nearly 85% of reefs within the Coral Triangle area.

Aside from climate change and unsustainable fishing, a further key to coral reef health is tourism, and specifically coastal and in-water tourism activities. These will be discussed in the next Section.

2.2 Tourism

Tourism has both direct and indirect impacts on the wider environment and coastal areas are no exception. The rationale driving this research will begin to be developed through understanding the relationships between tourism and the environment and how it is, and should be managed.

Tourism can be defined as:

“a social, cultural and economic phenomenon which entails the movement of people to countries or places outside their usual environment for personal or business/professional purposes.” (UNWTO, 2019: Page 1)

Tourism relies on 5 factors to function as an effective system: tourists, tourist generating regions, transit route, a tourist destination and a travel and tourism industry (Weaver and Oppermann, 2000). Tourism destinations can be both domestic and international, while the industry required relates to the presence of businesses that accommodate tourist activities (hotels, restaurants, recreational activities). In this study, the destination (study site) was required to attract domestic and international tourists (specifically SCUBA divers), while the businesses in the area were required to offer accommodation as well as recreational SCUBA diving activities.

Tourism has been growing since the 1950's; from 25 million tourists (Conrady and Buck, 2012) in the 1950's to 1,235 million in 2016 (UNWTO, 2017). Since 1985, tourism has been growing on average 9% per year (Honey and Krantz, 2007) with an estimated 1.5 billion international tourist arrivals in 2020. Conrady and Buck (2012) discuss the modern-day trends of tourism, stating that increased wealth and more disposable income have resulted in more fluidity and power for the tourist, making it harder for travel agents and the sector to separate tourists in traditional ways. Weaver and Oppermann (2000) suggest that as a country becomes more economically developed there becomes a greater demand within society for tourism opportunities. This is further enhanced by smaller family sizes, urbanisation and increased life expectancy together with improved transportation and technology including the internet (Buhalis, 1998; Dimitrios and Law, 2008). However, Conrady and Buck (2012) argue that the

growth of tourism is going to decline in the future as the ageing populations of European countries, and the increased costs of living will mean a reduced level of disposable income.

Honey & Krantz (2007) state that tourism is of particular importance to the least developed countries, where it accounts for 70% of exports, while Conrady and Buck (2012) show evidence that other than during the 2009 recession, tourism has continued to grow. South East Asia, is expected to have 6.3% annual growth of inbound tourists between 1995 and 2020 (WTO, 2011), which ties in with the predicted strong growth of beach and coastal tourism in these locations from European tourists (WTO 2011). The WTO (2011) report goes further to highlight South East Asia as one of the global hotspots for SCUBA diving and in-water activities for tourists, and again predicts strong growth over the next 5-10 years.

The United Nations General Assembly declared 2017 as the International year of Sustainable Tourism as they work towards the 2030 Agenda for Sustainable Development and the 17 Sustainable Development Goals (Nations, 2016). All aspects of sustainable tourism were promoted; sustainable economic growth, social inclusiveness and poverty reduction, resource and environmental protection, cultural values and mutual understanding. Sustainable tourism and a focus on these areas is vital for coral reef communities, who will often rely heavily on the environment for sustenance and financial security (S.2.1.4). As such, encouraging improved tourism management will benefit the long-term viability of coral health and community structure. Similarly, in a CESD report for the WWF, accepted definitions for various forms of tourism are provided:

Sustainable Tourism; *tourism that “meets the needs of present tourists and host regions while protecting and enhancing opportunities for the future”,*

and **Ecotourism;** *“responsible travel to natural areas which conserves the environment and improves the welfare of local people”. (Honey and Krantz, 2007)*

They state that these terms came about in the 1970's as a result of environmental and social damage being caused by tourism (Honey and Krantz, 2007). The key difference between ecotourism and sustainable tourism, based on these definitions, is that ecotourism focuses on travel to natural areas. Beyond this, the protection of both the environment and social well-being is similarly included in sustainable tourism.

Weaver and Opperman (2000) split tourism into two types of attractions: natural and cultural. While natural relates to the topography, climate, hydrology, wildlife, vegetation or location, cultural relates to historical, contemporary culture (communities or neighbourhoods and architecture), economic, recreational and retail. Building on this description different types of tourism can be determined, with the most relevant being marine and coastal tourism. As a sport, diving can be considered cultural, through recreation, however, the predominant attraction for divers comes from wildlife and the opportunity to view rare or impressive species underwater.

2.2.1 Marine and Coastal Tourism

Coastal tourism is defined as tourism that takes place within the coastal zone or near-shore environment; including all services such as accommodation and resorts, restaurants, recreational activities and infrastructure required to sustain the sector. Marine tourism brings together coastal tourism with recreational activities that take place offshore, including deep sea fishing, SCUBA diving, cruises and sailing (Hall, 2001). As with the whole tourism sector, marine and coastal tourism is growing (Wong, 1998; Hall, 2001; Davenport and Davenport, 2006), in part due to increased accessibility and development of infrastructure and resorts in previously difficult to visit locations. Wong (1998) states that Malaysia was already strongly

developed for tourism in 1998, while countries such as Indonesia and the Philippines were both in the early stages of development. Figure 2.3 (DMPM, 2017) shows the total number of visitors to Malaysian marine parks between 2000 and 2016. The blue line represents total visitor numbers to Malaysian marine parks, and, while there are occasional dips, the trend line shows a clear growth over the last 15 years. Similarly the red line, which represents marine parks in the state of Terengganu, where this study took place.

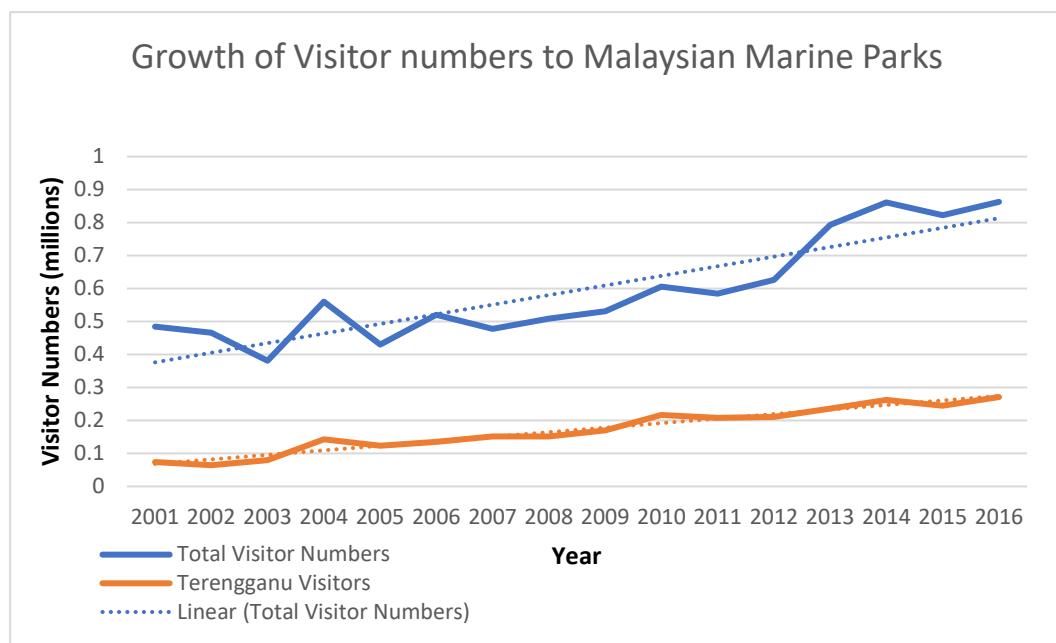


Figure 2.3 The total number of visitors to Malaysian Marine parks between 2000 and 2016. (DMPM 2017)

The growth of coastal tourism and the demand for sustainable and ecotourism show an accepted knowledge that tourism poses a risk to coral reef health. One risk is linked directly to increased tourist numbers. As demand has increased, local communities have been required to adapt and develop to meet demands. This includes extensive coastal development in prime locations, leading to run-off, pollution, dredging and land-filling (Wong, 1998; Hall, 2001; Burke *et al.*, 2012). This can directly impact coral health and their ability to grow or develop new coral. Another threat on coral health from tourism comes directly from

beach users. Presence of shallow-water, fringing reefs along the coast creates a direct conflict between beach users and coral health. Locations with high numbers of beach users have shown increased rates of mortality and breakages, particularly sites with high proportions of branching coral, which may suffer complete or high mortality (Davenport and Davenport, 2006; Juhasz *et al.*, 2010; Hannak *et al.*, 2011). Hannak *et al.* (2011) suggest that in order to reduce the threat of near-shore damage to coral reefs, improved education and guidance should be provided to tourists in an attempt to raise awareness and change behaviour. Alongside coastal and near-shore threats of snorkelling, swimming and trampling, comes the threat from diving contacts, which is the focus of this study and will be introduced in following Section.

2.3 SCUBA Diving

The most relevant threat to coral reefs for this study is the direct impact tourist activities, particularly those of SCUBA divers. SCUBA is an acronym for 'Self Contained Underwater Breathing Apparatus'. SCUBA diving provides participants with an opportunity to breathe underwater and move amongst coral reefs from below the surface. Being able to view the reef in close proximity can potentially develop a greater appreciation for nature, but also increases the risk of damage. Where snorkelers, surfers and jet skis are generally limited to surface waters, SCUBA divers can get within touching distance of the fragile reef ecosystem.

The Professional Association of Diving Instructors (PADI), a global leader in SCUBA diver training completed their 25th million certification on 29th December 2016 (PADI, 2017b) and have averaged 900,000 new divers annually for the last 19 years (PADI, 2015). However, while PADI have completed 25 million certificates, this figure accounts for beginner and advanced

training courses but does not account for divers no longer active in the sport. While it is difficult to gauge the number of active SCUBA divers at any one time, PADI divers, coupled with divers from other SCUBA dive agencies (e.g. SSI, NAUI and BSAC), it was estimated in 2011, and again in 2019 that the number of active divers was 6 million globally (WTO, 2011; DEMA, 2019).

PADI offer numerous courses for SCUBA divers allowing participants to choose their own route and specialties. An initial taster course is called the 'Discover SCUBA Diving'; a one-day course that covers basic safety theory and one instructor led dive, with minimal skill or training. This is designed to develop an interest in the sport and encourage participants to take up SCUBA diving. PADI's Open Water Diver (OWD) course is the first course that, upon completion, allows SCUBA divers to dive down to 18m unsupervised in conditions similar to those in which they are trained. After the OWD course, there is the option to carry out the Advanced Open Water (AOW) course, which allows divers to dive to 30m underwater. After this are the Rescue Diver course, which teaches the skills necessary to save yourself or another, and the Dive Master (DM) course, which is the first PADI professional level and allows divers to guide and assist on courses. Beyond the DM course, the option to train as an assistant or full instructor and higher become available. There are also a number of speciality courses which train divers to dive in specific conditions or with specific equipment (e.g. Deep Diver, Underwater Photography, Wreck Diver, Drift Diver and Night Diver). Speciality courses are numerous, and it is possible for instructors to write their own distinctive specialities (PADI, 2017a). While buoyancy training was looked at in this research, there is scope for further research to be conducted to investigate variations in behaviour between divers from different agencies and divers with different speciality training.

As the entry level course to SCUBA diving, the Open Water course is important for developing knowledge and skills that will enable SCUBA divers to remain safe underwater while having minimum impact on the marine environment. New divers undergo a minimum of 2 days training, covering theory and practical knowledge and skills that will prepare them for future dive adventures. The priority focus on skill development is safety and ensuring divers are able to deal with problems underwater should they arise. Early skills include assembling and disassembling equipment, pre-dive safety checks, deep-water entry, proper descent and ascent, regulator recovery, mask clearance, regulator (breathing apparatus) malfunction simulation, remove and replace equipment, neutral buoyancy and hovering skills (PADI, 2017a).

In 2016, PADI introduced a number of changes and updates to their Open Water diver course to include additional skills and training. One major point of change, and particularly relevant to this research was the weight or trim check. Previously, new divers were ‘properly weighted’ if they floated at eye level with holding a normal breath (a skill completed in water too deep to stand in). This skill has been updated to include proper distribution of weight to ensure a more horizontal position in the water to improve streamlining (and therefore air consumption) (PADI, 2017a). The skills circuit hasn’t been altered to such an extent that it will force behaviour change in SCUBA divers and based on personal experience, the primary factor that influences diver behaviour is the instructor and the effort to ensure all skills (particularly buoyancy related skills) are perfected during training. Further, that theory and knowledge imparted as to why certain behaviours should be prioritised. Over the course of both a recreational and professional diving career, personal experience has found that very little emphasis has been put on buoyancy, finning or positioning, either before the changes in 2016 or after. Generally, the bare minimum in buoyancy skills is completed during training to

ensure certification. In some instances, divers have been observed 'passing' the open water dive training after being supported through the duration of the dive by an instructor, highlighting an inability to control their own buoyancy, yet still being passed.

The level of environment-focused education within PADI courses could be considered an issue, though it can also be argued that it is not the responsibility of PADI to create environmental understanding. Dive centres and providers of courses and dives could be considered more important for educating against environmental impacts. However, due to dive centres being based in varying locations and environments, this would require a site-specific focus, meaning when divers visit a new location, any previous information may not necessarily be applicable. For example, diving on a coral reef may require different considerations to a wreck or sandy substrate. Therefore, the most suitable and potentially effective approach for initial education would be within the standard dive course offered by PADI and other organisations, which should be further pushed through dive centres and activity providers.

The next subsection will review current literature surrounding SCUBA diver impacts on coral health as relevant to this research.

2.3.1 SCUBA Diver Impacts

Interactions between SCUBA divers and coral reefs has been studied using two specific protocols. The first observes SCUBA diver behaviour underwater, specifically, contacts with substrate (Harriott, Davis and Banks, 1997; Medio, Ormond and Pearson, 1997; Roupheal and Inglis, 1997, 2001; Zakai and Chadwick-Furman, 2002; Barker and Roberts, 2004; Uyerra and

Côté, 2007; Worachananant *et al.*, 2008; Luna, Pérez and Sánchez-Lizaso, 2009; Camp and Fraser, 2012; Krieger and Chadwick, 2013; Toyoshima and Nadaoka, 2015; Roche *et al.*, 2016). Observing SCUBA divers underwater allows specific data to be collected and removes any outside influences on coral reef health (boat anchoring, snorkelling, natural damage), so any damage observed can be associated directly to divers. The second approach is through completing coral health (coral cover) surveys on sites, typically comparing sites of high use against those of low use (Hawkins and Roberts, 1992; Tratalos and Austin, 2001; Hasler and Ott, 2008; Guzner *et al.*, 2010; Hannak *et al.*, 2011; Lamb *et al.*, 2014; Hein *et al.*, 2015; Betti *et al.*, 2019). This approach removes the difficulties and ethical barriers in observing people, and instead relies on correct identification of substrate allowing for potentially greater accuracy. It also allows for a wider understanding of SCUBA impacts, including those associated with boat anchor damage and pollution. Methods for this approach are discussed in Section 2.1.5 and vary between line intercept transects and coral video transects.

As stated in Section 2.2.1, PADI have recorded an annual growth in new SCUBA divers. Observing SCUBA divers underwater provides an insight into behaviour and the effectiveness of training methods. It provides opportunities for research to develop new impact reduction approaches and interventions to reduce impact, while conducting reef surveys helps determine whether there is a causal link. As a result, this research will adopt methods from both approaches.

2.3.1.1 SCUBA diver contact

For the purpose of this study SCUBA diver contact has been defined as any instance where a SCUBA diver makes direct physical contact with, or disturbs (sedimentation event) the marine

substrate. This may be done either through their fins, hand, knee or equipment (including submersible pressure gauge, camera, pointer stick or reef hook) (Talge, 1990; Roupheal and Inglis, 1997; Zakai and Chadwick-Furman, 2002). There are a number of studies that adopted this method (S.2.3) and observed divers underwater for a set period of time, recording the number of contacts each diver had. Where previous studies have focused on the rate and point of contacts (Section 2.3), this study will analyse the *cause* of contact in greater detail. This will build on the research of Toyoshima and Nadaoka (2015) who looked at buoyancy as a factor related to contact rates.

All studies reviewed observed divers making contact with the substrate but the percentage of divers that make contact varied between studies. Roupheal and Inglis (1997, 2001) found 70% and 73% of divers made contact during their observations over two separate studies, correlating with results (73.9%) found by Barker and Roberts (2004). However these observations are considerably lower than other studies, where typically 88% (Roche *et al.*, 2016) and 96.7% (Luna, Pérez and Sánchez-Lizaso, 2009) observed contacts were recorded. Uyarra and Cote (2007) focused their study on diver behaviour in the presence of cryptic¹ creatures and found that 75% of divers made contact with the substratum when in the vicinity of these creatures, but only 25% made contact when not present. This suggests there is a much higher likelihood of contact being made when observing smaller, harder to see creatures. That all studies have found relatively high rates of contact proves therefore a need for new management and training protocols to reduce the rate.

Average contact rates vary between studies, the lowest being 1.16 contacts per 10 minutes (Roche *et al.*, 2016), going up to 46 contacts per 10 minutes (Uyarra and Côté, 2007) or 41

¹ Animals that camouflage themselves effectively or are small enough to be hard to spot

contacts per 10 minutes (Luna, Pérez and Sánchez-Lizaso, 2009). However, findings from Uyarra and Cote (2007) and Luna *et al* (2009) appear to be anomalous. Roupahel and Inglis (1997, 2000) and Toyoshima & Nadaoka (2015) found similar results of 5.4 and 5.3 contacts per 10 minutes, while Zakai and Chadwick-Furman (2002) and Krieger and Chadwick (2013) found a contact rate of 3.6 and 3.0 per 10-minute observation periods. Such variations between studies is difficult to explain, but it should be noted that Uyarra and Cote (2007) focused their study on cryptic creatures, and noted that when divers were more than 5 metres from a frogfish (*Antennarius sp.*) or seahorse (*Hippocampus sp.*), their contact rate dropped to an average 0 per 10 minutes. When these figures are extrapolated to cover the length of a full dive (approximately 45 minutes), the average number of contacts would be between 184 (Luna, Pérez and Sánchez-Lizaso, 2009) and 5.2 contacts per dive. To put into context, if every PADI certified diver went on one dive a year, the number of contacts annually could reach between 130 million and 4.6 billion and given that many divers do multiple dives annually, this number could be even higher.

Some studies did not record the extent of damage caused to the reef (Luna, Pérez and Sánchez-Lizaso, 2009; Camp and Fraser, 2012), while several attempted to segregate the type of contacts that resulted in breakages of coral colonies (Medio, Ormond and Pearson, 1997; Roupahel and Inglis, 1997, 2001; Zakai and Chadwick-Furman, 2002; Barker and Roberts, 2004; Toyoshima and Nadaoka, 2015). Barker and Roberts (2004) describe contacts in three categories: minor (abrasion only), major (breakage) and re-suspension of sediment. The wording used suggests that abrasion of coral is not as harmful as breakages, however there is evidence that contact and tissue abrasion on coral can increase the risk of predation and

disease (Guzner *et al.*, 2010; Lamb *et al.*, 2014; Zulaiha, Abidin and Mohamed, 2014). Lamb *et al.* (2014) found that at high use sites, coral disease was significantly more common. This was especially the case where contacts and breakages were present, along with increased disease in coral suffering from sediment accumulation. Guzner *et al.* (2010) linked SCUBA diver impact with increased predation by Sea Snails (*Drupella sp.*) and other predators. Predation further damages and weakens coral colonies resulting in a downward spiral of health. Zulhaila, Abidin and Mohamed (2014) state that contact from divers can result in a 'shut down reaction'; a scenario where the protective mucus covering a coral colony is removed, leaving polyps more vulnerable to predation and disease. This vulnerability is more prevalent at heavily visited sites than at less popular coral reefs.

Finning

All studies reviewed recorded diver contacts with the substrate, and a high proportion highlighted that the main point of contact was through diver fins (Harriott, Davis and Banks, 1997; Medio, Ormond and Pearson, 1997; Zakai and Chadwick-Furman, 2002; Barker and Roberts, 2004; Worachananant *et al.*, 2008; Luna, Pérez and Sánchez-Lizaso, 2009; Chung, Au and Qiu, 2013; Krieger and Chadwick, 2013; Roche *et al.*, 2016). Two studies (Worachananant *et al.*, 2008; Toyoshima and Nadaoka, 2015) found a correlation between contact rate and experience, suggesting specialisation is not a major factor in determining contact. Benthic assemblage appears to influence diver impacts (Rouphael and Inglis, 1997; Barker and Roberts, 2004), though it can be argued that proximity to the reef, buoyancy control, positioning and movement of fins (finning technique) are also major factors influencing contact rates.

Positioning

Positioning is not a factor that has been previously studied in relation to the cause and rate of contacts. However, it is a behaviour that is of interest and potential importance. Correct positioning is defined as swimming in a horizontal position (S.2.2.1), and has been included in PADI's updated open water course (PADI, 2017a). Toyoshima and Nadaoka (2015) include positioning in their assessment of buoyancy control, though as is discussed in this paper, the two are not always necessarily linked. Camp and Fraser (2012) conducted an evaluation of dive guide briefings and included 'proper positioning in the water' as a factor that should be stated, though they do not detail why it is important. Likewise, Ong and Musa (2012) cite the Marine Ecotourism for the Atlantic Area (2001) report which highlights guidelines for diver behaviour, including review and updating of buoyancy control, finning and positioning, which are all key behaviours analysed in this study.

Intentional or Unintentional

It is important to note that several studies highlight that most contacts were unintentional. Camp and Fraser (2012) found 55.4% of contacts observed were unintentional, compared to 81% noted by Barker and Roberts (2004) and 64.3% by Uyarra and Cote (2007). The latter study found unintentional contacts accounted for 64.3% when away from cryptic creatures but 86% when within 5 metres of cryptic creatures. These concur with other studies (Anderson and Loomis, 2011; Zulaiha, Abidin and Mohamed, 2014; Toyoshima and Nadaoka, 2015) and highlight the importance of training and skills, rather than awareness and a focus on environmental issues. If divers were intentionally making contact, environmental and ecological awareness would likely be more effective, but due to the significant number of unintentional contacts, focusing on improving behaviour through other means should be

more effective, particularly as divers may be unaware they are making contact with the substrate.

Experience

Worachananant *et al.* (2008) focused on experience when contemplating contact rates where factors such as the number of dives were considered. Participants were grouped accordingly: beginners were categorised as those having participated in fewer than 25 dives; novices as 26-50 dives; enthusiasts as 51-100 dives and experts as those having over 100 dives. In contrast, Uyarra and Cote (2007) grouped those with fewer than 20 dives as inexperienced and those with greater than 20 as experienced. While Uyarra and Cote (2007) found no correlation between diver experience and contact rates, Worachananant *et al.* (2008) concluded that as experience increased, the number of contacts and coral damage reduced.

Gender, Age and Nationality

Other factors that could contribute to contact rates, but have had limited research conducted are gender, age and nationality. Gender has been previously studied as part of wider research projects (Rouphael and Inglis, 2001; Uyarra and Côté, 2007; Luna, Pérez and Sánchez-Lizaso, 2009; Chung, Au and Qiu, 2013). Uyarra and Cote (2007) found no significant difference in contact rates between male and female divers. In contrast, Chung *et al.* (2013) found that female divers made significantly more contacts than male divers, unlike Luna *et al.* (2009) and Rouphael and Inglis (2001) who found that males were more likely to contact substrate than females. Gender will be considered as part of this research in attempt to determine a broad understanding of contacts and their causes.

To date, there have been no studies that have attempted to correlate age groups or nationalities with contact rates within the diving community. In order to determine whether there is a correlation between age, nationality and contact rates, this study will conduct tests to compare contact rates.

2.3.1.2 Pre-dive briefing

As well as the aforementioned factors, the use of a camera and the contents of a pre-dive briefing (Davis and Tisdell, 1995; Harriott, Davis and Banks, 1997; Medio, Ormond and Pearson, 1997; Rouphael and Inglis, 1997; Barker and Roberts, 2004; Thapa, Graefe and Meyer, 2005; Uyarra and Côté, 2007; Worachananant *et al.*, 2008; Hasler and Ott, 2008; Camp and Fraser, 2012; Krieger and Chadwick, 2013; Toyoshima and Nadaoka, 2015). PADI (2016) state that a dive briefing should cover 10 points: dive site name, site description, the guide's role, entry and exit techniques, emergency procedures, signal review, buddy check, environmental orientation and a pre-dive safety check. PADI do not specify the details for each section of the briefing, although only the 'environmental orientation' section would lend itself to raising any conservation awareness. While PADI and other organisations have developed standards for pre-dive briefings, it is the certified instructors and dive masters that are required to carry them out. This results in a huge variety of approaches and interpretations of the pre-dive briefing, often influenced by a dive guides own education in both diving and environmental awareness, along with their attitude towards the environment. The effectiveness of an environmental pre-dive briefing has been studied previously in five different forms (Harriott, Davis and Banks, 1997; Medio, Ormond and Pearson, 1997; Barker and Roberts, 2004; Worachananant *et al.*, 2008; Camp and Fraser, 2012; Toyoshima and

Nadaoka, 2015). Medio *et al.* (1997) and Toyoshima and Nadaoka (2015) both utilised a long and in-depth briefing, while Barker and Roberts (2004) opted to include a single sentence targeting environmental awareness. Harriott, Davis and Banks (1997) and Worachananant *et al.* (2008) both noted the inclusion of a short environmental aspect to the dive shop briefing while Camp and Fraser (2012) recorded and scored the dive shop briefing based on the level of environmental focus included. Giglio *et al.* (2018) by contrast examined the effect of a video briefing on diver impacts.

The studies have resulted in mixed outcomes and conclusions. Medio *et al.* (1997) found a significant improvement in the rate of contacts for divers who underwent a detailed briefing, while Toyoshima and Nadaoka (2015) found improved rates of contact for divers who were able to control their buoyancy after a briefing, but found buoyancy control was the biggest factor influencing contact rates. They state that 4 out of 8 divers had increased rates of contact after the briefing, suggesting the briefing wasn't as effective as Medio *et al.* (1997) had found. Both of these studies used some form of presentation (PowerPoint or photographs) to give detailed information on coral biology, while Medio *et al.* (1997) continued to point out live coral during the dive and began highlighting sections of substrate that divers were able to touch (non-living substrate). The continued influence and education by Medio *et al.* (1997) underwater potentially links to reduced contact rates as increased dive guide intervention has been found to be an effective preventative measure for contacts (Barker and Roberts, 2004).

Camp and Fraser (2012) concurred with Medio *et al.* (1997) and found a correlation between a coral biology focused pre-dive briefing and a reduced contact rate, suggesting an in-depth and detailed presentation about coral ecology, substrate and fragility is an effective measure

in reducing contact. However, few diving instructors are coral biologists and providing a 10-15 minute presentation for divers would be highly unlikely both through knowledge and time availability within dive centre daily planning (Othman *et al.*, 2014). Barker and Roberts (2004), Worachananant *et al.* (2008) and Harriott, Davies and Banks (1997) all looked at the impact a considerably shorter environmental briefing had on diver contact rates, but as with the difference between Medio *et al.* (1997) and Toyoshima and Nadaoka (2015), there were again result variations. Both Worachananant *et al.* (2008) and Harriott, Davies and Banks (1997) found diver contact rates were lower where they had attended a dive briefing which included a statement highlighting coral sensitivity and to avoid contact. In contrast, Barker and Roberts (2004) found no improvement in contact rates after the inclusion of a single sentence. Instead they note that intervention by the dive guide was the most effective way to reduce contact rates, stating that a detailed briefing, was an inappropriate approach due to the unlikelihood of SCUBA dive centres working to time constraints. Experience working within the SCUBA diving industry has shown this to be true. Dive centres run multiple dive trips a day, often with strict departure times for optimal tide and current conditions, and as such, briefings tend to last approximately 5 minutes, and are required to cover the key points as outlined by PADI (PADI, 2017a).

Giglio *et al.* (2018) used a completely different approach to those discussed above. The video briefing was designed locally to amplify and raise awareness of the beautiful local environment and highlighted key tips for divers to follow, including not touching, remaining in control of buoyancy and controlling positioning in the water. While they found reduced contacts from divers who had watched the video, the same divers were not observed in both observation periods and it is possible other factors influenced behaviour (experience, conditions, environmental awareness). Giglio *et al.* (2018) went on to ask the treatment group

what they remembered of the briefing and found a positive outcome within the group, suggesting that it is an effective tool. However, the local focus of the video suggests that potentially, a single video wouldn't be sufficient for every dive centre and that local organisations would be responsible for creating their own videos. Further, many dive centres do not have the resources to provide a video briefing before every dive.

Using pre-dive briefings as mitigation to-date is inconclusive, but results suggest that some approaches to the briefing work. However, only Toyoshima and Nadaoka (2015) and Medio *et al.* (1997) observed the same divers before and after a briefing: providing a more accurate outcome as it limits the effect of confounded variables (training level, number of dives and buoyancy) (Ong and Musa, 2012; Lucrezi, Saayman and van der Merwe, 2013; Toyoshima and Nadaoka, 2015). Comparing the contact rate for the same divers before and after a focused briefing allows direct monitoring of changes. Medio *et al.* (1997) observed 48 divers over multiple dives, while Toyoshima and Nadaoka (2015) observed a total of 105 divers, but only 14 were observed twice. The low sample size for both, but particularly Toyoshima and Nadaoka (2015) could explain conflicting results between the two studies. Further, none of the current studies focused on the cause of contact and purely focused on the number of contacts before and after briefings. Likewise, the rate of unintentional contacts was not considered significant or highlighted within the studies. Without understanding the cause of contacts it is difficult to fully understand and influence contact rates: diver contact rates can vary from dive to dive, particularly if conditions vary (strong currents, topography etc.) (Rouphael and Inglis, 1997; Camp and Fraser, 2012; Zulaiha, Abidin and Mohamed, 2014).

This study will develop a methodology for a pre-dive briefing based on key behaviour and predicted causes of contacts in an attempt to positively influence SCUBA diver behaviour to reduce contact rates. The briefing will be developed based on discussions with dive professionals, diver impact studies and a review of human behaviour drivers and focus on behaviour, rather than focus on coral biology.

2.3.1.3 Recreational Specialisation

A theory that is potentially highly relevant to this area of study is that of Recreational Specialisation (Ditton, Loomis and Choi, 1992). This theory places recreationists into groups or categories based on their experience and interest in an activity. It states that those with a higher level of experience (specialist) have a greater appreciation for the finer aspects of the activity. Regarding SCUBA diving, this could relate to a higher appreciation of reef conservation, buoyancy control (potentially leading to a lower contact rate), fish identification and practices that lead to protection. However, with the theory that greater levels of experience and specialisation comes a greater appreciation for the activity does not necessarily mean that behaviour would follow suit. While there is evidence that divers with greater levels of experience (skill and knowledge) have a different attitude towards behaviour than less experienced divers (Salim, Bahauddin and Mohamed, 2013), the actual outcome is not always as clear cut.

Salim, Bahauddin and Mohamed (2013) found that, based on questionnaires, inexperienced divers were more likely to make contact with substrate, lose buoyancy control or grasp substrate with their hands whereas a number of other studies found no significant correlations between experience and contact rate (S.2.3.1.1). However, these results were

based on self-reporting through the form of a questionnaire, had Salim, Bahauddin and Mohamed (2013) completed direct observations alongside the questionnaire, it is possible that discrepancies would be found between perceived behaviour and actual behaviour. As part of this research, both a questionnaire and direct observations will be carried out to determine links between perceived and actual behaviour.

The idea of experience resulting in improved behaviour and buoyancy (Ong and Musa, 2012; Salim, Bahauddin and Mohamed, 2013; Toyoshima and Nadaoka, 2015) as based on the theory of recreational specialisation has been countered by a theory that suggests greater experience might result in an interest in specific flora and fauna which in turn could result in more damage. Uyarra and Cote (2007) and Lucrezi *et al.* (2013) both discuss this issue resulting from greater levels of experience. They state that more experienced divers show a greater interest in specific or hard to find flora and fauna. According to Uyarra and Cote (2007) this can result in a greater level of negative interaction with the reef as these species can often be found hiding in crevices or require very close viewing for small species such as frogfish and seahorses. Personal experience has resulted in numerous occasions where divers have been observed holding, kicking and lying on coral to get a closer view or photographs of small and cryptic species.

In contrast, becoming a specialist in diving, through extensive experience or training, should naturally develop a higher appreciation and care for the underwater environment, which would result in greater acceptance of education and conservation efforts. This is confirmed by Anderson & Loomis (2011), who found that divers with a higher level of recreational specialism reported a greater level of care and obligation towards aquatic life when diving. In contrast, Thapa *et al.* (2010) state that specialisation acted as a strong partial mediator,

though not fully significant when affecting behaviour in the water. This tends to align with the research conducted by Medio *et al.* (1997) who stated that increased environmental knowledge resulted in reduced contact rates.

2.3.2 SCUBA Diving Carrying Capacity

The threat to coral health from SCUBA diving discussed in this chapter needs management. Various papers have previously broached the topic of SCUBA diver management with a common theme being to introduce limits on the number of divers visiting a coral reef per year (Davis and Tisdell, 1995; Schleyer and Tomalin, 2000; Zakai and Chadwick-Furman, 2002; Chung, Au and Qiu, 2013), a management strategy based on the carrying capacity of the site.

Davis and Tisdell (1995) state that defining carrying capacity is difficult. One definition claims carrying capacity to be *“the limits below which sustainability shows to be sufficient for humanity”* (Cheng *et al.*, 2019. P.43), whilst Davis and Tisdell (1995) quote Dixon *et al.* (1993), who state it is the level at which damage becomes noticeable to divers. In contrast, In unpublished work, Phillips defines carrying capacity as *“the level of use a natural resource can sustain without an unacceptable degree of deterioration of the character and quality of the resource”* (Davis and Tisdell, 1995. P.34), and, while difficult to accurately establish, helps management teams to determine how many divers to allow to a site annually. Arguably, any definition should be based on both impact on human use and on biodiversity and ecosystem health.

A site in Eilat (Egypt) was restricted to 4,000 divers per year (below the estimated 5,000-6,000 capacity for Eilat reefs for diving tourism but was still showing deterioration and high

predation levels (Zakai and Chadwick-Furman, 2002; Guzner *et al.*, 2010; Camp and Fraser, 2012). Likewise, the effectiveness of implementing limits to divers based on a pre-conceived carrying capacity was deemed, on its own, ineffective, though coupled with behaviour modification may prove a useful management tool (Musa *et al.*, 2011). The aim of this study is to develop a relationship model and management plan for SCUBA diving activities and will incorporate both carrying capacities and behaviour modification as suggested by Musa *et al.*, (2011), this recommendation reinforces the importance of this research.

While there has been some success in utilising carrying capacities (Zhang, Chung and Qiu, 2016) these studies highlight the difficulty in accurately gauging that limit. This study will utilise a briefing to modify behaviour of SCUBA divers, as suggested by Musa *et al.* (2011). Reducing the impact of divers should be a priority in management strategies and combined with other approaches, including carrying capacities.

2.4 Human – Environment Relationship

This Section will discuss literature related to the relationship between humans and the environment. It will initially introduce the field of conservation psychology, then discuss in detail various factors that attribute to human behaviour, including research related to pro-environmental actions. Finally, it will look at models that attempt to explain the process of behavioural change and case-studies where it has been previously attempted.

2.4.1 Background of Conservation Psychology

The field of conservation psychology was developed to *“not only understand the interdependence between humans and nature but to promote a healthy and sustainable*

relationship” (Clayton and Myers, 2009. P.2). In order to prevent or minimise human-induced environmental problems (conservation), such as the loss of coral reefs, an understanding of human behaviour (psychology) is required. The field was borne partially from the wider field of Environmental Psychology which looks at the influence the environment has on human experience, well-being and behaviour, as well as the influence humans have on the environment (Steg, Van Den Berg and De Groot, 2013).

Environmental Psychology first came from the influence of architecture on human behaviour and how humans responded and interacted to everyday physical settings (lighting, layout). This was developed to include interactions and responses to environmental change when environmental issues became more prevalent (Steg, Van Den Berg and De Groot, 2013). More recently, there has been extensive research that highlights health and well-being benefits humans gain from spending time in nature (Kaplan, 1995; Watson *et al.*, 2005; Lee and Maheswaran, 2010; Wheeler *et al.*, 2012; Carrus *et al.*, 2015; Sandifer, Sutton-Grier and Ward, 2015). Kaplan (1995) developed the Attention Restoration Theory (ART) which discusses four factors needed for restorative therapy, and evidences how nature can provide each of these. Wheeler *et al.* (2012) stated that coastal proximity plays a role in health and well-being. Furthermore, they suggest the benefits of coastal living can offset the negative impacts of socio-economic deprivation. Likewise, there is evidence that higher levels of biodiversity in green spaces can positively influence health and well-being (Carrus *et al.*, 2015). While research on the well-being benefits of SCUBA diving is limited, both papers highlight the potential importance of maintaining coral reefs from a health perspective. High biodiversity found in coral reef environments, as well as the benefits of being near the coast, are significant for local communities and SCUBA divers. Carrus *et al.* (2015) concluded that spending more time in and around green spaces can foster a greater appreciation and more

positive attitudes and behaviour towards nature (value). Other, concurring studies include Sapci and Considine (2014), who found a correlation between positive environmental attitudes and pro-environmental behaviour, and Heberlein (2012), who examined attitudes and their impact on intent-oriented behaviour. In his review of environmental attitudes, Heberlein (2012) found that having an environmentally positive attitude towards something doesn't necessarily mean behaviour will follow. An example provided is that of Aldo Leopold, who wrote passionately about wolves, but voted affirmatively to pay people to hunt and kill the few remaining wolves. Heberlein states that the gap between attitudes and behaviour is a fundamental problem with the 'education as a fix' approach to our impact on the environment.

One of the themes that runs through conservation psychology and behavioural theories is that of values and attitudes towards the environment (Stern, 2000; Clayton and Myers, 2009; Heberlein, 2012; López-Mosquera and Sánchez, 2012; Onwezen, Antonides and Bartels, 2013). However, as Heberlein (2012) highlights, altering attitudes isn't necessarily the key to behaviour change and needs to be complemented by other factors including the strength of the attitude. Where the strength of an attitude is weak, it is more likely to be influenced by other factors such as social norms or attitudes towards an opposite factor. In the case of Aldo Leopold, there is evidence in his previous writings of his disdain for wolves, so it is entirely possible that, although his attitude was changing, it was not strong enough to counter the public backlash from hunters should he vote against hunting wolves.

When the gap between attitude and behaviour is taken into consideration, the effectiveness of pre-dive briefings found in previous literature and discussed in Section 2.3.1.2 can be re-evaluated. An environmental briefing targeting attitudes, values and awareness (Harriott,

Davis and Banks, 1997; Medio, Ormond and Pearson, 1997; Barker and Roberts, 2004; Worachananant *et al.*, 2008; Toyoshima and Nadaoka, 2015) could be deemed ineffective based on Heberlein's (2012) theory that attitudes do not necessarily alter behaviour. That some studies saw a reduction in contact rates could, in this regard, be purely coincidental, or a result of other factors. Medio *et al.* (1997) continued to engage with divers in the water during the second observation period, which could be a reason diver contact rate reduced. It is thought that work within conservation psychology should address *how* humans care (have value) for and behave towards nature and *how* beliefs and knowledge about nature are developed (Clayton and Myers, 2009). The core aspects of conservation psychology are closely linked to behavioural models, particularly the Value-Belief-Norm (VBN) model (Stern *et al.*, 1999) discussed in the following Section.

This research will look to develop an understanding of SCUBA diver care for the marine environment, diver behaviour (perceived and actual) and how divers interact and follow social norms within the dive community and respond to new information in the form of a pre-dive pro-environmental behaviour briefing.

2.4.2 Human Behaviour

Human behaviour is varied and vast and often determined as a result of social, cultural, financial and environmental factors. Environmentally significant behaviour can be defined along two paths. Firstly 'intent-orientated' behaviour, which is based on beliefs and attitudes, (Stern, 2000; Clayton and Myers, 2009; Heberlein, 2012; Sapci and Considine, 2014; Wynveen and Sutton, 2015), and can show motives towards a behaviour, but not the environmental impact (Boersema and Reijnders, 2008). The second is 'impact-oriented' behaviour, which

directly results in changes to the environment. Both definitions are important when considering behaviour change as impact-oriented behaviour can be a direct result of intent-oriented behaviour.

Intent-oriented behaviour is focused on factors that contribute to driving behaviour. It has already been established that placing a value on the environment is key in determining actions (S.2.4.1). Human behaviour is complex and influenced by a variety of outside factors such as physical barriers, rules or lacking the skill or ability to complete a specific task (Clayton and Myers, 2009). In some circumstances, the individual may value the environment, but is physically unable to act in a way that conserves it (e.g. temperature control in the workplace is often out of the hands of employees; not taking a bus due to impracticality of route etc.). This influencing factor, also considered by Heberlein (2012), is called 'behavioural affordances' and is often poorly represented when discussing behaviour. In the case of this study, there should be no affordances that would prevent divers from not making contact, other than the lack of ability to maintain distance from the coral reef while diving(poor buoyancy control), which, as discussed in Section 2.3, is an element of diver training course and helps to explain the high percentage of contacts being unintentional in the literature.

A number of models have been developed to help explain environmental behaviour, including the Value-Belief-Norm Model, the Theory of Planned Behaviour and the Norm Activation Model. These three models relevant to this study will be discussed accordingly.

2.4.3 Behaviour Models

The Norm Activation Model (NAM) states that personal norms are driven by two factors; an awareness of behaviour consequences, and a feeling of responsibility (Onwezen, Antonides and Bartels, 2013). Combined, these factors are considered to determine moral obligations and personal norms. The Value Belief Norm (VBN) model builds on NAM by adding values. Stern (2000) states that individuals must value or care for the environment as well as be aware of consequences, while having a feeling of responsibility, which, in the VBN model, is termed as an Environmental World View. The Theory of Planned Behaviour (TPB) model focuses on behavioural intentions and states that three factors influencing intentions are: attitudes towards the environment (positive or negative), social norms from the pressures to behave in a certain way from a social group and the perceived behavioural control which relates to the perceived ease (or difficulty) in carrying out a specific behaviour. The TPB model differs from the first two as it focuses more on developing behavioural intentions, whereas the NAM and VBN model look at the factors that develop norms.

Both the NAM and the VBN model link behaviour to morality and base behavioural choices partly on an individual's level of awareness of a specific problem, and in the case of the VBN model, the value the individual places on the environment at risk (Stern, 2000; De Groot and Steg, 2009; Steg and de Groot, 2010; Steg, Van Den Berg and De Groot, 2013). The NAM is regularly interpreted as either a mediator model or a moderator model. A mediator model assumes that responsibility and awareness of consequences indirectly affect behaviour via influencing personal norms: a change in responsibility or awareness could alter norms and therefore behaviour. In contrast, the moderator model believes the relationship between personal norms drive behaviour, but the strength of the change is determined by the level of

awareness and consequence and improving one of awareness or understanding of consequences would be sufficient to change behaviour.

Steg and de Groot (2009) carried out a comparison across 5 studies with their findings supporting NAM being a mediator model, in that an individual must be aware of that a specific behaviour will have an impact (either positive or negative) before they are able to feel responsible for it, while responsibility leads to moral obligations towards pro-social intentions. The outcome of the comparison allowed a simplified version of the NAM to be developed, which shows a flow from awareness to responsibility to the development of a personal norm to the behaviour.

In the case of the NAM, 'problem awareness' is described as 'being aware of the consequences of acting in a specific way for others or for things others *value*'. While not initially developed with the environment in mind, it is thought that pro-environmental behaviour is pro-social behaviour as it benefits others and things others value (De Groot and Steg, 2009; Steg and de Groot, 2010). The VBN model is regarded as an extension of the NAM, as it contemplates similar factors that influence behaviour but builds on it by considering values (attitudes). It makes a case for there being three types of value relevant to pro-environmental behaviour: egotistical, altruistic or biospheric. These do not necessarily act independently of one another; some scenarios may result in a value encompassing all three definitions. How individuals value the environment, and the related behaviour can play an important role in determining behaviour: a strong value in favour of an environment will contribute to pro-environmental behaviour. Taken individually, it is suggested that egotistical values typically lead to negative outcomes on the environment, while altruistic and biospheric both lead to positive results. Clearly this is because egotistical values tend to be more focused

on private or personal value and gains. Steg, Van den Berg and De Groot (2013) consider values being long-term factors, compared to goal driven factors which are only in place until the goal is reached. It follows therefore that values provide a means to evaluate actions and behaviours, before and after they have taken place. When developing a behavioural briefing it is important to consider the types of value being targeted: where coral biology and environmental impacts are the focus, it targets the biospheric value only, in contrast, targeting behaviour and the benefits to the environment and individual would cross over both egotistical and biospheric, making it more effective in developing value.

The second aspect of VBN model is linked to responsibility and the belief that our actions make a difference. In the case of the VBN model, belief is a concept built around the idea of an individual's environmental world view (EWV)(Stern *et al.*, 1999; Stern, 2000; Wynveen and Sutton, 2015), and can be defined as the ability of an individual to perceive threats towards the environment. Importantly, it considered the perception of their own ability to reduce or change threats. The EWV ties in with Steg and De Groot's analysis of NAM, in that awareness of a threat is important in developing responsibility. The realisation that their behaviour can make a difference is a key factor in creating personal and social norms and influencing behaviour and is identified in multiple behavioural studies where awareness and education are key players in behavioural drivers and change (Medio, Ormond and Pearson, 1997; Clayton and Myers, 2009; De Groot and Steg, 2009; Anderson and Loomis, 2011; Heberlein, 2012; Sapci and Considine, 2014).

Once problem awareness, values and a sense of responsibility are all established, it can influence and lead to the development or 'activation' of norms within a personal or social context. Norms can be defined as an individual's obligation to act or behave in a specific way

and play a large role in behaviour, both driving and changing. Norms are driven by internal and external forces; sanctions and incentives (Heywood, 2002; Anderson and Loomis, 2011; López-Mosquera and Sánchez, 2012) and can be large scale (social and community) or small scale (family or personal). Internal sanctions or incentives can be seen as feelings of embarrassment or guilt (negative) or pride and happiness (positive). External sanctions could be formed with immoral, financially excessive or time-consuming behaviours. External incentives come in the form of physical rewards or compliments and positive emotions from others (Stern, 2000; Heywood, 2002; López-Mosquera and Sánchez, 2012).

Norms are an important aspect of the VBN model as their presence can influence the impact of values and belief within the model. Strong norms (obligations) to behave in a specific way may result in behaviour that goes against personal beliefs or attitudes in order to retain a positive outlook from the community (Stern, 2000; López-Mosquera and Sánchez, 2012). In contrast, weak norms will put emphasis on values and beliefs when deciding behaviour drivers. A norm's strength is determined by the intensity of alignment of feelings within the general consensus, and behaviour driven by a strong norm is considered normative behaviour (López-Mosquera and Sánchez, 2012).

Pro-environmental behaviour, as with other behaviours is also linked to norms and incentives. For example, it can include reducing costs for energy saving technologies or fines for fly-tipping. However, within the SCUBA diving community, there are no global external sanctions or incentives in place based on interactions with the marine environment. In marine protected areas (MPA), there are often guidelines and rules that divers and dive centres are required to follow, although there is rarely any enforcement of rules underwater. An

exception to this is found in Sabah, Malaysia, where dive marshals have been employed to police the underwater environment and enforce rules and protection of the reef (PADI, 2016).

2.4.4 Behaviour Change

The NAM, VBN and TPB models all discuss norms and the influence they have on behaviour, but both NAM and VBN models discuss how awareness and responsibility can influence behaviour. Understanding these key drivers behind behaviour creates an opportunity to elicit change in specific behaviour through targeted interventions focused on influencing key areas that can result in a change in such changes.

The Trans Theoretical Model (TTM) (Prochaska and DiClemente, 1982) describes 6 steps an individual must go through in order for a behaviour to change: pre-contemplation, contemplation, preparation, action, maintenance and termination. Unlike the VBN model, the TTM takes time into account and states that an immediate behaviour change is not possible and can take several months. Firstly, *pre-contemplation*, explains an individual's normal behaviour without consideration of a new behaviour or a reason for change. The second step, *contemplation*, is the stage that would coincide with previous theories related to awareness and understanding, as well as the VBN model. It is at this stage where the individual would, based on their new level of awareness and understanding, begin to analyse the pros and cons of both the current and new behaviour and assessing how an individual views the new behaviour stands in relation to their own value and norms. Steps 3 and 4 (*preparation* and *action*) describe the stages in which the individual is carrying out the new behaviour, but requires continued support to maintain that new behaviour. It is for this reason that it has been suggested that rather than a strictly linear transition, individuals may revert to previous

steps before progressing (Mair and Laing, 2013). This would also explain why behavioural change is not immediate. While improved awareness can trigger the desired behaviour change ideals, eliciting change is not immediate and should be considered in any management strategies. With this in mind, success of pre-dive briefings (S.2.3.1.2) found in research may not necessarily indicate complete behaviour change. In order to determine the long term effectiveness of a briefing, continued observation is necessary, as is repeat exposure to a pro-environmental behavioural briefing.

Literature states that, similar to values, norms are slow and difficult to change (Anderson and Loomis, 2011; Heberlein, 2012). This is a direct result of the conflicts between personal norms (formed through beliefs, values and attitudes) and wider societal or community norms. Personal norms can be altered through targeting of beliefs and improving awareness and understanding, whereas norms that are based on a social group require changes on a wider scale. One approach to behavioural change in this regard is to create new incentives or sanctions, such as the dive marshals within Sabah. Clayton and Myers (2009) state that care (or value) is a necessary component in driving behaviour, while Chiu *et al.* (2014) and Stern (2000) concur, highlighting value as an important factor alongside education and understanding. Stern's model (VBN model) states that an individual's behaviour depends upon their environmental worldview (EWV) (value and understanding of interactions between humans and nature), followed by their awareness of consequences (belief) of interactions and ascription of responsibility. Stern states that once an individual has accepted that their own actions can reduce negative or improve positive consequences, then their personal norm will alter, and they will achieve pro-environmental behaviour.

Chiu *et al.* (2014) approach behaviour from a similar angle, considering perceived value as the keystone to building pro-environmental behavioural norms. Research showed that a higher perceived value in tourists resulted in heightened environmental behaviour. However, they also state that participation in leisure activities also heightened environmental behaviour and confirmed that a high perceived value results in greater activity involvement. This highlights a strong link between value and behaviour, as well as a potential improvement in behaviour from a population actively participating in relevant activities. However, this model has not been designed to monitor behavioural change and is focused instead on the impact value and activity involvement can have on behaviour. For the purpose of this study, a combination of the three models discussed should be considered, taking into account the need for understanding (both awareness and personal involvement), egotistical, biospheric and altruistic values as well as action or participation.

Clayton and Myers (2009), discuss many aspects of conservation psychology, particularly mentioning human care for nature. They recognise that 'to care about' something can result in concern and an emotional attachment. It is this aspect that relates to this study and can prove an important factor when considering behaviour. SCUBA divers have shown an interest in the marine environment and specific species that reside within it (Todd, Graefe and Mann, 2002; Lucrezi, Saayman and van der Merwe, 2013). In essence this could represent a level of 'care' as described by Clayton and Myers (2009) however, the evidence has shown that even with this level of interest and motivation, SCUBA divers have a negative impact on the ecosystems (Medio, Ormond and Pearson, 1997; Barker and Roberts, 2004; Camp and Fraser, 2012). Clayton and Myers (2009) further discuss the need for people to be environmental custodians but that education is important in order to recognise the threat their behaviour can have, in this case, on coral reef and marine ecosystems. Along with being informed,

people must place a value on the subject, which will then create an emotional response and a change of behaviour. This coincides with Stern's VBN model, which theorises that as a person's care, or value and understanding is improved, a behavioural change will consequently occur. Steg *et al.* (2013) discussed values and their link to goal-directed behaviour, stating that values can result in specific goals being in place for an individual which can alter their behaviour. Unsworth *et al.* (2013) on the other hand directed green-goals into several categories: creating sustainable products, avoiding damage, conserving (reuse), influencing others (education) and taking action (activism). The common belief in these works state that valuing the environment can directly lead to the establishment of green-goals and suggest that enabling pursuit of individual goals will enact pro-environmental behaviour. However, there are often underlying values and interests that could pull a behaviour away from theory. For example, in the context of this study, a diver who is aware and understands the implications of touching coral may place a higher value on sighting specific marine species. This could potentially override the initial value of coral resulting in a behaviour that does not correlate with the perceived value and expected personal norm.

These theories and models will be tested through this study and a conceptual model developed to identify influences that act upon a diver during a dive with the aim of developing a relationship model that can target pro-environmental behaviour within diving communities.

2.4.5 Interventions

The idea of changing behaviour is not new; many studies have focused on the impact of various interventions in altering the way people behave. Nor is the idea solely located within the environmental sector. However, attempting to change and map behaviour within divers

has been limited to monitoring the impact of a targeted briefing prior to a dive with conflicting results (S.2.3.1.2): a more detailed ecological briefing has been found to be more effective than shorter 'single sentence' inclusions, though Heberlein (2012) stated that simply being more aware and valuing ecology wouldn't necessarily be sufficient to change behaviour (S.2.4.1).

One approach currently underway in South East Asia is the *Green Fins Initiative*. Implemented in 2004 by UNEP, the Green Fins Initiative focuses on unsustainable practices related to the SCUBA diving industry. Whereas this study is focused on individual diver behaviour, the Green Fins Initiative more specifically targets dive centres and the actions they can take to become more sustainable. This includes use of mooring lines as opposed to anchors (to reduce the risk of anchor damage to coral), waste management, dive briefings and in-water interventions and pollution (use of soap, sun tan lotion etc.). Dive centres are encouraged to sign up to the initiative at no cost and are provided training by Green Fins staff on sustainable practices, with annual monitoring assessments conducted at each dive centre. The method, which was designed based on IUCN classification of threats has been implemented in South East Asia since 2004, and has shown significant improvements (Hunt *et al.*, 2013). A case study of Green Fins dive centres in the Philippines showed 65% of dive centres received an improved score, highlighting the potential for success in reducing dive tourism impacts. However, the required in-depth training of dive centre staff and ongoing monitoring of centres could result in reduced success in areas where Green Fins staff are not regularly in contact with dive centres. This might explain the 35% of centres where scores increased, suggesting these dive centres were more of a threat in year 2.

In many locations, including Pulau Perhentian, SCUBA diving is a seasonal sport which leads to a high turnover in staff annually. As such, a dive centre that signs up to Green Fins in year one, may have an entirely new staff and/or management team in year 2. Therefore, it is perhaps better to target instructors and professionals during their own training, highlighting the importance of briefings, environmental education and dive guide intervention. Hunt *et al.* (2013) state that within the centres showing improvements, placement of Green Fins posters and signs, environmental briefings and guide interventions all play an important role in developing a 'No Touch' dive centre.

Outside the SCUBA diving industry, numerous interventions and methods for changing behaviour have been discussed and researched. One option that is often considered is the creation of laws and policies. This method allows external sanctions to act as an incentive for individuals to comply with predetermined behavioural norms. Galbiati and Vertova (2014) and Jones *et al.* (2013) discuss the effect laws have on behaviour and state that a new rule, or obligation, can positively affect behaviour. However they state that if an individual feels no obligation to take an action, an incentive or sanction will do little to change their actions (Jones, Pykett and Whitehead, 2013; Galbiati and Vertova, 2014). While an obligation without a sanction can still result in a positive behavioural change, they do concur with Heywood (2002) that obligation and sanctions combined return the greatest results.

Barr *et al.* (2011) state that using policy to target behavioural change is, unless through very broad guidelines, audience specific in that it relates to very precise targets. They state that many climate change policies are focused on household impacts, as opposed to other contributors such as travel. For this reason, the paper states that 'social marketing' (targeted groups) can be used to emphasise changes to key areas that are both attainable and practical,

and state that policies can be effective when directed towards active participation from the public. Barr *et al.* (2011) also disagree that broad, radical policies that target the whole population will be met with failure due to the consensus belief that a situation is not their fault. They found that the common focus on climate-change and sustainable lifestyle behaviours was on household outputs and behaviour, and failed to include other factors. They found that those who were most committed to sustainable lifestyles were wealthier, and that although behaviours in the household were sustainable, they were more likely to go abroad using air travel, which negates a sustainable lifestyle. It is for this reason that broad or more thorough policies are needed to target behaviour change to be truly effective and to reach the wider population (Barr, Gilg and Shaw, 2011).

For this study, population is defined as SCUBA divers, who, although come from a variety of backgrounds, all have a common interest in SCUBA diving. This link may afford some measure of success to a policy directed at specific SCUBA diver behaviour, though as with the policies towards climate change, there may be differences in diver perceptions and current behaviour that could isolate groups. In the context of this study, creating new laws and policies may help to encourage new pro environmental obligations to develop within the community, though creation of sanctions would be difficult due to the ability of authorities to police underwater dive sites. Policing could be carried out by dive centre staff, though this could potentially be seen as damaging business by the centres. Divers may be less likely to use their services if they face penalties and it would also require a combined effort by all centres in an area. It should also be noted that while social marketing can be employed to target divers, there will be a large portion of the diving community who do not believe they are having a negative effect, and will disregard the rules, whether they are or are not having an impact. This factor relates to perceived and actual behaviour.

A key aspect that has been mentioned in numerous studies, and already mentioned within this paper (S.2.4.3), is that of education and awareness. In a review of literature, Unsworth *et al.* (2013) found that mass media campaigns led to more positive attitudes within the population, but this did not always translate into significant behavioural change. This is potentially due to environmental action not being the main focus or goal. As discussed in Section 2.4.1, value can also be considered a key factor, and there is a need to consider the extent to which behaviour will affect the values of a person (self-concordance), which will also impact the duration of change. If there is only a small impact, then change is only likely to be short term (Unsworth, Dmitrieva and Adriasola, 2013). Where behavioural change and the impacts fit in with the self-concordance of an individual, there is likely to be a higher level and longer term change to their behaviour. In relation to this research, where SCUBA divers are the subject, raising values, awareness and understanding of coral reefs as well as specific behaviour benefits (buoyancy, finning technique, positioning and reducing contacts) could potentially result in long-term behaviour change.

Medio *et al.* (1997) and Barker and Roberts (2004), approached the issue of understanding and awareness through testing the impact briefings can have on behaviour. Through this, both studies attempted to provide on-site specific education before each dive, highlighting pro-environmental behaviour to divers directly before entering the water. While it could be argued that this approach only monitors short term changes in behaviour, inclusion of a more environmentally focused briefing as part of standards and protocols would mean that, for each dive, an individual's knowledge and awareness would be targeted. This in turn creates a short-term green-goal allowing long term behavioural change to be managed through regular instances of education and awareness. Unsworth *et al.* (2013) argue that the degree of

behaviour change will vary depending on how much it acts upon an individual's values, and a behaviour that positively acts on a green value is more likely to result in a long-term change.

All the potential behaviour change strategies discussed above (policies, education, incentives) have shown potential for success, but also weaknesses that need to be considered. For this reason, it is important when attempting to change behaviour, to consider a multidimensional approach (Stern, 2000; Unsworth, Dmitrieva and Adriasola, 2013; Galbiati and Vertova, 2014). However, as already discussed, enforcing laws in a SCUBA diving context is difficult, while offering incentives would potentially impact the financial viability of dive centres. Potentially, targeting a combination of values and education and following the VBN and TTM approach of values and understanding (belief) would develop marine citizenship within the dive community as well as create a regular reminder to participants.

Understanding of values and awareness within the dive community will allow analysis of perceived and actual behaviour and will feed into the relationship model, management plan and DPSIR framework as set out in the research aim.

2.4.6 DPSIR Framework

As discussed in Section 2.1.5, understanding coral reef resilience can be a useful approach to developing and designing management for the ecosystem. A greater understanding of all elements impacting and working within a system (either human or environmental) is key to effective management. The DPSIR framework (Kristensen, 2004) was born of the European Environment Agency (EEA) desire to develop a method to reporting on environmental impact assessments and to feedback appropriate information to policy makers. The framework

establishes a chain of events through which management is determined: Driving forces, Pressures, State, Impact and Responses. With effective research and understanding, the EEA is able to use the framework to create informative reports and plans that policy makers can utilise to manage and prioritise various environmental issues.

The DPSIR framework will be adapted within this study to allow greater understanding of the relationship between SCUBA divers and the marine environment. In this instance, the *Driving forces* of coral health degradation be based on the reasons people SCUBA dive (the drivers behind their desire to participate in SCUBA diving), the *Pressures* within the framework are a result of SCUBA diving impacts on coral reef health. The *State* of coral reefs refers to the biodiversity and resilience of a coral reef system, within this study, coral reef health will be assessed through surveying live coral cover while changes to the state is accounted for in impacts. *Impacts* refers to the changes to social and biodiversity states as a result of SCUBA diving activities: including economic, tourism, reduced biodiversity, loss of species, increase in predation etc. It can also be linked to wider impacts such as pollution (physical, chemical and nutritional) and demand for food resources, resulting in increased fishing, all of which can impact reef health (state). Finally, *Responses* are the management approaches that can be adopted to limit or prevent the impacts, some of which are discussed in this chapter and include pre-dive briefings, carrying capacity, dive permits and dive marshals but can also include creation of protected areas and marine parks, such as the site location for this study.

Having established the issue surrounding diver behaviour and the direct impact on coral health along with having explored the theory behind human behaviour and behaviour change, it is now necessary to introduce the study site for the research project. This will be done within the next chapter.

3.0 Study Site

The study site for this research was Pulau Perhentian, a small island chain (Figure 3.1) situated off the North East coast of Peninsula Malaysia, in the South China Sea (5.898252, 102.729636). The islands lie 9.91 miles from the mainland, where the River Besut enters the sea. The islands are sheltered by the mainland to the East and lie in the South of the Gulf of Thailand and West of Borneo.



Figure 3.1: Study site location in relation to Malaysia. (Google Maps, 2019)

The islands have two seasons, where monsoon conditions result in increased rainfall, greater wave action and stronger North Easterly winds (between November and March). Between March and November, wind and wave action is greatly reduced and this is considered peak tourist season. Based on daily readings from a SCUBA diving computer, sea surface temperature is fairly consistent varying between 27 and 32 °C throughout the season.

Warm shallow waters around the island (30-40 metres maximum in near-shore) are home to a network of small coral reef sites that, coupled with the white sandy beaches, have resulted in the islands being developed primarily as a tourist destination. Due to location, currents are considered low and are typically strongest at the change of the tide. Conditions are considered ideal for beginner SCUBA divers, while the network of reefs also attracts more experienced participants.

One village on the islands is permanently inhabited by a community of approximately 2,300 people (Reef Check Malaysia, 2017). The village is located on the South East corner of the small island Pulau Kecil. Here tourism growth has been considerable. Initially a fishing community, the village now employs many local residents in tourist-related activities, including at dive centres. The islands are not connected to the national grid, nor is there a central sewage system. Therefore water is piped in from the mainland but during high season it is common for water to run out until pressure builds up. Residents and resorts rely on septic tanks to manage sewage waste, but there is no protocol for emptying these. There is no recycling scheme on the islands and waste is collected on a daily basis by a single waste barge, collecting from the resorts first and the village last. Once the barge is full, it leaves any remaining waste for the following day, resulting in a visible rubbish problem on many of the beaches. The remnants of the fishing culture is still visible within the Marine Park, with multiple ghost fishing nets caught on reefs and crabbing cages littering areas of the sea bed.

The waters around the islands were established as a Marine Park in 1994 as part of the Malaysian Fisheries Act 1985 (Malaysia, 2012). The Marine Parks Malaysia Order states that waters two nautical miles from lowest tide are protected to ensure conservation of biodiversity. As part of this, certain activities were banned including fishing, jet skis and water

skiing. Since 1994, tourism has been growing rapidly and at the time of writing there are approximately 40 resorts and 15 dive centres operating on the island with SCUBA diving and snorkelling the most popular activities.



Figure 3.2: A map of dive sites in Pulau Perhentian: sourced from a local dive centre. Dive centres use different names and locations to map their sites. (Lua, 2008)

There are over 20 dive sites (Figure 3.2) within the marine park and they consist predominantly of fringing reefs with some submerged offshore. Coral reefs are home to a number of different species. Green (*Chelonia mydas*) and Hawksbill (*Eretmochelys imbricata*) sea turtles both nest and feed around the islands, while Black Tip Reef Sharks (*Carcharhinus melanopterus*) are also present. Common fish species found include Damsel (*Pomacentridae* sp.), Butterfly (*Perciformes* sp.), Grouper (*Epinephelus* sp.), Angel (*Pomacanthidae* sp.), Barracuda (*Sphyraena* sp.) and a variety of different wrasse. There has not been a detailed survey of coral species on the islands, however a variety of hard coral families have been identified including *Acropora*, *Porites* and *Turbinaria*. Reef Check Malaysia conduct annual

surveys on 10 sites to monitor coral health. Between 2012 and 2016 live coral cover has fluctuated but remained consistent around 50%. A bleaching event in 2010 is predicted to have resulted in the lower LCC in 2011 (36.38%), but rapid recovery suggests a degree of reef resilience (Reef Check Malaysia, 2017). A small but steady annual increase in sand found on reefs suggests this is due to increased levels of erosion from broken coral due to wave action.

Figure 3.3 displays the steady annual increase in tourist numbers to state marine parks between 2009 and 2016 and will be used to identify correlations between coral health over time against visitor numbers.

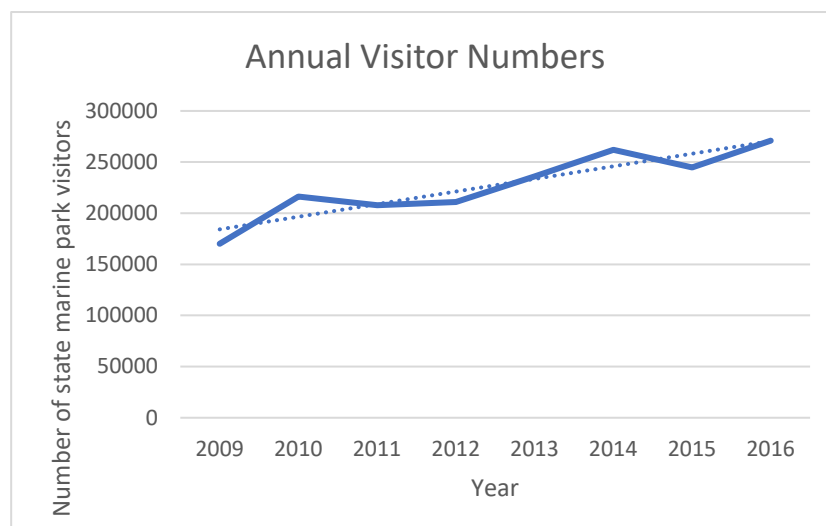


Figure 3.3 Baseline annual visitor data to Terengganu state marine parks, Malaysia. Trendline shows a steady growth in visitor numbers to the area. (Department Marine Parks Malaysia, 2017)

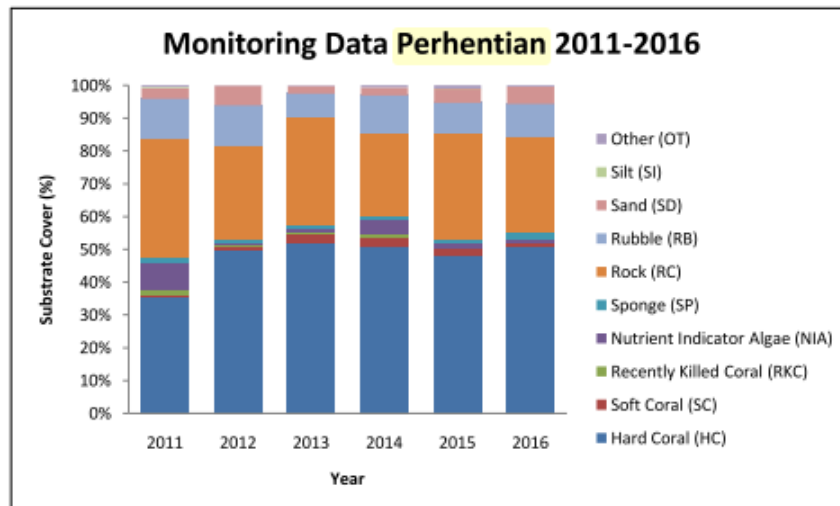


Figure 3.4 Reef Check (2016) annual survey data for the years between 2011 and 2016.

Highlighting changes in substrate cover.

When compared against Reef Check (2016) results (Figure 3.4), there is a slight correlation between visitor numbers and live coral cover. As stated, the bleaching event in 2010 was thought to be responsible for the low coral cover in 2011, 2010 was also the first year in which state visitor numbers rose above 200,000. During subsequent years (2010-2012), visitor numbers fell and this appears to coincide with LCC increases. Similarly, 2014 saw visitor numbers reach 260,000 and the following year a further reduction in LCC was reported, while 2015 saw a slight drop in visitor numbers and a slight increase in LCC consequently.

Ideally, this research study would have replicated surveys at all ten of the Reef Check sites for comparability. However, due to financial and time constraints, only two survey sites were used. Selection was made based on their popularity and use by dive centre staff on the islands. To confirm this, discussions with local dive centres were conducted and validated by visits on the part of the researcher to identify the dive route at each site. Batu Nisan (dive site A), on the Eastern coast of Pulau Kecil, and Shark point (dive site B) on the Southern coast of Pulau

Besar (Figure 3.2) were selected. Both coral reefs are visited on a daily basis during high season by multiple dive centres, but both also consist of areas of high and low usage.

Figure 3.2 depicts the locations of all dive sites within the marine park, while Figures 3.5 and 3.6 show the detailed location where surveys took place at each site.

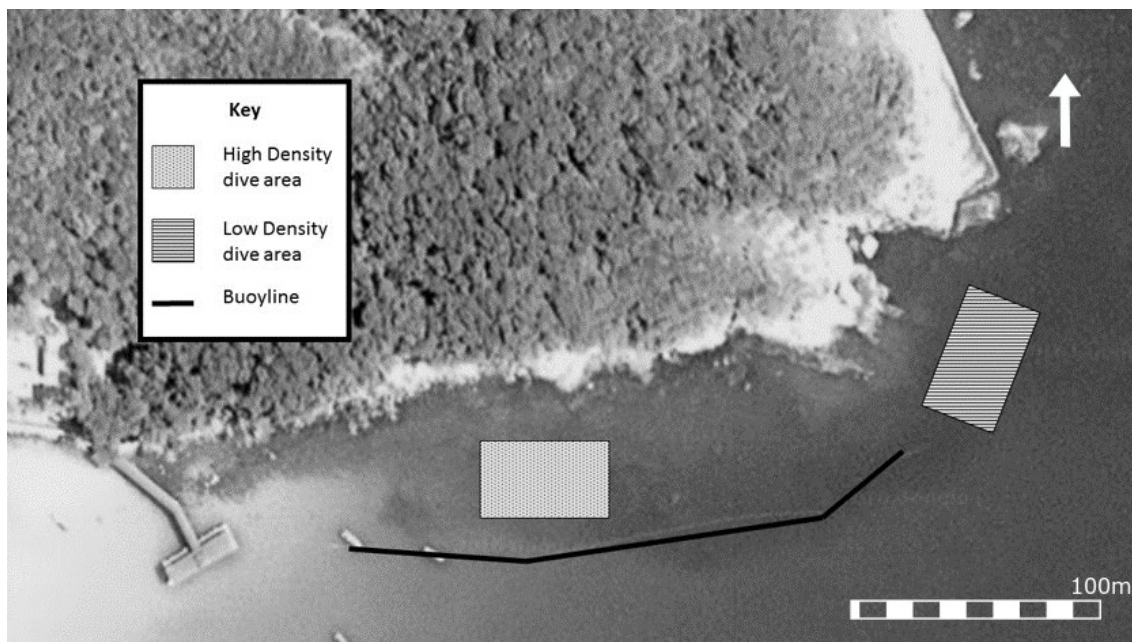


Figure 3.5 Batu Nisan (Reef A) dive site, with high and low intensity areas highlighted

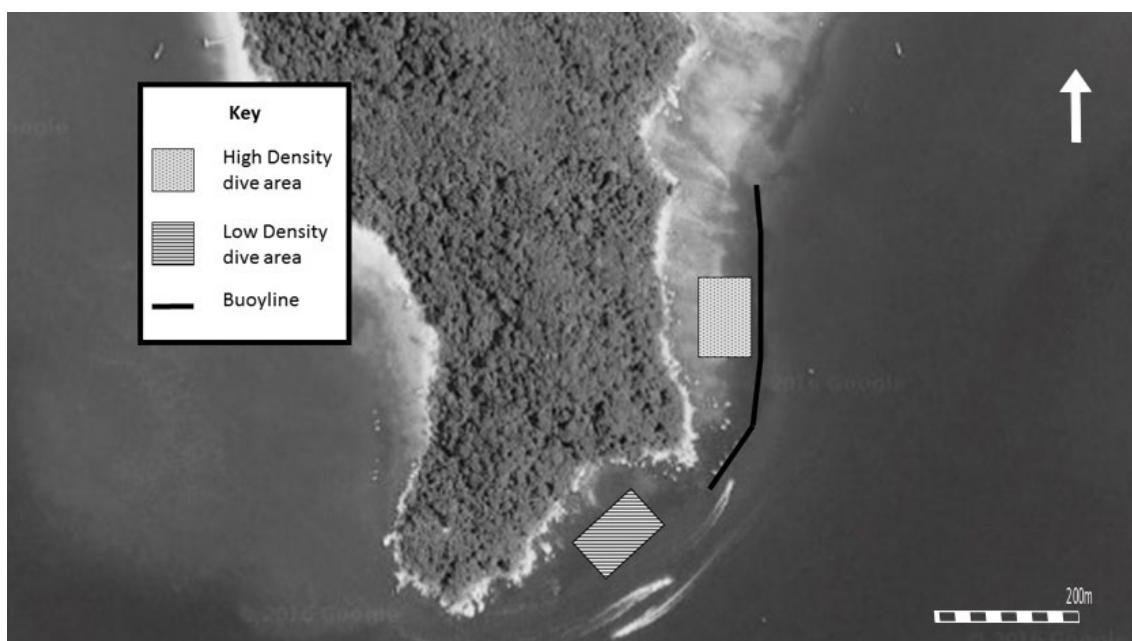


Figure 3.6 Shark Point (Reef B) dive Site, with High and Low intensity areas highlighted

Both sites are fringing reefs that start from 1.5m and descend to a depth of 18m. Batu Nisan (dive site A) is located on the headland of a popular backpacker beach and is accessed both from the shore and by boat. It is regularly used for beginner training as well as more experienced dive trips. Shark Point (dive site B) is popular for both snorkelling and diving activities due to the shallow waters and common sightings of Black Tip Reef Sharks (*Carcharhinus melanopterus*). Both SCUBA diving and snorkelling trips access the site by boat and the minimum 1.5m depth reduces the risk of snorkeler damage to the reef through trampling. High and low density areas for both sites are highlighted on the maps as well as the positioning of the buoy line, placed and maintained by the Marine Park authorities and designed to create safe, no-boat zones for snorkellers and divers.

Having determined suitable study sites for the research, it is now necessary to detail the methodologies used for data collection. This will be presented within the next chapter.

4.0 Methodology

The methodologies utilised have been designed based on methods and outcomes of previous studies (Altmann, 1974; Rouphael and Inglis, 1997; English, Wilkinson and Baker, 1997; Harriott, Davis and Banks, 1997; Medio, Ormond and Pearson, 1997; Tratalos and Austin, 2001; Zakai and Chadwick-Furman, 2002; Thapa, Graefe and Meyer, 2005; Kohler and Gill, 2006; Dolan, Peasgood and White, 2008; Carruthers, Thomas and Dennison, 2011; Anderson, Pratchett and Baird, 2012; Othman *et al.*, 2014; Safuan *et al.*, 2015; Reef Check Malaysia, 2017, 2016). The aim of this research is to develop a diver-environment relationship model, management strategy and recommendations for policy makers, training organisations and dive operators with regards to SCUBA tourism. Five objectives were identified on the back of a thorough review of literature linked to coral health, SCUBA diver impacts and behavioural theory.

- i. Assess and compare coral reef health at high-density and low-density dive sites to determine the impact recreational diving has on a fringing coral reef environment*
- ii. Assess SCUBA diver environmental awareness and values through questionnaire surveys*
- iii. Observe and analyse SCUBA diver behaviour, contact rates and interactions with the marine benthic environment*
- iv. Determine the effectiveness of pre-dive briefings in influencing diver behaviour and impact on contact rates*
- v. Analyse primary and secondary data to develop a relationship model, management strategy and policy frameworks for the SCUBA industry*

Achieving the aim and objectives for this study required data to be collected on three fronts: SCUBA diver behaviour, awareness and values, and coral health. This Section will discuss the methodology used to achieve each objective as well as provide background information and rationale for why each approach was adopted, and where necessary, adapted.

4.0.1 Summary

Below is a step by step summary of the methodology adopted for this research. Further information is given in the following sub-sections

1. Carry out coral reef growth and health surveys through standardised methods to determine relationships or correlation with diver numbers
2. Conduct underwater observations of SCUBA diver behaviour and contact
3. Complete a questionnaire with all participants to detail diver experience, environmental awareness and marine and coral values
4. Attempt to influence diver behaviour through a pro-environmental behavioural briefing, incorporating basic coral reef identification with key behaviours of interest
5. Conduct a second underwater observation to monitor participants on the same behaviours to allow identification of change

Ultimately the final output will be the development of a model, management plan and DPSIR framework in relation to literature and data collected and analysed from this study.

4.1 Coral Reef Health

In order to achieve the objective of assessing coral reef health, its ability to recover from diver-caused damage and to establish the relationship between SCUBA diver behaviour and coral health, two approaches were considered. First, a unique approach to the direct impacts of diver contacts that attempted to monitor the growth of damaged coral colonies for 12 months after damage. This would allow for comparisons in growth rate variations of damaged versus non damaged colonies. Secondly, the approach discussed in Section 2.1.6, where live coral cover is used to determine health of the reef using a standardised Reef Check classification system, and coupled with video point transects at high and low density dive sites (Rouphael and Inglis, 1997; Tratalos and Austin, 2001).

4.1.1 Coral growth rates

The staining, removing and analysing of coral (Oliver, Chalker and Dunlap, 1983; Browne, 2012) was not suitable for this research due to the necessity of removing the coral from the site. Instead, an in-situ approach was adopted (Anderson, Pratchett and Baird, 2012) which focused on seasonal growth of coral in a region. Baird & Marshall (2002) conducted their research for 40 weeks after impact, whilst Browne (2012) focused on 1 year recovery. Other studies vary, some starting observations at 7 months, and others reviewing health after 25 years (Lirman, 2000, 2003; Bruckner and Bruckner, 2001; Graham, Nash and Kool, 2011). For the purpose of this study, a 12-month period was adopted for growth rates of impacted and non-impacted colonies, with measurements occurring every 3 months.

Upon observing a breakage to an *Acropora sp.* coral, radial and length measurements were taken from a point marked by a zip chord (Anderson, Pratchett and Baird, 2012). In addition to the damaged branch, additional, non-impacted branches were tagged and recorded from the same colony and from adjacent colonies to provide comparisons in growth rate. Non-impacted coral colonies were chosen based on their proximity to the damaged colony to reduce the number of variables that affect growth rates (temperature, salinity, turbidity) (Rogers, 1990; Edinger *et al.*, 2000; Toda *et al.*, 2007; Mallela and Crabbe, 2009).

During the pilot study, 6 coral colonies were damaged by diver impact, with 6 branches affected. These were tagged and monitored over a 12-month period. During the 12-month period, 4 colonies were lost, either through the removal of tags or through damage from wave, tourist or boat action. The loss of colonies highlighted the need for regular monitoring and increased sample size to ensure a suitable sample size.

4.1.2 Coral Cover

Coral cover is an established method of determining the health of a coral reef. Reef Check surveys use indicator species and allow both long term and short term monitoring of coral reef health (Reef Check Malaysia, 2016). Data collected using Reef Check methods provides an estimated percentage of coral cover for a reef area. As discussed in Section 2.1.5, standardised coral cover categories have been established to provide a level of health for the reef; 0-24.99% hard coral cover (HCC) is considered poor health, 25-49.9% is fair health, 50-74.9% is considered good and above 75% is considered excellent. These categories will be used both for secondary and primary data within this study. Using secondary data from Reef Check Malaysia and Blue Temple Conservation, coral cover will be determined for a number

of key dive sites around the study site. When compared with the annual visitor numbers, it will be possible to begin to identify correlations between visitor numbers and coral health.

Alongside use of secondary data, primary data was collected in June 2016 at the dive sites detailed in Section 3.0 to investigate the impacts of diving on a reef environment. Video point transects were conducted at two key diving sites in the study area (Roupheal and Inglis, 1997; Tratalos and Austin, 2001) where ten 20m transects were conducted; five in high density and five in low density dive areas. Collecting data from both high and low density areas of each reef minimised confounded variables and resulted in comparable data for each dive site allowing diver-caused impacts to be analysed. Coral cover surveys were carried out during June, 2016.

Video footage was recorded along the 20m transects, 0.5m from the substrate. The video footage was then split into multiple still shots from which analysis was taken. Stills were taken every 4 seconds of the footage to ensure a detailed coverage of the substrate along the transect, producing 20 still images per 20 metre transect (English, Wilkinson and Baker, 1997; Carruthers, Thomas and Dennison, 2011; Safuan *et al.*, 2015). To reduce interference, the video footage aimed to traverse one side of the transect line to prevent the line covering the substrate.

Adopting previous methods (English, Wilkinson and Baker, 1997; Carruthers, Thomas and Dennison, 2011), the twenty stills were taken from the video footage for each transect and, using Coral Point Count (CPCe) software (Kohler and Gill, 2006), 50 randomly placed points were overlaid on each image, resulting in a total number of 5,000 data points per dive site. Following the standardised categories used by Reef Check, the substrate within each photo was identified as one of 10 variations; hard coral, soft coral, recently killed coral, rock, rubble,

sand, silt, sponge, nutrient indicator algae, other (Reef Check, 2016) or, for the purpose of this study, unidentifiable. From the data collected, estimates on live coral cover were determined, providing reliable results showing the health of the reef at both high and low density dive sites.

4.2 Selection of Sample

Agreements were made with 3 dive centres in Pulau Perhentian for the researcher to be allowed to join recreational dives as a guest to observe and collect data. The sample for the study was chosen by convenience and based on divers who were completing multiple dives during their stay. Dive centres alerted the researcher when they had divers who were completing multiple dives. To comply with ethics protocols, permission was requested from all divers for them to participate in the research; this approach differs to other studies who observed divers covertly, and where they knew they were being observed, their data not used (Harriott, Davis and Banks, 1997; Zakai and Chadwick-Furman, 2002; Camp and Fraser, 2012). To avoid bias in the results, participants were informed that observations would be made and that a questionnaire and briefing would be given after the first dive. As such, divers were unaware what specific observations were being made and so were unable to change their behaviour accordingly. No participants requested more information before the first dive and only 2 participants requested more information after the first dive during the pre-dive briefing.

Data was collected over 4 months between April and July 2016 during the tourist high season while a sample size of 150 was targeted at the beginning of the study, each to be observed twice. This figure identified as a suitable sample size based on previous studies, which vary

from 48 to 353 (Harriott, Davis and Banks, 1997; Medio, Ormond and Pearson, 1997; Rouphael and Inglis, 1997; Zakai and Chadwick-Furman, 2002; Barker and Roberts, 2004; Uyarra and Côté, 2007; Worachananant *et al.*, 2008; Luna, Pérez and Sánchez-Lizaso, 2009; Camp and Fraser, 2012; Krieger and Chadwick, 2013).

4.3 SCUBA diver awareness

The questionnaire was designed to achieve the research objective related to awareness, values and perceived behaviour (Appendix 1). It was completed after the first observation dive to avoid creating bias during the first observation dive and to avoid altering answers based on information given during the pre-dive briefing for the second dive. The principle investigator was on hand to answer any questions put forward by participants, and the estimated time to complete was 15 minutes thereby not being too onerous. The questionnaire was split into 5 sections, each determined to evaluate specific areas. Essentially, the outcome of the questionnaire allowed comparisons to be made within the dive community; comparing groups within the sample population to identify whether training, experience, age or nationality affect values and environmental considerations. Further, information collected provides a baseline of data that highlighted any discrepancies in diver perceptions, knowledge or values with regards to training and the environment.

4.3.1 Socio-Demographic

The first section consisted of 12 questions, determining basic demographic data and diver expertise. Diver experience has previously been determined by the number of dives

completed (Barker and Roberts, 2004; Salim, Bahauddin and Mohamed, 2013), however the number of dives does not necessarily represent diver expertise. Communications with several members of the professional diving community led to a number of key questions being identified as important in determining diver expertise (Othman *et al.*, 2014). Diver qualification, number of dives and years diving (Luna, Pérez and Sánchez-Lizaso, 2009) were considered, along with the regularity of dives, as important in establishing expertise. Inclusion of regularity, additional training of specialty courses and the date of their last dive allowed greater analysis of contact rates, as well as reducing confounded variables.

4.3.2 Perceived Behaviour

Based on previous literature and methodologies, this section focused on determining how divers perceive their behaviour whilst underwater, and how obligated they feel to carry out certain actions. A five-point Likert scale was utilised across 13 statements all highlighted as important in behaviour and derived from norms, awareness and values (Anderson and Loomis, 2011). This section allowed a direct comparison between perceived behaviour and actual behaviour and contribute to the understanding of why divers make contact with the reef. Further, it provided an insight into social norms (Heywood, 2002; Anderson and Loomis, 2011; Grønhøj and Thøgersen, 2012) surrounding diving and potential difficulties for interventions or misconceptions within the dive community.

4.3.3 Environmental Understanding

The method to determine participant understanding of coral and threats to coral reefs was adapted from previous literature (Thapa, Graefe and Meyer, 2005; Friedrich, Jefferson and Glegg, 2014) and included a number of True, False or Don't Know statements. This approach is a previously tested method and provided information to assess participant knowledge of corals and allowed analysis through non-parametric testing for variance and correlations with values, expertise and behaviour.

4.3.4 Values and Attitudes

In order to ascertain attitudes and appreciation of coral reefs, a method was adapted from previous literature (Dolan, Peasgood and White, 2008) and utilised a five-point Likert scale where participants were required to state how satisfied they would feel when faced with specific actions or scenarios. The statements utilised in the questionnaire were designed to gather information both if the participant observed an action by someone else, or if they committed an action themselves, the scenarios used are based on literature surrounding SCUBA diving impacts and threats to coral reefs (Medio, Ormond and Pearson, 1997; Wackernagel *et al.*, 1999; Zakai and Chadwick-Furman, 2002; Barker and Roberts, 2004; Hasler and Ott, 2008; Worachananant *et al.*, 2008; Luna, Pérez and Sánchez-Lizaso, 2009; Camp and Fraser, 2012). Determining emotive responses to certain situations allowed an understanding of diver value towards a coral reef and diving experiences. Understanding values and attitudes towards coral and coral reefs will allow greater understanding of behaviour drivers. Data will be analysed for variance and correlations alongside awareness, expertise and behaviour.

4.3.5 Interventions

The final section of the questionnaire targeted potential interventions. Participants were asked to rank a number of potential interventions on their effectiveness for changing diver behaviour, both as an individual and the community. This section will be used to aid in the development of effective interventions for future studies. After the questionnaire, participants were given a pre-dive briefing and were followed for a second dive with their in-water behaviour observed.

4.4 Diver behaviour observations

SCUBA divers were recruited and informed of research prior to each dive and chosen at random from the dive group without knowledge of diver ability or background. SCUBA divers not wishing to be included in the research were able to withdraw at any stage during data collection. However due to maintaining anonymity, requests to be removed after the day of data collection were not possible.

4.4.1 Sampling Method

Unlike previous studies, where data was collected only on the number of contacts and point of contacts (Hawkins and Roberts, 1992; Medio, Ormond and Pearson, 1997; Roupheal and Inglis, 1997, 2001; Liew, Chua and Chan, 2001; Tratalos and Austin, 2001; Zakai and Chadwick-Furman, 2002; Barker and Roberts, 2004), this study aimed to determine a more detailed understanding of SCUBA diver behaviour throughout a dive, observing diver behaviour for 10 minutes, along with all contact causes, point of contact and intentions.

Before determining which method to use, pre-determined behaviours were identified for recording (Damerose and Hopkins, 2002). These depended on the hypothesis for the study and a review of literature for guidance. In the case of this study, the likely causes of contact were identified through discussions with SCUBA dive professionals (Othman *et al.*, 2014) as well as through analysis of previous studies, which identified fins as the primary contact point (S.2.3), linked to positioning and finning technique. Buoyancy was highlighted both in informal discussions with professionals as well as previous literature as a potential behaviour causing contacts (S.2.3.1.1).

Once behaviours were identified, they were classed as either a state or an event (Altmann, 1974). A state is a behaviour that is on-going for a duration of time, whereas an event is something that takes place in an instant (Altmann, 1974). An example of this could be a diver who is holding the substrate is a state, whereas a diver who touches the substrate is an event. It can be argued that all behaviours take place over a period of time, but Altmann (1974) considers behaviours at the moment of onset. Altman (1974) also discussed 4 different methodologies for observing animal behaviour; focal instantaneous, sequence and one-zero sampling. Each method differs from the others and provide benefits and negatives, depending on the sample size, duration and hypothesis.

4.4.1.1 Focal Sampling

Focal sampling involves observing an individual for a pre-determined period of time and recording all occurrences of the pre-determined behaviours along with the duration for which each behaviour takes place (Altmann, 1974; Damerose and Hopkins, 2002; Hirschler *et al.*, 2016). The continuous observation requirements for this approach make it less suitable for

instances where multiple individuals are to be observed simultaneously due to the difficulty of monitoring all behaviours. Focal sampling should be used where only one, or a maximum of two individuals are observed simultaneously in order to improve data collection (Altmann, 1974; Hirschler *et al.*, 2016). Damerose and Hopkins (2002) used a personal computer and keyboard which had been programmed to link certain behaviours to keys on the keyboard, meaning quick and simple data recording was possible without losing sight of the individuals, a method not suited to this research.

4.4.1.2 Instantaneous Sampling

Instantaneous sampling is a method of recording behaviour states, rather than events. Observations are carried out over a predetermined amount of time, and data recorded at set intervals throughout the period (every minute for 10 minutes), recording the state for each behaviour of interest (Altmann, 1974; Hirschler *et al.*, 2016). This method allows observations of larger groups of individuals than focal sampling (Altmann, 1974; Hirschler *et al.*, 2016) and is useful in instances where behaviour is unlikely to change regularly. Hirschler *et al.* (2016) compared instantaneous sampling with focal sampling, but altered the times at which data was collected during instantaneous sampling depending on the activities of the species being observed. They state that where activity rate was low, data was recorded every 60 minutes, whereas when the activity rate was increased, data was recorded every 20 minutes, concurring with the statement that this approach is suitable where behaviour activity is low.

4.4.1.3 One Zero Sampling

Altmann (1974) discusses the one-zero method for behaviour observations and states that rather than recording the frequency or duration of a behaviour, this method focuses on whether a particular behaviour occurs during a given time. This method, whilst easier and quicker to complete, misses a lot of information that could be acquired through focal or instantaneous sampling. It is useful in instances where large groups are being observed on a regular basis over a long period of time, but Altman (1974) argues that the loss of information through the simplification of the method makes this unsuitable for many studies.

4.4.1.4 Sequence Sampling

Sequence sampling is a method not dissimilar to focal sampling. The method utilised is similar in that all behaviours within a given time period are observed and recorded. The difference is that the time period starts and ends based on a separate behaviour being observed. The example provided by Altman (1974) discusses social interactions of crabs, where data collection begins when two crabs begin walking towards each other and all social interactions that take place until they separate were recorded.

For the purpose of this study, focal sampling methods were employed to observe only the contact and interaction actions determined in behaviours of interest. The amount of data collected during the observation period, along with the observation of two divers simultaneously (who may not always be near each other) means that continuous observation of behaviours of interest was not effective. As such instantaneous sampling provided a more effective method for determining the percentage of time spent in any one state). One-zero

and sequence sampling were not considered suitable as one-zero provides too little data on behaviour, whilst sequence sampling would be most effective if data were being collected over the period of a whole dive where the duration of each behaviour of interest could be recorded.

Instantaneous sampling has not been used on SCUBA divers previously. As such it provides a unique insight to SCUBA diver behaviour throughout a dive, allowing analysis of contacts to be more detailed and thorough and determine whether contact rate is influenced by (an adjudged) constant poor behaviour or whether one-off behaviour actions are the primary result of contacts. This can be used to direct future training and educational protocols for SCUBA organisations.

4.4.2 Behaviour of Interest

Behaviours of interest were observed during both observation dives to provide comparable results. Behaviours of interest were identified based on analysis of previous literature and through discussions with professional SCUBA divers. As discussed in subsection 2.3.1, fins were the primary cause of contact across 11 of the studies analysed whilst some studies state buoyancy, particularly proximity to the reef as another key cause of contacts.

To identify behaviours of interest for this study, the events leading up to the fin contact need to be analysed. Fins can come into contact with the reef via three different actions (Othman *et al.*, 2014);

1. Loss of buoyancy control, or poor buoyancy control can see divers unable to maintain their position in the water column and can result in them sinking towards the

substrate. In this instance, many divers will swim upwards to avoid contact, while others may allow themselves to touch the substrate.

2. Positioning is something that can be controlled by an individual during a dive. The ideal position when diving is horizontal (PADI, 2017a). This reduces drag and therefore improves efficiency and reduces air consumption. Likewise, a horizontal position ensures your body is kept level and away from the substrate. Poor positioning is often seen where poor buoyancy or weighting is in effect and results in fins being pointed downwards, with the head at the highest point.
3. There are two approaches to finning when SCUBA diving, the first, and most common with beginners, is the flutter kick, which sees the fins move in a vertical direction up and down. The downward stroke, when combined with poor positioning or buoyancy control, can bring the fin into close proximity with the substrate, resulting in greater contact rates. The second approach is called the 'frog kick', which is a method that sees the fins move horizontally through the water, ensuring improved efficiency and reduced risk of downward movement and contact.

Buoyancy, as a behaviour is difficult to assess based on instantaneous sampling methods. As such, it was observed throughout the 10 minute period and a score given to the individual based on judgement from researcher. Where divers were observed to have poor control (inability to stay at one depth or seen to be going up and down a lot, or resting on the substrate), they were scored '0', divers who appeared to have good control of buoyancy were scored '1'.

The two key behaviours of interest that were observed and recorded as part of the instantaneous sampling were positioning and finning technique. Other behaviours of interest that were included in the study were based primarily on discussions with SCUBA dive professionals. Trim was observed as part of the instantaneous sampling whilst photography was given a score based on whether the individual took a camera whilst diving.

4.4.2.1 Positioning

It is recommended by SCUBA professionals and organisations (PADI, Open Water Course) that a horizontal position is the most effective and efficient form of swimming whilst diving (Othman *et al.*, 2014; PADI, 2017a). A review of the literature found that fin contacts are a dominant source of substrate contacts (Rouphael and Inglis, 1997, 2001; Worachananant *et al.*, 2008). Fin contacts can be linked to positioning and maintaining a horizontal positioning rather than a vertical, fin down position reduces the likelihood of a diver's fins coming into contact with the substrate. Positioning will be recorded on a 3-point scale, where the axis of the body will be considered, rather than just the position of the fins. The scoring will be 0 = shoulders higher with knees and fins pointed downwards; 1 = horizontal positioning from shoulders to knees and 2 = shoulders lowest with knees pointed upwards, as shown in Figure 4.1.

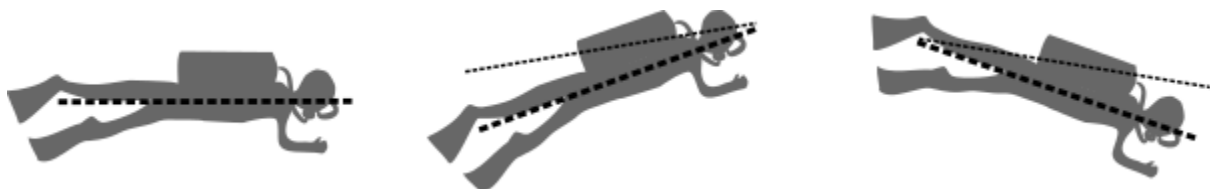


Figure 4.1;. Left; horizontal positioning scoring 1; Centre; shoulders up/down positioning scoring 0; The smaller of the dotted lines represents the variations in positioning below which each score is given

4.4.2.2 Finning Technique

Finning technique is based on the various methods utilised to propel a diver through the water. There are two predominant types of fin kicks available to divers: the flutter kick, defined as the vertical movement of legs as if swimming freestyle, and the frog kick, a style of finning similar to that of breaststroke where the diver's knees are bent upwards, away from the reef. This second approach, the frog kick, is considered best as it maintains a greater distance from the benthos and does not result in fin kicks towards the substrate. Further, it uses less energy to propel through the water, reducing air consumption. Using instantaneous sampling, finning technique will be recorded every minute during the ten minute observation period. As with positioning, finning technique contributes to the number of contacts due to the direction of movement and resting position of the fins (Figure 4.2).



Figure 4.2: Left diver showing movement and resting position of fins when using the 'flutter kick' technique. Right diver showing movement and resting position of fins when using 'frog kick' technique. Fins in frog kick position remain raised above knees during resting and movement horizontal, whilst fins in flutter kick position are level with or below knees and move vertically downwards towards the substrate

4.4.2.3 Trim

Trim, defined as being streamlined in the water with regards to equipment, will be recorded where gauges or octopus (alternative breathing apparatus) or other equipment are seen to be dangling loose, below the diver. This behaviour could be a result of improper preparation prior to the dive or failure to re-secure after use during a dive. Where equipment hangs away from the body, it represents a risk of increased contact with the substrate. Loose equipment is also thought to be a cause of diver contact (Hasler and Ott, 2008; Camp and Fraser, 2012; Ong and Musa, 2012) and it is believed that proper 'trim', defined in this study as being streamlined with all equipment secured to the body of the diver, can reduce diver contacts.

4.4.2.4 Photography

The results of underwater photographer impacts on coral reefs have, to date, been inconclusive. Studies vary between increased and decreased risk of damage from photographers when compared against non-photographers (Rouphael and Inglis, 2001; Worachananant *et al.*, 2008). The inclusion of photography as an action in this study will expand the literature on the topic whilst identifying whether photography correlates with expertise, value or awareness when considering diver-caused changes. Due to photography being a non-continuous behaviour, it was not monitored every minute, instead divers were scored as either carrying (1) or not carrying (0) a camera during their dive. This information, coupled with determining the number of contacts that occurred as a result of photography allowed an effective analysis of the effect underwater photography has on diver impacts.

4.4.2.5 Buoyancy control

Within diving, buoyancy control is defined as the ability of the diver to control their vertical position in the water without kicking their fins or flapping their arms. Buoyancy control is particularly important where the divers are stopped in the water, either waiting to view or viewing something of interest. In this instance, divers who kicked their fins to stay up, or flapped their arms were deemed to have poor control of their buoyancy, whilst divers who were able to control their position using their breathing were considered good. As discussed in Section 4.6.2, buoyancy was observed throughout the ten-minute period and scored at the end based on assessment by researcher. This is different to previous studies, where diver positioning was used as an aid in determining buoyancy control (Toyoshima and Nadaoka, 2015). However, divers with good buoyancy control will often swim in a fin down position due to weight distribution, or will hover in a fin down position, as such, positioning is not ideal in determining buoyancy control.

Collecting data based on a snapshot of diver buoyancy every minute, as with the other behaviours is ineffective as it does not represent an accurate account of behaviour. Instead, buoyancy control was evaluated by the researcher over the course of the 10-minute period. Where divers were assessed to have good buoyancy control, a score of 1 was given, where poor control, a 0. The key factor that led to buoyancy scoring was the vertical movement of the diver over the 10-minute period. Poor buoyancy was scored where the diver was observed to regularly move in a vertical direction regularly and necessarily, while good buoyancy was scored where the diver was able to maintain their position vertically in the water with seeming ease.

As stated in 2.3.1.2, Toyoshima and Nadoaka (2015) defined good buoyancy control as swimming in a horizontal position, and the ability to hover without moving fins. However, although they are linked, poor positioning does not necessarily mean poor buoyancy, likewise, hovering whilst fins are moving does not necessarily mean poor buoyancy control. As such, the method used to determine buoyancy control in this study was adapted.

Prior to the pilot study, proximity to the reef was considered as part of the buoyancy control score (where divers further from the reef, or too close were considered to have poor control). However, the pilot study showed that divers with the ability to control their buoyancy (maintain vertical positioning) did not necessarily stay close to the reef, some were observed to stay at a greater distance. As such, proximity to the reef was added to the data observations for the research proper. This was scored with a 0 if the diver was <1m from the substrate, 1 if the diver was 1-2m from the substrate and 2 if the diver was 3 or more meters from the substrate.

4.4.3 Diver Contact

A contact in this study has been defined as any interaction between the diver and substrate, either touch, breakage or disturbance of sediment (sedimentation). Sedimentation has been linked with reduced coral health (Hubbard and Scaturo, 1985; Rogers, 1990; Toda *et al.*, 2007; Browne, 2012) and as such was included as an interaction observed within the study. Contacts were recorded as in previous studies where each time the diver made contact with the substrate, information was gathered. Where previous studies recorded categories to include; intention, point of contact, and severity of contact, this study also recorded the cause of contact to further understand the relationships between behaviour and coral health.

Each category was split into sub-categories which were assessed and recorded upon contact being made. The cause of contact was split into; positioning, finning, buoyancy control, trim, photography and viewing. Point of contact was split into hands, fins, knee or equipment. Severity of contact was split into touch, break, sedimentation and holding whilst intent was either intentional or accidental. Table 4.1 shows an example of the data collection slate for diver behaviour and contacts.

Table 4.1: Example of underwater data collection table

Time	Positioning	Finning	Trim		Contact Cause	Contact point	Breakage	Intentional

4.4.4 Duration and Repetition

Literature on the length (minutes) of observation periods varies from 7 minutes (Medio, Ormond and Pearson, 1997) to the whole dive (Harriott, Davis and Banks, 1997). However, in order to be both cost and time effective, observations were conducted over 10 minutes, allowing at least two observation slots per 30-40 minute dive (Rouphael and Inglis, 1997; Zakai and Chadwick-Furman, 2002; Worachananant *et al.*, 2008), this time was adjudged to be the most cost-effective time to complete observations without affecting the results (Rouphael and Inglis, 1997). Using instantaneous sampling methods, behaviours of interest were recorded every minute for the 10-minute period, whilst interactions with the substrate

(contact or sedimentation event) were recorded using focal sampling methods, as and when they occurred.

As stated in Section 4.1, divers were selected for participation based on the number of dives they were completing during their trip, preferably conducting multiple dives on one day. This allowed the researcher to conduct the questionnaires detailed in subsection 4.2 as well as conduct a pro-environmental pre-dive briefing prior to conducting a second observation dive.

To test the intervention briefing, divers were observed, following the same methods discussed in this Section, over two dives.

4.5 Pre-dive behavioural briefing

After completion of the first observation dive and the questionnaire, participants were given a pro-environmental behavioural briefing. It was carried out as part of the normal pre-dive briefing carried out by the dive centre and took 3-5 minutes depending on interaction levels from the participants.

As discussed in Section 2.3.2, pre-dive briefings to reduce diver contact rates has been utilised before, with mixed results. The unique observation method adopted for this study resulted in a more focused briefing to target specific behaviours. This approach allowed not only the rate of contacts before and after the dive to be analysed, but also the general diving behaviour, thus giving a greater image of the effectiveness of the briefing.

The briefing consisted of 2 sections, the first a basic introduction to coral to highlight the need to avoid contact whilst the second targeted behaviours of interest. Printed out images were used in each section to reinforce the verbal briefing.

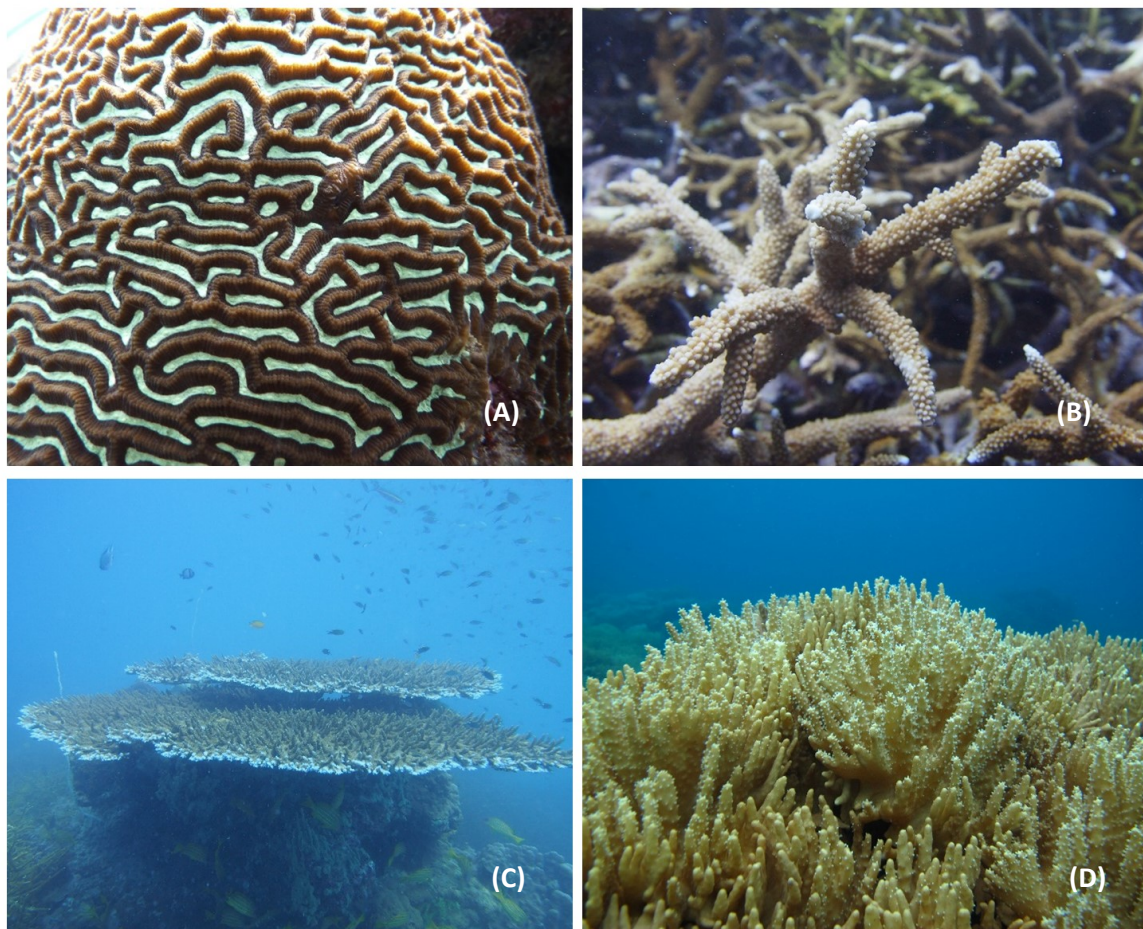


Figure 4.3: Images of coral growth forms used in pre-dive behavioural briefing. (a): brain coral; (b): branching coral; (c): plate coral; (d): soft coral

To introduce coral, four images of different types of coral (Figure 4.3) were shown to the participants, where they were asked to state what they thought was in the image after which they were informed that coral are animals, slow growing and important for biodiversity in a coral reef. The second section of the briefing comprised the bulk of the briefing and covered the behaviours of interest (S. 4.4.2). Positioning, finning technique and trim were all discussed using printed out images, whilst buoyancy was discussed as a part of positioning.

Figure 4.4 shows the image used to discuss positioning and buoyancy during the pre-dive briefing. The image shows two divers in different positions in the water. The image attempted to highlight the benefits of diving in a horizontal position both for the reef (reduced contact) and to the diver (improved vision and streamlining). During the briefing, divers were informed that diving in a horizontal position will also improve the dive experience through reduced drag and improved air consumption, allowing more relaxed and longer dives. Whereas divers in a more vertical position are more likely to make contact with the reef and use more energy, therefore more air, shortening dive length.

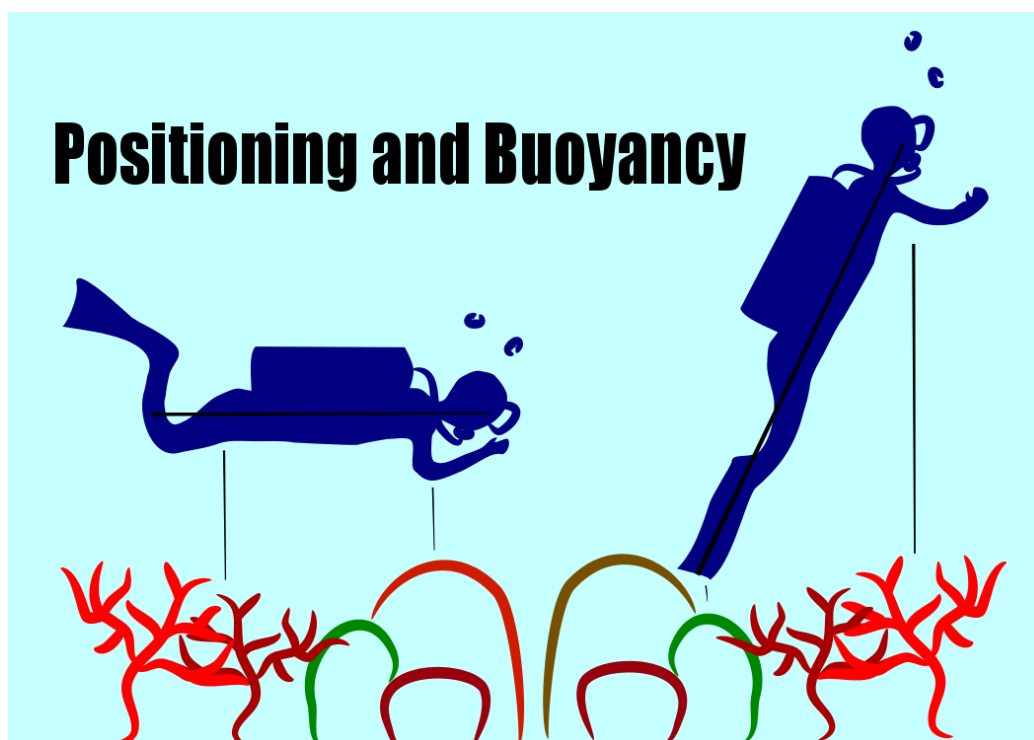


Figure 4.4 Image used to discuss positioning and buoyancy as part of the pro-environmental pre-dive briefing

Figure 4.5 shows the image used within the pre-dive briefing to discuss finning technique. This aspect is the most difficult to teach through discussion due to the difficulty in displaying fin

movement in still images. Examples of fin movement were therefore given during the briefing through visual movements of the arms and legs by the researcher. The image also shows a more detailed explanation of how to carry out the ‘frog kick’ method to finning and was left with the participants to review prior to the second dive.

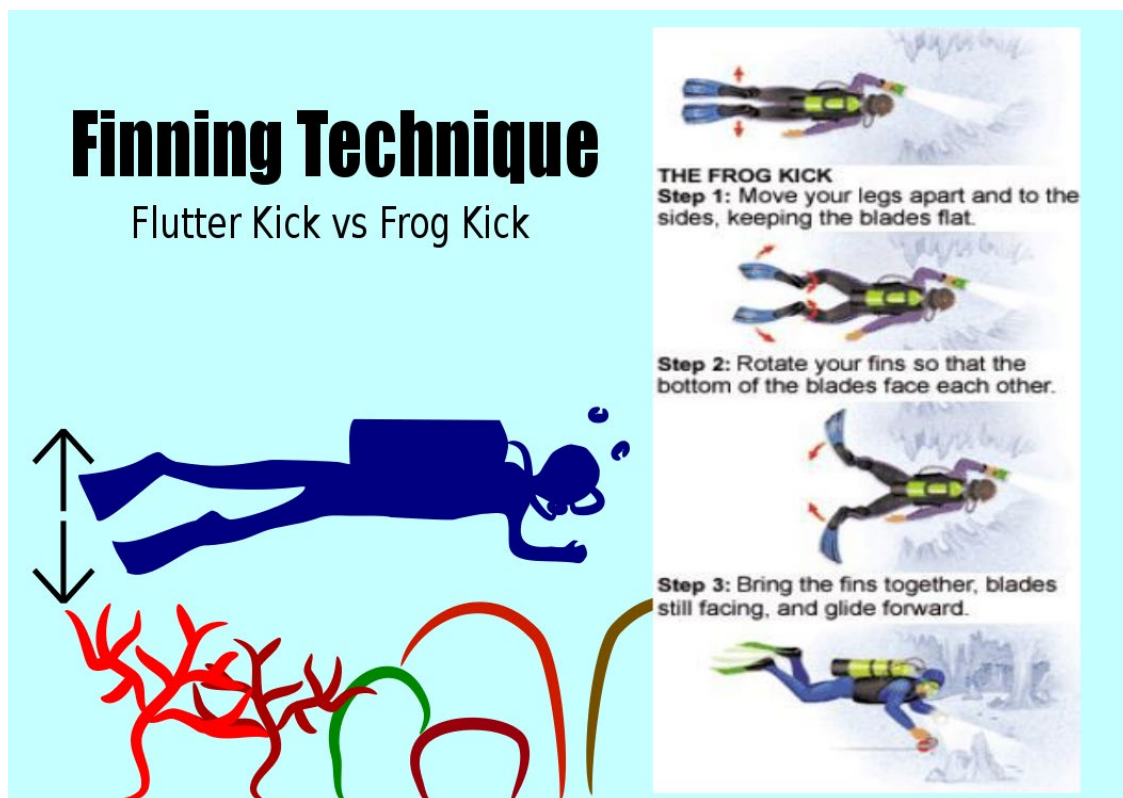


Figure 4.5 Image used to discuss finning technique in the pro-environmental pre-dive briefing

Figure 4.6 shows the image used in the pre-dive briefing to discuss trim with participants. This image was used to explain the meaning of trim, whilst further discussions were carried out to determine how to avoid the scenario in the image; primarily focusing on preparation before a dive and during the descent. The four images combined targeted the behaviours of interest discussed in Section 4.3 and reinforced the points within the briefing.

Trim; Streamlining

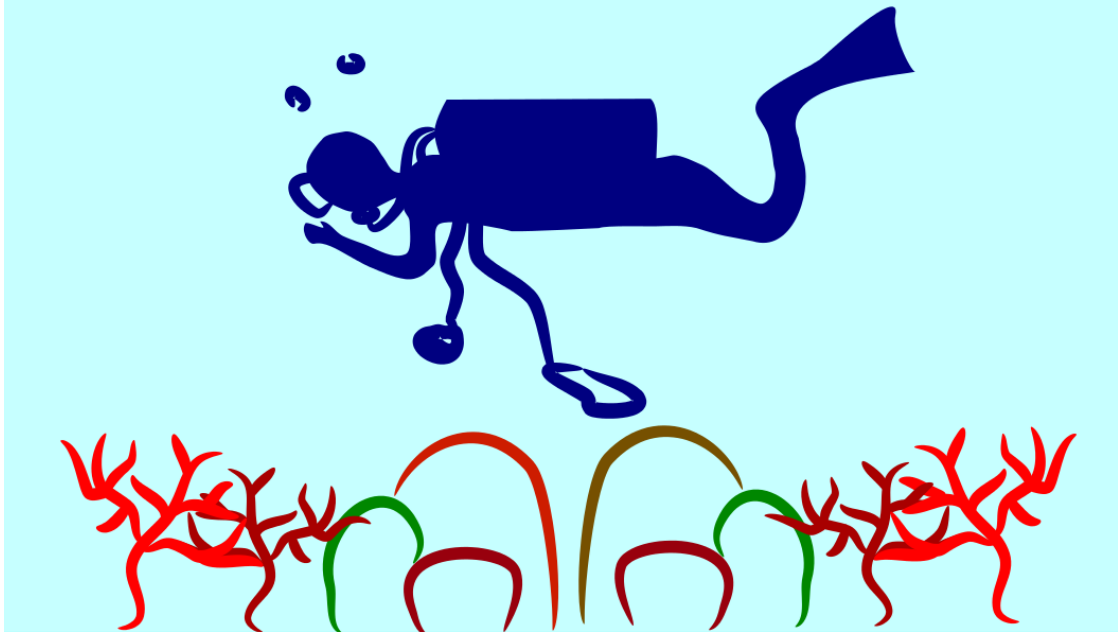


Figure 4.6 Image to discuss trim in the pro-environmental pre-dive briefing. Highlighting loose and dangling equipment

4.6 Data Analysis

The data was subsequently analysed through MS Excel, SPSS and Coral Point Count excel (CPCe) software. Participant behaviour was analysed before and after the pro-environmental behavioural briefing and compared for significant difference. Contact rate, positioning, finning technique and trim were all compared before and after, while analysis was carried out to test for correlations between experience, contacts and behaviour.

Further comparisons were made based on diver background, including gender, age, nationality, number of dives and certification level. Analysis of the questionnaire was carried out in SPSS, and based on Sullican and Artino's (2013) definition, the Likert data was treated

as ordinal data, scores were used to determine population obligations and values. While there is an argument to conduct non-parametric tests on ordinal data, if the sample is large enough, it is believed that parametric tests are robust enough to return accurate results, even if the normal distribution is skewed (Sullivan & Artino 2013). Considering this, the median, not the mean for scores on the Likert scale was used along with Pearson's correlation test which was carried out on responses against actual behaviour to determine the strength and effectiveness of norms within the dive community.

Coral health data as derived from the video transects was analysed using Coral Point Count excel (CPCe) (Kohler and Gill, 2006) software to calculate live coral cover at both high and low density dive sites and compared for significance to determine if high density dive routes are more damaging to coral health.

4.7 Model and Framework development

Design and development of a model and framework for management of SCUBA diving activities will be completed as a result of the data collected within the study and reinforced by secondary data and information from literature. A DPSIR framework (S.2.3.2.1) will be established based on coral health data, observations and literature. The framework will utilise information available to provide a summary of drivers, pressures, states and impacts acting upon coral reef as a result of SCUBA diving. Data collected within the study, alongside literature will allow a series of potential responses to be established.

An in-depth review of the pre-dive behavioural briefing will be carried out, with the effectiveness of behavioural change on contact rates taken into account. Likewise, the cause

of contacts will be analysed to determine the dominant causes. Once completed a refined behavioural briefing will be developed to help shape future training and briefings for dive guides, instructors and training organisations. The SCUBA diver behavioural model will also establish predicted change in behaviour and link it directly to environmental, social and economic responses, including change to coral health (based on the outcome of the coral health surveys), contact rates and potential economic outcomes from improvements.

Having established the methodology for data collection and analysis, the following chapter will examine and analyse the results to begin formulation of the model and framework.

5.0 Results

As detailed in chapter 4, data collection was carried out during the 2016 high season (March – September) in Perhentian Islands through underwater observations, coral reef surveys and participant questionnaires. This data was used initially to determine coral reef health in areas of high intensity SCUBA diving in comparison with low intensity diving. SCUBA diver contacts and behaviour was analysed pre and post pro-environmental intervention briefing to whether such intervention could change behaviour and reduce contact rates of divers. Finally, the questionnaire responses were analysed to determine correlations between perceived and actual behaviour and behaviour with value and awareness.

5.1 Coral Reef Health

This Section will discuss the results related to coral health in relation to objective 1 of the research. In other words to assess and compare coral reef health at high-density and low-density dive sites (S.1.0). Previous studies found degraded coral where diver numbers were higher (S.2.3.1). The initial aim of this element of research was to tag and monitor regrowth of coral damaged by diver activity. However, whilst 5 colonies and 6 branches were damaged and tagged in the *pilot study*, no breakages were observed during the main study. All observed breakages were recorded at dive site B (Shark point), of the 6 colonies of *Acropora species* tagged in the pilot study, 4 were either lost or damaged during the monsoon period. The remaining 2 colonies were monitored 9 months later prior to the start of the research proper, each colony had 6 tags attached, one on the damaged branch and 5 undamaged for comparison. Table 5.1 shows the growth of both the damaged and undamaged branches.

Table 5.1: Coral Growth Data after 9 months

Branch Tag	Start Length (mm)	Length after 9 Months (mm)	Growth (mm)
A11 (damaged)	11	12	1
A12 (undamaged)	45	49	4
A13 (undamaged)	38	40	2
A14 (undamaged)	27	29	2
A15 (undamaged)	26	26	0
A16 (undamaged)	17	19	2
A50 (damaged)	31	33	2
A51 (undamaged)	39	41	2
A52 (undamaged)	39	43	4
A53 (undamaged)	30	31	1
A54 (undamaged)	34	36	2
A55 (undamaged)	44	45	1

Table 5.1: Shows growth of coral branches tagged during pilot study after 9 months.

The average growth after 9 months on the undamaged coral branches was 2mm. In contrast, the average growth of the damaged coral branches was 1.5mm. Furthermore, given the slow growth rates of coral recorded in previous studies (S.2.1.1) coupled with the small growth rates found over 9 months in this study prove that much longer periods are required to accurately compare recovery rates and to consider various abiotic factors that influence growth rates (Huston, 1985; Dullo, 2005; Sheppard *et al.*, 2009; Anderson, Pratchett and Baird, 2012). However, due to the lack of breakages during the full research, this element was

not able to be completed and it is recommended that further study be completed on this element in future.

In order to determine estimates on the impact of SCUBA diving in Pulau Perhentian, Malaysia, coral cover, and therefore reef health was determined by combining established methods and comparing high density areas against low density areas of two popular dive sites at the study site.

5.1.1 Live Coral Cover

Reef Check Malaysia have conducted annual surveys on 10 coral reefs within the Pulau Perhentian marine park boundaries for 10 years. Since 2011, fluctuations in live coral cover (LCC) have been recorded. The low Hard Coral and high algal cover in 2013 was attributed to the previous year's bleaching event (Reef Check 2016). LCC increased annually from 2011 to 2013, then showed a slight decline over 2 years before recovering partially in 2016. The relatively high levels of algal growth on the reefs has been attributed to high levels of nutrients in the water, a result of poor sewerage on the islands.

When coral reefs were considered individually, as they were in this study, coral reef B, also known as Shark Point, showed a strong correlation between hard coral cover and algal cover ($r = -0.888$, $p = 0.001$). The significant correlation shown suggests that the two are interlinked, with increased algae resulting in a lower amount of hard coral cover. This is an expected outcome, as algae can threaten reefs through smothering, a similar process to eutrophication within a lake. In contrast, coral reef A (Batu Nisan) did not show a significant correlation between hard coral and algal cover.

Over the 10-year period of study conducted by Reef Check Malaysia, coral reef B displayed a significantly higher level of live coral cover ($p=0.00$) than at coral reef site A. However, in three of the years, the coral cover at site B reduced significantly to be closer to the levels found at site A. Two of these years (2010 and 2011) can be explained by the coral bleaching event recorded in 2010. However, when compared to annual visitor numbers to the region, it could be theorised that tourist numbers combined with the bleaching event contributed to lower numbers. However, there was no significant correlation found between visitor numbers and live coral cover.

To test if the impact of tourist activity is seen in the following years coral health survey, the graph was adjusted to show direct correlation (moving the visitor numbers 1 year later). However, as with Figure 5.1, the adjusted graph (Figure 5.2) didn't show any significant correlation between tourist numbers and coral health, suggesting the number of people visiting the islands doesn't necessarily impact coral health. However, this does not consider the number of SCUBA divers annually, only the number of visitors. It is possible that in years where coral shows a lower percentage cover, SCUBA diving was particularly popular the previous year. However, as there is no way to access the number of divers from years gone by, this is impossible to analyse and it is recommended that further studies be conducted to determine diver numbers annually, for comparisons to future coral health.

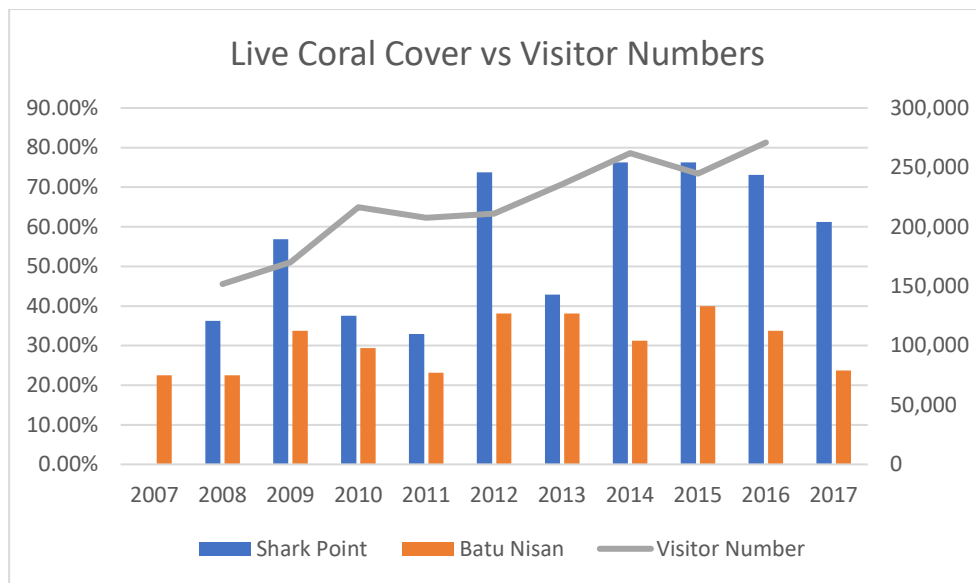


Figure 5.1: Results for hard coral cover at the two coral reef sites, overlaid with visitor numbers. Unadjusted; visitor numbers represent the year they are plotted

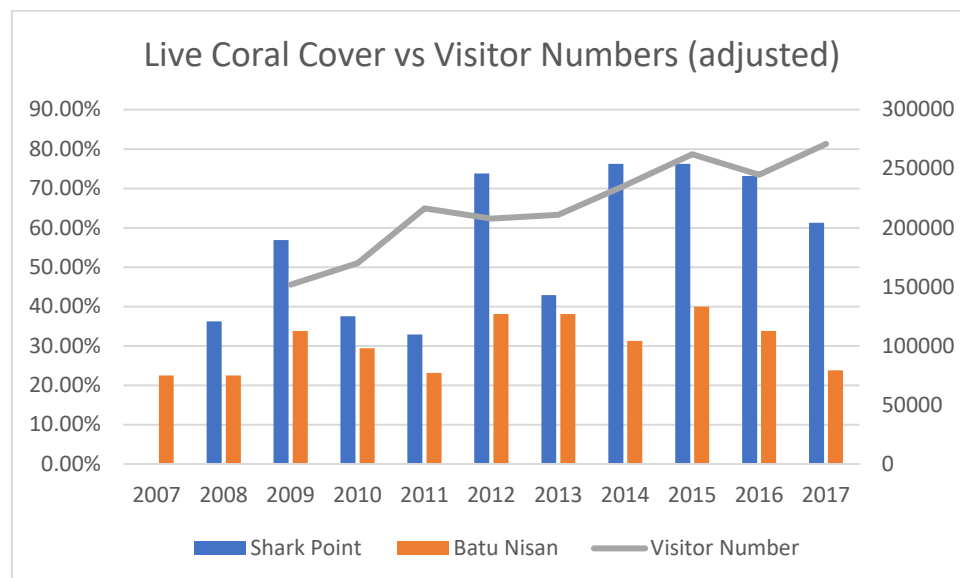


Figure 5.2: Results for hard coral cover at the two coral reef sites, overlaid with visitor numbers. Adjusted; visitor numbers are plotted in the year following to correlate with the following year coral survey

The significant difference in coral cover between the two sites could be explained by positioning of the reefs on the island. Reef A is located on a headland which is open to the South China Sea, meaning it feels the force of annual monsoons more than reef B, which is located on the Southern coast of Pulau Besar. Further, reef A is located on the headland of a popular backpacker beach and is easily accessible from the shore by snorkelers and SCUBA divers alike. In contrast, site B is located on a quieter beach with fewer resorts and is not so easily accessible from the shore. The impact of the monsoon and tidal currents on site A are visible when non-living substrate is covered (rock, rubble, sand and silt).

5.1.2 Video Point Transect Data

In order to ascertain whether SCUBA diving has a lasting impact on coral reef health, coral video transects (CVT) were completed at the two coral reef sites, data collected across five 20m transects at areas of high intensity and low intensity at both reef A and B have been analysed to provide a detailed percentage cover of substrate.

At the high intensity site at Reef A, LCC accounted for 21.36% of the 5,000 data points. The other substrate with the highest percentage cover at this site were rock (32.48%) and rubble (20.60%). Likely a result of the positioning of the reef in correlation to annual monsoon direction. As a result of photograph quality and dark spots, 6.46% of the data points were unidentifiable. In contrast, the low intensity site at Reef A found LCC to account for 48.7% of data points, a difference of 27.34% from the high intensity site, whereas rock and rubble both decreased in percentage cover at the low intensity site (-28.88% and -4.30%). A two-sample t-test found a significant difference in live coral cover between high and low intensity sites ($t=28.65$, $p=0.00$).

Reef B also showed a significant difference in LCC ($t=2.80$, $p=0.01$). However, where reef A showed a higher amount of LCC, reef B resulted in a lower percentage of LCC at only 29.28% on the low intensity site, compared to 31.86% LCC at the high intensity site. In contrast, the percentage cover of algae identified on reef B was considerably higher than at reef A, accounting for 28.98% of substrate at the high intensity site, and 35.88% at the low intensity site.

The difference and variation in results could be explained by the predominant growth forms of coral at each site. A qualitative survey determined that reef A comprised larger, more boulder like coral growth forms, whereas reef B was formed of more fragile branching corals. This difference in growth forms could also explain the difference in the percentage of substrate that was unidentifiable. Across both high intensity and low intensity sites of reef A, only 653 of 10,000 data points were unidentifiable. In contrast, reef B produced 1794 unidentifiable data points. This is due to the increased depth of field in photos and the rugosity² of the reef making more areas less clear, along with increased areas of shadow and crevices. To determine a more accurate understanding of substrate, and subsequently LCC, the unidentifiable data points were removed, and the adjusted data analysed as before.

² The complexity of the reef from a cross-section view

Table 5.2: Adjusted data for substrate cover percentage: Unidentifiable data points removed from analysis

	Reef A High Intensity	%	Reef A Low Intensity	%	Reef B High Intensity	%	Reef B Low Intensity	%
LCC	1068	22.84	2435	52.14	1593	36.26	1464	38.39
Other	161	3.44	23	0.49	106	2.41	4	0.10
Recently Killed Coral	17	0.36	19	0.41	88	2.00	60	1.57
Inorganic	3132	66.97	1714	36.70	1150	26.18	479	12.57
Soft Coral	19	0.41	44	0.94	3	0.07	1	0.03
Sponge	87	1.86	12	0.26	4	0.09	1	0.29
Algae	193	4.13	423	9.06	1449	32.98	1794	47.05
Total	4677		4670		4393		3813	

Removal of the unidentifiable data points had a minimal impact on the data collected for reef A, which still showed a significant increase in LCC at the low intensity dive site in comparison to the high intensity site. A percentage of 52.14% LCC at the low intensity site shows 29.30% more live coral than at the high intensity site ($t=29.26$ $p=0.00$). In contrast, removal of unidentifiable data points resulted in a definite change in data for reef B. When all data points were included, the LCC at the low intensity site resulted in a lower percentage than the high intensity site. However, once removed, the LCC percentage became higher at the low intensity site 38.39%, compared to 36.26% at the high intensity site. A significant difference ($t=1.99$, $p = 0.05$) at a 95% significance rate.

A key point to note is the percentage cover for algae across the sites. Reef A showed very low levels of algae, averaging 6.60% across the high and low intensity sites. In contrast, reef B showed an average of 40.02% algal cover across both sites. This could help to explain the smaller difference between high and low intensity sites for LCC. Where algal growth is high there is increased competition for space, meaning the slow growing coral will struggle to establish bare rock areas before algae grows (S.2.1.5). Higher levels of algae can be explained by increased nutrient levels in the water that encourage plant growth at reef B compared to reef A. Likewise, the levels of recently killed coral (RKC) differs between the two sites, with reef B showing a considerably higher level of RKC. This can, potentially, be explained by the growth forms of the coral found at each site. As discussed, reef B is formed predominantly of more fragile branching growth forms, compared to reef A's boulder form. This could result in higher levels of damage from tourist activities and therefore more RKC.

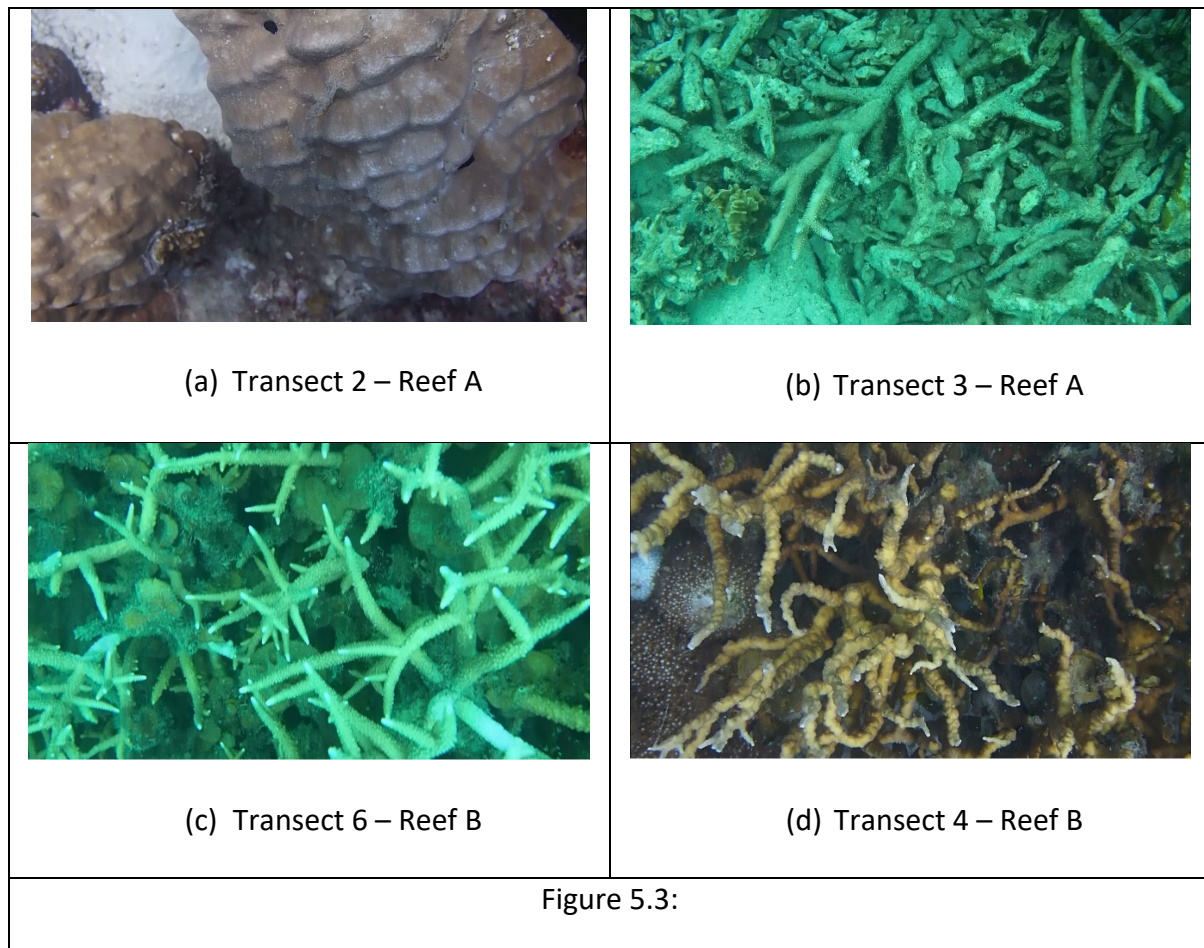
Data obtained in this study differs to results obtained by Reef Check Malaysia (S.5.7.1). In 2017, RCM found reef A (Batu Nisan) to have 23.75% LCC compared to a maximum of 52.14% found in this study, whilst reef B (Shark Point) was found to have 61.25% LCC by RCM, compared to a maximum of 38.39% in this study. The difference is likely due to positioning on the reef and the methods chosen. RCM use a 100m transect (split into four 20m sections), running at one depth with a focus on running the transect along the best possible section, whereas this study focused on specific areas of the reef based on diver visitation. Further, utilising CPCe as a means to analyse the video transects and randomly identifying 50 points per image meant that there was no favouritism towards particularly healthy or unhealthy sections of images.

Analysis of data has shown significantly higher live coral cover percentages where there is a lower intensity of SCUBA diver activity, concurring with current literature (S.2.3.1). This provides evidence that managing dive sites is an effective tool in protecting coral reefs and conforms with current management strategies found throughout Asia, particularly Sipidan, in Eastern Borneo, where divers and dive centres are required to obtain permits to dive key sites, with limited numbers available on a daily basis. In contrast to this management technique, some sites have allowed unlimited dive and visitor numbers and have seen coral reefs suffer as a result. It was reported in the Guardian in 2018 that Koh Phi Phi in Thailand would be closed to tourism to allow time for the coral to recover. However, managing numbers as a form of prevention is likely to prove more effective in long term sustainability and protection for important reef sites (Telegraph, 2018). Beyond management of coral reef sites, this research has proven that SCUBA diving has an impact on the health of a coral reef and therefore the examining the influence of pro-environmental intervention briefings is vital in determining the type, cause and level of impact as well as reducing it.

While confounded variables were limited during this research, issues arose around the methodology and approach of using video point transects to collect data for substrate and live coral cover. It was found during data collection that the quality of the image would vary depending on sea conditions, particularly during poor visibility and the presence of thermoclines³, which drastically alter the ability for the camera to maintain focus. While enough data points were identified to carry out a basic analysis of coral reef cover, it is recommended that future studies utilise photographic stills, rather than taking stills from video. This method, while slower in the water would potentially produce considerably sharper

³ A sudden and drastic change in water temperature, usually a sudden drop in temperature with depth

stills, allowing easier identification. This study benefited from the knowledge and experience of the primary researcher, who spent several years diving the reefs at the study site and gained an excellent understanding and knowledge of the substrate types and variations.



Therefore, the impact of poorer quality photographic stills, was minimised and abled the data to be accurately assessed and analysed for the purpose of this study. Although there were issues with the methodology, the results of the CVT portion of the study add substance to the diver behaviour portion of the study and reinforce the necessity of altering diver behaviour to reduce direct impacts. As coral health impacts have been proven significant based on diver numbers, it is now necessary to consider diver demographics and behaviour data.

5.2 Demographic Distribution.

Previous studies found varying results when considering correlations between demographics and contact rates with the substrate. This Section will dissect and analyse results from this study to determine whether there were any correlations between gender, age, nationality, diver experience and contact rates. Any significant correlations will be included in further analysis and to determine recommendations for further studies and management matrices.

Between the months of March and July 2016, 145 SCUBA divers were observed over 40 dives and 42.3 hours underwater (S.4.3.3). Four participants did not return for the second dive, nor complete the questionnaire and as such, the data from these was omitted from the results, leaving a full sample size of 141. The questionnaire collected basic demographic information for the sample population, including gender, age range and nationality.

5.2.1 Gender

Of the 141 participants surveyed, 59% (83) were male, whilst 41% (58) were female. The split corresponds with PADI's most recent statistics, which have shown a growth in female divers over the last three years, accounting for 37.2% of all new and advanced training courses completed by PADI in 2016 (S.2.3). As discussed in sub-section 2.3.1.1, gender has been linked to contact rates in previous studies. Prior to the intervention pro-environmental briefing, male divers made an average of 2.59 contacts, higher than the female divers, who made an average of 1.96 contacts per observation period. However, after running an independent sample t-test there was no significant difference between the contact rates ($p = 0.62$). After the pro-environmental intervention briefing, male diver contacts reduced to an average of

1.49, whilst female diver contact rates dropped to 0.95 per observation period. Again, while there was a difference, it was not significant ($p = 0.12$) between genders.

5.2.2 Age Range

Age has not previously been considered in relation to contact rates within the dive community (S.2.3.1.1). Figure 5.4 displays the age range distribution for the sample population. The largest group was 18-29 year olds, who accounted for 45.89% (67) of the population, followed by the 30-39 year olds, who account for 26.71% (39). Participants over 40 account for the remaining 23.97% (35) of the population, which is further broken down into 40-49 year olds (13.7%), 50-59 year olds (8.9%) and over 60's (1.37%).

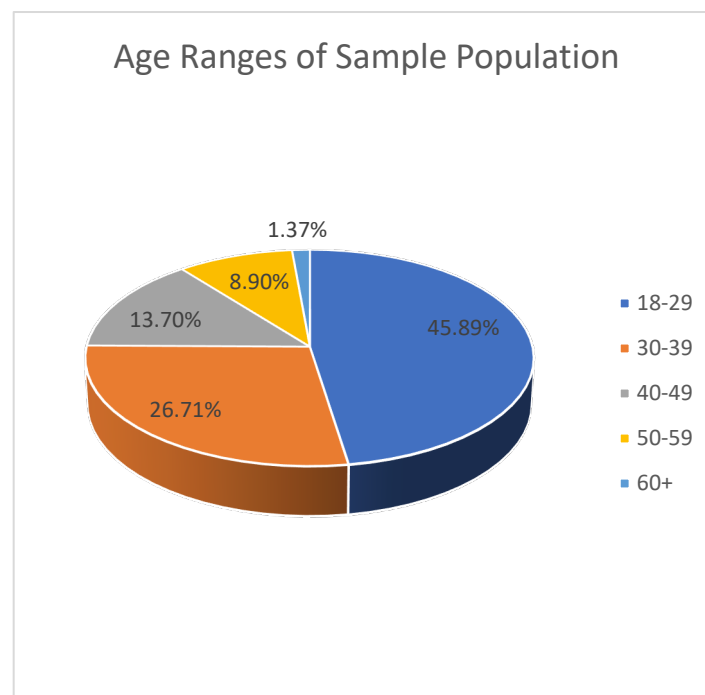


Figure 5.4: Percentage of age ranges for the sample population

Table 5.3 displays the variations in the average number of contacts per age group for both observation dives. The 50-59 year olds had the highest average number of contacts both before (2.77) and after (1.08) the intervention briefing. The group with the fewest contacts before the intervention briefing were the over 60's. However, only 2 participants were in this group and they had the second highest number of contacts in the second dive.

Table 5.3: Variations in contact numbers between age ranges. (Including average number of contacts per group and standard deviation)

Age Range	Observation Dive 1 Contacts			Observation dive 2 Contacts		
	N	Mean	Std Dev.	N	Mean	Std Dev
18-29	67	2.39	2.48	67	0.79	1.44
30-39	39	1.97	2.13	39	0.62	0.91
40-49	20	2.65	2.58	20	0.65	1.27
50-59	13	2.77	1.79	13	1.08	1.61
60+	2	1.5	2.12	2	1.00	1.41

Although differences were present in the average number of contacts between age groups, an Anova test found no significant difference, either before ($p = 0.73$) or after ($p = 0.83$) the intervention briefing.

5.2.3 Nationality

The sample population ranged from 17 different countries, including Malaysia (74), the United Kingdom (16) and Germany (14). A number of the countries only accounted for a

minimal percentage of the sample population. Table 5.4 details the full breakdown of the population distribution, whilst figure 5.5 displays distribution based on wider regions; Asia, Europe, America's and Australasia, to allow for improved accuracy during analysis.

Table 5.4 Sample population nationality distribution

Nationality	# of sample	% of sample
Malaysian	74	52.48%
British	16	11.35%
German	14	9.93%
Swiss	5	3.55%
Finnish	2	1.42%
Swedish	2	1.42%
Dutch	6	4.26%
Polish	2	1.42%
French	8	5.67%
Central America	2	1.42%
Canadian	1	0.71%
Austrian	1	0.71%
Australian	1	0.71%
Japanese	3	2.13%
Danish	1	0.71%
American	1	0.71%
Spanish	2	1.42%
TOTAL	141	100.00%

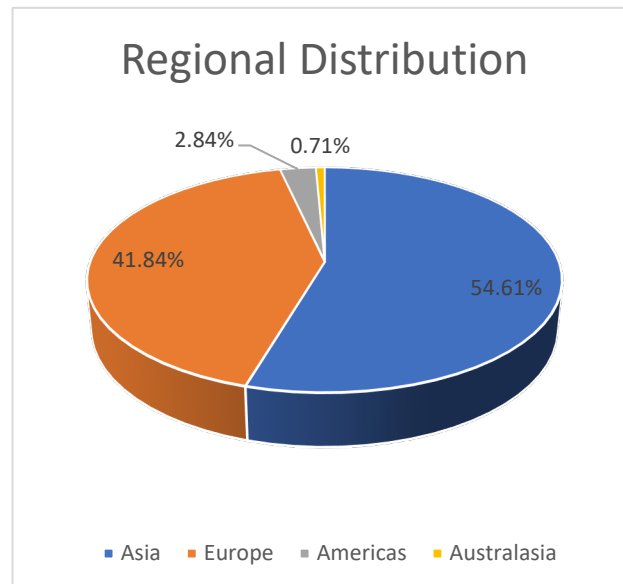


Figure 5.5: Chart displaying the regional of the sample population.

Most of the sample population were Malaysian nationals, accounting for 52.48% of data. When combined, European nations account for 41.84% of the data whilst participation from the America's and Australia is considerably lower (2.84% and 0.71% respectively). Comparison using the ANOVA test in the number of contacts based on these groupings showed no significant difference between the groups either before ($p=0.593$) or after the intervention briefing ($p = 0.374$) suggesting that in this instance, nationality does not impact pro-environmental behaviour.

This Section discussed the demographics of the sample population and determined there were no significant differences in contact rates based on gender, age or nationality. As such they have been ruled out of further analysis as these factors do not influence diver behaviour and contact rates.

5.3 SCUBA Diver Demographics

Data was collected to evidence the sample populations diving background and experience (S.4.2.1) Data obtained included: dive organisations, certification level, number of dives, participation in peak performance buoyancy training, regularity of dives and reasons for diving.

Table 5.5 shows the distribution of diver training organisations within the sample population. The Professional Association of Diving Instructors (PADI) represent a significantly larger portion of the population (75.18%). The next largest was the Confederation Mondiale des Activités Subaquatiques (CMAS), also known as the World Underwater Confederation, who accounted for only 9.22% (13) of the population. The distribution found was predicted based on the figures discussed in Section 2.3, where it was identified that PADI average 900,000 new divers annually, whilst all 15 dive centres on Pulau Perhentian provide PADI training courses.

Table 5.5 Distribution of SCUBA diver training organisations

Dive Organisation	Number of Divers	Percentage
PADI	106	75.18%
SSI	9	6.38%
CMAS	13	9.22%
SDI	4	2.84%
NAUI	3	2.13%
TDI	1	0.71%
Other	5	3.55%
Total	141	100.00%

Comparing the contact rates based on diver training organisations showed no significant difference during the first observation dive ($p=0.483$), but a significant difference after the intervention briefing ($p=0.008$). All training organisations will differ in their approach to diver

training, for example the British Sub Aqua Club (BSAC) divers are required to undergo a more thorough theory-based training before diving than PADI divers. However, as the predominant training organisation in this study was PADI, focus remained on their training practices. A post-hoc analysis of the variations is not possible due to the low numbers in the other groups. As such, it is recommended that further studies be carried out with a focus on training organisations other than PADI to determine effectiveness of the pro-environmental briefing and to further analyse how training methods differ.

As shown in Table 5.5 PADI represent the highest proportion of the population (75.18%) and by their own admission are 'the way the world learns to dive'. Taking this into account, dive organisations were analysed again, comparing PADI trained divers with other organisations to determine if PADI trained participants differed in the contact rates.

An independent sample T-test showed no significant difference in contact rates between PADI divers and divers trained by other organisations either before ($p=0.189$) or after the intervention briefing ($p=0.221$) suggesting that training methods are similarly regulated and designed across organisations. Likewise, a Pearson's test of correlation found no correlation between participant training organisation and contact rates, neither as individual organisations ($p = 0.86$) or when grouped against PADI ($p = 0.13$).

As with the population demographic results, the lack of significant difference between dive organisations suggests contact rate is not influenced by SCUBA dive organisation training methods and has been excluded from further analysis.

Certification levels varied within the sample population, diver certification completed with dive organisations other than PADI are included as their equivalent PADI certification. The distribution of diver certification levels is shown in Figure 5.6. Participation by SCUBA

professional and rescue divers is considerably lower than the two-entry level dive courses; Open Water (41.84%) and Advanced Open Water (43.26%).

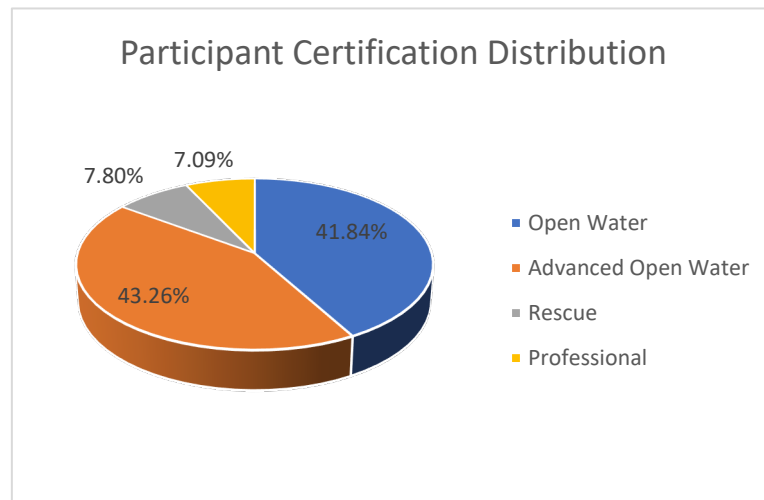


Figure 5.6: Participant certification distribution chart. Showing maximum training level for the population

As discussed in Sections 2.3.1.1 and 2.3.1.2, experience and expertise have been linked to behaviour in the past and suggested that greater experience or expertise would result in fewer contacts. An ANOVA test was carried out to determine the variations between contact rates across certification levels. While Advanced Open Water divers made the highest number of contacts (mean=2.48) during the first observation period, no significant difference was found between the groups ($p=0.852$). After the intervention briefing, all groups saw a reduction in the mean number of contacts, with Open Water Divers making the most (mean=0.92). However, there was again no significant difference between groups ($p=0.613$). Further analysis focused on comparing Open Water Divers with Advanced Open Water divers to determine if the additional 5 dive course impacted on contact rates. Again, there was no significant difference in contact rates either before ($p=0.316$) or after ($p=0.522$) the intervention briefing. As with SCUBA diver organisations, the influence of diver certification level on contact rates is insignificant and will be removed from further analysis.

A second approach to analysing diver experience is through the number of dives completed. In this study, the number of dives completed by participants varied from 5 to 2000. Figure 5.6 separates the sample population by the number of dives completed, due to the variety in responses, the results were grouped into categories.

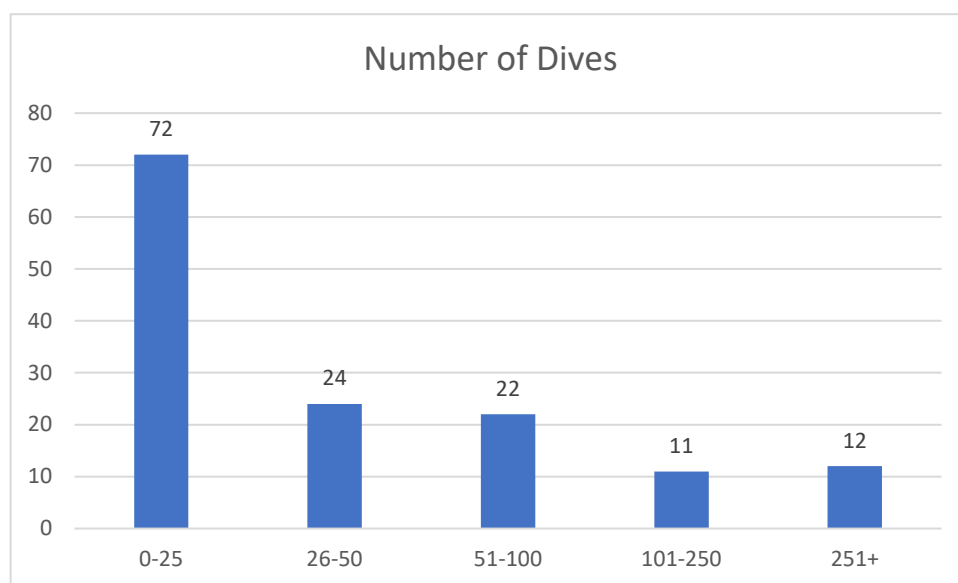


Figure 5.7: Bar chart displaying the number of divers within each bin for number of dives

Figure 5.7 shows that the predominant range for the number of dives within the sample population is 0-25 dives, with 72 (51.06%). The high proportion of divers within the lower range coincides with data from figure 5.5, which shows that 41.84% of the sample population are Open Water divers and 42.26% are Advanced Open Water divers, which are the two lowest certification levels for SCUBA divers and can both be completed with a minimum of 9 dives. In contrast, in order to become a professional diver, a minimum of 60 logged dives are required. This fact is further highlighted in table 5.6, which breaks down the number of dives further and separates certification levels.

Table 5.6: Number of logged dives per certification level

# Dives	Open Water	Advanced Open Water	Rescue	Professional
0-25	48	24	0	0
26-50	9	14	1	0
51-100	2	16	4	0
101-250	0	6	5	0
251+	0	1	1	10

Table 5.6 shows that 48 of the 59 (81.36%) open water divers surveyed have completed less than 25 dives. Whereas none of the 22 divers certified at rescue diver or above had completed less than 25 dives, and only 1 had completed under 50 dives. Divers certified as advanced open water divers showed the most variation in the number of dives though.

The groupings for the number of dives was based on discussions with SCUBA professionals (S.4.3.1) as well as the literature, predominantly Worachananant *et al.* (2008) who grouped divers into 4 categories of experience. For the purpose of this study, the groupings used by Worachananant *et al.* (2008) were adapted to include 101-250 and over 250 dives to allow for the vast difference in number of dives.

In contrast to the study by Worachananant *et al.* (2008), a Pearson's correlation test found no significant correlation was found between contact rates and the number of dives (Correlation = 0.66, $p = 0.43$). Coupled with the lack of correlation between certification levels and contact rates, it can be concluded that diver experience does not directly influence contact rates. This evidence concurs with literature reviewed in Section 2.3.1.1, where only 2 studies found correlation between experience and contact rates.

Following on from the idea that buoyancy control influences diver contact rates (S.2.3.1.1), participants in this study were asked whether they had undergone any additional buoyancy

training as part of their dive training, specifically a peak performance buoyancy dive. Over half of participants (60.9%) stated they had not participated in additional training, whilst the remaining 39.1% stated they had. While experience and expertise were found not to influence contact rates, evidence suggests that improved buoyancy should correlate (S.2.3.1.1). However, after completing a Pearson's correlation test, no significant correlation was found between those who had participated in buoyancy training and reduced contact rates ($p = 0.321$) suggesting that the additional buoyancy training offered is ineffective in reducing contacts and highlights the need for a greater understanding of contacts, specifically the cause of contacts and behaviours linked to them.

5.4 SCUBA Diver Contact

This Section will analyse results collected during the underwater observations of divers based on the contacts made. It will build on analysis of coral health and focus on the actual, observed impact of divers and determine the effectiveness of the pro-environmental behavioural briefing in reducing contacts (objectives 3 and 4 of the research).

5.4.1 Pre-Pro-environmental Behavioural Briefing

As found in the previous literature (S.2.3), divers observed during this study made contact with the substrate during the observation period. The percentage of divers who made contact (70.20%) was similar to some studies (Rouphael and Inglis, 1997, 2001; Barker and Roberts, 2004), though lower than results found by Roche *et al.* (2016) and Luna *et al.* (2009) who observed 88% and 96.7% of divers making contact during observations. In contrast, only

39.0% of the population made contact after the pro-environmental intervention briefing, showing a significant ($p = 0.00$) increase of 104.7% in divers who didn't make contact.

In total, 326 contacts were observed during the first observation dive, a mean of 2.33 (st. dev = 2.33). Unintentional contacts accounted for 239 (73.3%) of contacts, a significant proportion that highlights the importance of improving diver skill and behaviour. As found in previous studies (S.2.3.1.1) fins accounted for the primary point of contact with 237 (72.7%) while diver knees accounted for the fewest contacts (6). Divers made contact by hand on 62 (19.0%) occasions, while loose equipment was responsible for 21 (6.4%) contacts. Sedimentation occurred after 45 (13.8%) of the observed contacts, 41 of which were a result of finning activity and the remaining 4 by hand contact. The biggest cause of contacts was poor positioning, which accounted for 144 (44.2%) contacts, the remaining contacts accounted for by buoyancy (21.78%), finning technique (14.2%), observing (11.0%), photography (4.9%) and loose equipment (3.7%).

While no breakages were observed during the study, the number of abrasive contacts still raises concerns due to the increased risk of predation and disease (S.2.3.1.1). The high number of contacts in the first observation period provides evidence that the rate of abrasion and risk of predation and disease is likely to be increased. With this in mind, further research is recommended to focus on the rates of disease and predation in high and low intensity sites.

5.4.1.1 Cause of Contact

In some contact instances, more than one cause could be highlighted as relevant to a contact. For the purpose of the study, a predominant cause was identified based on the key behaviours and the order in which each behaviour took place. For example, a diver with poor positioning and fins too close to the reef could result in any large fin kicks making contact with the

substrate. In this example, the researcher was required to assess whether the contact would still have taken place if the positioning was good. If the answer is no, then positioning was marked as the cause. If the contact would still have happened with good positioning, then finning would be marked as the cause of contact.

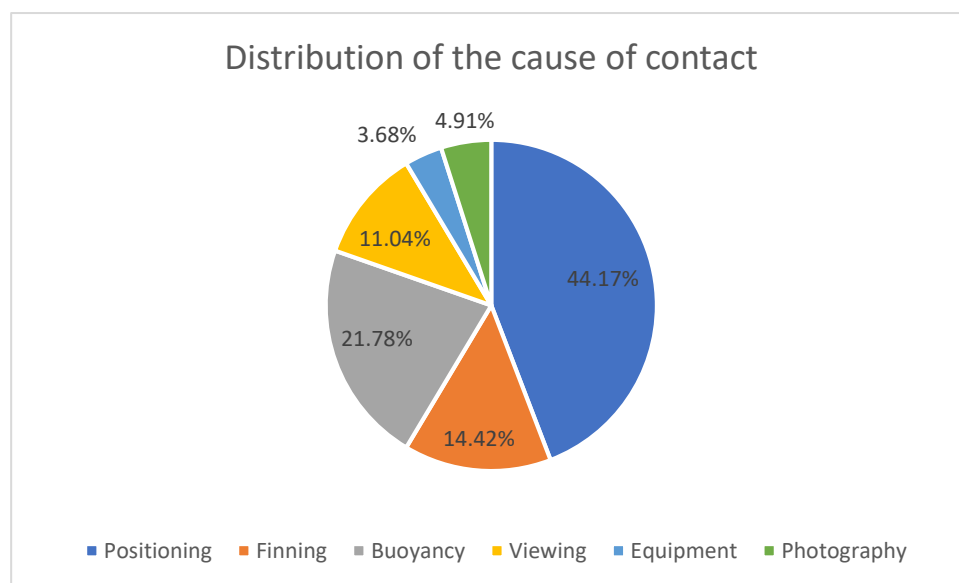


Figure 5.8: The causes of the 326 contacts during observation dive 1, displayed in percentages

As discussed in Section 5.3.1, and shown in Figure 5.8, poor positioning accounted for most contacts (44.2%) during the first observation period. Buoyancy (21.8%) and finning technique (14.4%) were the second and third largest contributors whilst viewing, loose equipment and photography accounted for the fewest contacts. Poor positioning is defined as diving in a position whereby the diver's waist and feet are below the chest and shoulders (S.4.3.2.1) and would be expected to show a correlation with the point of contact. A Pearson's test found a weak, but statistically significant ($p = 0.02$), linear correlation ($r = 0.13$) between cause of contact and point of contact and whilst the correlation is weak, evidence suggests a closer link between the two. Of the 144 contacts made due to poor positioning, 140 were made by

diver fins (97.22%) further evidence that the point of contact is closely linked to the cause, particularly where positioning is a factor.

5.4.1.2 Point of Contact

As stated previously (S.5.3.1) and shown in Figure 5.9, fin kicks were the predominant point of contact during the first observation period, accounting for 72.70% of all contacts. This figure coincides with previous literature (S.2.3.1.1) where fins were found, consistently, to be the main point of contact.

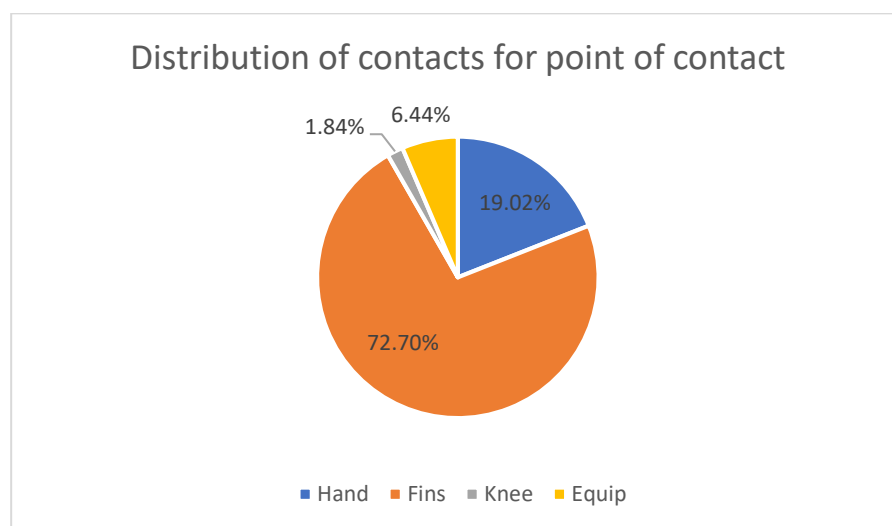


Figure 5.9: the distribution of the point of contact for the 326 contacts observed in observation dive one.

A correlation between point of contact and cause of contact has already been stated and was predicted in Section 2.3.1.1 where poor positioning would be expected to show a higher number of fin contacts. Where the point of contact was observed as diver hands, poor positioning wasn't registered as a cause. Of the 62 hand contacts, 19 (30.60%) were caused by poor buoyancy; 29 (46.80%) were caused by viewing specific species close up; 12 (19.40%)

were caused by taking a photo; 1 (1.6%) was a result of poor finning and the result of swimming into substrate; and 1 (1.6%) as a result of loose equipment and the result of holding onto substrate whilst fixing equipment. As expected, most (90.32%) hand contacts were intentional as generally, divers propel themselves through the water with their legs and fins, whilst arms and hands are expected to stay relatively stationary. Therefore any contacts with hands are reactive to something happening during the dive (losing buoyancy, viewing interesting species, control during equipment alteration). In theory, intentional contacts, particularly those made by hand, should reduce when faced with ecological briefings such as those carried out by Medio *et al.* (1997)

5.4.1.3 Unintentional Contacts

As stated in Section 5.3.1, unintentional contacts accounted for 239 (73.3%) of the 326 contacts recorded during the initial observation period. This figure differs to those found in previous studies (S.2.3.1.1) where unintentional contacts accounted for between 64.3% and 86% (Uyarra and Côté, 2007) or 55.4% (Camp and Fraser, 2012) and 81.2% (Barker and Roberts, 2004). In all the studies, unintentional contacts account for the majority of all contacts, and as such, it is a key target in reducing overall contacts.

When only unintentional contacts ($n = 239$) are considered, poor positioning remains the primary cause of contacts (58.6%), whilst finning moves above buoyancy into the second biggest cause of contact (19.7%). Buoyancy (14.6%), loose equipment (5.0%), photography (1.3%) and observing (0.8%) account for the remaining unintentional contacts. Interestingly, 97.22% of contacts caused by positioning ($n = 144$) were unintentional, suggesting a high level of correlation between intention and cause of contacts, backed up by a statistically significant

($p = 0.00$) strong linear correlation (0.60) between the cause of contact and whether it was intentional.

When only unintentional contacts are considered, the percentage of contacts made by fins increased to 89.1% ($n = 213$). Of the 237 contacts made by fins, 89.87% were unintentional. As with the cause of contact, a moderate but statistically significant ($r = 0.40$, $p = 0.00$) linear correlation was found between the point of contact and whether contacts were intentional or not. During the first observational period, 62 intentional contacts were observed. Of these, 56 (90.3%) were made by diver hands. As stated in Section 5.3.1.1, fins are the dominant limb used to propel a diver through the water, meaning that hands are rarely used, except in instances of poor buoyancy control or holding to take a photograph/observation. Likewise, the correlation between intentional and cause of contacts, with the dominant cause being positioning (fins closer to the reef resulting in higher number of unintentional contacts) the links between intentions, point and cause of contact can be explained.

As predicted, 42 of the 45 (93.33%) contacts that caused a sedimentation event were unintentional as divers are not presumed to want to disturb the sediment due to reduced visibility and dive enjoyment.

5.4.2 Post Pro-environmental behavioural briefing

After the pro-environmental behavioural briefing, 106 contacts were observed (mean= 0.75, SD = 1.29). During the first observation period, divers made contact on average 2.33 times, or 0.23 times per minute. When extrapolated, this could equate to an average of 10.49 contacts per 45-minute dive. In contrast, after the pro-environmental behavioural briefing the average

of 1.29 contacts per 10 minutes (0.13 contacts per minute) equates to 5.81 contacts per 45-minute dive. A paired t-test shows this as a statistically significant ($p = 0.00$) reduction of 67.48% in contacts from the initial observation period and provides categoric evidence that the behavioural briefing was effective at reducing contact rates.

The significant reduction in contact rates can be directly explained by the behavioural briefing. Heberlein (2012) discussed human attitudes towards the environment as a factor influencing behaviour (S.2.4.2), while Clayton and Myers (2009) and Stern (2000) concurred, claiming values and care were important factors. This research targeted a more self-serving value alongside care for the environment: informing participants that behavioural changes would improve diver enjoyment and skill as well as protect the coral reef. That this approach has been successful opens up future avenues for behaviour change research and models.

5.4.2.1 Cause of Contact

As established in Section 5.3.2, the number of contacts significantly reduced after the pro-environmental intervention briefing. The same process was followed for all contacts in both dives and the cause of contacts in the second period was also recorded. As during the first observation period, poor positioning was observed to be the biggest contributor to contacts, recording 35 contacts (33.02%). Figure 5.10 shows the breakdown of contacts based on the cause of contact. Buoyancy and finning technique make up the 2nd and 3rd highest causes, as they did during the first observation period. A paired sample t-test found that the cause of contacts differs significantly after the pro-environmental intervention briefing. The total number of contacts reduced significantly which resulted in the cause of contact also reducing for every category. Figure 5.11 displays results for outputs pre and post briefing, utilising

percentages to provide improved visual comparison. As can be seen, whilst the percentage of contacts caused by poor positioning reduced, the shortfall was made up by an increase in all other categories, other than loose equipment.

Unlike data from the first observation period, a Pearson's correlation test found no statistically significant correlation between cause and point of contact after the intervention briefing ($r = 0.02$; $p = 0.84$).

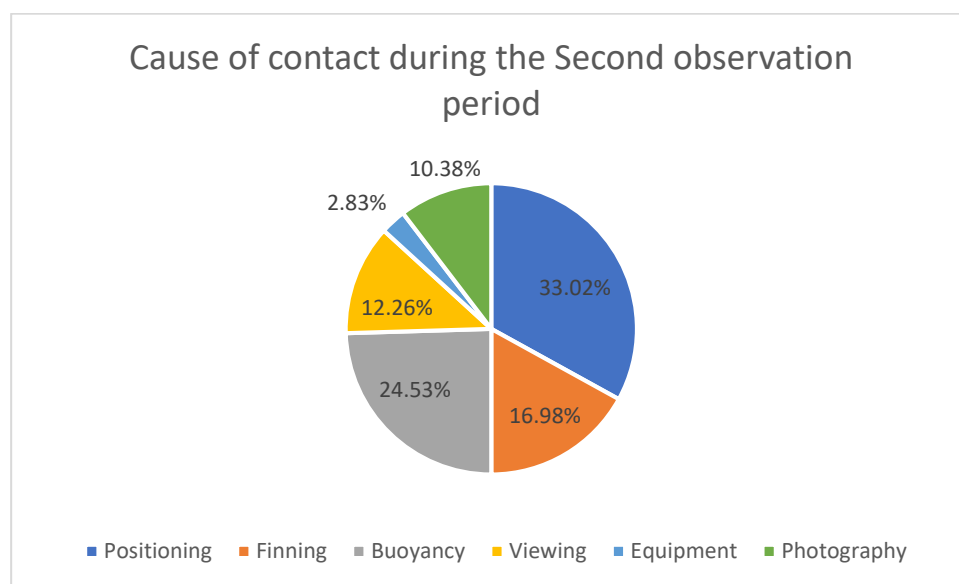


Figure 5.10: The distribution of the cause of contacts recorded during the second observation period

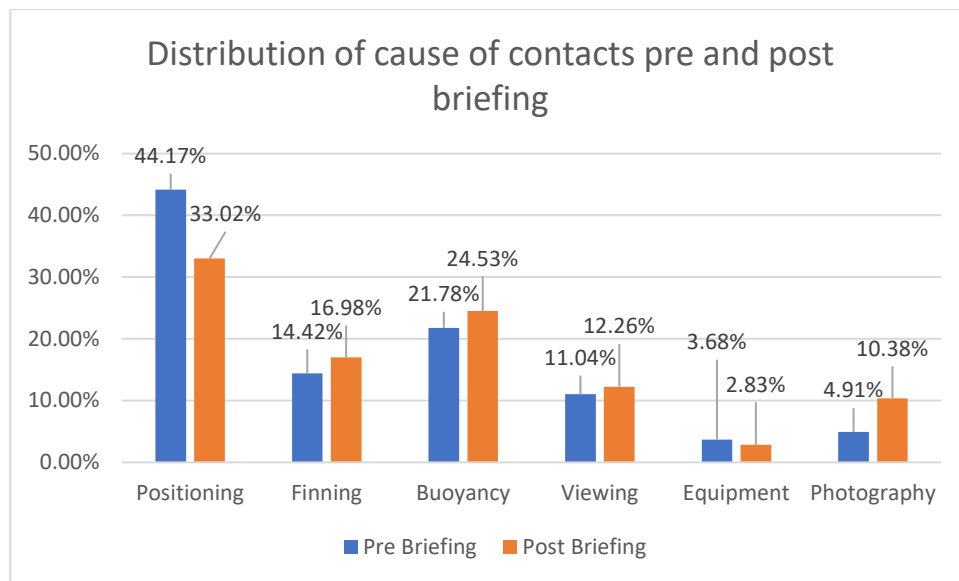


Figure 5.1: Graph comparing the cause of contacts before and after the pro-environmental behavioural briefing

The three main causes of contacts remained the same after the pro-environmental intervention briefing; positioning, buoyancy and finning technique. However, whilst there was a statistically significant reduction in the percentage caused by positioning ($t = 2.024$, $p = 0.04$), it was counteracted by statistically insignificant increases in contacts caused by finning, buoyancy and viewing and a statistically significant ($t = 2.02$, $p = 0.04$) increase in contacts caused by photography: likely a result of the significant reduction in contacts caused by positioning.

5.4.2.2 Point of Contact

Fin contacts were again the most common point with 70 of the 106 (66.04%), followed by hand contacts with 15 contacts (14.15%), loose equipment with 14 contacts (13.21%) and knee contacts with 7 (6.60%). The percentage of contacts made by fins and hands both decreased, though not statistically significantly. In contrast, the percentage of contacts made

by knee ($t = 2.53, p = 0.01$) and equipment ($t = 2.23, p = 0.03$) both show statistically significant increases due, potentially, to the larger focus of the briefing on finning technique and positioning. However, a paired sample T-test found no significant difference in point of contact after the pro-environmental intervention briefing ($p = 0.10$). Fins remain the primary point of contact and the key in diver impact.

5.4.2.3 Unintentional Contacts

Unintentional contacts remained the predominant type of contact after the pro-environmental briefing with 76 of the 106 contacts recorded as unintentional (71.7%). This data coincides with literature discussed in Section 2.3.1.1, where unintentional, or accidental contacts are the dominant type of contact. It is higher than results found by Camp and Fraser (2012), but slightly lower than those of Barker and Roberts (2004) and Uyarra and Cote (2007). As stated in S.5.3.1.3 a strong correlation was found during the first observation period between cause of contact and whether a contact was intentional, however in the second observation period, this drops slightly to a correlation coefficient of 0.501 ($p = 0.000$) which can be partially explained by the correlation between intentional contacts and point of contact ($r = 0.27; p = 0.01$). This data shows that intentional contacts are, at least partly, caused by specific points of contact, in this case: hand contacts.

Point of contact, as during the first observation period, shows a low to moderate correlation and is explained by the dominance of fin and hand contacts, which although reduced in the second observation period, remained the main points of contact. When only intentional contacts are considered ($n=30$), the predominant point of contact is hands (50.00%), whilst

fin contacts account for only (30.00%). Knee and Equipment percentages remain level with only a 0.1% change.

In contrast, when only unintentional contacts are considered ($n=76$), fins are the dominant point of contact (80.26%), whilst hands do not feature as a point of contact and knees (6.58%) and equipment (13.16%) remain unchanged. This explains the correlation between point of contact and whether the contacts are intentional: unintentional contacts, the most common type of contact, are the outcome of finning.

The cause of contact for intentional contacts during the first observation period are more evenly split than the entire sample, poor positioning accounting for 15 (50.00%), whilst finning (13.33%), viewing (13.33%) and buoyancy (23.33%) account for the remaining. In contrast, a wider split occurs when only unintentional contacts are considered: positioning accounts for 46.05% of unintentional contacts, and finning is the second largest contributor causing 23.68% of unintentional contacts, after this, buoyancy (17.11%), photography (7.89%), Equipment (2.63%) and viewing (2.63%). When only unintentional contacts are considered, there is a weak, but statistically significant, correlation between the cause and point of contact ($r = 0.23$; $p = 0.05$), providing evidence for a link between the two, suggesting that improved behaviour can reduce contacts.

The strongest variables that influence SCUBA diver impact so far are buoyancy control and positioning, whilst unintentional contacts are the predominant source of contacts, within which fins are the main point of contact and positioning remains the main cause of contact (58.6% of unintentional contacts).

As the results in this study concur with previous literature (S.2.3.1.1) that the majority of contacts are unintentional, it can be stated that merely increasing awareness regarding the fragility and biology of a coral reef is insufficient in reducing contacts. As discussed in Section 2.4.3, behavioural models, such as the VBN and NAM models, highlight the need for value and awareness first, but state the individuals need to believe that their own actions have an impact. The briefing developed for this research targeted both egotistical and biospheric agendas within divers, encouraging them to become better divers and gain more enjoyment, with reduced contact rates a side effect of improved behaviour, based on this.

5.4.3 SCUBA Diver Contact Summary

The underwater observation of SCUBA divers concurred with previous literature which found a high percentage of divers make contact with the reef. In this study, 70.6% of divers made contact with the reef prior to the intervention briefing, with a total of 326 contacts made between them. Of all the contacts, 73.3% were unintentional and 44.2% caused by poor positioning, with fins accounting for 72.7% of the contact points. The moderate correlation between poor positioning resulting in fins as the point of contact add to existing literature and highlight the importance of the behaviours of interest identified in S.4.3.2.

After the pro-environmental intervention briefing, contact rates were significantly reduced ($p=0.00$) with only 39% of the sample population making contact. While positioning and fins remained the dominant causes and points of contact, the significant reduction in contacts has proven the effectiveness of a pro-environmental behavioural briefing that is focused on positive behaviour, rather than focusing on biology of coral and reefs.

While there was a significant correlation between the cause of contact and point of contacts in the first observation period, no significant correlation was found after the briefing, suggesting that the changed behaviour and greater level of awareness influenced the point of contact.

The success in reducing contact rates significantly has shown the behavioural briefing to be a successful and vital tool in reducing SCUBA diver impacts. The study site for the research provided dive sites that had good visibility, low currents and warm waters; ideal conditions for SCUBA diving. Based on the high number of contacts recorded prior to the briefing it can be theorised that in more challenging conditions there is a likelihood that a higher rate of contacts would be observed. The briefing targeted behaviour change, rather than awareness, providing the belief that individual behaviour can make a difference, both to diver enjoyment and impacts. In more challenging conditions, behaviour change could be key in reducing impacts as divers with greater understanding of behaviour and skills are more likely to be able to cope with challenging environments. In contrast, divers faced with an environmental focused briefing may not have the tools or skill to prevent contacts in more challenging conditions: making the use of the behavioural briefing of significant importance in minimising impacts and improving behaviour and further study should be conducted on divers in different diving conditions.

5.5 SCUBA Diver Behaviour

This Section builds on the data analysed in Section 5.4 to understand and determine SCUBA diver behaviour during a dive. The behaviours of interest: positioning, buoyancy and finning

technique were highlighted as the predominant causes of contact in this study and this Section will further aim to understand any relationships between diver behaviour and their contact rates and further establish outcomes for objectives 3 and 4.

One of the objectives for this research was to identify how effective the pre-dive briefing is at reducing diver contacts and promoting pro-environmental behaviour. Section 5.4 focused on an in-depth analysis of the recorded contacts, including the cause of contact, point of contact and whether unintentional. This Section will focus specifically on the behaviours of interest identified in Section 4.4.2, both before and after the pre-dive briefing. The analysis carried out in Section 5.4 will overlap and build towards a larger understanding of influencing pro-environmental behaviour.

As stated in Section 5.4.2, there was a significant reduction in the contact rate after the pro-environmental behavioural briefing delivered to participants by the researcher. The focus of the briefing differed to those discussed in Section 2.3.2 where focus was predominantly on raising awareness of coral reef biology and environmental considerations. The briefing for this research attempted to influence pro-environmental behaviour through increasing value, awareness and normative understanding of specific behaviour.

5.5.1 Positioning

5.5.1.1 Pre-Pro-environmental behavioural briefing

Identified in Section 5.4 as the primary cause of contacts both before (44.17%) and after (33.02%) the pro-environmental behavioural briefing, positioning has been shown to be the key behaviour of importance when considering SCUBA diver impact on the reef. During the

first observation period the mean score for positioning was 5.77 (std. dev. = 2.87). This equates to divers holding themselves in good positioning for 5.77 minutes of the observation period and resulted in a low to moderate, but statistically significant correlation with the number of contacts made ($r=-0.30$, $p=0.00$). This correlation provides further evidence and builds upon data in Section 5.4 which highlighted poor positioning as the main cause of contacts.

Weak correlations between positioning and certification level ($r=0.24$ $p = 0.01$) and number of dives ($r=0.18$ $p = 0.04$) were also found, suggesting that divers with higher levels of training and number of dives have a slightly better position whilst diving, though, as discussed in Section 5.3, there were no correlations between experience and the number of contacts, suggesting that experience indirectly influences contact rates. Further analysis of key behaviours found no correlation between trim (loose equipment) and positioning ($r=0.01$ $p = 0.96$) but moderate correlations between positioning and buoyancy control ($r = 0.33$ $p = 0.00$) and finning technique ($r = 0.34$ $p = 0.00$). and based on a linear regression model, together can explain 17.7% ($r=0.42$) of diver positioning (while certification and number of dives prove insignificant in this model) with a statistical significance of 0.00. The relationship between buoyancy control and positioning can generally be explained through the ability of a diver to maintain their position vertically in the water without finning or 'flapping' their hands. When a diver has poor buoyancy control, they will regularly use their fins to kick to ensure they do not sink (putting them in a poor position). Likewise, divers who practice frog kicking, rather than flutter kicking (S.4.3.2) tend to naturally orientate themselves horizontally due to the placement and process of kicking.

5.5.1.2 Post Pro-environmental Behavioural Briefing

SCUBA diver positioning during the second observation dive showed a statistically significant ($t=-2.03$ $p = 0.00$) increase from 5.77 to a mean of 7.80 (Std dev. = 2.39), this equates to an additional 1 minute and 47 seconds spent in good positioning after the pro-environmental intervention briefing. In contrast to the first observation period, there was no statistically significant correlation between positioning and the number of contacts after the intervention briefing ($r = -0.15$ $p = 0.08$). As during the first observation period, there is a weak correlation ($r = 0.25$ $p = 0.00$) between positioning and certification level, however there was no correlation between the number of dives and positioning. There was a statistically significant moderate correlation ($r=-0.31$ $p=0.00$) between improved positioning and the change in contact rates which can be explained through analysis of the cause of contact. Poor positioning was the biggest cause of contacts, so improved positioning is expected to correlate with reduced contacts.

PADI include a weight check as part of their Open Water course (Section 2.3), which aims to ensure divers have the correct amount of lead weighting to maintain good buoyancy. However, in practice, weight distribution is as important as the amount of weight. Where weights are too low down on the body (for example, the standard weight belt) the diver will experience extra weight on their hips, pulling their legs downwards and creating poor positioning. This can be counteracted through the diver's conscious effort to maintain positioning, without altering weight or its distribution. This is demonstrated by the results, where divers used the same set-up, weights and equipment on both dives but positioning significantly improved during the second observation period. As discussed in Section 2.3, PADI introduced a new weight check skill that put more focus on horizontal positioning and

distribution of weights. However, during the course of the research, no variations in the use of weight belts were observed, implying that dive centres and staff have not altered their approach to weight distribution.

5.5.1.3 Positioning Summary

There was a statistically significant improvement in diver positioning after the pre-environmental intervention briefing (S.5.4.1.2) and moderate significant correlations between the three behaviours of interest identified in Section 4.3.2; positioning buoyancy and finning. There was a low-moderate correlation between positioning and contact rates for divers and further correlations between an improved positioning with reduced contact rates.

Analysis of data in this Section has shown evidence of the importance of good positioning and its association with contact rates. Positioning is not a factor that has been previously analysed in the literature, although as discussed in Section 2.3.1.1, it is a behaviour considered important in diver contacts. Results show that there is a correlation between contact rates and positioning and that it is a behaviour that should be addressed in briefings and training, particularly as the briefing used in this study showed significantly improved positioning over the two dives, accounting for 8.13% of reduced contacts.

As shown here and stated in S.5.3.3, the significant improvement in positioning and reduction in contact rates proves the briefing utilised to be an effective moderator of behaviour and contacts and is a vital tool for reducing diver impact globally, specifically where diving conditions are more challenging and behavioural improvements are particularly important.

5.5.2 Buoyancy Control

5.5.2.1 Pre-Pro-Environmental Behavioural Briefing

Buoyancy control was observed to be the second highest cause of contacts prior to the intervention briefing (21.78%). It is a skill that is taught through multiple skills within SCUBA diving training and all divers should be competent at buoyancy control before being certified. Of the sample population, 81 (57.45%) were deemed to have good buoyancy control, the remaining 60 (42.55%) were deemed to have poor buoyancy control. As found by Toyoshima and Nadaoka (2015), a weak correlation was found here between buoyancy control and contact rates ($r = -0.29$ $p = 0.00$). The mean number of contacts for divers with good buoyancy during the first observation period was 1.78 (std dev. 20.2), in contrast, divers with poor buoyancy scored a mean of 3.08 (std dev. 2.52). An independent t-test found the number of contacts for divers with good buoyancy control was significantly different to those observed to have poor buoyancy control ($t = 3.41$ $p = 0.00$), with those with good buoyancy control making contact significantly less than those with poor buoyancy control. This statistic concurs with Toyoshima and Nadaoka (2015) and highlights the importance of good buoyancy control in reducing diver impacts.

A Pearson's correlation analysis found weak, but significant, correlations between certification level and buoyancy control ($r = 0.24$ $p = 0.01$), as well as between buoyancy control and number of dives ($r=0.20$ $p = 0.02$) but no correlation between buoyancy control and participation in additional buoyancy training ($r = 0.13$ $p = 0.13$), confirming, as in Section 5.3, that the additional buoyancy training available isn't sufficient in improving abilities and reducing impacts.. While there is a correlation between buoyancy and experience, the strength does not necessarily mean they are key variables in improving buoyancy control,

although it can be argued that they are invaluable in long-term improvements. The lack of correlation between buoyancy control and additional training suggests that the current 'peak performance buoyancy' training offered is not suitable or effective enough. Considering the effectiveness of the behavioural briefing tested in this research, these behaviours should be included in required training, not only additional and optional training.

The correlation between buoyancy and certification level concurs with Toyoshima and Nadaoka (2015) who found more experienced divers had improved buoyancy control. However, buoyancy control has been defined differently and, while results concur, this should be taken into account. Toyoshima and Nadaoka (2015) defined good buoyancy as swimming in a horizontal position and the ability to hover without moving their fins. In contrast, this study observed divers for 10 minutes and determined a diver's buoyancy control based on their vertical movement during a dive along with their ability to stay level without kicking upwards. This decision was made due to understanding that good buoyancy can be achieved without good positioning (horizontal) and with fin movements during hovering.

As stated in Section 5.3, positioning is more closely related to buoyancy control, potentially because in instances where a diver is struggling with buoyancy their positioning will adapt to counter the downwards (or upwards) movement; meaning that they would be swimming slightly towards the surface, to counteract the downward movement.

5.5.2.3 Post Pro-environmental Behavioural Briefing

Although not an expected outcome from the intervention briefing, diver buoyancy control after the intervention briefing was found to have changed significantly ($p = 0.02$). In the

second observation period 94 (66.67%) of the sample were judged to have good buoyancy control, an increase of 16.03.%. Although unexpected, the improvements found in buoyancy control can be directly linked to improved positioning, which showed a positive correlation ($r = 0.33$ $p = 0.00$) with buoyancy. While buoyancy training occurs in beginner and specialist training courses, it is generally considered a skill that is perfected over time, rather than immediately (Othman *et al.*, 2014). Therefore, the improvement based on the behavioural briefing was unexpected, although it can now be theorised that the inclusion of the pro-environmental behavioural briefing influenced buoyancy through raising awareness, consideration and knowledge for the skill. Data from the second observation period found a moderate correlation between buoyancy control and number of contacts ($r = 0.37$ $p = 0.00$), showing that as buoyancy improved, contact rate decreased, an important and significant relationship.

After the pro-environmental intervention briefing, the mean number of contacts for divers with good buoyancy was 0.41 (std dev. = 0.89), a statistically significant reduction from the 1.78 recorded in the first observation period ($t = 5.95$; $p = 0.00$). Likewise, divers with poor buoyancy also recorded a reduction in contact rates; the second observation period found a mean of 1.43 contacts per 10 minutes (std dev. = 1.67), again a statistically significant reduction ($t = 3.87$; $p = 0.00$). The greater reduction found in those with good buoyancy provides evidence of the link between buoyancy and contact rates, and again highlights the importance of delivering the behavioural briefing prior to every dive. In contrast to results in this study, Toyoshima and Nadaoka (2015) found that an environmental briefing only served to improve contact rates of those with established buoyancy control. They found that a 15-minute briefing was only effective for divers with buoyancy control, and state that 4 of the 8 divers observed after the briefing showed increased contact rates after the briefing. Both the

sample size and the different approach to the briefing can potentially explain the difference in effectiveness. Toyoshima and Nadaoka (2015) conducted a 15-minute presentation to divers, focusing on coral biology and including quizzes, whereas this study targeted diver behaviour, both from an ecological conservation perspective (biospheric) as well as a social enjoyment and self-improvement perspective (egotistical) (S.2.4.3). As discussed in sub-Section 2.4.3, influencing behaviour relies on impacting change in values, awareness and norms. Utilising a briefing that targets diver skill and enjoyment, as used during this study, has shown to influence behaviour more significantly across the entire group, rather than only those with experience making it a more effective tool in behaviour change.

5.5.2.4 Buoyancy Summary

Buoyancy has been shown to correlate with both positioning and contact rates and like positioning, has been found to be an important aspect in influencing contact rates. Unexpectedly, buoyancy significantly improved as a result of the pro-environmental behavioural briefing ($p = 0.02$), while the relationship between buoyancy and contact rates was shown to moderately correlate in the second observation period, highlighting an important link between the two factors. As a result of the significant improvements and relationship with contact rates, buoyancy will be pulled into the diver behavioural model in the next chapter.

5.5.3 Proximity to the substrate

One factor that can be linked to buoyancy control is proximity to the substrate. While there is limited evidence or discussion of this factor in the literature, how close a diver is to the reef

would inevitably correlate to the contact rate. Consequently, a diver who spends the majority of their dive more than a metre from the substrate should make fewer contacts than someone who is within a metre of the substrate for prolonged periods. This proved accurate in the current study, where an r value of -0.508 ($p=0.000$) was recorded when a correlation analysis was carried out for proximity against contact rates. Where the proximity was scored low ($<1\text{m}$) the rate of contact was found to increase. On this statistic, 25% of contacts in the first observation period are explained by close proximity to the reef. Perhaps tellingly, proximity to the reef showed a weak correlation with buoyancy control ($r=0.326$, $p = 0.000$).

This output indicates that where divers scored well in buoyancy control, they also scored a greater distance from the substrate, suggesting divers with good buoyancy were less commonly found close to the reef during the observation period. This goes some way to explain the links between buoyancy and contact rates. Proximity to the reef does not correlate with the number of dives ($r= -0.064$, $p=0.454$) or certification level ($r= -0.007$, $p=0.935$), and so does not appear to be linked to experience in any way.

5.5.4 Finning Technique

5.5.4.1 Pre-Pro-environmental Behavioural briefing

As with positioning and buoyancy control, finning technique was identified in Section 4.4.2 as a behaviour of interest. Results both in this study (Section 5.4.2) and previous literature (2.3.1.1) found the predominant point of contact to be diver fins. As explained in Section 5.4.1, this is due to the fact that divers propel through the water using only their fins and that

they are an unusual extension to the limbs. There are variations in the way fins can be used, predominantly the flutter kick and the frog-kick.

During the first observational period, the mean score for finning technique was 3.31 ($SD=3.57$). This score means that on average, divers spent approximately 3 minutes and 19 seconds using the frog kick method. However, 51 (36.17%) of the sample population were not observed using the frog kick method at all. Over half (56.03%) were observed using the frog kick technique on only 3 occasions, whilst only 15 (10.64%) were observed using the technique for the entire duration. Although finning technique was the cause of 14.42% (47) of contacts, there was no significant correlation between finning technique and contact rate ($p = 0.27$).

Although there was no correlation with contact rates, there was a correlation between finning technique and buoyancy ($r = 0.36$ $p = 0.00$) and positioning ($r=0.34$ $p = 0.00$). Both were positive correlations, meaning that where divers were recorded having good finning technique, they were more inclined to swim in a better position. Likewise, good buoyancy can be linked to good finning technique, and vice versa. This highlights the importance of the three behaviours of interest identified for this study and their interlinking relationships. Based on the results discussed in this chapter, evidence that the briefing is key to influencing diver behaviour is provided and these three behaviours should be included in both briefings and future training.

5.5.4.2 Post Pro-environmental behavioural briefing

The figure for finning technique increased in the second observation period to 5.40 ($SD = 3.41$) as divers attempted to change their behaviour based on the intervention briefing. This change showed an increase of approximately 2 minutes and 5 seconds spent using the frog kick

technique; a significant increase ($p = 0.000$). Where 51 (36.17%) of the sample population were not observed using the frog kicking method during the first observation period, only 20 (14.18%) were observed not attempting the frog kick method after the briefing; a significant decrease of 60.80% ($p = 0.00$) and based solely on the inclusion of the behavioural briefing. Similarly, the number of divers observed using the frog kick method for the full duration of the observation period increased from 15 (10.64%) to 20 (14.18%) an increase of 33.27%, although this is not a significant change within the sample population. The frog kick method is less natural than the flutter kick method and is not taught during training, which explains why after a briefing, there was an increase in its use. As divers were made aware of the benefits of using the frog kick method, they became inclined to attempt it, but due to the more natural approach of flutter kicking, divers resumed this approach throughout the dive and only appeared to utilise the frog kick method after focus and consideration.

Unlike the first observation period, a weak correlation was found between finning technique and contact rates ($r = -0.22$ $p = 0.00$) and a negative correlation shows that as finning technique improved, contact rates reduced. The results provide evidence that improved finning technique can contribute to a lower contact rate, this is further established with a moderate correlation with positioning ($r = 0.45$ $p = 0.00$). As finning technique improves, positioning is naturally improved through the movement and position of the legs during the frog kick. The two behaviours are interlinked and combined can result in significantly lower contact rates.

5.5.4.3 Finning Technique Summary

Fins have been identified as the primary point of contact between divers and the substrate (S.5.4.1.2). However, no correlation was found between finning technique and contact rate

during the first observation period, while correlations were found between finning technique and positioning and buoyancy. This suggests that although positioning was found to be the main cause of contacts, this behaviour is in turn influenced by finning technique. This highlights the need for management strategies to consider finning technique alongside positioning and buoyancy, particularly when post-briefing data is considered, which found a significant improvement in finning technique ($p = 0.00$) and a weak correlation ($p = 0.00$) between finning technique and contact rates, showing that improved technique can reduce contact rates. The close relationship found between three behaviours of interest; positioning, buoyancy and finning technique, highlights the importance of the behavioural briefing in raising awareness, understanding and belief in an attempt to influence and change behaviour, based on the behavioural models discussed in Section 2.4.3.

5.6 Questionnaire Analysis

The questionnaire was designed to determine how divers perceived their behaviour, level of coral reef awareness and the emotional values that divers hold for the reef. To determine any trends, qualitative data analysis was combined with non-parametric testing.

5.6.1 Perceived Behaviours

As stated in Section 2.4.3, social and personal norms are key factors in defining human behaviour. In this instance, obligations provide an effective indicator of the norms within the sample population, meaning that the results discussed in this Section should act as behaviour drivers and contribute towards the behaviour observed.

Divers were asked to state how obligated they felt to touch coral on a five-point Likert scale. The median was 1, showing a strong obligation not to touch coral within the sample population. The low score suggests there is a common understanding within the sample population that contact should be avoided with the coral. However, 14 of the divers felt either obligated, or very obligated to touch the coral during a dive, suggesting further awareness and training is required in this area. As with positioning and finning, no significant correlation was found between contact rates and obligation to touch coral, partially explaining the average contact rate of 2.33 for the sample population.

As a key behaviour of interest, how divers perceive their positioning and how obligated they felt to swim in a horizontal position was of key interest. A median score of 4 on the five-point Likert scale shows that the sample population have a strong obligation towards swimming horizontally and maintaining a good positioning. However, there is no significant correlation between perceived behaviour and actual behaviour in this instance ($p=0.489$), which shows that whilst there is an obligation to maintain good positioning, it does not mean this behaviour occurs. Similarly, this as was shown in the positioning behaviour analysis and a potential reason positioning was the main contributing behaviour to contact rates. An explanation for the observed difference between perceived and actual behaviour in relation to positioning may be that divers did not consider it during a dive or were unaware of it as an important factor or that it can improve air consumption. Information provided by the briefing will have brought positioning to the fore of divers' minds and made them more inclined to try, resulting in the difference.

Likewise, obligations to maintain good buoyancy control resulted in a similarly high median, scoring 5 on the five-point Likert scale, suggesting a significant social norm linked to

maintaining buoyancy control. In contrast to positioning, a small, but highly significant correlation with actual behaviour ($r=0.236$, $p=0.01$) was found. This result means that, while there is a similar obligation to maintain good buoyancy control (as there is to maintain horizontal positioning), divers are more prone to focus on buoyancy control. This correlation could explain why positioning resulted in more contacts than loss of buoyancy and is likely a result of training, where buoyancy control has a greater focus than good positioning.

Ensuring fins were kept away from the reef resulted in a median score of 5 on the five-point Likert. Again, the high score shows that divers feel obligated to keep their fins away from substrate and concurs with the responses to not touching. However, as discussed in Section 5.4.1.1, fins were the dominant point of contact both before and after intervention, suggesting that perceived behaviour does not coincide with actual behaviour. This could be a result of poor positioning, meaning fins remain close to the reef more regularly as a result of the failure to remain horizontal or due to an unawareness of body and fin positioning and proximity to the reef. As with positioning, a Pearson's correlation test did not return a significant correlation between obligated and actual behaviour.

As stated in 5.5.4, the relationship between diver trim and contact rates is insignificant, with only 3.5% of contacts in the first observation period a result of poor trim. Likewise, divers maintained good trim for the majority of both observation dives. However, as with other behaviours, there is no significant correlation between levels of obligation and actual behaviour. Likewise, where the sample population returned a median of 5 in response to keeping equipment away from substrate, no significant correlation ($p=0.812$) was found with the actual trim observed in the first observation period.

Unlike buoyancy control, significant negative correlations were found between contact rates and responses to two of the statements in this Section of the questionnaire; avoid touching for photo ($r = -0.27$ $p = 0.04$) and keeping fins away from coral ($r = -0.28$ $p = 0.001$). The negative correlations provides evidence that divers who perceive themselves to avoid touching the substrate for a photo and who know to keep fins away from the reef are less likely to make contact. This was an expected outcome as divers with an understanding and obligation to avoid touching would be deemed likely to make fewer contacts. However, though this was only observed during the first observation period, no correlation was found after the briefing. This suggests that the briefing influenced behaviour sufficiently for divers who previously scored incorrectly on these two points to reduce their contact rate, removing the correlation.

Significant outputs from the Likert scale focused on determining diver obligations surrounding the behaviours of interest (positioning, buoyancy, finning and trim) point towards there being strong norms within SCUBA diver behaviour. However, the lack of correlation between perceived and actual behaviour suggest that they are not a major influence on divers in-water behaviour. In relation to both the Value Belief Norm (VBN) model and the Norm-Activation-Model (NAM), the presence of strong norms displayed in the results suggests that the awareness and values present within the SCUBA population are effective in creating the norms discussed here. However, the lack of correlation between norms (perceived behaviour) and actual behaviour coupled with the high percentage of unintentional contacts provides evidence that training and briefings are not being properly utilised in the dive community to improve diver skill. Clearly greater emphasis should be placed on egotistical and biospheric reasoning as to why these skills are important and, as carried out in the briefing in this study, how divers can alter their positioning, finning and buoyancy.

5.6.1.1 Influence of experience on Norms

The theory of recreational specialisation states that a greater level of experience and interest in an activity will result in a higher appreciation for the finer aspects of it (S.2.3.1.3). In the case of SCUBA diving, a greater understanding and obligation to behave appropriately can be assumed. As in Section 5.3, diver experience was split into categories based on the number of completed dives, and in the case of this analytical test, was split into inexperienced (less than 50 dives) and experienced (more than 50 dives) (Toyoshima and Nadaoka 2015).

With regard to obligations, the only statement where the level of experience showed a significant difference was in the obligation to swim in a horizontal position ($p=0.03$). Where divers with more than 50 dives were analysed, a median of 5 was found on the Likert scale, showing a strong obligation to remain in horizontal position. Of the 51 divers with more than 50 dives, only 4 (7.8%) responded with neither an obligation to do or to not do. In comparison, divers with fewer than 50 dives were much more varied in their responses. A median of 4 was returned, but 4 respondents stated they felt obligated not to stay horizontal, while 11 stated they didn't feel obligated either way to remain horizontal.

On this evidence, it can be stated that with experience, and more dives, comes a greater appreciation for positioning in the water. The lack of significant difference in other areas (including contact and buoyancy control) could be explained by inclusion of these aspects within initial dive training, and highlights the need for increased awareness and education of in-water positioning. Along with dive numbers, responses to the statements were compared against diver training organisations. No significant difference was found between PADI divers and divers from other organisations, suggesting that a similar level of education and training is given by all agencies.

5.6.2 SCUBA Diver Environmental Awareness

As discussed in Section 2.4.3, the VBN model and the NAM both consider an individual's awareness of a specific problem to the development of a behaviour. This can also be referred to as an Environmental World View (EWV), whereby the individuals assessing their actions based on the impacts they have on other individuals and the environment. For SCUBA divers to properly assess their actions, a level of awareness is required, and a belief or understanding that their actions impact upon the environment. In the case of this study, divers were found to have a good understanding of coral reef health and threats.

Table 5.7 shows the percentage responses to the statements. The figures in bold highlight the option that received the highest percentage of responses for each statement. The statements were adapted from Thapa *et al* (2005) to include additional data on awareness of coral biology.

Based on the distribution of results relating to coral reef knowledge, it is concluded that there is a relatively good level of understanding for coral reefs. However, there is evidence to suggest that further understanding could be developed, as 29.8% of responses do not believe coral to be an animal. Similarly, the impact algae can have on coral is not fully understood with over 50% of participants responding incorrectly or 'don't know'. When asked whether touching the reef was unavoidable when diving, 85.2% responded false, indicating that the dive community knows it is possible to avoid contact, whilst 83.7% state breaking coral whilst diving results in lasting damage.

Table 5.7: Participant responses to questions relating to coral health

Question	True %	False %	Don't Know %
Coral are animals (T)	58.9	29.8	11.3
Coral are an important part of marine ecosystems (T)	97.2	2.1	0.7
All coral is fast growing and can grow 1 metre each year (F)	7.1	66.7	26.2
Coral grows well in poor visibility (F)	5.7	56.0	38.3
Coral relies on microalgae and sunlight for survival (T)	76.6	6.4	17
Breaking coral whilst diving results in no lasting damage to the reef (F)	11.3	83.7	5.0
Physical contact with the reef during diving is unavoidable	11.3	85.2	3.5
Algae can smother coral and kill it (T)	40.4	14.2	45.4

When comparisons were made between responses to the environmental statements and the number of dives, no significant differences were found. Suggesting that an increased number of dives does not influence environmental knowledge and that it comes instead from initial education and personal interest. While there is scope to improve diver knowledge of coral and marine ecology, the process for carrying out the education is more challenging. As discussed in Section 2.3.1.2, the briefings utilised by Medio *et al.* (1997) and Toyoshima and Nadoaka (2015) comprised of detailed marine ecology and coral identification information, briefings that were shown to work to some extent in changing behaviour. However, it is unrealistic to expect SCUBA diver guides and instructors to attain the same level of knowledge as this, particularly as divers learn across the globe, where underwater habitats vary greatly. Instead of focusing on educating divers about marine ecology, focus should be placed on

behaviour and skills which has shown to be effective in this study, along with resources made available and promoted to divers to enable self-teaching about the ecology of an area.

5.6.3 Participant Values

This Section discusses the results from the questionnaire that targeted diver value for the reef and marine environment. A five-point Likert scale was used to determine levels of satisfaction within the population on theoretical scenarios. Scenarios that returned the lowest median (and therefore the lowest level of satisfaction) were causing damage to coral, witnessing another diver picking up dead coral, unmanaged fishing and/or collection of coral for the aquarium trade. All these scenarios returned a median of 1, providing evidence that the sample population would be very unsatisfied in the given scenarios. Witnessing another diver kicking up sediment or seeing broken coral on the reef both scored higher, recording medians of 2 (slightly unsatisfied). Although the median is higher for seeing broken coral, it is not significantly different to witnessing another diver pick up dead coral. Interestingly, there is a significant difference between damaging coral themselves and seeing broken coral on the reef ($p=0.00$). Likewise, there is a significant difference between the scores for damaging coral themselves and witnessing others picking up coral ($p=0.000$) or kicking up sediment ($p=0.000$). This shows that divers are significantly less satisfied when they are personally responsible for damage to the reef, as opposed to it being the fault of others. This contributes to the strong norms discussed in 5.6.1, where obligations were found to be strong in relation to behaviours specific to contacting or damaging the reef and further highlights the need for the behavioural briefing to target egotistical responses, highlighting the benefit divers will get by changing behaviour.

In contrast, divers were said to be very satisfied (median = 5) if all coral reef sites were deemed protected areas, though this reduces to slightly satisfied (median = 4) if dive sites had limits on the number of divers allowed per year. Running a Wilcoxon Signed ranks test to compare differences in the non-parametric data proved a significant difference ($p=0.002$). Evidence that suggests divers are keen for dive sites to be protected, but significantly less satisfied if they were to be limited access. This can lead to the assumption that the sample population would put their own satisfaction above protection of reefs, again highlighting the importance of the egotistical approach to the behavioural briefing; evidence has shown that divers, whilst they are keen for the environment to be protected, not if it affects their ability to enjoy it.

In contrast to the recreational specialisation theory (Section 2.3.1.3), there were no significant differences in responses to satisfaction between experienced (over 50 dives) and inexperienced (under 50 dives) after an independent sample t-test. Evidence that as experience increased, the sample population did not obtain a greater sense of value for the marine environment.

Evidence from the 8 scenarios shows that SCUBA divers value the marine environment, only two of the 8 scenarios produced medians that were 'not very satisfied' or 'unsatisfied'; witnessing another diver kicking up sediment and diver limits at dive sites. The concern regarding dive site limits has been explained above, while the median of 2 (slightly unsatisfied) for witnessing another diver kicking up sand can be explained by the reduced visibility after sand is disturbed, making the dive experience less enjoyable. Dissatisfaction seeing another diver disturb sediment can only partially be explained by the impact it can have on coral as in the environmental awareness section, 44% of the sample population were not aware that

coral suffers in waters with poor visibility (high turbidity), 23.4% were unaware that coral needed sunlight and 59.6% were unaware algae could smother and kill coral. As discussed in Section 2.1.1, the lack of understanding regarding sedimentation and issues caused is a concern within diving as sedimentation events are common during initial dive training. Qualitative observations made by the researcher in this study noted regular instances of sediment being disturbed during early training dives and skills sessions, which were often held within a reef environment. This early exposure to sedimentation events may alter the views of divers in relation to the impacts sedimentation can have on a coral reef, meaning they are less likely to be concerned in future.

Another approach to valuing the environment can be from a monetary perspective. For the purpose of this study, the sample population was asked for the annual spend on diving activities, along with whether or not they would be willing to pay more to dive in a protected area. This ranged from £0.00 to £5,000 ($n=124$), with a mean spend of £955 annually. The wide range can be explained by diver experience. As would be expected, significant correlations were found between annual spend and the number of dives ($p=0.00$) and certification level ($p=0.00$); as diving is not free, divers with greater experience are likely to spend a higher amount than beginners. Both of these correlations are moderately strong resulting in r values of 0.505 (certification level) and 0.407 (number of dives) suggesting that 42.06% of annual spend by divers is explained by these factors. This is to be expected as the cost of a dive course is approximately £200-300 depending on the location of training.

From a monetary perspective, diver value of reefs increases with experience. However, when divers were asked whether they would be prepared to spend more money to dive in a protected area, 85.8% ($n=141$) stated that they would be prepared to pay a fee, whilst 14.2%

stated they would not be prepared to pay. There was no significant correlation with either number of dives or certification levels, suggesting that divers understand there are benefits to diving in a marine protected area and would be willing to pay to experience it.

5.6.4 Responsibility

Divers were asked who they thought was responsible for diver behaviour and impacts during a dive. The question was left open, but participants provided only three responses, the diver themselves (83.7%), the dive centre (5.7%) and the dive guide/instructor (10.6%) ($n=141$). Although 16.3% of the sample population expected the dive centre or guide to manage behaviour, the majority were of the belief that they were responsible for their own behaviour. Therefore, the belief that they are responsible should correlate with improved behaviour. However, there was no significant correlation between contacts before or after the intervention or with the change in contact rates and responsibility. Consequently, evidence of understanding responsibility of the individual does not correlate with improved behaviour.

5.6.5 SCUBA Diver Questionnaire Summary

Data shows that although it is not perfect, SCUBA divers typically have a good knowledge of coral reefs, particularly regarding contact and impacts. Further, there is evidence to show that SCUBA divers value the marine environment and coral reefs, for both egotistical and biospheric benefits. The combination of these factors has led to strong social and personal norms, as shown in the first section focused on obligations. There were very few significant correlations between perceived and actual behaviour, only buoyancy control showed a

correlation, where divers who felt obligated to maintain buoyancy control were more likely to do so. Likewise, SCUBA diver values for the reef appear high, but lack correlation with actual behaviour.

This proves the norm activation and value believe norm models, which discuss the formation of norms through increased awareness and values for the action/environment. However, evidence proves the theoretical consensus, but in practice no correlations were found between obligations, awareness and values with contact rates or behaviours. Likewise, SCUBA diver experience did not influence or correlate with any factors in the questionnaire other than the obligation to maintain good positioning and annual spend.

Based on the questionnaire, it has been established that SCUBA divers should, in theory, behave in an appropriate manner when diving. The value, awareness and strong norms all suggest that the behaviour should follow. However, data shows that SCUBA divers do make regular contact with the reef when not provided additional information. Contact rates of 2.33 per 10 minutes in the first observation period reduced to 0.75 contacts per 10 minutes after the intervention briefing, whilst significant improvements in behaviour was recorded across all behaviours of interest except for buoyancy control. This categorically proves that an intervention briefing focused on changing behaviour, rather than increasing coral ecology knowledge, is effective in changing diver behaviour and reducing the number of contacts.

Unintentional contacts accounted for most contacts in both dives and help to explain why behaviour focused briefings are effective in influencing contact rates. While a greater understanding of coral biology increases awareness, it does not provide the knowledge to adapt underwater behaviour to reduce contacts. Focusing on improving diver ability through behavioural information is effective as divers can put into action that information. Likewise,

utilising the briefing to highlight diver benefits as well as the coral itself can further influence behaviour change. Further research should be conducted to compare the effectiveness of using an environmental briefing against a behavioural briefing to determine whether there is a significant difference.

5.7 Summary of Results

When all the data is considered, particularly regarding unintentional contacts, evidence suggests that the fundamental threat from SCUBA diving needs to be tackled at the source, which is the training and education of divers at both the beginning of their diving career and continuing through briefings, shown in this study to be effective when targeting key behaviours. Evidence from the questionnaire has highlighted the importance of egotistical and self-serving interventions. Divers have responded positively to marine areas being protected, but negatively to permitting, while satisfaction was lower where they damaged or touched the reef themselves. These points highlight one of the reasons the behavioural briefing utilised in this study was so successful: behaviour was targeted from both a biospheric and egotistical perspective, with divers informed how certain behaviours can improve their diving experience.

5.7.1 Limitations

Water quality and visibility issues during the coral video transects resulted in mixed quality footage from which stills were taken for analysis. Limited budget for data collection meant that the sample size and number of observation periods per diver were limited, while a predominance of PADI trained divers limited analysis of variations between training

organisations. Despite limitations, data collected and analysed has proven sufficient and significant for the purpose of the research aim, however, it is recommended that future research utilise photographic stills, rather than video transects to ensure high quality images.

6.0 Model formulation and Management Strategy

Having analysed data and established the effectiveness of the pro-environmental behavioural briefing in changing behaviour and reducing diver impacts, the aim for the research can now be addressed. This chapter will set out a management strategy for SCUBA diving: introducing a model, DPSIR framework and refined briefing based on the data discussed in Chapter 5. Finally, a number of recommendations based both on the data and available literature to focus management and policy towards improved behaviour and reduced impact from SCUBA diving.

The aim of the research was to develop a diver-coral relationship model to highlight the effectiveness of a pro-environmental behavioural briefing in reducing damage to coral reefs and how that would benefit the wider ecosystem and populations. The initial objective, to determine the impact of diving activities on coral health was achieved through coral health surveys at low-density and high-density dive sites, finding significant differences in live coral cover. Awareness, norms and values (objective 2) for SCUBA divers were determined through a questionnaire and highlighted strong values and norms within the community and a typically good knowledge of coral biology. SCUBA diver behaviour and contacts, and improvements (objectives 3 and 4) based on the briefing were analysed based on underwater observations before and after the briefing with correlations, significant differences and changes noted.

Based on the data collected and analysed through objectives 1 to 4, the final objective and aim for the research has been conducted in this chapter.

6.1 Model and Framework

The aim of this research was to develop a model to explain the relationship between SCUBA divers and coral reef health. Significant data collected within the research coupled with available literature has allowed an informative model to be developed for further testing.

6.1.1 SCUBA Diver Behavioural model

Behaviour change as a result of the pro-environmental behavioural briefing was significant and demonstrates that it can act as a catalyst for change in behaviour and contact rates. Contact rates reduced significantly (326 contacts prior to the briefing, reduced to 106 after the briefing), whilst the 70.21% of divers that made contact with the reef during the first observation period, reduced to 39.01% after the briefing. Figure 6.1 illustrates this change, highlighting the effectiveness of the dive briefing. It can be used to help determine risk of diving activities to the reef and support the development of a human-environment system model related to SCUBA.

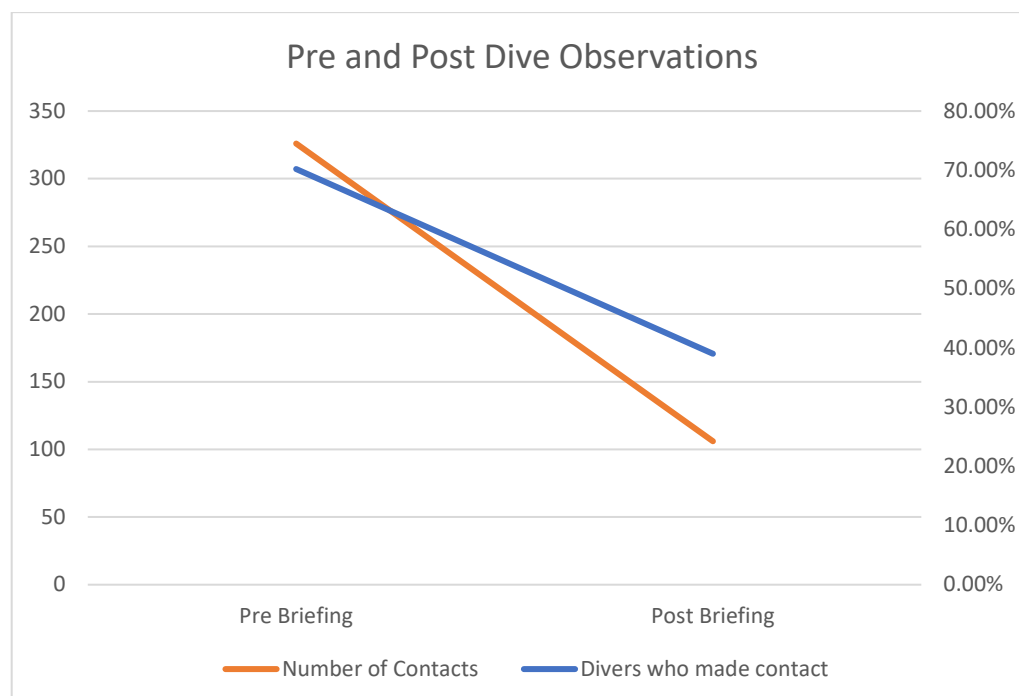


Figure 6.1: Pre and Post Dive Observations; changes in contacts and percentage of divers making contact

Of 326 contacts in the first observation period, 86.20% (281) resulted in substrate, the remaining 13.80% resulted in a sedimentation event. While sedimentation has been deemed damaging to coral reef health (S.2.1.1), it is a common occurrence in shallow reef systems due to natural physiological and biological actions (wave, current, storm, erosion and fish production). With this in mind, the impact of diver-caused sedimentation can be considered low risk. In contrast, abrasion results in a direct impact to coral through a weakening of defences, resulting in greater predation rates (S.2.3.1) and vulnerability to disease. For this reason, abrasion has been considered a moderate risk to coral health. High and catastrophic risk categories for diver impact can be linked to coral breakage, minor breakages (high) and major breakage (catastrophic). The insignificant changes to the type of contacts (abrasion, sedimentation) after the briefing shows that while overall risk of damage has been significantly reduced the more specific outcomes were unaffected. For example, the likelihood of a contact resulting in sedimentation before the briefing (13.80%) is not significantly different to that post briefing (18.87%) when scoring probability on a scale of 5 (1 = 0-10%, 2 = 10.01 – 20.0%, 3 = 20.01 – 40.0%, 4 = 40.01% - 50.0%, 5 = >50%).

The development of a model to explain and quantify SCUBA diver behaviour and impact on coral reef ecosystems has been achieved through amalgamation of primary and secondary data collected in this study, and from other literature. Figure 6.2 illustrates key correlations and relationships found during the first observation period and highlights drivers behind diver contacts with the substrate. The primary causes and correlations are between positioning, buoyancy and contact rates. However, positioning and buoyancy show correlations with certification levels, finning technique and number of dives.

The relationships between certification and the number of dives with positioning and buoyancy can be linked to recreational specialisation (S.2.3.1.3) and previous literature which discussed the importance and influence of diver experience on diver contact rates (S.2.3.1.1). This study found no direct correlation between experience and contact rates, however as shown in Figure 6.2, the influence of these factors on behaviours of interest is significant and indirectly influences contact rates.

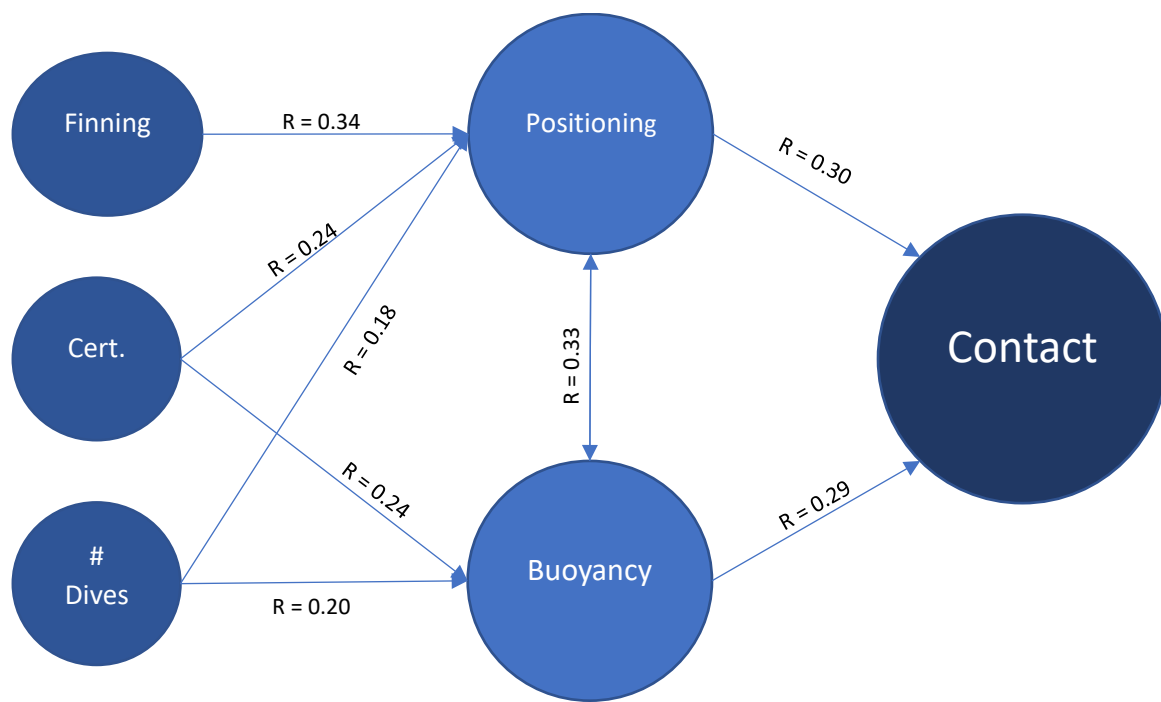


Figure 6.2: Driving relationships and influential actions for contact rates **pre-behavioural briefing**

The pro-environmental behavioural briefing altered these relationships. While certification level and number of dives remained relatively constant in their correlation with key behaviours, positioning no longer correlated with the rate of contacts (whilst remaining the

primary cause of contact). In contrast, finning technique showed a weak correlation with contact rates, whilst buoyancy remained a moderate influence on contact rates. Figure 6.2 shows the relationships in visual form along with correlation rates.

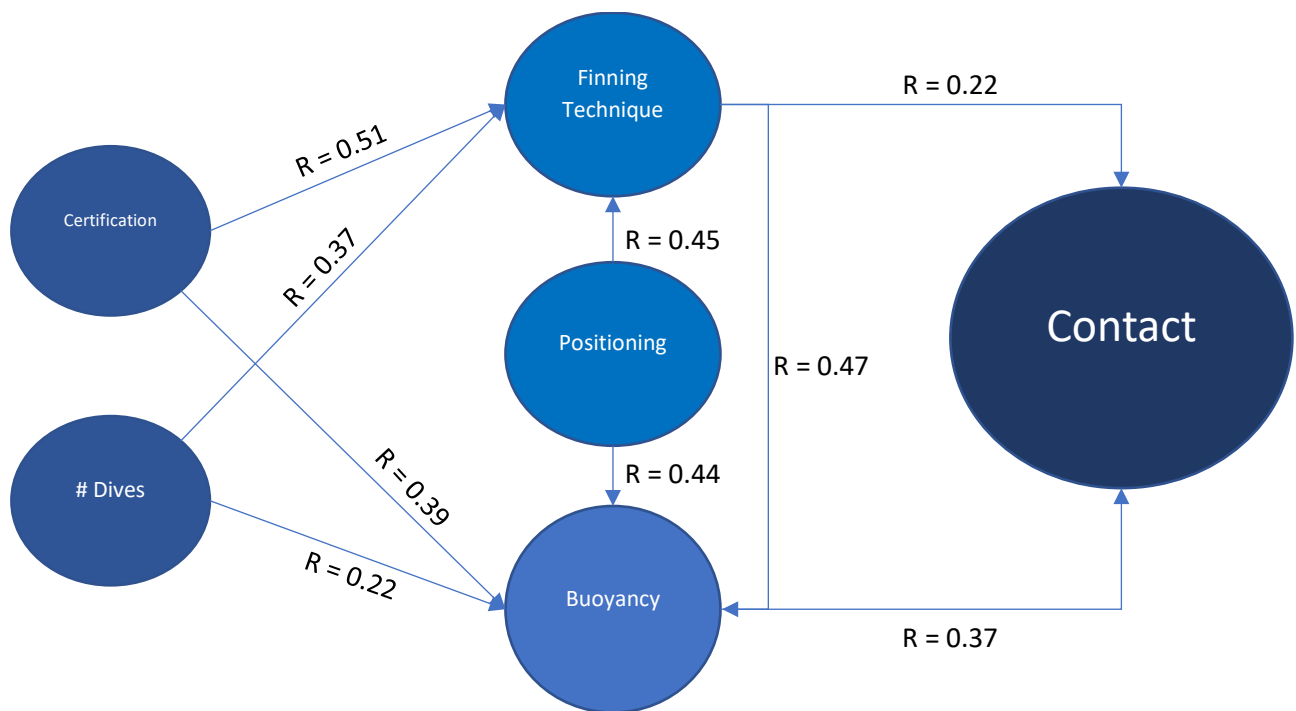


Figure 6.3: Key relationships and influential factors driving contact rates in the **post-behavioural briefing** observation dive

Interestingly, while positioning shows no significant correlation with contact rates, inter-relationships between the three key behaviours appears to be a major influencer in relation to contact rates. Certification and the number of dives remain constant for both pre and post briefing observations; the only change is based on the information provided in the briefing which targeted these behaviours. As in the first observation period, the influence over behaviour of certification level and number of dives is significant, further validating the work of Worachananant *et al.* (2008) and Toyoshima and Nadaoka (2015). In addition, the theory

of recreational specialisation, which states that those with more experience show a greater level of appreciation of the finer aspects, could in this study, relate to behaviour and the ability and understanding to change behaviour. However, while there were correlations between experience and behaviour, there were no significant correlations between experience and contact rates, either before or after the behavioural briefing.

Results and outcomes from this study have led to the development of a specific behavioural model focused on the briefing effectiveness, including potential improvements in both contact rates and coral health. Figure 6.4 shows predicted improvement in behaviour, contact rates and coral health based on inclusion of the behavioural briefing designed and utilised in this study. The model predicts behavioural change in divers based on the delivery of a refined briefing, which then feeds into a predicted improvement in contact rates and coral health. It was established in Section 5.6 that the major factors driving SCUBA divers is marine life, exploration and adventure, concurring with literature. Based on the model designed in this study, a predicted increase of more than 50% LCC can be expected based on reduced SCUBA diver impact. In this regard, coral reef rugosity and biodiversity are likely to be higher, making them more appealing to SCUBA divers.

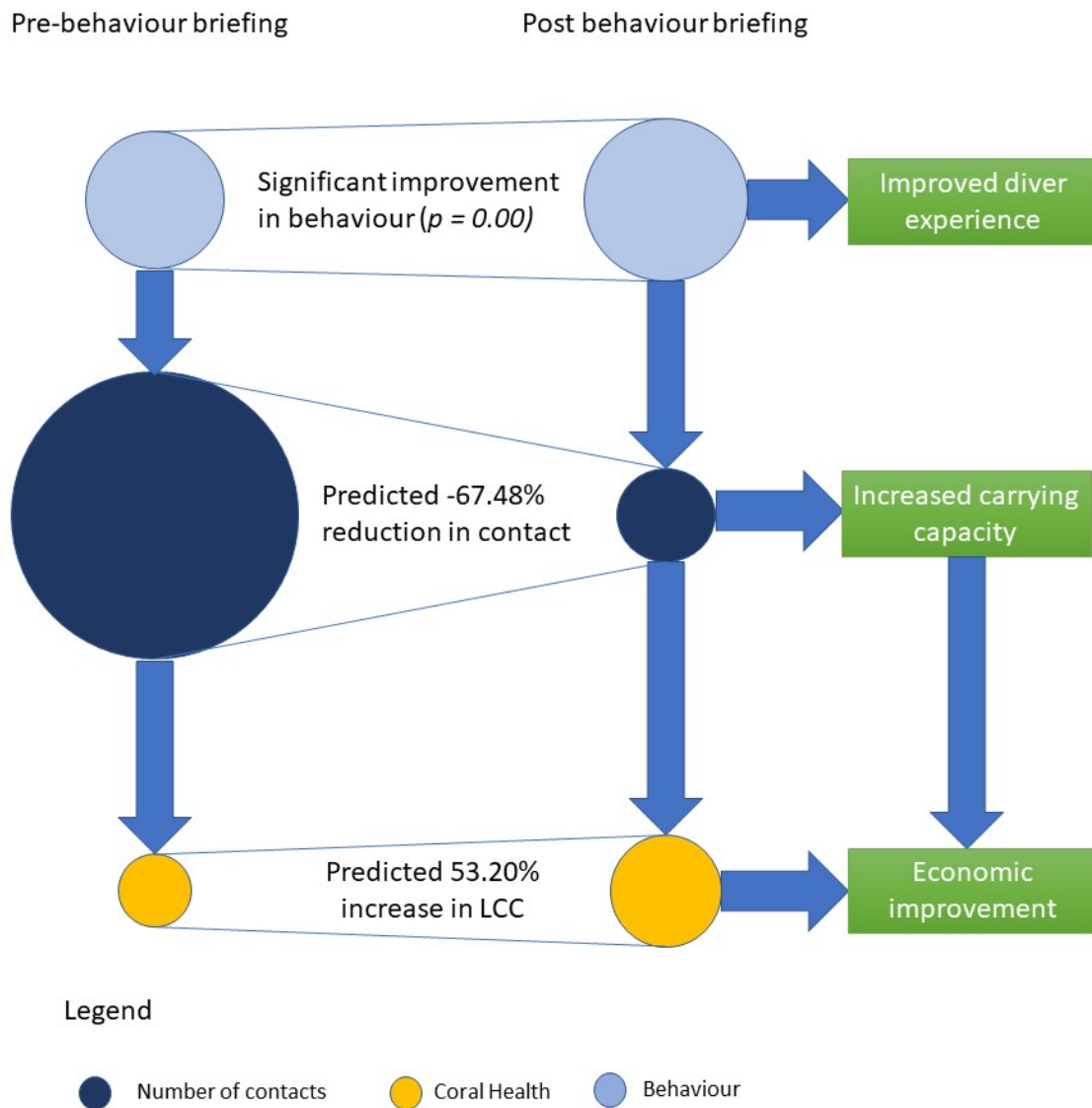


Figure 6.4: SCUBA Diver behavioural model. Displaying predicted improvements in behaviour, contact rates and live coral cover (LCC) based on the influence of the pro-environmental behavioural briefing

Based on literature (S.2.3.2), it was suggested that utilising a carrying capacity as a sole approach to managing impact was ineffective, however, combining with behaviour change would likely be more successful. This study has proven the theory stated by Musa *et al.* (2011) and shown that improved behaviour (achieved through the pro-environmental behavioural

briefing) reduced the impact of divers and when reduced impact is considered, a carrying capacity can be increased and deemed effective.

Increased carrying capacities and reduced diver impact, resulting in healthier, more biodiverse coral reefs, is predicted to lead to an economic and social improvement in local, coastal communities as well as far reaching benefits to the fishing industry. Increased numbers of divers visiting the area provide an economical boost to the local community whilst improved biodiversity helps maintain larger fish stocks for fishing industries.

6.1.2 SCUBA Diver Behavioural briefing system design

The briefing tested within this study was developed based on literature, personal experience and discussion with dive professionals (S.4.5). The briefing focused primarily on key diver behaviour and developed value for the behaviour based on diver enjoyment and skill, alongside coral health. Based on observations and data collected, a refined briefing has been developed for use alongside the standard 10-point PADI briefing (S.2.3.1.2) within dive organisations and for further testing.

Dive Briefing

Substrate



Introduce the ecology

- Detail what to expect in relation to substrate – use images to help identify specific species
- Highlight risk to divers and substrate
- Highlight areas of sand/sediment
- Discuss importance of substrate for biodiversity
- Link substrate to behaviours of interest

Positioning



Benefits

- Improved streamlining makes it easier to move through the water
- Feel more confident in your skill as a diver
- Reduced air consumption meaning longer dives
- Significantly reduced risk of contact with, and damage to the substrate

Buoyancy Control



Benefits

- Reduced air consumption meaning longer dives
- Feel more confident in your skill as a diver
- Greater dive enjoyment through better control of self in water
- Reduced risk of contact with the substrate through flapping or rapid descent
- Improved safety – runaway ascent/descent minimised

Finning Technique



Benefits

- Less energy to swim meaning reduced air consumption and longer dives
- Maintain streamlining naturally
- Keep fins away from the substrate automatically to reduce risk of cuts, grazes or damage to ecology
- More professional and confident diving making your dive more enjoyable

Figure 6.5: Refined Dive Briefing points to be included alongside standard 10-point briefing required by PADI: focused on ecology and behaviour; specific to key behaviours, how and why to improve, both egotistical and biospheric.

The refined briefing shown in Figure 6.5 highlights the need to introduce substrate ecology and risks (to divers and ecology) associated with it alongside relevant factors linked to key behaviours identified as significant within this research. The substrate aspect is an element that should be included through the dive site description and environmental orientation as standard (points 2 and 9 of the PADI briefing guide) (S.2.3.1.2). However, the refined briefing

here brings together the ecological element which links directly to highlighted behaviours and allows the briefing to cover benefits to ecology and diver.

Based on the significance of results discussed throughout Chapter 5, positioning, buoyancy and finning technique make up the primary focus of the briefing. As the non-dominant causes of contact, the refined briefing excludes photography and trim. Figure 6.5 also highlights key talking points around each behaviour and utilises the theories established in Sections 2.4.1 and 2.4.3 that environmental attitudes and values help define behaviour. Further, it targets self-serving values that highlight how improved behaviour can result in more enjoyable and longer dives. In this instance, the briefing should highlight the benefits of improved behaviour to both diver experience and substrate and influence change in values and belief towards both. This approach targets both the egotistical needs, as found in the questionnaire data (S.5.5) and biospheric needs while also providing divers information on how to change.

6.2 DPSIR Framework development

As discussed in Sections 2.3.2.1 and 4.7, the DPSIR framework was adopted and modified to suit the nature of this research (Figure 6.6). Based on current results and data from previous literature, an in-depth framework has been developed to help direct policy and legislation within SCUBA and tourism industries. Driving forces are varied but represent the sample population and are based on the research questionnaire where the three dominant drivers for people starting to SCUBA dive were: new adventures (36.88%); biodiversity and marine life (29.79%); and to explore (19.56%). Other, less common factors include: to learn (7.09%), socialise (4.26%) and other (2.13%). Diver satisfaction is determined by a variety of activities and act as drivers for visits to coral reef environments. This is further strengthened by the

work of Schuhmann *et al.* (2013), who found coral cover and biodiversity of marine life were causes of highest satisfaction level. However, they highlight that visibility and price are also major factors in diver satisfaction and quality of diving. (Schuhmann *et al.*, 2013). Continued growth of the SCUBA industry (S.2.3) and continuous development and improvement in transportation to more remote locations has meant that even more coral reefs are accessible than ever before, increasing the spread of pressures throughout.

Figure 6.6 highlights the pressures identified as part of the DPSIR framework. In Section 2.3.2 it was shown that coral reefs have a carrying capacity and a threshold before impacts become lasting. This was further confirmed by results of this research, which found dive sites with high numbers of divers have a significantly lower level of live coral cover and therefore a reduced health when compared to sites with lower diver numbers (Reef A had 21.36% LCC at high density dive site compared to 48.7% at the low density dive site. Reef B had 36.20% LCC at high density dive site compare to 38.39% at the low intensity dive site). Determination of carrying capacity is difficult but is based on stress level that intersects the number of dives and damage or stress to the reef. It is argued that reef carrying capacity can be increased where diver behaviour improves through increased awareness and education, and therefore results in decreased physical damage (S.2.3.2).

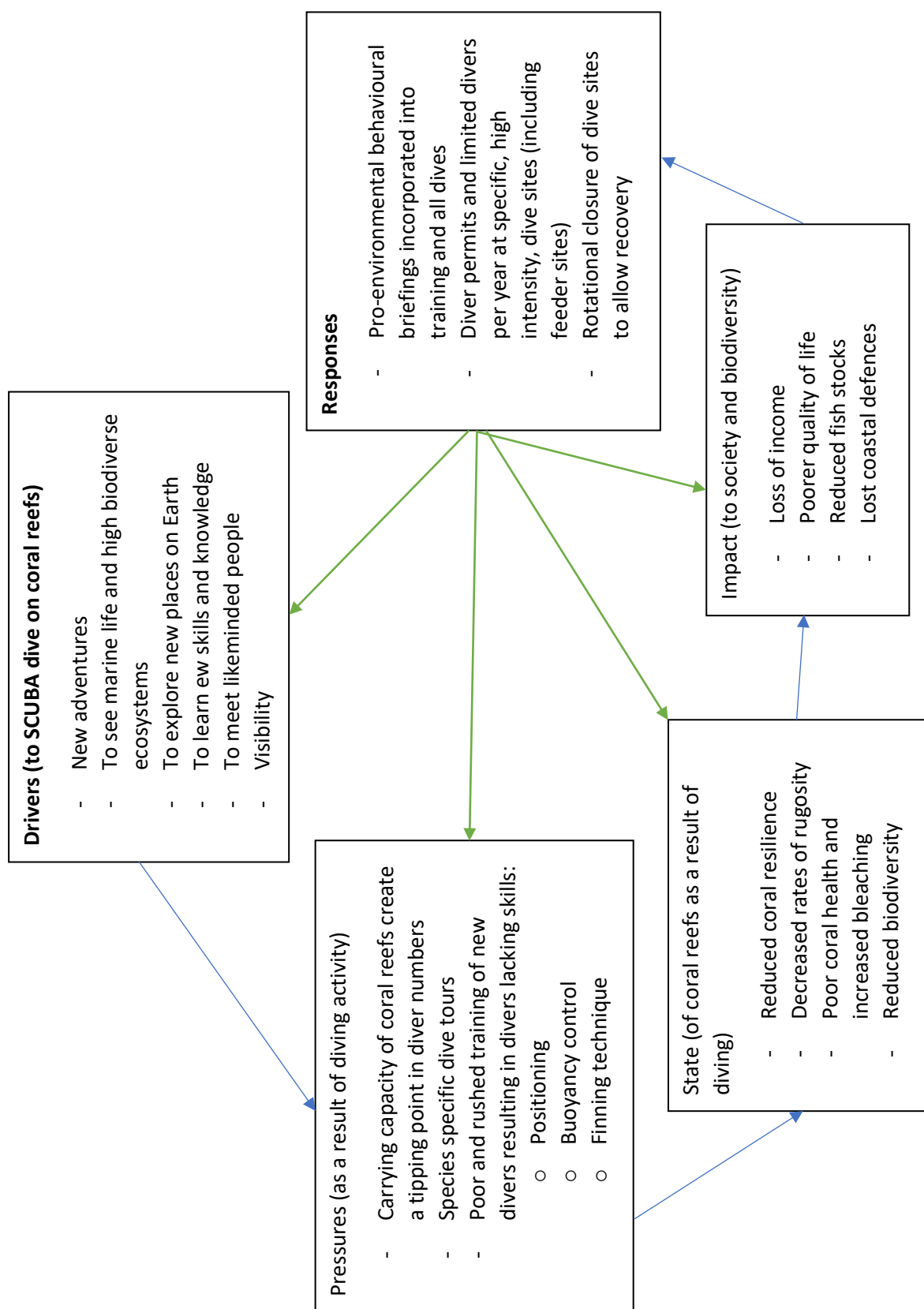


Figure 6.6 DPSIR Framework for SCUBA diving impacts

Another pressure highlighted is training methods within initial dive training. The ability to become a fully qualified SCUBA diver in as little as 3 days through PADI training has shown to be ineffective in providing sufficient practical training for new divers. Divers who have benefitted from additional training in the form of a pro-environmental intervention briefing, and additional development before being allowed to dive, would result in a decrease in SCUBA diver impacts on coral reefs. This of course also assumes there would be pro-environmental interventions within all future dives. The link between training and key behaviours was highlighted in the effectiveness of the pro-environmental briefing, which proved even an additional 3-minute briefing can influence behaviour during a dive. Positioning and buoyancy control both showed significant correlations with the contact rate, while finning technique was found to have a significant correlation after the pro-environmental briefing, but not before. These three behaviours are the result of diver training and diver numbers and are the predominant cause of coral health decline.

A final pressure highlighted in literature and included in the DPSIR framework is that of species-specific dive tours. Uyarra and Cote (2007) studied the difference in contact rates by divers who were looking for cryptic species and found that significantly more contacts were made when divers were near Frogfish and seahorses. In addition, qualitative and informal observations made during researcher dive experience have noticed high numbers of contacts during observation of small species such as Nudibranchs. This highlights the increased level of risk of contacts when there is a desire to view specific, particularly small and cryptic species.

Reef condition (state) as a result of pressures highlighted in Figure 6.6 (S.5.1), was significantly different in terms of coral health between high and low use sites. This correlates with Hawkins and Roberts (1992), Tratalos and Austin (2001), Lamb *et al.* (2014) and Lyons *et al.* (2015) who

all found reduced coral health in areas of high intensity SCUBA diving. Abrasion was found to be the dominant outcome of contacts in this study followed by sedimentation events, both previously highlighted as threats to coral reef (Camp and Fraser, 2012; Krieger and Chadwick, 2013). Essentially, removal and damage to the thin surface layer of coral membrane (abrasion) and the smothering of coral polyps (sedimentation) reduces coral resilience to disease and infection. Barker and Roberts (2004) highlighted the threat of minor and major breakages and whilst none were observed in either observation period during this study, several minor breakages of *Acropora sp.* coral were observed during the pilot study. On a larger scale, damage to coral can result in decreased levels of rugosity (Lyons *et al.*, 2015) which is an important factor in maintaining high biodiversity (S.2.1.5). Likewise, coral resilience can be affected through high intensity diving activities, while a coral reef with a high level of resilience is likely to withstand low intensity activity, it is probable that high intensity and regular activities will result in a collapse of the reef, particularly where multiple reefs in the area face the same challenge. Further, without fully understanding coral resilience within an ecosystem, it is difficult to manage diver activity. Knowing which reef systems act as feeders for the whole ecosystem is key in maintaining.

The impact of these states would be both biological (reduced biodiversity and ecosystem collapse) and social/economical. SCUBA diving is a global industry that contributes towards economic sustenance for populations worldwide. Coral reefs have an estimated value of \$36 billion USD, or 9% of global coastal tourism in countries home to coral reefs (S.2.1.4), therefore, any potential threats and damage to reefs will directly impact upon those figures, and, if only locally initially, SCUBA diving growth and the reach of the sport will potentially impact all reefs.

An example of a response to the impact of tourism, and specifically SCUBA diving was shown in Thailand in 2016. The Thailand government chose to disrupt tourism profits through closure of 10 of their dive sites that had been showing bleaching effects from warming waters and damage by SCUBA divers (Guardian, 2016). This is a reactive response that will significantly impact income to local communities in these areas, while tourists and the money they spend will be redirected towards other dive sites. Therefore, reactive responses such as this are less effective in the long run and have a more damaging impact on local communities and the coral reef system. Reef resilience relies on a network of healthy coral reefs that feed into each other, allowing coral spawn to move throughout the network to maintain health (S.2.5.1). Understanding reef resilience is vital in managing them. Knowing how resilient a specific coral reef is can help determine carrying capacity and how often, if ever, it should be closed to allow recovery. A better approach, is a planned annual rotational closure of sites to allow a rest period and opportunities to recover, although research and an understanding of resilience and place in the ecosystem is needed before making decisions (reefs that act as a source of spawn may need additional protection). Alongside rotational closures, diver permits should be considered at particularly popular or important dive sites, such as those seen in Sipidan, Borneo. This allows management teams to monitor and control the number of divers visiting a site daily, thereby reducing crowding and stress on coral and fish living at the reef.

The final response is the behavioural briefing, as adopted in this study and proven to be an effective measure to change behaviour and significantly reduce contact rates. Therefore, this should be factored into all pre-dive briefings, as well as underpinning all training levels to ensure a long-term behaviour change.

6.3 Management Strategy

Following the model development, refined briefing and DPSIR model, a management strategy has been devised to aid policy makers, SCUBA organisations and tourism operators in decision making, planning and conservation. When combined, the refined briefing (Figure 6.5), the behavioural model (Figure 6.4) and the DPSIR framework (Figure 6.6) will act as management tools to maintain healthy coral reefs in relation to SCUBA diver impacts. The management strategy and recommendations detailed in this Section are set out to target different sectors of the industry: training organisation, tourism facilitators and policy makers. The three sectors together provide a broad coverage for management and target all aspects of the SCUBA industry. Figure 6.7 displays a breakdown of the strategies recommended for use by the three sectors which are further detailed in the recommendations in the following chapter.

Management Strategy



Figure 6.7: Management strategy designed based on both primary and secondary data, to highlight which sector within the industry is responsible for each element.

- Training Organisations

PADI are considered the largest of the SCUBA training organisations globally and train over 900,000 new SCUBA divers annually (S.2.3) and were the dominant training organisation for the population sample with 75.18% (S.5.2). As part of this project, PADI, along with other training organisations (BSAC and SSI) have been approached to discuss the outcome of the observations and key findings in an attempt to influence and alter training protocols. At the time of writing, no responses from the training teams have been received. PADI, SSI and BSAC are three of numerous dive training organisations and are responsible for developing and providing training for new and experienced SCUBA divers globally. This makes them perfectly

placed to introduce and affect diver behaviour through training of recreational and professional divers and through introducing industry standards for the behavioural briefing.

- Tourism Operators

Tourism operators, specifically SCUBA diving resorts and centres, are responsible for the 'on the ground running' of SCUBA activities including training and fun dives. Ultimately, it is the job of the resorts to influence, monitor and control diver behaviour as well as uphold industry standards as developed by the training organisations. The pre-dive behavioural briefing should be delivered to SCUBA divers before every dive by staff at dive resorts and centres. Operators would also be responsible for adhering to and feeding into the policies for site closure, carrying capacities and permit use.

- Policy Makers

The policy makers are governmental organisations who manage coastal and marine areas. Specific to the study, the governmental department of Marine Parks Malaysia are responsible, while the Environment Agency and Natural Resources Wales manage policies and plans in the UK. As policy makers, they are responsible for setting out environmental guidance and management, specifically monitoring health and managing use by the public. With this in mind, they are responsible for rotational closures of dive sites and the distribution of permits for sites with limited visitation.

7.0 Conclusion

The primary aim of this research was to develop a relationship model to explain and predict SCUBA diver behaviour and the impact it has on coral reef health. This was achieved through the successful completion of 5 objectives, each of which focused on specific outcomes and contributed to the wider outputs of the research project.

Objectives

- vi. *Assess and compare coral reef health at high-density and low-density dive sites to determine the impact recreational diving has on a fringing coral reef environment*
- vii. *Assess SCUBA diver environmental awareness and values through questionnaire surveys*
- viii. *Observe and analyse SCUBA diver behaviour, contact rates and interactions with the marine benthic environment*
- ix. *Determine the effectiveness of pre-dive briefings in influencing diver behaviour and impact on contact rates*
- x. *Analyse primary and secondary data to develop a relationship model, management strategy and policy frameworks for the SCUBA industry*

SCUBA Diver impacts

Coral health was surveyed at two sites within the study area where significant differences were found in live coral cover between high and low intensity dive sites on the same reef (Reef A; 27.34% increase in LCC at low intensity site: Reef B; 2.13% increase in LCC at low intensity site). The control of confounded variables during the surveys, proves categorically

that diving has a negative impact on coral reef health and when combined with results from literature (S.2.3.1), further proves the rationale for the need of the study, model and management strategy.

Observations of divers underwater during the first observation period concurred with literature (S.2.3.1.1) and observed high levels of contacts with the substrate. Within the study, 140 divers were observed for period of 10 minutes during two dives. During this time, key behaviours were monitored along with each contact with the substrate recorded. In the first observation period, 326 contacts were recorded, of which 73.3% were unintentional. Of the behaviours deemed key, positioning, finning technique and buoyancy control were observed as the three main causes of contacts, whereas photography and trim were deemed insignificant. Alongside this, fins were observed as the main point of contact, an outcome that can be partially explained by the cause of contacts: positioning and finning technique.

Pre-dive behavioural briefing

SCUBA diver behaviour and contact with the substrate were observed before and after the pre-dive behavioural briefing. The total number of contacts reduced significantly from 326 in the first period to 105 in the second. Likewise, measurable improvements in positioning, buoyancy control and finning technique were all observed. No correlations were found between contact rates and experience or between contact rates and buoyancy training, though evidence was found that experience and number of dives can influence the ability of divers to adjust their behaviour. On the basis of evidence found in the study, it can be stated that current training methods are not suitably robust enough to ensure divers leave with sufficient skill levels to minimise environmental impacts likewise, it is clear that the standard

pre-dive briefing can be improved to minimise contacts. A point further established when the intention of contacts was considered; 73.3% of contacts before and 71.7% of contacts after the briefing were deemed unintentional. It is theorised that due to fins being the dominant point of contact, divers were unaware of many of the contacts made and no amount of coral ecology knowledge would result in significant long term change. When considered against the behavioural models (VBN, NAM), knowledge and awareness of the environment is only part of the problem; an understanding of *how* an individual's behaviour impacts the environment is key to behaviour change as it develops a sense of responsibility.

When behaviour is considered in line with the Value Belief Norm and Norm Activation models, as discussed in Section 2.4, the questionnaire completed by divers provided an opportunity to develop an understanding of environmental awareness and values, and behavioural norms present within the dive community. Not unexpectedly, and likely due to the high levels of biodiversity, divers place a high value on coral reefs. Divers also showed low levels of satisfaction when faced with contacting, damage or disturbance on the reef, either by them as individuals, or as witnessing others disturbing the reef. This again, was an expected outcome and ties into the theory of recreation specialisation (S.2.3.1.3). While a lack of knowledge of coral reef ecology was found, the presence of strong values and obligations to behave in a certain way suggested that perceived behaviours would be, if not beneficial, neutral to coral reef health. However, perceived behaviours did not correlate with actual behaviour and perceived behaviours appear to be egotistically focused, rather than biospheric and further highlight the importance of behavioural focused briefings and enhanced training protocols as shown as effective in this research.

The significant reduction in contacts highlights the success and effectiveness of the behavioural briefing and is further compounded by the measurable improvement in observed behaviour across all recorded key behaviours (positioning, buoyancy, finning technique) after the briefing. The success of this research has been highlighted by multiple significant results in reduced contacts and improved behaviour and led to the development of the relationship model, DPSIR framework and management strategy.

Relationship model, DPSIR Framework and Management Strategy

Analysis of the post behavioural briefing data showed significant and measurable improvements in behaviour and contact rates with the substrate. Collation of data, correlations and relationships between behaviours and influencing factors led to the evolution and development of the diver-coral relationship model, designed to inform and predict coral health change where the behavioural briefing is utilised. Using secondary data and literature, the model moves to theorise cumulative effects of improved coral health on biodiversity, local communities and the economy, proving the need for a pro-environmental behavioural briefing to be included in all future diving activities, including training. The refined briefing highlights key behaviours unearthed within the results and due to the focus on behaviour, is easily transferable to different regions. It does not require dive guides and instructors to be coral reef ecologists.

Building on the relationship model and further utilising available literature, a DPSIR framework was developed to provide a unique and detailed understanding of the drivers, pressures, state and impacts surrounding SCUBA diving and the specific responses deemed suitable based on the data collected here and in the literature. The impact of coral

degradation on biodiversity and social wellbeing and the economy can be, in part, limited through utilisation of the responses section, which, along with the relationship model, feed into the management strategy.

Through the course of this research project, three key influencers were established when considering management of SCUBA diver activities: training organisations (PADI, BSAC, SSI etc.), tourism operators (dive centres, resorts) and Policy makers (tourism authorities, marine park authorities, governments etc.). The management plan developed in this study has evolved and been informed by data collected within the study and combined with secondary data and the literature, both of which feed into the DPSIR framework.

The management strategy presented breaks down the recommendations and provides suggestions for the responsible parties in ensuring compliance. As contacts were observed after the behavioural briefing within this study, it is considered vital that no single approach to management is effective. Instead a combined approach of improved training, briefings and coral reef management and closures are needed to ensure longevity of high-density dive sites.

The key focus for this research has been determining the threat of SCUBA diving through coral health surveys and determining the effectiveness of a pro-environmental behavioural briefing. While further research is recommended to further test the results found, the significance of the results shows that the pro-environmental behavioural pre-dive briefing, has successfully and significantly improved key behaviours that were identified as major causes of contact. While there were certain limitations found during the research (S.5.7.1), it has been shown possible to significantly reduce contact rate and develop a greater understanding of diver behaviour, impacts and contacts, including motivations and egotistical feelings within the dive community through utilisation of the pre-dive behavioural briefing.

The model, DPSIR framework and management strategy developed based on these results and reinforced by the literature provide a broad approach to reducing the impact SCUBA diving has on coral reefs, making it a more sustainable activity and one that can promote both biodiversity and economic benefits.

7.1 Recommendations

The recommendations derived from the research are compiled and displayed in the management strategy in Chapter 6 and are further detailed here.

- *Pro-environmental behavioural briefing to be included in all pre-dive briefings*

Data collected and analysed in this research provide significant evidence that the pro-environmental behavioural briefing is an effective tool in changing SCUBA diver behaviour and reducing their direct, physical impact on the reef. When combined with the difference in coral health at low and high intensity dive sites, there is further evidence to argue inclusion in this briefing would be an effective approach to minimising SCUBA diving impacts on coral reefs. This has been quantified in the SCUBA diver model (Figure 6.4), which also highlights the likely outcome of such changes; improved diver experience, increased carrying capacity and economic development.

The briefing tested in this study differed from those used in literature as it focused predominantly on diver behaviour, rather than coral biology (Medio, Ormond and Pearson, 1997). While the original briefing included a combination of substrate identification, and key diver behaviours: positioning, finning, buoyancy, trim and photography, the refined briefing (Figure 6.5) has removed insignificant results and focused on the areas of relevance: positioning, buoyancy finning and substrate identification. It is recommended that this

refined briefing be used, combining the VBN theory of behaviour to ensure that divers value the behaviours in question, through highlighting improved diver experience and enjoyment as a result of the change, as well as the ecological conservation. The inclusion and focus on improved diver enjoyment and skill is considered vital, based on the outcome of the questionnaire, which highlighted several self-serving feelings of obligation and satisfaction.

All observations in this research were made within tropical, coral reef environments with low currents, and still found high numbers of contacts with the substrate. It can be theorised that more challenging dive conditions (low visibility, strong currents etc.) would make contact rates increase further. The significant success of the briefing in this research makes it a vital tool for improving diver behaviour and is particularly necessary in more challenging conditions.

- *Positioning and finning to be included in diver training, with a greater emphasis on buoyancy control*

Positioning was found to be the dominant cause of contacts both before and after the behavioural briefing. Correlations between key behaviours and contacts were found to be moderate, and the significant improvement observed in behaviours after the briefing highlight the ease and effectiveness of this approach to reducing diver impact. Whilst PADI introduced positioning (S.2.3) as a skill when considering weight distribution, a larger emphasis is required to ensure divers remain streamlined and comfortable in the water, ensuring their body remains horizontal to reduce contact and sedimentation events.

As with positioning, buoyancy control and finning technique showed significant improvements after the behavioural briefing and, with positioning, combined improvements can help to explain the reduction in contact rates.

It is vital to ensure new divers are provided sufficient opportunities to learn and practice their skills, both for their own enjoyment and safety and to reduce contact rates.

- *Introduction of SCUBA diver permits at popular dive sites based on carrying capacities*

The literature highlights a need for carrying capacities (S.2.3.2) to be considered in coral reef management. Analysis of coral health at low and high intensity sites (S.5.1.2) revealed a significant difference in health. High intensity dive sites were found to have a lower percentage of live coral cover when compared to low intensity sites on the same coral reef. This provides categorical evidence that managing diver numbers is key to maintaining coral health.

One approach to managing diver numbers is through dive permits, which are already enforced in some sites, specifically Sipidan, Borneo. By creating a scenario where divers are required to obtain a license prior to diving both limits the number of divers and raises a conservation awareness. Although evidence suggests divers would be unhappy to see permits enforced at dive sites, this is purely an egotistical response and evidence for carrying capacities and limiting diver use outweighs it.

- *Rotational closure of dive sites to give time for recovery*

In areas where there are multiple dive sites, and based on the theory of ecosystem resilience (S.2.1.5) providing opportunities for coral reefs to recover is important. SCUBA diving impacts on coral reef health (S.5.1.2) provide the evidence that high intensity diving needs to be managed, through carrying capacities and through coral reef closures. A rotational system is recommended, whereby coral reefs are closed to tourism activities on a seasonal basis, particularly where a reef is considered a source of spawn to others. Providing 12-month

periods whereby no activities are taking place would allow coral and fish to recover and return without the stressors associated with diving.

The number of annual reef closures would be site specific and would require additional research prior to carrying out such action to ensure a better understanding of which reefs are most at risk and of their place in the ecosystem.

- *Further research focused on diver contact and change to coral health*

While a direct link between diver presence and coral health has been established, further research is recommended to enhance the understanding of changes to coral health, including comparing abrasion and breakage impacts and monitoring coral's ability to recover from damage at a dive site over a period of years. This research would allow a greater understanding of the relationship between divers and reefs, particularly creating an understanding of the relationship between divers and coral growth forms.

Additionally, research that compares diver behaviour between diver training organisations is recommended, as well as diver behaviour in different conditions. Observations in more challenging environments is recommended to determine any significant differences; particularly focusing on fresh water, high currents and low visibility to determine the effectiveness of behaviour change and contact rates.

Finally, it is recommended that the models and refined briefing based on the data collected in this study be tested fully to ensure further success and effectiveness at multiple sites and with a larger sample population.

7.2 Summary

SCUBA divers have been proven to be a threat to coral reef health, whether experienced or beginners (S.2.3.1). The result of poor diver behaviour has been shown to lead to degraded reef health which in turn impacts upon the livelihood of local communities and contributes to the wider threats to coral reefs in the form of climate change (acidification, sea level rise and sea temperature increase) and overfishing (S.2.1.6).

The pre-dive briefing developed in this research has proven to be an effective approach to significantly reducing the rate of contact by divers during a dive through improved behaviour (S.6.1). The resulting relationship model and DPSIR framework explain the complexities of the interactions and set forward a recommended management strategy for training organisations, tourism operators and tourism authorities (S.6.3). The three key outputs from the research should be used to shape policy and management moving forwards while dive professionals and training organisations should be made aware of the effectiveness of the behavioural briefing in reducing contact rates and improving diver behaviour.

8.0 References

- Allison, N., Cole, C., Hintz, C., Hintz, K., Rae, J. and Finch, A. (2018) 'The effect of ocean acidification on tropical coral calcification: Insights from calcification fluid DIC chemistry', *Chemical Geology*, 497(September), pp. 162–169.
- Altmann, J. (1974) 'Observational Study of Behavior: Sampling Methods', *Behavior*, 49(3), pp. 227–267.
- Anderson, K., Pratchett, M. and Baird, A. (2012) 'Summer growth rates of corals at Lord Howe Island, Australia', *Proceedings of the 11th International Coral Reef Symposium*, (July), pp. 9–13.
- Anderson, L. E. and Loomis, D. K. (2011) 'SCUBA Diver Specialization and Behavior Norms at Coral Reefs', *Coastal Management*, 39(5), pp. 478–491.
- Anthony, K. R. N., Marshall, P. A., Abdulla, A., Gooch, M., Graham, N. A. J., Green, A. and Heron, S. F. (2015) 'Operationalizing resilience for adaptive coral reef management under global environmental change', pp. 48–61.
- ARC Centre of Excellence for Coral Reef Studies (2019) *Global warming disrupts recovery of coral reefs*. Available at: <https://www.coralcoe.org.au/media-releases/global-warming-disrupts-recovery-of-coral-reefs> (Accessed: 5 August 2019).
- Baird, a and Marshall, P. (2002) 'Mortality, growth and reproduction in scleractinian corals following bleaching on the Great Barrier Reef', *Marine Ecology Progress Series*, 237, pp. 133–141.
- Barker, N. H. L. and Roberts, C. M. (2004) 'Scuba diver behaviour and the management of diving impacts on coral reefs', *Biological Conservation*, 120(4), pp. 481–489.

Barr, S., Gilg, A. and Shaw, G. (2011) “‘Helping People Make Better Choices’: Exploring the behaviour change agenda for environmental sustainability’, *Applied Geography*. Elsevier Ltd, 31(2), pp. 712–720.

Betti, F., Bavestrello, G., Fravega, L., Bo, M., Coppari, M., Enrichetti, F., Cappanera, V., Venturini, S. and Cattaneo-vietti, R. (2019) ‘On the effects of recreational SCUBA diving on fragile benthic species : The Portofino MPA (NW Mediterranean Sea) case study’, 182(September), pp. 1–9.

Boersema, J. and Reijnders, L. (2008) *Principles of Environmental Sciences*. 1st edn. Aldershot, United Kingdom: Springer Science & Business Media. p.537

Brown, B. E. (1997) ‘Coral bleaching: causes and consequences’, *Coral Reefs*, 16(0), pp. S129–S138.

Browne, N. K. (2012) ‘Spatial and temporal variations in coral growth on an inshore turbid reef subjected to multiple disturbances’, *Marine Environmental Research*. Elsevier Ltd, 77, pp. 71–83.

Bruckner, A. and Bruckner, R. (2001) ‘Condition of restored *Acropora palmata* fragments off Mona Island, Puerto Rico, 2 years after the Fortuna Reefer ship grounding’, *Coral Reefs*, 20(3), pp. 235–243.

Bruno, J. F. and Selig, E. R. (2007) ‘Regional decline of coral cover in the Indo-Pacific: Timing, extent, and subregional comparisons’, *PLoS ONE*, 2(8), pp. 1–8.

Buhalis, D. (1998) ‘Strategic use of information technologies in the tourism industry’, *Tourism Management*, 19(5), pp. 409–421.

Burke, L., Kathleen, R., Mark, S. and Perry, A. (2012) 'Reefs at Risk', *World Resources Institute*. Washington DC. Available at: <https://www.wri.org/publication/reefs-risk-revisited> (Accessed: 16 May 2015).

Camp, E. and Fraser, D. (2012) 'Influence of conservation education dive briefings as a management tool on the timing and nature of recreational SCUBA diving impacts on coral reefs', *Ocean and Coastal Management*. Elsevier Ltd, 61, pp. 30–37.

Carr, L. M. and Mendelsohn, R. (2003) 'Valuing Coral Reefs : A Travel Cost Analysis of the Great Barrier Reef', *Ambio*, 32(5), pp. 353–357.

Carrus, G., Scopelliti, M., Laforteza, R., Colangelo, G., Ferrini, F., Salbitano, F., Agrimi, M., Portoghesi, L., Semenzato, P. and Sanesi, G. (2015) 'Go greener, feel better? The positive effects of biodiversity on the well-being of individuals visiting urban and peri-urban green areas', *Landscape and Urban Planning*. Elsevier B.V., 134, pp. 221–228.

Carruthers, T., Thomas, J. and Dennison, B. (2011) 'Coral Health Index measuring coral community health', *Phoenix Usa*, p. 16.

Casoli, E., Nicoletti, L., Mastrantonio, G., Jona-Lasinio, G., Belluscio, A. and Ardizzone, G. D. (2017) 'Scuba diving damage on coralligenous builders: Bryozoan species as an indicator of stress', *Ecological Indicators*. Elsevier Ltd, 74, pp. 441–450.

Cheng, F., Su, F., Chen, M., Wang, Q., Jiang, H. and Wang, X. (2019) 'An evolving assessment model for environmental carrying capacity : A case study of coral reef islands', *Journal of Environmental Management*. Elsevier, 233(November 2018), pp. 543–552.

Chiu, Y. T. H., Lee, W. I. and Chen, T. H. (2014) 'Environmentally responsible behavior in ecotourism: Antecedents and implications', *Tourism Management*. Elsevier Ltd, 40, pp. 321–329.

Chung, S. S., Au, A. and Qiu, J. W. (2013) 'Understanding the underwater behaviour of scuba divers in Hong Kong', *Environmental Management*, 51(4), pp. 824–837.

Clayton, S. and Myers, G. (2009) *Conservation Psychology: Understanding and Promoting Human Care for Nature*. 1st edn. Oxford: John Wiley & Sons. p.265

Conrady, R. and Buck, M. (2012) *Trends and Issues in Global Tourism*. 1st edn. Edited by R. Conrady and B. Martin. London: Springer. p.235

Cruz-Trinidad, A., Aliño, P. M., Geronimo, R. C. and Cabral, R. B. (2014) 'Linking Food Security with Coral Reefs and Fisheries in the Coral Triangle', *Coastal Management*.

Damerose, E. and Hopkins, W. D. (2002) 'Scan and focal sampling: reliability in the laterality for maternal cradling and infant nipple preferences in olive baboons, *Papio anubis*', *Animal Behaviour*, 63(3), pp. 511–518.

Davenport, J. and Davenport, J. L. (2006) 'The impact of tourism and personal leisure transport on coastal environments: A review', *Estuarine, Coastal and Shelf Science*, 67(1–2), pp. 280–292.

Davis, D. and Tisdell, C. (1995) 'Recreational scuba-diving and carrying capacity in marine protected areas Derrin Davis a & Clem Tisdell b', *Ocean & Coastal Management*, 26(1), pp. 19–40.

DEMA (2019) *Fast Facts: Recreational Scuba Diving and Snorkelling*. Available at:

[https://www.dema.org/store/download.aspx?id=7811B097-8882-4707-A160-](https://www.dema.org/store/download.aspx?id=7811B097-8882-4707-A160-F999B49614B6)

F999B49614B6 (Accessed: 29 December 2019).

Department Marine Parks Malaysia (2017) *Marine Park Visitor Numbers*. Available at:

www.dmpm.nre.gov.my (Accessed: 5 February 2017).

Dimitrios, B. and Law, R. (2008) 'Twenty years on and 10 years after the Internet: The state of eTourism research', *Tourism Management*, 29, pp. 609–623.

Ditton, R. B., Loomis, D. K. and Choi, S. (1992) 'Recreation specialization: re-conceptualization from a social worlds perspective', *Journal of Leisure Research*, pp. 33–51.

DMPM (2018) *Statistik Pelancong Ke Taman Laut Terengganu dari 2000-2017*. Available at:

<http://www.data.gov.my/data/dataset/statistik-pelancong-ke-taman-laut-terengganu-dari-2000-2017/resource/c6d0510b-4099-4c15-b43d-1c689f475fbe>.

Dolan, P., Peasgood, T. and White, M. (2008) 'Do we really know what makes us happy? A review of the economic literature on the factors associated with subjective well-being', *Journal of Economic Psychology*, 29(1), pp. 94–122.

Done, T. J. (1999) 'Coral Community Adaptability to Environmental Change at the Scales of Regions, Reefs and Reef Zones', *American Zoologist*, 39, pp. 66–79.

Donner, S. D., Skirving, W. J., Little, C. M., Oppenheimer, M. and Hoegh-Gulberg, O. (2005) 'Global assessment of coral bleaching and required rates of adaptation under climate change', *Global Change Biology*, 11, pp. 2251–2265.

Dullo, W.-C. (2005) 'Coral growth and reef growth: a brief review', *Facies*, 51(1–4), pp. 33–48.

Edinger, E. N., Limmon, G. V., Jompa, J., Widjatkomo, W., Heikoop, J. M. and Risk, M. J.

(2000) 'Normal coral growth rates on dying reefs: Are coral growth rates good indicators of reef health?', *Marine Pollution Bulletin*, 40(5), pp. 404–425.

Elliff, C. I. and Silva, I. R. (2017) 'Coral reefs as the first line of defense: Shoreline protection in face of climate change', *Marine Environmental Research*, 127, pp. 148–154.

English, S., Wilkinson, C. and Baker, V. (1997) *Survey manual for tropical Marine resources*. Townsville: Australian Institute of Marine Science. p.390

Fenner, D. (2012a) 'Challenges for managing fisheries on diverse coral reefs', *Diversity*, 4(1), pp. 105–160.

Fenner, D. (2012b) 'The Largest Fish on Coral Reefs were the First to Go . Or “ You don ’ t know what you ’ ve got “ till it ” s gone ,” as we ’ re only now finding out .’ Department Marine & Wildlife Resources, American Samoa, pp. 1–31.

Ferrario, F., Beck, M. W., Storlazzi, C. D., Micheli, F., Shepard, C. C. and Airolidi, L. (2014) 'The effectiveness of coral reefs for coastal hazard risk reduction and adaptation', *Nature Communications*, 5, pp. 1–9.

Friedrich, L. a., Jefferson, R. and Glegg, G. (2014) 'Public perceptions of sharks: Gathering support for shark conservation', *Marine Policy*. Elsevier, 47, pp. 1–7.

Galbiati, R. and Vertova, P. (2014) 'How laws affect behavior: Obligations, incentives and cooperative behavior', *International Review of Law and Economics*. Elsevier Inc., 38, pp. 48–57.

GBRMPA (2019) 'Reef Health'. Available at: <http://www.gbrmpa.gov.au/the-reef/reef-health> (Accessed: 5 August 2019).

Giglio, V. J., Luiz, O. J., Chadwick, N. E., Ferreira, C. E. L., Giglio, V. J., Luiz, O. J., Chadwick, N. E., Ferreira, C. E. L. and Chadwick, N. E. (2018) 'Using an educational video-briefing to mitigate the ecological impacts of scuba diving'. *Taylor & Francis*, 26(5), pp. 782–797.

Google (2019) *Google Maps*. Available at: <https://www.google.co.uk/maps/> (Accessed: 22 April 2020).

Grønhøj, A. and Thøgersen, J. (2012) 'Action speaks louder than words: The effect of personal attitudes and family norms on adolescents' pro-environmental behaviour', *Journal of Economic Psychology*, 33(1), pp. 292–302.

De Groot, J. I. M. and Steg, L. (2009) 'Morality and prosocial behavior: the role of awareness, responsibility, and norms in the norm activation model.', *The Journal of social psychology*, 149(4), pp. 425–449.

Guardian (2016) *Thailand closes dive sites over coral bleaching crisis*. Available at: <https://www.theguardian.com/environment/2016/may/26/thailand-closes-dive-sites-over-coral-bleaching-crisis> (Accessed: 12 November 2019).

Guzner, B., Novplansky, A., Shalit, O. and Chadwick, N. E. (2010) 'SCUBA diving: Patterns of growth and predation in branching stony corals', *Bulletin of Marine Science*, 86(3), pp. 727–742.

Hall, C. M. (2001) 'Trends in ocean and coastal tourism: The end of the last frontier?', *Ocean and Coastal Management*, 44(9–10), pp. 601–618.

Hammerton, Z. (2017) 'Determining the variables that influence SCUBA diving impacts in eastern Australian marine parks', *Ocean and Coastal Management*. Elsevier Ltd, 142, pp. 209–217.

Hannak, J. S., Kompatscher, S., Stachowitsch, M. and Herler, J. (2011) 'Snorkelling and trampling in shallow-water fringing reefs: Risk assessment and proposed management strategy', *Journal of Environmental Management* Hannak, J. S., Kompatscher, S., Stachowitsch, M. and Herler, J. (2011) 'Snorkelling and trampling in shallow-water fringing reefs: Risk assessment and proposed management strategy', *Journal of Environmental Management*. E. Elsevier Ltd, 92(10), pp. 2723–2733.

Harriott, V. J., Davis, D. and Banks, S. A. (1997) 'Recreational diving and its impact im marine protected areas in eastern Australia', *Ambio*, 26(3), pp. 173–179.

Hasler, H. and Ott, J. a. (2008) 'Diving down the reefs? Intensive diving tourism threatens the reefs of the northern Red Sea', *Marine Pollution Bulletin*, 56(10), pp. 1788–1794.

Hawkins, J. P. and Roberts, C. M. (1992) 'Effects of recreational SCUBA diving on fore-reef slope communities of coral reefs', *Biological Conservation*, 62(3), pp. 171–178.

Heberlein, T. (2012) *Navigating Environmental Attitudes*. Oxford University Press. p.240

Hein, M. Y., Lamb, J. B., Scott, C. and Willis, B. L. (2015) 'Assessing baseline levels of coral health in a newly established marine protected area in a global scuba diving hotspot', *Marine Environmental Research*. Elsevier Ltd, 103, pp. 56–65.

Heywood, J. L. (2002) 'The Cognitive and Emotional Components of Behavior Norms in Outdoor Recreation', *Leisure Sciences*, 24(3–4), pp. 271–281.

Hinds, N. (2016) 'Photographs'.

Hirschler, I. M., Gedert, J. L., Majors, J., Townsend, T. and Hoogland, J. L. (2016) 'What is the best way to estimate vigilance? A comparison of two methods for Gunnison's prairie dogs, *Cynomys gunnisoni*', *Animal Behaviour*. Elsevier Ltd, 121, pp. 117–122.

Hoegh-Guldberg, O. (1999) 'Climate Change, coral bleaching and the future of the world's coral reefs', *Marine and Freshwater Research*, 50(8), pp. 839–866.

Hoegh-Guldberg, O., Mumby, P. J., Hooten, A. J., Steneck, R. S., Greenfield, P., Gomez, E., Harvell, C. D., Sale, P. F., Edwards, A. J., Caldeira, K., Knowlton, N., Eakin, C. M., Iglesias-Prieto, R., Muthiga, N., Bradbury, R. H., Dubi, A. and Hatzioolos, M. E. (2007) 'Coral Reefs under Rapid Climate Change and Ocean Acidification', *Source: Science, New Series*, 318(5857), pp. 1737–1742.

Honey, M. and Krantz, D. (2007) 'Global Trends in Coastal Tourism', *Washington DC: Center on Ecotourism and Sustainable Development*, (December), pp. 1–140.

Hubbard, D. K. and Scaturo, D. (1985) 'Growth Rates of Seven Species of Scleractinean Corals From Cane Bay and Salt River , St . Croix , Usvi', *Bulletin of Marine Science*, 36(2), pp. 325–338.

Hughes, T. (1987) 'Skeletal density and growth form of corals', *Marine Ecology Progress Series*, 35, pp. 259–266.

Hughes, T. P., Baird, a H., Bellwood, D. R., Card, M., Connolly, S. R., Folke, C., Grosberg, R., Hoegh-Guldberg, O., Jackson, J. B. C., Kleypas, J., Lough, J. M., Marshall, P., Nyström, M., Palumbi, S. R., Pandolfi, J. M., Rosen, B. and Roughgarden, J. (2003) 'Climate change, human impacts, and the resilience of coral reefs.', *Science (New York, N.Y.)*, 301(5635), pp. 929–933.

Hunt, C. V., Harvey, J. J., Miller, A., Johnson, V. and Phongsuwan, N. (2013) 'The Green Fins approach for monitoring and promoting environmentally sustainable scuba diving operations in South East Asia', *Ocean and Coastal Management*. Elsevier Ltd, 78, pp. 35–44.

Huston, M. (1985) 'Variation in coral growth rates with depth at Discovery Bay, Jamaica', *Coral Reefs*, 4(1), pp. 19–25.

International Coral Reef Initiative (1994) *What are corals?* Available at:

<http://www.icriforum.org/about-coral-reefs/what-are-corals> (Accessed: 12 February 2016).

Jones, R., Pykett, J. and Whitehead, M. (2013) 'Behaviour Change policies in the UK: An anthropological perspective', *Geoforum*. Elsevier Ltd, 48, pp. 33–41.

Juhasz, A., Ho, E., Bender, E. and Fong, P. (2010) 'Does use of tropical beaches by tourists and island residents result in damage to fringing coral reefs? A case study in Moorea French Polynesia', *Marine Pollution Bulletin*. Elsevier Ltd, 60(12), pp. 2251–2256.

Kaplan, E. and Kaplan, S. (1982) *A Field Guide to Coral Reefs of the Caribbean and Florida*. Boston: Houghton Mifflin Company. p.289

Kaplan, S. (1995) 'The restorative benefits of nature: Toward an integrative framework', *Journal of Environmental Psychology*, 15(3), pp. 169–182.

Kavousi, J., Tanaka, Y., Nishida, K., Suzuki, A., Nojiri, Y. and Nakamura, T. (2016) 'Colony-specific calcification and mortality under ocean acidification in the branching coral *Montipora digitata*', *Marine Environmental Research*, 119, pp. 161–165.

Kohler, K. E. and Gill, S. M. (2006) 'Coral Point Count with Excel extensions (CPCe): A Visual Basic program for the determination of coral and substrate coverage using random point count methodology', *Computers and Geosciences*, 32(9), pp. 1259–1269.

Krieger, J. R. and Chadwick, N. E. (2013) 'Recreational diving impacts and the use of pre-dive briefings as a management strategy on Florida coral reefs', *Journal of Coastal Conservation*, 17(1), pp. 179–189.

Kristensen, P. (2004) 'The DPSIR Framework', in *Assessment of the vulnerability of water resources to environmental change in Afrca using River Basin approach*. Nairobi, Kenya: UNEP.

Lamb, J. B., True, J. D., Piromvaragorn, S. and Willis, B. L. (2014) 'Scuba diving damage and intensity of tourist activities increases coral disease prevalence', *Biological Conservation*. Elsevier Ltd, 178, pp. 88–96.

Lee, A. C. K. and Maheswaran, R. (2010) 'The health benefits of urban green spaces: A review of the evidence', *Journal of Public Health*, 33(2), pp. 212–222.

Leujak, W. and Ormond, R. F. G. (2007) 'Comparative accuracy and efficiency of six coral community survey methods', *Journal of Experimental Marine Biology and Ecology*, 351(1–2), pp. 168–187.

Liew, H. C., Chua, Y. S. and Chan, E. H. (2001) 'The impact on coral reefs by leisure divers in Redang', *National Symposium on Marine Park and Islands in Terengganu: Towards Sustainable Usage and Management of Islands*2, pp. 1–7.

Linton, D. M. and Warner, G. F. (2003) 'Biological indicators in the Caribbean coastal zone and their role in integrated coastal management', *Ocean and Coastal Management*, 46(3–4), pp. 261–276.

Lirman, D. (2000) 'Fragmentation in the branching coral *Acropora palmata* (Lamarck): Growth, survivorship, and reproduction of colonies and fragments', *Journal of Experimental Marine Biology and Ecology*, 251(1), pp. 41–57.

Lirman, D. (2003) 'A simulation model of the population dynamics of the branching coral *Acropora palmata* Effects of storm intensity and frequency', *Ecological Modelling*, 161(3), pp. 169–182.

López-Mosquera, N. and Sánchez, M. (2012) 'Theory of Planned Behavior and the Value-Belief-Norm Theory explaining willingness to pay for a suburban park', *Journal of Environmental Management*. Elsevier Ltd, 113, pp. 251–262.

Lucrezi, S., Saayman, M. and van der Merwe, P. (2013) 'Managing diving impacts on reef ecosystems: Analysis of putative influences of motivations, marine life preferences and experience on divers' environmental perceptions', *Ocean and Coastal Management*. Elsevier Ltd, 76, pp. 52–63.

Luna, B., Pérez, C. V. and Sánchez-Lizaso, J. L. (2009) 'Benthic impacts of recreational divers in a mediterranean marine protected area', *ICES Journal of Marine Science*, 66(3), pp. 517–523.

Lyons, P. J., Arboleda, E., Benkwitt, C. E., Davis, B., Gleason, M., Howe, C., Mathe, J., Middleton, J., Sikowitz, N., Untersteggaber, L. and Villalobos, S. (2015) 'The effect of recreational SCUBA divers on the structural complexity and benthic assemblage of a Caribbean coral reef', *Biodiversity and Conservation*. Springer Netherlands, 24(14), pp. 3491–3504.

Mair, J. and Laing, J. H. (2013) 'Encouraging pro-environmental behaviour: the role of sustainability-focused events', *Journal of Sustainable Tourism*, 21(8), pp. 1113–1128.

Malaysia, G. of (2012) *FISHERIES ACT 1985*. Available at:

<http://www.agc.gov.my/agcportal/uploads/files/Publications/LOM/EN/Act 317 - Fisheries Act 1985.pdf>.

Mallela, J. and Crabbe, M. J. C. (2009) 'Hurricanes and coral bleaching linked to changes in coral recruitment in Tobago', *Marine Environmental Research*. Elsevier Ltd, 68(4), pp. 158–162.

Medio, D., Ormond and Pearson (1997) 'Effects of briefings on rates of damage to corals', *Biological Conservation*, 3207(96), pp. 91–95.

Movilla, J., Calvo, E., Pelejero, C., Coma, R., Serrano, E., Fernández-Vallejo, P. and Ribes, M. (2012) 'Calcification reduction and recovery in native and non-native Mediterranean corals in response to ocean acidification', *Journal of Experimental Marine Biology and Ecology*, 438, pp. 144–153.

Musa, G., Seng, W. T., Thirumoorthi, T. and Abessi, M. (2011) 'The Influence of Scuba Divers' Personality, Experience, and Demographic Profile on their Underwater Behavior', *Tourism in Marine Environments*, 7(1), pp. 1–14.

Nagelkerken, I., Velde, G. Van Der, Gorissen, M. W., Meijer, G. J. and Hof, T. Van (2000) 'Importance of Mangroves , Seagrass Beds and the Shallow Coral Reef as a Nursery for Important Coral Reef Fishes , Using a Visual Census Technique', pp. 31–44.

National Oceanic and Atmospheric Administration (2000) *NOAA's Coral Reef Conservation Program*. Available at: <https://coralreef.noaa.gov/> (Accessed: 12 February 2016).

National Oceanic and Atmospheric Administration (2018a) *What is coral spawning?*, Website. Available at: <https://oceanservice.noaa.gov/about/welcome.html#cite> (Accessed: 30 July 2019).

National Oceanic and Atmospheric Administration (2018b) *What is the Great Barrier Reef?* Available at: <https://oceanservice.noaa.gov/facts/gbrlargeststructure.html> (Accessed: 5 August 2019).

Nations, U. (2016) *General Assembly*. Available at: https://www.un.org/en/ga/search/view_doc.asp?symbol=A/RES/70/193&referer=/english/&Lang=E (Accessed: 3 July 2017).

Newton, K., Côté, I. M., Pilling, G. M., Jennings, S. and Dulvy, N. K. (2007) 'Current and Future Sustainability of Island Coral Reef Fisheries', *Current Biology*, 17(7), pp. 655–658.

Oliver, J. K., Chalker, B. E. and Dunlap, W. C. (1983) 'Bathymetric adaptations of reef-building corals at Davies Reef, Great Barrier Reef, Australia. I. Long-term growth responses of *Acropora formosa* (Dana 1846)', *Journal of Experimental Marine Biology and Ecology*, 73(1), pp. 11–35.

Ong, T. F. and Musa, G. (2012) 'Examining the influences of experience, personality and attitude on SCUBA divers' underwater behaviour: A structural equation model', *Tourism Management*. Elsevier Ltd, 33(6), pp. 1521–1534.

Onwezen, M. C., Antonides, G. and Bartels, J. (2013) 'The Norm Activation Model: An exploration of the functions of anticipated pride and guilt in pro-environmental behaviour', *Journal of Economic Psychology*. Elsevier B.V., 39, pp. 141–153.

Othman, A., Ng, N., Long, S. L. and Gramaglia, S. (2014) 'Informal discussion with SCUBA Professionals'. Kuala Besut, Malaysia.

PADI (2015) *Worldwide Corporate Statistics 2015 PADI Historical Over-View*. Available at: www.padi.com/scuba-diving/documents/2015-WW-Statistics/ (Accessed: 5 November 2019).

PADI (2016) *Sipidan's New Underwater Marshals*. Available at: <https://blog.padi.com/2016/03/09/sipadans-new-underwater-marshals/> (Accessed: 6 August 2019).

PADI (2017a) 'Instructor Manual'. Santa Margarita, CA: PADI.

PADI (2017b) *PADI Celebrates a Milestone with 25 Million Certifications*. Available at: <https://blog.padi.com/2017/01/27/padi-celebrates-a-milestone-with-25-million-certifications/> (Accessed: 3 July 2017).

PADI (2017c) *Worldwide Corporate Statistics 2017, Statistics*. Available at: [https://www.padi.com/sites/default/files/documents/2017 PADI WW Statistics.pdf](https://www.padi.com/sites/default/files/documents/2017%20PADI%20WW%20Statistics.pdf) (Accessed: 5 November 2019).

Pearson, R. (1981) 'Recovery and Recolonization of Coral Reefs ', *Marine Ecology Progress Series*, 4, pp. 105–122.

Pratchett, M. S., Baird, A. H., McCowan, D. M., Coker, D. J., Cole, A. J. and Wilson, S. K. (2008) 'Protracted declines in coral cover and fish abundance following climate-induced coral bleaching on the Great Barrier Reef', *Proceedings 11th Int. Coral Reef Symp.*, (25), p. 5.

Prochaska, J. O. and DiClemente, C. C. (1982) 'Transtheoretical therapy: Toward a more integrative model of change.', *Psychotherapy: Theory, Research and Practice*, 19(3), pp. 276–288.

Reef Check Malaysia (2015) *Status of Coral Reefs in Malaysia*. Available at:
<http://www.reefcheck.org.my/media-information/annual-survey-reports>.

Reef Check Malaysia (2016) *Status of Coral Reefs in Malaysia, 2015*. Available at:
<http://www.reefcheck.org.my/media-information/annual-survey-reports>.

Reef Check Malaysia (2017) *Status of Coral Reefs in Malaysia, 2016 Reef Check Malaysia*. Available at:
http://www.reefcheck.org.my/images/documents/survey_report/2016_Annual_Survey_Report.pdf.

Roche, R. C., Harvey, C. V., Harvey, J. J., Kavanagh, A. P., McDonald, M., Stein-Rostaing, V. R. and Turner, J. R. (2016) 'Recreational Diving Impacts on Coral Reefs and the Adoption of Environmentally Responsible Practices within the SCUBA Diving Industry', *Environmental Management*. Springer US, 58(1), pp. 107–116.

Rogers, C. (1990) 'Responses of coral reefs and reef organisms to sedimentation', *Marine Ecology Progress Series*, 62, pp. 185–202.

Rouphael, A. B. and Inglis, G. J. (1997) 'Impacts of recreational scuba diving at sites with different reef topographies. &', *Biological Conservation*, 82(97), pp. 329–336.

Rouphael, A. B. and Inglis, G. J. (2001) "'Take only photographs and leave only footprints"?: An experimental study of the impacts of underwater photographers on coral reef dive sites', *Biological Conservation*, 100(3), pp. 281–287.

Sadovy, Y. J., Donaldson, T. J., Graham, T. R., F. McGilvray, G.J. Muldoon, Philipps, M. ., Rimmer, M. A., Smith, A. and Yeeting, B. (2003) *While Stocks Last : The Live Reef Food Fish Trade, Development*. p.169

Safuan, M., Wee, H. B., Hii, Y.-S., Liew, H.-C. and Bachok, Z. (2015) 'Optimization of Coral Video Transect Technique for Coral Reef Survey : Comparison with Intercept Transect Technique', *Open Journal of Marine Science*, 5(October), pp. 379–397.

Salim, N., Bahauddin, A. and Mohamed, B. (2013) 'Influence of scuba divers' specialization on their underwater behavior', *Worldwide Hospitality and Tourism Themes*, 5(4), pp. 388–397.

Sandifer, P. A., Sutton-Grier, A. E. and Ward, B. P. (2015) 'Exploring connections among nature, biodiversity, ecosystem services, and human health and well-being: Opportunities to enhance health and biodiversity conservation', *Ecosystem Services*. Elsevier, 12, pp. 1–15.

Sapci, O. and Considine, T. (2014) 'The link between environmental attitudes and energy consumption behavior', *Journal of Behavioral and Experimental Economics*. Elsevier Inc., 52, pp. 29–34.

Schleyer, M. H. and Tomalin, B. J. (2000) 'Ecotourism and damage on South African coral reefs with an assessment of their carrying capacity', *Bulletin of Marine Science*, 67(3), pp. 1025–1042.

Sheppard, C., Davy, S., Pilling, G. and Graham, N. (2009) *The Biology of Coral Reefs*. First. Oxford: Oxford U. p.384

Shidqi, R. A., Pamuji, B., Sulistianoro, T., Risza, M., Faozi, A. N., Muhammad, A. N., Muharam, M. R., Putri, E. D., Hartini, R., Valentina, B., Fakhri, R. Z., Putra, G. G., Kurniawan, R., Pratomo, A. and Syakti, A. D. (2018) 'Coral health monitoring at Melinjo Island and Saktu Island: Influence from Jakarta Bay', *Regional Studies in Marine Science*. Elsevier B.V., 18, pp. 237–242.

Spalding, M., Burke, L., Wood, S. A., Ashpole, J., Hutchison, J. and Zu Ermgassen, P. (2017) 'Mapping the global value and distribution of coral reef tourism'.

Stanley, G. D. and Swart, P. K. (1995) 'Stanley and Swart 1995.pdf', *Paleobiology*, 21(2), pp. 179–199.

Steg, L., Van Den Berg, A. E. and De Groot, J. I. M. (2013) *Environmental Psychology; An Introduction*. 1st edn. Oxford: John Wiley & Sons. p.398

Steg, L. and de Groot, J. (2010) 'Explaining prosocial intentions: testing causal relationships in the norm activation model.', *The British journal of social psychology / the British Psychological Society*, 49(Pt 4), pp. 725–743.

Stern, P. C. (2000) 'Toward a Coherent Theory of Environmentally Significant Behavior', *Journal of Social Issues*, 56(3), pp. 407–424.

Stern, P. C., Dietz, T., Abel, T. D., Guagnano, G. A. and Kalof, L. (1999) 'A Value-Belief-Norm Theory of Support for Social Movements : The Case of Environmentalism A Value-Belief-Norm Theory of Support for Social Movements : The Case of Environmentalism', *Research in Human Ecology*, 6(2), pp. 81–97.

Sullivan, G. M. and Artino, A. R. (2013) 'Analyzing and Interpreting Data From Likert-Type Scales', *Journal of Graduate Medical Education*, 5(4), pp. 541–542.

Thapa, B., Graefe, A. R. and Meyer, L. a. (2005) 'Moderator and Mediator Effects of Scuba Diving Specialization on Marine-Based Environmental Knowledge-Behavior Contingency', *The Journal of Environmental Education*, 37(1), pp. 53–67.

Toda, T., Okashita, T., Maekawa, T., Alfian, B. A. A. K., Rajuddin, M. K. M., Nakajima, R., Chen, W., Takahashi, K. T., Othman, B. H. R. and Terazaki, M. (2007) 'Community structures of coral reefs around peninsular Malaysia', *Journal of Oceanography*, 63(1), pp. 113–123.

Todd, S., Graefe, A. R. and Mann, W. (2002) 'Differences in SCUBA diver motivations based on level of development', in *2001 Northeastern Recreation Research Symposium*. Newton Square, pp. 107–114.

Tortolero-Langarica, J. J. A., Rodríguez-Troncoso, A. P., Carricart-Ganivet, J. P. and Cupul-Magaña, A. L. (2016) 'Skeletal extension, density and calcification rates of massive free-living coral *Porites lobata* Dana, 1846', *Journal of Experimental Marine Biology and Ecology*. Elsevier B.V., 478, pp. 68–76.

Toyoshima, J. and Nadaoka, K. (2015) 'Importance of environmental briefing and buoyancy control on reducing negative impacts of SCUBA diving on coral reefs', *Ocean & Coastal Management*. Elsevier Ltd, 116, pp. 20–26.

Tratalos, J. a and Austin, T. J. (2001) 'Impacts of recreational SCUBA diving on coral communities of the Carribean island of Gran Cayman', *Biological Conservation*, 102, pp. 67–75.

Unsworth, K. L., Dmitrieva, A. and Adriasola, E. (2013) 'Changing behaviour: Increasing the effectiveness of workplace interventions in creating pro-environmental behaviour change', *Journal of Organizational Behavior*, p. 10.

UNWTO (2017) *Sustained growth in international tourism despite challenges*.

Uyarra, M. C. and Côté, I. M. (2007) 'The quest for cryptic creatures: Impacts of species-focused recreational diving on corals', *Biological Conservation*, 136(1), pp. 77–84.

Wackernagel, M., Onisto, L., Bello, P., Linares, A. C., López Falfán, I. S., Méndez García, J., Isabel, A., Guerrero, S. and Guadalupe, M. (1999) 'National natural capital accounting with the ecological footprint concept', *Ecological Economics*, 29, pp. 375–390.

Watson, R. T., Rosswall, T., Steiner, A., Töpfer, K., Arico, S. and Bridgewater, P. (2005) *Ecosystems and human well-being, Ecosystems*. Edited by R. T. Watson, T. Rosswall, A. Steiner, K. Töpfer, S. Arico, and P. Bridgewater. World Resources Institute (Millennium Assessments).

Weaver, D. and Oppermann, M. (2000) *Tourism Management*. Sydney: John Wiley & Sons.

Wheeler, B. W., White, M., Stahl-Timmins, W. and Depledge, M. H. (2012) 'Does living by the coast improve health and wellbeing', *Health and Place*. Elsevier, 18(5), pp. 1198–1201.

Wong, P. P. (1998) 'Coastal tourism development in Southeast Asia: Relevance and lessons for coastal zone management', *Ocean and Coastal Management*, 38(2), pp. 89–109.

Woodley, J. D. *et al.* (1981) 'Hurricane Allen's Impact on Jamaican Coral Reefs.', *Science* (New York, N.Y.), 214(4522), pp. 749–755.

Worachananant, S., Carter, R. W. (Bill), Hockings, M. and Reopanichkul, P. (2008) 'Managing the Impacts of SCUBA Divers on Thailand's Coral Reefs', *Journal of Sustainable Tourism*, 16(6), p. 645.

World Tourism Organisation (2019) *International Tourist Arrivals Reach 1.4 billion Two Years Ahead of Forecasts*, Press Release.

WTO (2011) *Tourism 2020 Vision - Global Forecasts and Profiles of Market Segments*, World Tourism Organization. Available at: [http://sete.gr/files/Media/Ebook/110303_Global Forecasts and Profiles of Market Segments.pdf](http://sete.gr/files/Media/Ebook/110303_Global_Forecasts_and_Profiles_of_Market_Segments.pdf).

Wynveen, C. J. and Sutton, S. G. (2015) 'Engaging the public in climate change-related pro-environmental behaviors to protect coral reefs : The role of public trust in the management agency', *Marine Policy*. Elsevier, 53, pp. 131–140.

Zakai, D. and Chadwick-Furman, N. E. (2002) 'Impacts of intensive recreational diving on reef corals at Eilat, Northern Red Sea.', *Biological Conservation*, 105, pp. 179–187.

Zhang, L., Chung, S. and Qiu, J. (2016) 'Ecological carrying capacity assessment of diving site : A case study of Mabul Island , Malaysia', *Journal of Environmental Management*. Elsevier Ltd, 183, pp. 253–259.

Zulaiha, S., Abidin, Z. and Mohamed, B. (2014) 'A Review of SCUBA Diving Impacts and Implication for Coral Reefs Conservation and Tourism Management 2 SCUBA Diving Impacts on Coral Reefs', 12.

9.0 Appendices

9.1 Appendix 1: Questionnaire

The aim of this project is to observe scuba divers in an underwater setting to identify changes in behaviour based on activities and to identify values and motivations in a post-dive questionnaire. Participants are encouraged to ignore researchers and participate in their dive as normal. The researchers will not actively disrupt the dive and will observe from a distance. The questionnaire aspect will be completed upon return to the dive centre and will take approximately 10-15 minutes.

The survey is completely anonymous, with no personal data or information recorded. As such, your identity will be protected. The survey is voluntary, and participants are at liberty to withdraw at any time. Refusal to participate will not affect your rights, or access to other services. By participating in this survey, you acknowledge that, due to anonymity, upon departure there will be no option to withdraw due to specific participant data being unidentifiable. Participating in this research will not increase the level of risk you face and will not result in harm. However, there are still risks involved with scuba diving which you should be made aware of by the dive centre.

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Please Initial Box

- | | | |
|----|--|--------------------------|
| 1. | I confirm that I have read and understand the information sheet for the above study and have had the opportunity to ask questions. | ☐ |
| 2. | I understand that my participation is voluntary and that I am free to withdraw at any time, without giving reason. | ☐ |
| 3. | I agree to take part in the above study. | ☐ |

Name of Participant

Date

Signature

Name of Researcher

Date

Signature

1. Gender		Male			Female
2. Age Group	18-29	30-39	40-49	50-59	Over 60
3. Nationality					
4. Which SCUBA organisation did you complete your training with (e.g. PADI, SSI, BSAC, etc)?					
5a. What is your highest level of dive training?	Beginner (Open water)	Advanced	Rescue	Pro (Divemaster or Inst.)	

5b. Do you have any additional speciality courses completed? (if yes, please specify)

6. Total number of dives (to date)

7. Date of last dive

8. When did you start diving? (Year)

9. How often do you dive?
(approximately)

10. Have you ever participated in a buoyancy training dive? (Peak Performance Buoyancy)

10. Approximately how many of the following types of dive have you completed?	0	1-5	6-15	16-25	Over 25
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Deep Dive (>18m)

Current (Drift) Dive

<5 metre visibility dive

11. Why did you start scuba diving? (Please tick one)

- Adventure
- Learning
- Status
- Social Interaction
- Exploration
- Marine Life
- Other (specify)

Section 2

Please rate the following statements on a scale of 1 – 5 on how obligated you feel to carry out the outlined behavioural aspects of SCUBA diving

Strong Obligation to not do	1
Slight Obligation to not do	2
No Obligation either way	3
Slight Obligation to do	4
Strong Obligation to do	5

Maintain horizontal positioning

Grasp substrate to steady yourself for photograph

Maintain close contact with buddy

Swim close to or touch marine animals

Arrange equipment and streamline upon reaching desired depth

Check Pressure gauge regularly

Get close to corals

Avoid sandy bottoms

Maintain buoyancy control

Pick up dead corals and/or shells

Reprimand others for poor or unsafe practices

Ascend Slowly

Keep your fins away from coral

Collect litter/trash during a dive

Touch corals

Section 3

Please read the following statements and state whether you: Agree (A), Disagree (D) or Don't Know (K)

Feeding fish can be harmful to fish

Coral Reefs rely on sunlight for survival

Scuba diving causes no physical harm to a coral reef

Picking up broken corals does not affect the environment

Coral is a plant

Sediment in the water does not affect coral growth

Coral is fast growing

Holding onto the sea floor during a dive causes no damage to marine life

Physical contact with the reef during diving is unavoidable

Breaking coral whilst diving results in no lasting damage to the reef

Algae can smother coral

What is coral?

What makes coral colourful?

Where do corals get nutrition from?

How much do you think coral can grow in 1 year?

Section 4

Please rate how you would feel based upon the following scenarios. Give each statement a rating of 1 – 7 on your Satisfaction.

Very Unsatisfied	1
Slightly Unsatisfied	2
No feeling either way	3
Slightly Satisfied	4
Very Satisfied	5

You saw another diver kicking up sediment into the water

You broke a piece of coral

You saw a rare species such as a Turtle, Dolphin or Whale Shark

You saw another diver picking up dead coral

You visited a dive site with 20 other divers

You saw broken coral on a reef

Dive sites had limits on the number of divers allowed per year

All coral reef sites were deemed protected

Unmanaged fishing was allowed within a coral reef environment

Collection of corals was allowed for aquarium trade

Divers were banned from visiting certain coral reef sites

What is your average annual expenditure on all diving activities?

Would you be willing to spend more to dive in a marine protected area?

Section 5

Rank the following scenarios on their effectiveness, both for you as an individual, and for the dive community in changing behaviour whilst diving.

1	Very Effective
2	Moderately Effective
3	Neither effective nor ineffective
4	Slightly ineffective
5	Very ineffective

Scenario

Effectiveness Individually

Effectiveness on Dive community

Informative posters, fliers and signs advising
behaviour in dive centres and on dive boats

Continuing SCUBA dive **training and education**

Improved environmental and behaviour focus within
pre-dive briefing

Intervention by dive leader during a dive upon
witnessing poor behaviour

Intervention by another diver or dive buddy during a
dive upon witnessing poor behaviour

Inclusion of more **behaviour education within**
beginner dive course

More **enforcement and legislation**

Whose responsibility is it for ensuring good diver behaviour underwater?

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Thank you for your time!