THE UNIVERSITY OF HULL

# *The Economic, Social and Conservation Benefits of Recreation-orientated Artificial Reefs*

being a Thesis submitted for the Degree of

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Anne Elizabeth Kirkbride-Smith

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*Petrarch's Principle; "is to know things unseen,*
*yet to ignore things seen"*

**Francesco Petrarch (1358)**

# Abstract

Coral reefs are highly diverse and economically important. Despite this, a confluence of anthropogenic threats endangers reefs globally. The diving tourism industry is an important beneficiary of coral reefs, especially reefs located within the tropical latitudes. With a recent increase in popularity of diving tourism concomitant with a global expansion of marine coastal tourism, reef managers and policy makers are presented with fresh challenges. This study explores the potential economic, social and conservation impacts of artificial reefs as recreational scuba diving resources and investigates their use as a reef management strategy within a marine protected area. A majority of the study was conducted on the Caribbean island of Barbados, West Indies. In the first part of the thesis, I estimate the economic benefits of recreation-orientated artificial reefs through a synthesis of data, and find that artificial reefs have a substantial recreation value. The need for more detailed, high-quality artificial reef valuation studies, that use a standard reporting protocol, is recommended. The second part of the thesis is based on field work using questionnaires to solicit information from users of artificial reefs. Interviews reveal novice divers have a preference for artificial reefs for local diving in contrast to experienced divers who have an overriding preference to dive on natural reefs. Moreover, an inverse relationship exists between diver experience and satisfaction of artificial reef diving, with novices being very satisfied with the experience. Using 24 variables to measure diver enjoyment between artificial and natural reef sites, I establish participants experience significantly higher levels of enjoyment at artificial reefs. Further, it was shown that enjoyment of artificial reefs is attributed to the challenge of the dive, new experiences and photographic opportunities. Irrespective of reef type, I find novices are significantly more influenced by personal incentive attributes of the dive (e.g. updating diving skills), while biophysical aspects of the reef and photography contribute significantly more to experienced divers enjoyment. A contingent valuation study of visitors to pay a daily marine park entrance fee reveals a higher mean willingness to pay (US$18.33) for natural reef conservation than for protecting and maintaining artificial reefs (US$17.58). Variables that exhibit significant explanatory power of willingness to pay include the number of species viewed, age of respondent and level of concern for coral reefs.

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# General Introduction

The marine environment hosts a range of tourism and recreational pursuits represented by a diversity of activities including sport fishing, marine viewing, snorkelling and self contained underwater breathing apparatus (scuba) diving (Orams, 1999; Dimmock, 2007; Musa and Dimmock, 2013). Coral reefs due to their abundance of wildlife and ubiquitous aesthetic appeal provide an ideal environment for the majority of these activities, especially scuba diving. In recent years, recreational diving has emerged as a growing niche within the tourism sector, with an estimated 10 million active divers presently worldwide (Garrod and Gössling, 2008). Many factors contribute to the rapid growth of this leisure sport, notably; access to remote diving sites, technical advances in equipment, an increase in leisure time as well as a rising societal interest in nature conservation and environmental awareness (e.g. Garrod and Wilson, 2003; Musa and Dimmock, 2013).

However, continued growth in reef-based tourism coupled with an increased demand for good diving sites may conflict with the ecological values of many coastal areas causing degradation of reefs and reduced amenity values. Many papers have dealt with the impacts of divers on reefs (e.g. Rouphael and Inglis, 1997, 2001, 2002; Hawkins *et al.*, 1999; Tratalos and Austin, 2001; Barker and Roberts, 2004; Warachananant *et al.*, 2008; Chung *et al.*, 2013; Au *et al.*, 2014), though ancillary effects associated with coastal tourism, such as sedimentation from hotel development (Nemeth and Nowlis, 2001; Burke and Maidens, 2004; Uyarra, 2009) and sewage disposal (Tomascik, 1990; Mora, 2008; DeGeorges *et al.*, 2010; González-De Zayas *et al.*, 2013) represent significant threats to coral reefs also. Human impacts to coral reefs are not necessarily localized. Changing climatic conditions leading to episodic coral bleaching has resulted in massive mortality among corals in recent years, notably 1998 was documented as unprecedented in severity for causing coral deaths globally (e.g. Wilkinson *et al.*, 1999; Westmacott *et al*., 2000; Berkelmans *et al.*, 2004). Losses of net revenue due to bleaching were reported for some diving resorts (Cesar, 2000; Westmacott *et al.*, 2000), together with losses in welfare from divers identified by their reduction in willingness to pay for bleached coral reefs (Doshi *et al.*, 2012). Moreover, in 2005, the southeastern

Caribbean region experienced a severe and unparalleled bleaching event (Donner *et al.,* 2007; Oxenford *et al.*, 2008a, 2008b). As a result of this, Hime (2008) noted substantial financial losses to the scuba diving and snorkelling industries of the British Virgin Islands.

Notwithstanding, diving tourism has become an increasingly important and lucrative source of income to the tourism industry (e.g. Burke and Maidens, 2004; Cesar and van Beukering, 2004; Burke *et al.,* 2011; Sarkis *et al.*, 2013), particularly in many tropical islands in the Caribbean and Pacific basins that have undergone economic restructuring (Albuquerque and McElroy, 1992; Burke *et al.,* 2008). Typically, reef-based tourism is concentrated along relatively small coastal strips of tropical countries (Dimmock, 2007; Lew, 2013), that offer the clear, warm waters in which coral reefs thrive, eroding naturally to maintain many fine coralline beaches worldwide (Dharmaratne and Brathwaite, 1998). The economic value derived from coral reef tourism is significant (Brander *et al.,* 2007). In Belize for example, tourism based on coral reefs generated up to US$175 million in 2007 (Burke *et al.*, 2011) and in Thailand divers are estimated to contribute *circa* US$150 million annually to the local economy (Dearden *et al.,* 2006). The Caribbean region is particularly attractive to divers. Burke and Maidens (2004) reported that divers represent 10% of all Caribbean visitors and van't Hof (2001) noted that more than half of the world's several million active scuba divers seek out reefs in the Caribbean. Whilst diving tourism is clearly of economic importance to many tropical countries (Westmacott *et al*., 2000), there is consensus amongst some researchers that scuba diving is not, for the most part, beneficial for coral reefs (e.g. Uyarra and Côté, 2007; Hasler and Ott, 2008; Thurstan *et al.,* 2012; Thirumoorthi *et al.,* 2013). In fact, Thurstan *et al.* (2012) assigned a high impact risk score to scuba diving (and snorkelling) based on the likely level of threat this activity poses to wildlife and reef habitat within marine protected areas.

Despite many initiatives to protect coral reefs regionally (Alcolado *et al.,* 2001) and globally (Hodgson, 1999), these fragile ecosystems continue to suffer high levels of mortality, especially in the Caribbean region (e.g. Gardner *et al.,* 2003; Ginsburg and Lang, 2003; Burke and Maidens, 2004; Perry *et al.,* 2013). In the most recent *Reefs at Risk* report, Burke *et al.* (2011) suggested that 75% of the world's reefs are threatened by local and global pressures. At a local level, countries relying on their coral reefs for tourism and other important uses such as fisheries, acknowledge their combined efforts in managing local reef resources, are crucial (Alcala *et al.,* 2006; Townsend, 2008; Bottema and Bush, 2012). Over the past two decades, various ideas to directly manage reef tourism and minimize diver impacts have been proposed. For example, prohibitive measures of limiting access to reefs using carrying capacity methods (Hawkins and Roberts, 1997; Schleyer and Tomalin, 2000), total exclusion to reefs for periods of rest (Epstein *et al.,* 1999; Tratalos and Austin, 2001; Jameson *et al.*, 2007) and indirect strategies using education (Madin and Fenton, 2004) and modification of diver behavior using pre-dive briefings (Medio *et al.,* 1997; Camp and Fraser, 2012; Krieger and Chadwick, 2013), have been adopted. However, regulations of this nature neither preserve the reef resource nor the economy reliant upon it. As an emerging practice, the use of artificial reefs is being increasingly recognized as an effective management strategy to help alleviate user pressure on sensitive reef habitats (van Treeck and Schuhmacher, 1999; Zakai and Chadwick-Furman, 2002; Leeworthy *et al.,* 2006; Hasler and Ott, 2008; van Treeck and Eisinger, 2008; Polak and Shashar, 2012). These structures have been widely used to host scuba diving and other recreational activities in many locations worldwide (e.g. Mead and Black, 1999; Sutton and Bushnell, 2007; Edney, 2012) and are becoming increasingly more numerous (Johns *et al.,* 2001; Pendleton, 2005), with significant economic returns documented for recreational diving (e.g. Milton, 1988; Johns *et al.*, 2001; Pendleton, 2005). However, in order to maximize the conservation and economic benefits of using artificial habitats as alternative 'sacrificial' sites for natural coral reefs, many factors need to be understood and quantified.

In this thesis I have investigated issues relating to the use of artificial reefs, both as substitute diving and snorkelling sites for naturally occurring reefs, and from the broader social and economic dimensions of their recreational use. I conducted my study in Barbados, West Indies, a low lying coralline island that relies on its naturally occurring reefs (and artificial reefs) to support its diving and snorkelling tourism industries. Barbados is the most easterly landmass of the Caribbean archipelago (13°10'N, 59°32'W), situated some 150 km east of the Windward Islands of the Lesser Antilles (Figure A). Whilst it is a relatively small island with an area of only 431 km², it has a current resident population of 276,300 (Barbados Statistical Service, 2010), making it one of the most densely populated islands in the Caribbean (Belle and Bramwell, 2005).

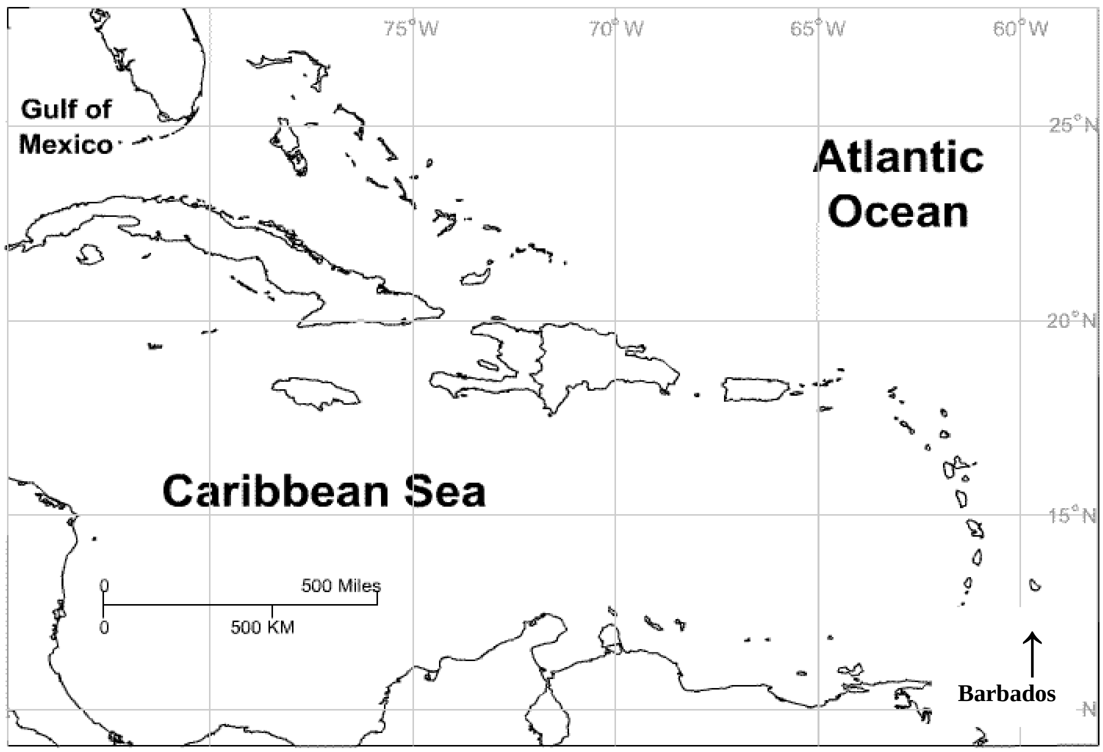


**Figure A. Location of Barbados situated within the Caribbean Basin, West Indies.**

Barbados's economy relies significantly on tourism, providing approximately 54% of the countries foreign exchange revenue (Worrell *et al.*, 2011). Ninety-two $km^2$ of fringing, patch and bank reef extending along the leeward coast of Barbados is a regular attraction with tourists, especially divers and snorkellers (Inter-American Biodiversity Information Network, 2010). However visible signs of anthropogenic degradation are apparent upon the reefs (Oxenford *et al.*, 1993; Government of Barbados, 2002), especially to sites adjacent to the densely populated tourist areas of the west coast (Cumberbatch, 2001). In fact, within the past 25 years, the fringing reefs in particular, have degraded both structurally (Lewis, 2002) and biologically (Bell and Tomascik, 1993). Various stressors, such as eutrophication (Tomascik and Sanders, 1985; Tomascik and Sanders, 1987a, 1987b; Tomascik, 1990; Tomascik, 1991; Lewis, 1997), bleaching (Oxenford *et al.*, 2008a, 2008b), *Diadema* mortality (Hunte *et al.*, 1986), hurricane damage (Mah and Stearn, 1986) and sedimentation

(Bell and Tomascik, 1993), have deteriorated the once flourishing reef system (Lewis, 1960; Stearn *et al.,* 1977; Pandofi and Jackson, 2006).

Formal protection of the islands reefs is minimal, being served by one small marine park consisting of 2.1 $km^2$ of reserve waters (Cumberbatch, 2001) located adjacent to the impacted west coast. With reef quality still threatened (Tomascik, 1990; Lewis, 2002; Oxenford *et al.,* 2008a, 2008b), the Government of Barbados recognize the urgent need to develop more effective conservation and management of their coral reef ecosystem (National Commission on Sustainable Development, 2004). A healthy reef system will not only continue to underpin the islands marine-based tourism, but it ensures greater resilience of the reefs to future threats of global warming (Oxenford *et al.,* 2008a, 2008b). In a bid to help conserve the natural coral reefs from visitor impacts, several artificial reefs have been gradually developed to diversify tourism amenity for divers and snorkellers (Agace, 2005). Indeed, the intention of the Government of Barbados to deploy further tourism-orientated artificial reefs (Hoetjes *et al.,* 2002; J. Blades, personal communication, March, 2009) over the forthcoming years, provided a strong incentive to conduct this research.

The principle aims of this thesis were to study the potential economic, social and conservation impacts of recreation-orientated artificial reefs and to evaluate their role in managing diving and reef-based tourism. In addition, I investigated the use of artificial reefs as an additional reef management strategy within Barbados's marine protected area; Folkestone Marine Reserve.

My research objectives were to:

1) Identify gaps in knowledge and establish future research priorities with relevance to the use of artificial reefs as recreational resources for scuba divers.

2) Quantify the reported recreational values (both market and non-market values) associated with artificial reef use worldwide.

3) Determine the characteristics, motivations and dive practices of recreational scuba divers in Barbados, West Indies, and report on their use, opinions and preferences towards artificial reefs as recreational scuba diving resources.

4) Use key attributes and motivational factors to measure diver enjoyment between artificial reef and natural reef sites in Barbados. Establish specific attributes of the artificial reef dive that significantly contribute to the enjoyment and satisfaction of the scuba diving experience.

5) Quantify the consumer surplus of visitor use of Folkestone Marine Reserve, by estimating:

a) Willingness of reef users to pay marine park entrance fees to conserve the natural reefs within reserve waters.

b) Willingness of reef users to pay marine park entrance fees to protect and maintain artificial reefs within reserve waters.

Using both a quantitative and qualitative approach to my research, this thesis is divided into six chapters. Chapter 3 through to Chapter 5 represents the results of field data collected in Barbados. In Chapter 1, I present a literature review concerned purely with the use of artificial reefs as recreational scuba diving resources. I divide my review into five thematic subject categories; general review and theory, environmental engineering, social dimensions of scuba diving and socio-economic and ecological impacts of artificial reefs. I then summarize my findings and make recommendations for future research priorities presented within the context of marine diving tourism on artificial reefs.

In Chapter 2, I quantify the recreational value of artificial reefs through a synthesis of data. I use artificial reef valuation studies that provide estimates of market values (expenditures) and non-market values (consumer surpluses) associated with the recreational uses of these resources. I calculate and present the resulting statistics for artificial reef values by; recreational activity, valuation methodology and region and compare values imputed to those presented by Brander *et al.* (2007) for natural coral reef recreation.

Chapter 3 explores the perceptions of recreational divers in Barbados. To achieve the aims of this research, I collect both quantitative and qualitative information from resident and visitor divers via a semi-structured, self-administered questionnaire (Appendix A). The survey instrument, consisting of four discreet sections, has the purpose of establishing divers' attitudes to and opinions of artificial reefs as diving resources, their artificial reef use, awareness and preferences, as well as the demographic profile of respondents. Moreover, using data collected from the survey, I explore the relationship between recreation specialization of scuba divers and resource substitution behavior relating to artificial reefs in Barbados.

To achieve the aims of Chapter 4, I extract information from the latter questionnaire (Chapter 3) to: (a) identify the most popular diving sites fringing the island (both artificial reefs and natural reefs) and (b) compile a list of key reef attributes and motivational factors that contribute to diver enjoyment and satisfaction. I use (in part) the extracted data supplied by respondents to compile a brief, one page self-administered survey (Appendix C), from which I directly measure divers' enjoyment between artificial reef dives and natural reef dives conducted in Barbados. Moreover, I aim to identify specific attributes of the artificial reef dive experience that contribute the most to diver enjoyment. I then go on to explore if certain diver characteristics (i.e. degree of diver experience, age and gender) are influenced by potential factors present within the enjoyment data, and if so, to what extent.

For the purpose of Chapter 5, I develop a survey (Appendix E) to quantify the value that divers and snorkellers place on conserving and maintaining both natural and artificial reefs within a marine protected area. By using a contingent valuation method from which to impute values; I conduct interviews to estimate visitors' willingness to pay marine park entrance fees to conserve either: (a) natural reefs within the marine reserve or (b) future artificial reef habitat for amenity enhancement. I use several variables embedded in the survey, including age, education, reef and marine concern and repeat visitation to the reserve, to help explain variations in willingness to pay. I also collect information on visitors' perceptions of artificial reefs, reef material preferences, reef conservation awareness and ratings on present conditions experienced within the marine waters of Folkestone Marine Reserve.

In the final chapter of my thesis; Chapter 6, I summarize the results by highlighting the main issues covered in each of the chapters and by discussing the key findings of my work, including the implications of my research for coral reef management. I then clarify the limitations of my research and go on to explore future avenues of enquiry where applicable. Finally, a conclusion is presented.

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# Chapter 1

## *The Use of Artificial Reefs as Recreational Scuba Diving Resources: Investigating the Potential*

### 1.1 Abstract

Coral reefs worldwide are attracting increasing numbers of recreational scuba divers leading to growing concerns of damage to these fragile and sensitive ecosystems. This chapter examines the increasing practice of utilizing artificial reefs as resources upon which to base scuba diving recreation and tourism activity. Research suggests that artificial reefs have the potential to divert scuba divers away from vulnerable reef habitats, helping alleviate anthropogenic pressures on natural coral reefs. In order to provide a frame of reference for this chapter, an overview of artificial reefs; their history, application and design, is first discussed, followed by a review of the literature evaluating the present knowledge specifically concerned with the use of artificial reefs for scuba diving amenity. Upon examination of the research, five main thematic categories emerged; general review and theory, environmental engineering, social dimensions of scuba diving and socio-economic and ecological impacts of artificial reefs. The chapter concludes by identifying areas of research requiring additional attention in this field of enquiry, and suggestions are given to develop new directions for future studies concerned with artificial reefs as recreational resources for the scuba diving industry.

### 1.2 Introduction

Coral reefs, despite their obvious value of beauty and diversity, are in precipitous global decline (Hoegh-Guldberg, 1999; Wilkinson, 2000, 2004; Burke *et al.,* 2011). The reasons for this are myriad; a multitude of natural and anthropogenic stressors acting in concert to erode the quality of ecological services that coral reefs provide. While coral reefs may have the ability to recover from natural perturbations such as storms and hurricanes (Nystrom *et al.,* 2000), it is the persistent and often chronic multiple anthropogenic disturbances that may threaten the existence of many coral reefs globally (reviewed in Dubinsky and Stambler, 2011). Negative impacts include; climate change and ocean acidification (Hoegh-Guldberg *et al.*, 2007; Perry *et al.*, 2013), over-fishing (Pauly and Chua, 1988; Burke and Maidens, 2004), pollution (Pastorok and Bilyard, 1985; Mora, 2008), invasive species (Betancur *et al.*, 2011), coastal development (Uyarra, 2009), sedimentation (Cortés and Risk, 1985; Nemeth and Nowlis, 2001) and uncontrolled dive tourism (e.g. Hawkins and Roberts, 1992; Leujak and Ormond, 2007). In addition, the decline in coral reefs comes at a time when marine coastal tourism is greatly expanding (Orams, 1999; Hall, 2001; World Tourism Organization, 2001), particularly coral reef recreation involving scuba diving and snorkelling (Ong and Musa, 2011; Musa and Dimmock, 2013).

Until recently, scuba diving on coral reefs was thought to be a relatively benign form of activity causing negligible damage to reefs, or at worst, low environmental impact. However, a plethora of research suggests that cumulative effects of diver impacts on corals such as damage caused by direct physical contact of fins and equipment, can cause significant localized destruction to reefs (e.g. Harriott *et al.,* 1997; Medio *et al.*, 1997; Rouphael and Inglis, 1997, 2001, 2002; Hawkins *et al.,* 1999; Tratalos and Austin, 2001; Barker and Roberts, 2004). If impacts occur, certain coral morphologies appear to be more susceptible to breakage than others. Branching corals of the genus *Acropora* (e.g. *A. cevicornis*) appear to sustain a majority of the damage caused by divers (Rouphael and Inglis, 1997; Zakai and Chadwick-Furman, 2002; Hasler and Ott, 2008; Au *et al.*, 2014). Breakage to corals has been shown to reduce overall growth and increase predation (Guzner *et al.*, 2010) affect sexual reproduction (Zakai *et al.*, 2000) and increase coral disease prevalence (Lamb *et al.*, 2014). Moreover, divers may also cause harm to corals by inadvertently stirring up benthic sediments, potentially subjecting corals to increased sediment loads (Zakai and Chadwick-Furman, 2002; Hasler and Ott, 2008). Several empirical studies have indicated that a minority of scuba divers with certain characteristics are generally responsible for the majority of damage occurring to coral reefs. For example; male divers (Rouphael and Inglis, 2001), inexperienced divers (Roberts and Harriott, 1994; Walters and Samways, 2001; Warachananant *et al.*, 2008; Chung *et al.*, 2013) and camera users (Rouphael and Inglis, 2001; Walters and Samways, 2001; Barker and

Roberts, 2004; Chung *et al.*, 2013), are all documented as having higher than average contact rates with the surrounding reef.

Research into management strategies to directly control diver impacts has typically focused on interventions restricting numbers of individuals to popular reefs. This has been achieved by pre-determining a ‘safe’ level of carrying capacity for recreational divers on reefs (Hawkins and Roberts, 1997). However, determining a safe limit for scuba diver numbers is an inexact task (Davis and Tisdell, 1995) confounded by a combination of factors that may vary widely between reef sites (Jameson *et al.*, 1999). For example; the type and vulnerability of corals (Rouphael and Inglis, 1997; Schleyer and Tomalin, 2000), the level of diving education and environmental awareness of participating divers (Rouphael and Inglis, 1997) and the presence of other anthropogenic stressors such as particulate pollution (Hawkins and Roberts, 1997). Such a diverse range of variables, which are highly subjective, may alter over time as factors change, thus the whole concept of carrying capacity as a paradigm for sustainable reef management has been challenged as unworkable (McCool and Lime, 2001).

More recently, Di Franco *et al.* (2009) suggested the use of a scuba trail vulnerability index to augment carrying capacity measures or to be used in isolation, while Lloret *et al.* (2006) suggested the use of benthic mapping and community vulnerability as a complementary tool for managing diving activities. However, these concepts require continual monitoring by marine personnel, something that can be time consuming and costly (Estrada *et al.*, 2004). Furthermore, such management strategies may not be successful at an ecological level, as neither extract the source of the potential impact; the diver. Increasingly, a more positive management measure adopted by diving resource managers is to use artificial reefs with the aim of diverting numbers of visitors away from sensitive reef habitats; mitigating damage caused by scuba divers (Leeworthy *et al.*, 2006; van Treeck and Eisinger, 2008; Polak and Shashar, 2012).

Artificial reefs, a form of modified space in aquatic ecosystems (Lawton and Weaver, 2001), can offer acceptable alternatives to natural reefs (e.g. Blout, 1981; Stolk *et al.*, 2005; Leeworthy *et al.*, 2006; Polak and Shashar, 2012) by providing divers with a nature-based experience as well as new and novel dive opportunities. Soon after deployment, artificial reef aggregates fish species (Stone *et al.*, 1979; Bohnsack *et al.*, 1994; Arena *et al.,* 2007) and other mobile marine organisms, and over time denuded reef material is colonized by a succession of algae and invertebrate species (Bailey-Brock, 1989; Perkol-Finkel and Benayahu, 2004, 2005, 2007; Al-Horani and Khalaf, 2013). Artificial habitat may also attract snorkellers (if deployed in sufficiently shallow water) and anglers, with all three activities positively contributing to local host economies (e.g. Johns *et al.,* 2001; Johns, 2004; Leeworthy *et al.,* 2006). Whilst angling is viewed as a consumptive activity, scuba diving together with snorkelling are non-consumptive and viewed by some as exemplary forms of marine ecotourism (Garrod and Wilson, 2003). In fact, it is suggested that scuba diving demonstrates the key principles of ecotourism; in that it can be sustainably managed, it can provide opportunities within environmental education and is clearly a nature based experience where humans may interact with their natural environment (Blamey, 2001). However, some observers may argue that the very size of the world scuba diving industry prevents it from being considered as a true form of ecotourism (Carter, 2008), especially when the practice of diving contributes to the degradation of coral reefs (e.g. Hawkins *et al.,* 1999; Tratalos and Austin, 2001; Barker and Roberts, 2004; Hawkins *et al.,* 2005).

While a plethora of research exists on artificial reef design, biology and ecology (reviewed in Bohnsack and Sutherland, 1985), few academic studies have been published concerning the recreational use of artificial reefs including the social and economic dimensions in this field of enquiry. As a consequence, many issues surrounding the recreational use of artificial reefs remain largely vague and speculative. For example; a greater understanding of what roles these resources play within the diving choice spectrum is required for decision makers and policy makers to plan management strategies linked to the phenomenon of divers' choices. A predictive understanding of habitat choice between natural reefs and artificial reefs could be highly beneficial for economic reasons, as artificial reef projects are costly to plan and execute (Pendleton, 2005). Ultimately, increasing the socio-economic understanding of recreation-orientated artificial reef use and dive practices will help contribute to reef conservation and the sustainability of the diving tourism market.

## 1.3 Purpose and Aims of Chapter 1

The purpose and aims of this chapter were as follows. To first provide an overview of artificial reefs; their history, geographical distribution, application and design, and to then briefly discuss the activity of scuba diving within the context of artificial reefs. In order to gain an understanding of the recreational use of these structures by divers, the second section reviews the published literature concerned purely with artificial reefs as recreational diving resources. The chapter concludes by identifying and recommending future projects and areas of research in need and worthy of additional study, with relevance to the use of artificial reefs for scuba diving amenity.

## 1.4 Artificial Reefs

### 1.4.1 Definition

The definition of an artificial reef in the modern era of reef-building, has evolved over the last half century (Seaman and Jensen, 2000), possibly due to some confusion amongst academics, politicians and coastal planners, as to what actually constitutes an artificial reef (Pickering *et al.*, 1998). Accidental shipwrecks for example, are typically classified as artificial reefs (Seaman and Jensen, 2000), as adopted in this thesis. However, under some definitions, shipwrecks are not considered artificial reefs because they are not intentionally sunk (Jensen, 1997). In addition, the definition of artificial reef has been widened to 'artificial habitat', though not commonly used in purely marine based studies as it is a term used to cover both freshwater and saltwater settings (Seaman and Sprague, 1991). In contrast, Pitcher and Seaman (2000) differ to use the term 'artificial' for reef, as they perceive it as having negative connotations, and instead employ the term 'human-made reefs'. Notwithstanding, for the purpose of this thesis, the term 'artificial reef' and 'artificial habitat' will be used interchangeably. Table 1.1 presents examples of ecologically based definitions of artificial reefs derived from the literature.

**Table 1.1** Selected artificial reef definitions.

| ***Author (Year)*** | ***Definition*** |
|---|---|
| Brock *et al.* (1985) | Artificial reefs may be viewed as the development of productive habitat in an otherwise unproductive location (p.318). |
| EARRN, refer to Jensen (1997) as cited in Pickering *et al.* (1998) | An artificial reef is a submerged structure placed on the substratum (seabed) deliberately, to mimic some characteristics of a natural reef (p.505). |
| Seaman and Jensen (2000) | An artificial reef is one or more objects of natural or human origin deployed purposefully on the seafloor to influence physical, biological or socioeconomic processes related to living marine resources. Artificial reefs are defined physically by the design and arrangement of materials used in construction and functionality according to their purpose (p.5). |
| Anonymous (2003) | Any material or matter deliberately placed in an area of the marine environment where that structure does not exist under natural circumstances for the purpose of protecting, regenerating, concentrating or increasing populations of living marine resources, or for enhanced recreational use of the area (p.45). |

### 1.4.2 History and Geographical Distribution

Historically, the establishment of artificial reefs has had a long tradition especially in tropical and subtropical waters. It has been postulated that Neolithic observations occurring at shorelines around the world, led to the discovery that deployed materials such as logs, attracted and resulted in a greater harvest of marine life (Seaman and Sprague, 1991; Seaman and Jensen, 2000). However past information is vague and realistically such activities may have occurred a great deal earlier than the Neolithic period.

In more recent times, the first artificial reefs to be constructed in the United States were carried out in the mid-1800's (Stone, 1974; Murray and Betz, 1994), preceded by the Japanese, who had begun artificial reef construction several hundred years earlier (Ino, 1974). While the lack of a formal world database (Stone *et al.,* 1991) for artificial reef construction makes it more difficult to determine the precise geographical distribution of artificial reef habitats, a database does exist for European projects through the establishment of the European Artificial Reef Research Network (EARRN) (Baine, 2001). Despite no global database, a literature review (Baine, 2001) reported that artificial reef construction and research spanning the past two decades, has been dominated by North America, followed by Japan and Europe, with Italy being the leading country in Europe. In addition, Australia, Canada and the Caribbean and Pacific Ocean islands represent notable areas of the world concerned with artificial reef development and research effort (Seaman and Sprague, 1991).

However, when it comes to the development of artificial reefs for 'purely' marine-based recreation; it is the United States that is viewed as the leading authority and expert in the field (Seaman and Jensen, 2000). Deployment and research activity appears to have been concentrated in offshore waters of Florida, Texas and Louisiana, where structures are used as a means of expanding recreational pursuits such as scuba diving (Ditton *et al.,* 2002; Leeworthy *et al.,* 2006) and fishing (Ditton and Auyong, 1984). In addition, the Canadian and Australian governments have both supported a number of successful 'ships to reef' programmes aimed at recreation (Jones and Welsford, 1997; Dowling and Nichol, 2001; Schaffer and Lawley, 2007).

### 1.4.3 Purposes

The goals of artificial reef deployment are myriad depending on the purposes for which they were designed and built. In modern times, placement of structures underwater to create artificial habitat has become an important resource enhancement technique, naturally increasing numbers of reef associated species such as macro-algae, invertebrates and fishes. Traditionally, artificial reefs were typically used in fisheries management as fish aggregating devices to enhance local fisheries (Bohnsack and Sutherland, 1985; Collins *et al.,*1990; Pickering *et al.,* 1998; Seaman, 2000), with this still remaining the most ubiquitous reason for their construction to date (Svane and Petersen, 2001). In a more controlled situation, artificial reefs are used to provide multipurpose complexes that support aquaculture and ranching of marine species like oysters (Fabi and Fiorentini, 1990) and provide shelter for lobster (Lozano-Alvarez *et al.,* 1994; Jensen and Collins, 1995; Hernkind *et al.,* 1997). The protection of biological habitat is a common use of artificial reefs in southern Europe (Bombace, 1997; Charbonnel and Bachet, 2011). For example; in the western Mediterranean Sea, structures have been used as barriers and anti-trawling devices in a bid to protect *Posidonia oceanica* seagrass beds (Guillen *et al.,* 1994) and in marine protected areas, constructed reefs are used as tools for demarcation and preservation purposes (Harmelin, 2000; Claudet and Pelletier, 2004).

Additional objectives for artificial reefs have been expanded to include, *inter alia;* the creation of recreational amenity for diving and fishing (e.g. Milton, 1989; Pendleton, 2005; Leeworthy *et al.,* 2006), diver impact mitigation to natural reefs (van Treeck and Schuhmacher, 1999a, 1999b; Leeworthy *et al.,* 2006; Polak and Shashar, 2012), coastal protection (Harris, 2003; Ranasinghe and Turner, 2006; Christie, 2009; Rendle and Esteves, 2010; Ng *et al.,* 2013), water quality enhancement (Miller, 2002), scientific study (Tupper and Hunte, 1998; Rilov and Benayahu, 2000) or any combination of these objectives. Mead and Black (1999) studied the multifunctional objectives of an artificial reef programme in New Zealand. Designed primarily for coastal protection, the reef programme was also aimed at coastal amenity enhancement, particularly surfing, diving and snorkelling. A unique feature of the project was the ability to remove the reef structure in the event of any negative effects to the environment. As a final point, artificial reefs form important components of coral reef restoration efforts globally (e.g. Pratt, 1994; Rinkevich, 1995; Pickering *et al.,* 1998; Rogers and Garrison, 2001; Seaman, 2007). Restoration projects are particularly evident within coastal waters of Florida, mainly as a result of boat groundings and anchor damage (Jaap and Hudson, 2001; Pretch *et al.,* 2001), and also in the Maldives, where reef flats have been degraded by coral mining for the construction industry (Clark and Edwards, 1994; Clark and Edwards, 1999).

While numerous positive benefits are clearly derived from artificial reef generation, they can also have a range of potential negative environmental impacts that are still being debated by scientists (reviewed in Bortone, 2006). For example, the fish ‘attraction versus production’ debate prevails (Pickering and Whitmarsh, 1997; Pitcher and Seaman, 2000; Arena *et al.,* 2007), that focuses on the likely diversion of mobile species from natural reefs to artificial habitat causing changes in trophic or food web structure (Bohnsack *et al.*, 1994) and an imbalance in predators, grazers or competitors present (Bortone *et al.*, 1998; Dafforn *et al.*, 2012). Also, due to the concentration of fishes on artificial reefs (Stone *et al.*, 1979; Bohnsack *et al.*, 1994; Arena *et al.*, 2007), the potential for exacerbation of over fishing exists (Polovina, 1989). Moreover, artificial reefs may act as ecological corridors for the introduction of marine pests, pollutants, alien species and diseases into the surrounding natural habitat (Pears and Williams, 2005). Other potential risks associated with reef deployment include beach erosion (Roshanka and Turner, 2006) and effects on local hydrology (Spieler *et al.*, 2001).

### 1.4.4 Materials

Materials used commonly for the deliberate creation of artificial reefs are numerous and vary across the globe. They include; concrete, tyres, rock, decommissioned vessels and obsolete petroleum platforms (Bohnsack and Sutherland, 1985; Aabel *et al.*, 1996; Pendleton, 2005). Derelict vessels are particularly attractive to divers (e.g. Blout, 1981; Ditton *et al.*, 2002; Stolk *et al.*, 2005; Shani *et al.*, 2011; Edney, 2012) having been used to enhance scuba diving destinations worldwide (Wilhelmsson *et al.*, 1998; Dowling and Nichol, 2001; Pendleton, 2005; Leeworthy *et al.*, 2006; Morgan *et al.*, 2007; Leeworthy, 2011). However prior to sinking, vessels need to be rendered diver safe, by detaching objects which may ensnarl individuals. In addition, hazardous or toxic materials such as mercury or hydrocarbons need to be removed from ships (Jones and Welsford, 1997). For general reef construction, concrete is by far the most favoured and utilized reef material (Baine, 2001), especially in European projects (Bombace *et al.*, 1993) as well as being the key material in Japanese reef building programmes (Pickering *et al.*, 1998). Concrete maybe fashioned into pipes, blocks and cubes and used in combination with additional materials such as fuel ash and gypsum (Collins *et al.*, 1994) or tyres (Gillam *et al.*, 1995) to form reefs. The biological efficacies of reefs constructed of concrete have been confirmed (e.g. Brock and Norris, 1989), as well as novel reef materials using concrete. For example, a waste ceramic-concrete aggregate was found to be a ‘biologically’ productive material for reef construction, based on invertebrate settlement assessment (Bedoya *et al.*, 2014). Moreover, decommissioned offshore platforms are employed extensively in the Gulf of Mexico to form reef structures (Wilson and van Sickle, 1987; McGurrin and Fedler, 1989; Sammarco *et al.*, 2013) often providing a focus for recreational diving and fishing (Dugas *et al.*, 1979; Stanley and Wilson, 1989). More recently, offshore wave power foundations have been documented as structures that can function as reefs, providing suitable sites upon which the colonization process can take place (Langhamer *et al.*, 2009). However, wind farm structures may exert a negative effect on fisheries, especially the inshore sector through displacement of fishing effort (Rodmell and Johnson, 2002).

In previous years, a majority of artificial reefs, especially those in the United States, were constructed from materials of opportunity (Stone *et al.*, 1991); discarded surplus materials such as automobile bodies, tyres and debris from demolition projects. Scientists have since established that many of these materials contain substances toxic to marine biota, such as heavy metals present in scrap tyres (Collins *et al.*, 2002) and in alloys and paints (Wells, 2004) which potentially have cumulative and long lasting environmental effects. Moreover, marine ecologists challenge the dumping of waste materials on the seabed, not only because they may be toxic and unsightly, but because they are poor substrates for invertebrate colonization (Fitzharding and Bailey-Brock, 1989), are resistant to diagenetic processes such as those performed by borers (van Treeck and Schuhmacher, 1999a) and offer inappropriate protection for fish (Brock and Norris, 1989). In general, reefs constructed of junk offer little, if any, ecological value (Brock and Norris, 1989). Furthermore, poor deployment methods of waste tyres in the United States resulted in the tyre reefs breaking up and individual tyres washing ashore after storm events. This led to the restrictive use and banning of tyres for reef construction in United States coastal waters (Collins *et al.*, 1995). Figure 1.1 presents an image of waste tyres dumped off the coast of Florida to form an unsightly and un-productive artificial reef.

**Figure 1.1 Tyre reef.** Tyres deployed in the 1970s to form an unsightly artificial reef (www.nytimes.com/2007/02/18/us/18tire.html).

More recently, the use of ecologically sound materials have been favoured for the creation of artificial reefs. This is essential if artificial reefs are to represent and function as effectively as natural substrates. With a greater environmental awareness, purpose designed reefs fulfill many criteria. For example, they are aesthetically pleasing (Hudson *et al.,* 1989), they can provide multidimensional and non-repetitive habitats (Tallman, 2006) and offer a desirable substrate for colonization to take place (van Treeck and Schuhmacher, 1999b; Shahbudin *et al.,* 2011). Three well established reef technologies are now available for fabricating module reef structures; Biorock (electrochemical accretion technology), Ecoreefs and Reef-Balls™. These materials have been used for purpose designed reef systems for various projects around the world (Tallman, 2006).

#### 1.4.4.1 Biorock

Biorock technology (www.biorock.org) was first proposed and described by Hilbertz *et al.* (1977) and further developed by Schuhmacher and Schillak (1994). The patented technique involves the formation *in situ* of semi-artificial reef substrates by electrolysis, using calcium and magnesium ions present in seawater. When a metal matrix is connected to a DC power supply, magnesium and calcium minerals precipitate upon the cathode (generally a conductive material such as steel mesh), while chlorine and oxygen molecules evolve around the anode. The accreted material is chemically similar to reef limestone consisting mainly of aragonite (calcium carbonate) and brucite (magnesium hydroxide) that has a load bearing strength (80 Newton's/$mm^2$) far superior of ordinary cement (Goreau, 2010). Due to the materials natural composition, it is viewed as a suitable substrate for natural colonization of a variety of reef species (van Treeck and Schuhmacher, 1999a). Also, the steel mesh matrix has the advantage that it may be shaped into a variety of morphologies giving rise to reef complexity and at the same time being aesthetically pleasing.

van Treeck and Schuhmacher (1999a, 1999b) have explored the use of accretion technology and developed a concept for the creation of an underwater park to function as a diver aggregation device (reviewed in section 1.5.2). They have a visionary idea to create underwater attractions in unobjectionable areas in order to divert user pressure from vulnerable coral reefs. With some success, van Treeck and Schuhmacher (1999b) have conducted experiments in the Red Sea to test simultaneous attachment of living coral nubbins to the electrochemically deposited substrate. Figure 1.2 presents the development of a Biorock proto-reef community over a 5 year period (van Treeck and Eisinger, 2008).

**Figure 1.2 Biorock reef.** Tetrahedron structure 5 years after installation consisting of accreted Biorock and developing coral nubbins (van Treeck and Eisinger, 2008).

A number of significant environmental benefits have been suggested using the Biorock technology for reef construction. For example; no alien material (apart from the metal matrix) is introduced into the marine environment, it is a 'carbon negative' material if used with protocells (Armstrong and Spiller, 2010) and the substrate may be created at the site eliminating the need to transport construction materials. Moreover, experiments conducted in Indonesia suggest reefs constructed of Biorock exhibit higher coral growth rates, brighter tissue colour, greater branching morphology and support higher densities of zooxanthellae, compared to natural reef substrate (Goreau *et al.,* 2004). This innovative technology, described by Goreau and Hilbertz (2005) as emerging 'seascape architecture', appears to be gaining momentum around the world with artificial reef installations using Biorock in Jamaica, St. Croix and Bali (Kaufman, 2006; Bottema and Bush, 2012). Approval has recently been granted to develop a sizeable Biorock reef for recreation, off the Fort Lauderdale coast, Florida, using solar energy to power the accretion process (www.blueseascourtyard.com). With the claim that Biorock structures have up to nearly 100% live coral cover (Goreau and Hilbertz, 2005), they may in due course represent highly desirable tourism attractions to marine recreationists.

1.4.4.2 EcoReefs

In contrast to the gradual accretion of Biorock, EcoReefs (www.ecoreefs.com) are best described as snowflake shaped stoneware modules that have the overall appearance of grouped Acroporid coral colonies (Figure 1.3). The modules are ideal for coral and invertebrate settlement as they are chemically inert, non-toxic and have a large surface area available for recruitment processes (Moore and Erdmann, 2002). In addition, the branching coral morphology includes many vertical surfaces that are generally preferred by coral larvae for settlement (Baynes and Szmant, 1989; Wendt *et al.,* 1989; Knott *et al.,* 2004). Upon installation, the EcoReef modules look instantly organic, interlinking to create a spatially complex habitat for the refuge of coral reef fishes and invertebrates. Figure 1.3 shows the interlocking nature of the EcoReef modules. The branching design of the units also allows for the quick attachment of coral nubbins with a cable tie, whilst each module has a settlement plate situated at the centre to further enhance coral recruitment and to create a microenvironment (Moore and Erdmann, 2002).

**Figure 1.3 EcoReef.** Teardrop butterfly fish *Chaetodon unimaculatus* grazing on EcoReefs **(**www.ecoreefs.com).

EcoReefs fulfill two principal roles by combining function with aesthetic appeal. The latter is of particular importance in popular dive destinations in order to attract and satisfy the requirements of marine recreationists seeking productive, visually appealing reefs. Moreover, Moore and Erdmann (2002) point out that EcoReefs are important components of reef restoration programmes, as they provide physical stability and are suitable for a variety of topographies including placement on slopes. Over a 3 year period, Moore and Erdmann (2002) investigated the performance of EcoReef clusters in restoring rubble fields on reefs damaged by blast fishing at Bunaken National Park, Indonesia. After 8 months, they reported the reef had flourished with coral recruits, invertebrates and a variety of fish species. Apart from the latter authors, no other published research appears to be available using EcoReefs as the standard.

#### 1.4.4.3 Reef Balls™

Reef Balls™ developed by Todd Barber of the Reef Ball Foundation Inc. (www.reefballs.org), are state of the art designed artificial reefs. They are claimed to be the most widely used purpose designed reef modular system in the world used in over 1,000 projects (Barber, 2000). The internationally patented technology appears appealing due to its level of flexibility allowing for the creation of custom designed reefs. The cast hemispheres are made from pH stabilized concrete and are available in a variety of morphologies and sizes depending on the biological and physical requirements of a project. Examples of the various forms into which Reef Balls™ may be moulded are presented in Figure 1.4. To a certain extent, these artful structures appear to mimic large, eroded, massive coral heads (Ortiz-Prosper *et al.*, 2001); a formation commonly found on Caribbean reefs.

Reef Balls™ possess many features that mimic natural reef conditions such as hole sizing, void spacing, stability, surface chemical composition and surface texture. The latter is important as physical texture has been found to affect larval settlement and species composition on artificial reef (Tomascik, 1991; Reyes and Yap, 2001). Because of the custom designed nature of this product, the surface texture of Reef Balls™ may be altered to suit specific requirements of a project. To construct the units, fiberglass moulds containing buoys are filled with concrete mixed to give a pH that matches the surrounding seawater. The void spaces are created using the placement of various sizes of inflatable balls prior to filling. These openings are important as they are used by fishes and other marine species for refuge and are vital in creating vortexes around the units to capture biologically important nutrients (Barber, 2000).

**Figure 1.4 Examples of Reef Balls™**. Standard Reef Balls™ (left) in three sizes and a layer cake Reef Ball™ (www.reefball.org).

Once deployed, stability of modules on the seabed is achieved by either rods or piling, or by attaching the reef units to articulated mats (Harris, 2006). Due to the varying morphologies and sizes of the units (Figure 1.4), variations in topography may be achieved when designing an artificial reef using this technology. For example, the modules when grouped may be used to create 1-3 meters of vertical relief (Kaufman, 2006). Structures as large as breakwaters, used as part of beach nourishment projects, have been created (Harris, 2006), the largest one to date being a reef deployed off the coast of Antigua (Kaufman, 2006) (Figure 1.5). Many reef restoration projects, especially off the Florida coast, appear to use the Reef Ball™ modular framework for damaged reefs (e.g. Glynn *et al.*, 2002). Typically, Reef Balls™ are used to create new reefs in biologically depauperate areas for the purpose of ecological enhancement, and to provide new opportunities for scuba diving, snorkelling and recreational fishing. Barber (2000) identified that over fifty percent of all Reef Ball™ reefs are built to support scuba diving activities. Individual projects may also serve a variety of functions. For example, the breakwater project in Antigua (Figure 1.5) was also developed as a recreational feature combining snorkel and diving trails.

**Figure 1.5 Aerial photograph of a 5-row Reef Ball™ breakwater structure in Antigua.** Gaps and special areas have been incorporated into the design to accommodate divers and snorkellers (Harris, 2006).

A great deal of gray literature on Reef Ball™ projects is archived on a dedicated website (www.artificialreefs.org). In spite of the fact that the Reef Ball™ Development Group are willing to provide free moulds to Universities and other research institutes (Barber, 2000), just two scientific studies have been published to date using this technology. The most recent study (Ortiz-Prosper *et al.*, 2001), investigated the survivorship and attachment of selected coral species on Reef Ball™ units and over dead coral heads in waters off Puerto Rico. After one year and despite the stress of Hurricane George and a widespread bleaching event, a survival rate of 93% was recorded for the Reef Ball™ treatment compared to 85% survival on dead coral heads. These results concur with the findings of Hudson *et al.* (1989) who built a small patch reef using concrete modules implanted with hard corals. Ten years post deployment, the modules showed no signs of deterioration whilst the overall survivorship of corals was 87.5%. These limited but positive data indicate the potential use these concrete modules have for both reef restoration projects and the creation of new marine habitat. The two studies described, used a similar sampling methodology, bringing a degree of consistency to the projects. However, Bortone (2006) points out, that there is still a need to achieve greater standardization in sampling methodology in artificial reef research. Because of the widespread use of

Reef Balls™ he suggests these modular units have the potential of becoming a 'worldwide defacto reef standard', serving as a means of calibrating reef dependent biological data.

### 1.4.5 Planning of Artificial Reefs

Unplanned artificial reefs such as shipwrecks, breakwaters and oil and gas platforms, are considered by some researchers as novel experiments in marine community development (Perkol-Finkel and Benayahu, 2004; Rilov and Benayahu, 2000). In contrast, planned artificial reefs are purpose designed structures that are a means of creating carefully planned habitat offering the opportunity to increase resources and manipulate marine organisms (Seaman *et al.*, 1989). However, in order to ensure an artificial reef project is successful and yields the desired outcome(s); a rigorous planning procedure ideally needs to be followed. In a bid to up-date past artificial reef planning philosophies, Gordon and Ditton (1986) present a systems framework to guide future planning efforts in artificial reef development. They propose six sequential elements integrated into artificial reef development; advance planning, site location and reef design, permitting, construction and deployment, maintenance and management and lastly, project evaluation. Each one of these elements is used to frame the following examination, with an emphasis placed on the recreational uses of artificial reefs.

#### 1.4.5.1 Advance planning

Prior to the deployment of an artificial reef, demonstrable onshore and ecological benefits need to be accurately assessed as well as determining if sufficient demand exists for a new or expanded artificial reef. Only then can reef goals and objectives be incorporated into a planning framework based on community or regional needs. Understanding reef demand and usage patterns is required to provide optimally used artificial reefs. For example, if the reef is intended to be used by local residents or by a wider international population? Questions regarding the reefs accessibility (near or offshore) need to be addressed, as well as an examination on the type of reef (e.g. sunken vessel, concrete modules, Biorock) and depth of deployment. If the aim of a project is to provide local tourism income, a certain degree of 'tourism appeal' needs to be embodied within the reef project.

A necessity to forge ties between governmental bodies, reef building organizations, local businesses (e.g. diving school operators) and the general public are all important to accommodate for compromise in the reef planning process and may help initiate multiple opportunities. Loftus and Stone (2007) suggest the creation of an artificial reef committee and outreach programme to facilitate information exchange and stimulate public interest. The advance planning stage of reef development is an ideal time to anticipate potential conflicts of use that may arise. Pre-site selection discussions and exclusionary mapping processes may be necessary to minimize latent contention occurring (Loftus and Stone, 2007). Gordon and Ditton (1986) also emphasize the need to devote early attention to financial budgets at the advance planning stage. Loftus and Stone (2007) noted inadequate funding as being the limiting factor for a majority of past reef programmes. Suitable fiscal control can be coordinated through the creation of a non-profit organization that can accept donations as well as review, account and disseminate funding (Loftus and Stone, 2007). Such acquisitions for artificial reef creation include; transportation of reef material and deployment, insurance, marker buoys, maintenance and evaluation studies. Final budget costs are generally conducted at the end of the next phase.

#### 1.4.5.2 Site location and reef design

The correct site location for artificial reef deployment is critical to their ecological, physical and economic success. Reported reef failures are numerous (reviewed in Bohnsack and Sutherland, 1985), including the disappearance of artificial reef material into bottom substrate (Mathews, 1978) and a reef deployed in eutrophic waters (Lindenberg, 1973). Pickering and Whitmarsh (1997) cite ocean floor type as being crucial to the locating of an artificial reef, where the bed must support the weight of reef material. Areas of high sediment loading in the water column also need to be avoided, for both erosion/accretion reasons (Lockwood *et al.*, 1991) and for water clarity purposes; an important factor determining diver site choice (Fitzsimmons, 2009). Water depth of deployed material is an additional consideration, being important for determining species composition and for regulatory and navigational reasons (Loftus and Stone, 2007). Divers also have preferred depths at which to dive (Ditton *et al.,* 2002; Chapter 3). To help identify potential artificial reef sites, Gordon and Ditton (1986) recommend an inventory of existing artificial reefs, access points and shore based infrastructure to assist in the decision. Accessibility and travel time to a reef resource have also been recorded as important determinants of reef choice (Milton, 1989; Pendleton, 1994; Stolk *et al.,* 2005).

A key factor in the siting of an artificial reef is the proximity of the structure to the natural reef substrate. According to Kuwatani (1982), the location chosen for the reefs placement (from a biological perspective), was more important than the actual reef design. This is because natural reef habitat can provide an important source of transient fishes (Campos and Gamboa, 1989; Koeck *et al.,* 2013), juvenile fish larvae (Stone *et al.,* 1979) and planulae larvae (Reyes and Yap, 2001) to the recruitment of artificial reefs. In addition, water depth (Walton, 1979), water temperature (Nakamura, 1982) and oceanic conditions such as wave direction and force (Grove and Sonu, 1983), are all documented as influencing the biological success of artificial reefs. If an artificial reef project is to provide resources for recreational diving, a biologically productive reef is important to attract users (e.g. Milton, 1989; Ramos *et al.,* 2006; Musa *et al.,* 2006; Fitzsimmons, 2009; Polak and Shashar, 2013).

The biological success of planned artificial reef is also linked to design considerations with many factors considered important (Bohnsack and Sutherland, 1985; Spieler *et al.,* 2001). These include the size of reef (e.g. Bohnsack *et al.,* 1994; Bombace *et al.,* 1994), orientation of structure (e.g. Nakamura, 1982; Rilov and Benayahu, 2000), complexity of reef (e.g. Rilov and Benayahu, 1998; Connell and Jones, 1991) and material choice (e.g. Scott *et al.,* 1988; Clark and Edwards, 1999). Practical considerations linked to material use include recruitment of desired target species, such as potential settlement of coral larvae; influenced by texture and composition of reef material (e.g. Fitzharding and Bailey-Brock, 1989; Reyes and Yap, 2001). In addition, fishes are documented as exhibiting texture (Eckert, 1985; Jones and Syms, 1998) and colour preferences (Grove and Sonu, 1985) of artificial reef materials. The types of materials used for artificial reef construction are reviewed by Baine (2001), who suggests the use of inert, non-polluting, durable materials that are compatible with robust biotope management.

To facilitate ecological processes and reduce the time taken for contrived reefs to develop functional reef communities, transplantation of coral fragments or propagules may be used (e.g. Hudson *et al.*, 1989; Oren and Benayahu, 1997; van Treeck and Schuhmacher, 1999b; Yap, 2003; Abelson, 2006; Polak and Shashar, 2012; Ammar *et al.*, 2013), achieving instant aesthetic appearances to structures (Figure 1.6). However, survival rates for transplanted coral can be low (Garrison and Ward, 2012). Additionally, chemical morphogens (e.g. crustose coralline algae) may be used to promote settlement of coral larvae and other planktonic larvae on denuded artificial reef material (Morse and Morse, 1996; Neo *et al.*, 2009). Aesthetic components such as the latter examples are typically built into artificial reef designs aimed at tourism markets (Kaufman, 2006), especially the scuba diving sector (van Treeck and Schuhmacher, 1999b; Polak and Shashar, 2012).

**Figure 1.6 A standard Reef Ball™ module.** The module is planted with propagated coral fragments *Acropora* spp. (on rim of Reef Ball™) and rescued and transplanted *Gorgonians* and *Porites astreoides* fragments. Adult reef squid; *Sepioteuthis sepioidea*, are displaying mating colours (www.reefball.org).

In general, Gordon and Ditton (1986) note that design and location factors should be evaluated with relevance to present and future needs of the artificial reef and in light of project objectives. They also emphasize the importance of potential interactions between accessibility, reef size and general offshore location, and highlight the fact that an accessible artificial reef may be over utilized, diminishing the overall enjoyment of those using it.

1.4.5.3 Permitting

Regardless of the country concerned with artificial reef deployment, the permitting process is put in place to ensure protection of the natural environment and to promote public wellbeing and safety**.** However, as Pickering *et al.* (1998) comment, for the majority of countries, institutional frameworks governing artificial reefs are complex, as essentially artificial reefs on the seabed are a matter of property rights. In most legal systems the seabed belongs to the state (Pickering, 1997), thus consent to occupy the seabed for purposes of artificial reef creation has to be sought, and a lease, licence, permit or concession obtained from the governing body of the country. In the United Kingdom, three permits/licences are required from the Crown Estate; navigational consent, seabed lease and a works licence, as well as a marine construction licence to deploy within the 12-mile territorial limit (Pickering, 1997). In the United States, state permits are applied for through the United States Army Corps of Engineers (Gordon and Ditton, 1986).

For licence assessment purposes, reef plans detailing the location, siting, construction, use and maintenance, as well as a programme to manage and monitor the intended reef, are required (Gordon and Ditton, 1986). Responsibilities towards the marine environment are key factors in the licencing processes that include a provision the proposed reef has been designed for an acceptable purpose. Additional legal conditions include safety of navigation and safety of coastal defense works. Once an artificial reef is *in situ*, issues of access can arise. In the absence of well defined property rights, open-access to artificial reef territories pertains (Pickering, 1997). However, exclusive rights for reef owners can exist for marine resources harvested from artificial reefs, including certain types of shellfish, lobster and other crustacean (Milton *et al.*, 2000).

1.4.5.4 Construction and deployment

Gordon and Ditton (1986) assert that the construction and deployment phase of artificial reef development is the most challenging and complex element of a project. The purchase of materials and their transport as well as the organization of deployment equipment and manpower, all need to be coordinated in a timely, cost-effective way. A pre-planned work schedule is effective in merging these various elements and in keeping costs down. Suitable localities to clean, prepare or modify reef materials, need to be chosen prior to deployment. For deployment purposes, the use of a barge, landing craft or other vessel is usually required, with the exception of Reef Balls™ which, with smaller projects in particular, can have a floating deployment (Barber, 2000). To avoid materials being sited in the wrong locality or dispersed upon the seabed, the precise location for deployment must be identified and made clear to the technical team. Reef maps are a useful tool, not only to locate the site, but to document specific configuration requirements and to provide a baseline for future evaluations of reef stability (Lindberg and Relini, 2000). Once deployed, certain reef materials including Reef Balls™ (especially those sited in shallow waters), need to be stabilized (Harris, 2006), using for example; rods, pilings or articulated mats (Barber, 2000). Studies have identified movement and/or destruction of artificial reefs resulting from severe storm events (Bell and Hall, 1994), causing for example; damage to natural reefs (Blair *et al.*, 1994) or causing portions of artificial reefs to be thrown ashore (Spieler *et al.*, 2001). Under certain circumstances, navigation buoys fixed to the artificial reef site may be required (Gordon and Ditton, 1986), representing an extra cost to the overall project.

1.4.5.5 Maintenance and management

Following successful deployment, the maintenance and management elements of an artificial reef programme are important, though often overlooked. This is despite the fact that issued permits specify the requirement to conduct ‘compliance’ monitoring by those responsible (Gordon and Ditton, 1986). On-going monitoring not only assesses the viability of a reef project, it monitors functional issues such as ensuring the reef has not destabilized or has the potential to be a hazard to navigation (Gordon and Ditton, 1986). Loftus and Stone (2007) suggest the use of side scan sonar or general positioning system to define the location, height and any movement of artificial reef material. General maintenance costs of a reef should be addressed, ideally, at the fist stages of the planning process. Costs of maintenance can be considerable (Sutton and Bushnell, 2007), especially if a well designed and constructed buoy system is installed. Even if a buoy system is not required by law, they serve as navigational aids, reducing the incidence of legal liability to the reef permit holder, and also act as site locators for divers and fishers.

The general requirement for the management of the reef resource is reflected by the way the artificial reef is being used. In many instances, an artificial reef is used by many interest groups, frequently leading to conflicts over use and resource allocation. Typically, conflicts may arise for example, between commercial and sports fishing (Sport Fishing Institute, 1985) and between divers and fishermen (Brock, 1994). Even among the diving fraternity, incompatibility may arise between consumptive and non-consumptive divers. To help mitigate such contention, Bohnsack and Sutherland (1985) suggest the use of colour coded buoys, multiple reefs and different 'types' of artificial reef for designated use. Outreach discussions with affected parties (e.g. commercial fishing operations) may minimize issues of conflict.

#### 1.4.5.6 Project evaluation

Seaman and Jensen (2000) place the highest importance on this final stage of the reef planning framework, simply because evaluation studies answer whether an artificial reef or reef system is satisfying the purposes for which it was built. This feedback process identifies accrued user benefits gained from the deployment of the reef system and any management concerns recognized. Portier *et al.* (2000) recommend that each study should have clearly stated objectives, appropriate measurement techniques, adequate sampling and powerful statistical analysis. Each evaluation study is unique, with a typical focus on biological activity relating to a reefs development (Smith *et al.*, 1979; Wantiez and Thollot, 2000) and/or the socio-economic effectiveness of a reef associated with user patterns and distribution (Ditton and Auyong, 1984; Milton, 1989; Dowling and Nichol, 2001; Leeworthy *et al.*, 2006). Social-science information is important as it provides an understanding into the extent to which the public interest is being served by artificial reef generation (e.g. Ditton *et* *al.*, 2002; Leeworthy *et al.*, 2006; Chapter 3). For example, if reef deployment is an effective public investment, as well as providing data on the direct commercial gains associated with reef use (e.g. Dowling and Nichol, 2001; Pendleton, 2005). Inclusively, information gathered from social based studies can be used as an efficiency gauge of whether a reef programme has cost more than benefits obtained (Gordon and Ditton, 1986). Milton *et al.* (2000) provides a comprehensive description of social and economic evaluation methods, while Bortone *et al.* (2000) presents methods to evaluate fish and macro-invertebrates associated with artificial reefs and their development.

By evaluating artificial reef projects and reporting the results, managers and policy makers can accept or reject current strategies, with any changes implemented to current development efforts and evaluation results extended to future reef projects. In a majority of cases and certainly in the United States, evaluation efforts are ultimately the responsibility of the reef programme sponsor. However, under the terms of the permit, surprisingly there are no requirements for the sponsor to conduct this final, but highly important stage of performance evaluation (Gordon and Ditton, 1986). Even in the published literature, the quality of evaluation studies appears meager. In a review of reef performance assessment conducted by Baine (2001), he identified a considerable lack of satisfactory examples of artificial reef self-appraisal, which he related to an inadequate adoption of planning and managerial procedures. Likewise, Linberg and Relini (2000) noted a similar trend suggesting this may be due in part to evaluation efforts simply being an afterthought or of low priority in the overall planning procedure.

#### 1.4.5.7 Summary of artificial reef planning

This brief synopsis of artificial reef planning has characterized the interdisciplinary nature and good professional practice of responsible artificial reef development. An emphasis has been placed on the importance of performance evaluation and self-appraisal as tools to measure satisfactory conclusions to artificial reef creation; whether for ecological, social or economic design.

### 1.4.6 Comparison of Artificial Reefs with Natural Coral Habitats

To help evaluate the performance of artificial reefs relative to their biological capacities, a range of studies have compared reef communities between artificial and natural reefs. A majority of these investigations have focused on fish assemblages (reviewed in Bohnsack and Sutherland, 1985), as opposed to coral communities.

#### 1.4.6.1 Fish assemblages

In most cases, research has shown artificial reefs have greater fish abundance and biomass than comparable sized natural reefs with a similar community composition (e.g. Wilhelmsson, 1998; Ambrose and Swarbrick, 1989; Clark and Edwards, 1994; Rilov and Benayahu, 2000; Arena *et al.,* 2007; Dupont, 2008; Santos *et al.,* 2013). For example, Randall (1963) found experimental artificial reefs contained eleven times the concentration of fish compared with natural reef areas, Fast and Pagan (1974) reported seven to eight times the biomass and Walton (1979) found sixteen times the density but the same biomass of fishes when comparing artificial reefs to control reefs. In some instances, commercial fish abundances have been recorded as being significantly higher on artificial reefs relative to natural habitats (Dupont, 2008; Arena *et al.,* 2007; Santos *et al.,* 2013). In contrast, only a handful of studies report less fish biomass and abundance on artificial reefs (Lindenberg, 1973; Carr and Hixon, 1997; Thanner *et al.,* 2006).

A number of these latter enquiries focused on the relationships between refal complexity, artificial and natural, and the associated assemblages of fishes. Reef complexity including the design, spatial arrangement and reef size, as well as the number and sizes of chambers and openings, has been found to influence reef fish communities (Chang *et al.,* 1977; Koeck *et al.*, 2014). Rilov and Benayahu (2000) found higher fish abundance and species richness around vertical artificial reefs (concrete pillars) and suggested vertical structures were more attractive to fish settlement and recruitment than the moderately sloped bottoms of the fringing reefs studied. In line with this, Arena *et al.* (2007) suggested that the high vertical relief of four vessel reefs studied, may have accounted for increased settlement of juvenile fishes leading to greater fish abundance and species richness recorded. Of interest, Granneman and Steele (2014) found total fish tissue production tended to be greater on artificial reefs than natural reefs, with a positive correlation occurring between tissue production and the abundance of large boulders that were more numerous on artificial reefs. In contrast, Murdy (1979) reported larger fishes on natural reefs versus tyre reefs. Both authors (Murdy, 1979; Granneman and Steele, 2014) suggested their findings were likely to be a function of shelter-scaling effects relating to the availability of refuge and predator-free space. Koeck *et al.* (2014) demonstrated the effects of structural habitat complexity on fish assemblages, reporting that more complex artificial reef structures with the presence of crevices and overhangs, supported greater fish densities that the natural reefs did.

In most cases, community structure of fish species is found to be similar between reef habitats inspected (e.g. Jones and Thompson, 1978; Talbot *et al.,* 1978; Murdy, 1979; Smith *et al.*, 1979; Stone *et al.*, 1979; Walton, 1979; Gascon and Miller, 1981; Ambrose and Swarbrick, 1989; Carr and Hixon, 1989; Clark and Edwards, 1994; Dupont, 2008; Santos *et al.*, 2013). However, there are exceptions. Relative to natural reefs; Fast and Pagan (1974) and Rooker *et al.* (1997) recorded fewer fish species on a tyre reef and oil production platform, respectively, in contrast to Rilov and Benayahu (2000) and Arena *et al.* (2007) that observed greater species richness on concrete pillars and shipwrecks, respectively.

#### 1.4.6.2 Coral assemblages

Several studies have also examined the structure of benthic artificial reef communities relative to natural reefs. Many recorded differences in the species composition and abundance of benthic communities found on the two reef types (e.g. Wendt *et al.,* 1989; Clark and Edwards, 1999; Perkol-Finkel and Benayahu, 2005), with recruitment of soft corals generally on artificial reefs and slow growing massive species on natural reefs. In relation to this, research has focused on the roles of structural features (e.g. Chou and Lim, 1986; Wilhelmsson, 1998) and age of man-made reefs (e.g. Aseltine-Neilson *et al.,* 1999; Perkol-Finkel *et al.,* 2005) in influencing sessile benthos. In many instances, structural alignment appears to dictate community differences. For example, Perkol-Finkel and Benayahu (2004, 2005) noted the vertical alignment of relatively young artificial reefs was dominated by soft corals and porifera, as apposed to the horizontal orientation of the natural reefs, which were dominated by stony corals. In settlement plate experiments, Perkol-Finkel and Benayahu (2007) found differential recruitment between artificial and natural reefs that corresponded to plate orientation and the resident species assemblages; recruitment of mainly soft corals to the former and stony corals to the latter reef type.

Some authors note however, that given sufficient time and similar structural features, differences in benthic community structure can become almost indistinguishable (Aseltine-Neilson *et al.,* 1999; Thanner *et al.,* 2006). Perkol-Finkel *et al.* (2005) studied seven shipwrecks of differing ages (20 to 100 years old) and observed increasing age of the artificial reef influenced its degree of similarity to its adjacent natural reef. This was most evident with stony coral cover. Moreover, Perkol-Finkel *et al.* (2006) noted a similar benthic community structure on a 119-year old shipwreck to that of a neighbouring natural reef.

Additionally, investigations to understand the influence of current regimes and sediment loads in shaping coral assemblages on artificial reefs, have been conducted. Bayes and Szmant (1989) found strong water circulation and low sedimentation around a wreck, corresponded to areas of high sessile benthic cover and species diversity, compared to control natural reef. Further, Perkol-Finkel and Benayahu (2009) attributed a unique suite of environmental conditions in observed differential survival of transplanted corals on two reef types. Coral survival was greater on artificial reefs where the current velocity was higher and the sedimentation load lower.

### 1.4.7 Artificial Reefs, Recreational Enhancement and Scuba Diving

Artificial reef planning and development holds significant potential for reef structures to be used as effective recreational resources, especially for the non-consumptive activity of scuba diving. Indeed, well conceived artificial reefs can offer many benefits to divers. For example, new diving opportunities or the enhancement of existing diving opportunities can be created through the provision of various types of reef (van Treeck and Schuhmacher, 1999a; van Treeck and Eisinger, 2008) as well as some artificial habitat attracting different marine species that divers wish to view (Wilhelmsson *et al.,* 1998; Clark and Edwards, 1999; Perkol-Finkel and Benayahu, 2004). Additionally, artificial reef can provide more accessible diving opportunities when deployed in close proximity to access points (Milton, 1989) and deployed structures may help distribute use of reefs throughout a given area thereby reducing user congestion and crowding on reefs (Davis *et al.*, 1995; Leeworthy *et al.*, 2006; Polak and Shashar, 2012).

While natural reefs that have taken hundreds of years to develop, may be more appealing to some divers (Johns *et al.*, 2001; Ramos *et al.*, 2006; Oh *et al.*, 2008), artificial reefs have often been viewed as a unique, original type of diving experience (Blout, 1981; Shani *et al.*, 2011). As a recreational asset, artificial reefs are especially popular with sports divers (Blout, 1981, Edney, 2012), possibly because of the complex and challenging nature that some structures (particularly wrecks) can offer divers (Stolk *et al.,* 2005). In a recent poll conducted by Scuba Travel (2006) four out of the top ten voted dive sites in the world were sunken shipwrecks. Stolk *et al.* (2005) found the experiences provided by diving on artificial reefs are valued by many individuals, particularly as a means of broadening the diving resource base available and experiences they provide. Some artificial structures, like the World War II relics found in Chuuk Lagoon, Micronesia (Edney, 2012), can provide a link with local cultural heritage thus enabling the diver to engage with history in a novel underwater setting. Moreover, underwater art in the form of sculptures, are becoming an increasingly popular type of artificial reef that are creative approaches to help reduce the amount of diving pressure on natural reefs. Artist, Jason de Caires has created the world's first underwater sculpture park in the National Marine Park of Cancun (www.underwatersculpture.com). His sculptures will gradually develop as artificial reefs using propagated corals transplanted onto the structures. De Caires (2012) remarked that "eventually the underwater gallery will be totally assimilated by marine life, transformed to another state, a metaphor for the future of our own species". Figure 1.7 depicts 'Silent Evolution' underwater sculpture following deployment in Cancun, Mexico (www.underwatersculpture.com). A smaller sculpture park developed by the same artist can be found in Moilinere Bay, Grenada, West Indies.

**Figure 1.7 Silent Evolution by Jason de Caires.** Underwater sculptures following immersion (www.underwatersculpture.com).

As Stolk and Markwell (2007) comment, artificial reefs, as well as hosting recreational diving pursuits, may also attract other marine based leisure activities. These include; snorkelling (Harris, 2006), swimming and surfing (Mead and Black, 1999), submarine viewing trips (Brock, 1994) and recreational fishing (Milton, 1989; Stanley and Wilson, 1989). However, out of all the leisure based activities performed on or around artificial reef structures, the following literature review concentrates solely on the sport of scuba diving. This is because diving appears to be the most common activity associated with artificial reefs (Chapter 2), it is a growing leisure activity (Dignam, 1990; Tabata, 1992; PADI Worldwide Certification, 2013) with a reasonably well documented history associated with artificial reef sites (Stolk and Markwell, 2007).

A variety of often vague or incomplete definitions of recreational scuba diving occur in the 'gray' and even published literatures. Therefore for the purpose of this thesis, a conceptual and indeed 'personal' definition is offered that embodies the technical, physical and social nature of recreational diving, and is defined as "a type of non-solo diving that uses scuba equipment to reach depths of no more than 39 meters for the purposes of stimulation, leisure and enjoyment". In contrast to recreational diving, Garrod and Gössling (2008, p.7) define 'diving tourism' as; "involving individuals traveling from their usual place of residence, spending at least one night away, and actively participating in one or more diving activities such as scuba diving".

Scuba diving is a skill-driven recreational activity requiring comprehensive training by a professional body such as the Professional Association of Diving Instructors (PADI) (www.padi.com/scuba/). Skill and knowledge acquisition includes buoyancy control and underwater conservation awareness that helps minimize diver impacts on reefs (Barker and Roberts, 2004; Lindgren *et al.,* 2008). The marine education components of dive training are critical as many divers do not progress past open-water entry level qualification (Johansen and Koster, 2012). Indeed, the activity of recreational diving is characterized by a high 'drop-out' rate (PADI Worldwide Certification, 2013). Despite this, recreational diving has become a global activity with an estimated several million active divers worldwide (Garrod and Gössling, 2008; Musa and Dimmock, 2013). Through images of exoticism and natural beauty, it has been claimed that diving tourism is one of the fastest growing markets of the tourism industry (Tabata, 1992; Musa, *et al.,* 2006; Musa and Dimmock, 2013). Technical advances in equipment, improved training techniques, increased leisure time and often the desire to escape the pressures of everyday life, have resulted in the increased popularity of this leisure sport (Garrod, 2008; Musa and Dimmock, 2013). According to figures generated by PADI, almost 1 million new divers were certified in 2013 (PADI Worldwide Certification, 2013). Figures for new certifications have grown consistently since the organization was founded in 1967, with approximately 22 million divers presently having PADI certifications globally (PADI Worldwide Certification, 2013). The recent strong growth of scuba diving in the Asian market has contributed to this rise (World Tourism Organization, 2001), as have the emergence of the Brazilian, Russian, Indian and Chinese (BRIC) economies (Musa and Dimmock 2013).

In addressing the many pressures imposed by recreational diving on natural reef systems, and considering their fragility, there exists a huge potential to improve the management of diving by using artificial reef generation. If planned, developed and managed appropriately, artificial reefs could augment the supply of natural marine resources available to the diving fraternity without compromising their preferred diving experience (Stolk and Markwell, 2007; Oh *et al.,* 2008), but at the same time enhancing reef protection (van Treeck and Schuhmacher, 1999a; Leeworthy *et al.*, 2006; Polak and Shashar, 2012). To this end, by conducting a literature review and inspecting previous research, a greater appreciation and understanding of scuba diving and its association with artificial reefs can then be formulated.

## 1.5 Artificial Reefs and Scuba Diving Research

A review of the published literature based on the recreational use of artificial reefs as scuba diving resources, was published by Stolk and Markewell (2007). The authors review a total of six research papers that engage with the subject. However since this time, six additional papers have been published in this subject area, and a further two papers (Pendleton, 2005; Stolk *et al.*, 2005) directly relevant to the subject, were omitted by Stolk and Markwell (2007). In order to give the reader a plenary knowledge of the current research effort, all fifteen papers (including Stolk and Marwell, 2007) are reviewed in this chapter. No un-published 'gray' literature has been included.

Stolk and Markwell (2007) proposed three subject categories to place the reviewed material within. For consistency, the same three categories are used in this review with the addition of two further categories (a) and (e).

(a) General review and theory.

(b) Environmental engineering.

(c) Social dimensions of scuba diving on artificial reefs.

(d) Socio-economic impacts of artificial reefs.

(e) Ecological impacts of artificial reefs.

### 1.5.1 General Review and Theory

In their review, Stolk and Markwell (2007) report on the growing practice of developing and promoting the use of artificial reefs for diving recreation and tourism markets. The authors critically re-examine several published papers discussing the various themes relating to reviewed studies. Based on their analysis, the authors identify the need to develop more robust theoretical tools and conceptual models to facilitate the examination of data generated from studies. They also suggest greater consistency in research effort should be adopted, especially within the overall framework and focus of studies and in the approaches and methods used by scientists.

In response to their observations, the authors present a marine typology of artificial reefs that attempts to organize the artificial structures based on their role, appearance and materials used. Given the acronym TARRR (typology of artificial reef as recreational resources) it allocates three classes of artificial reef and the recreational use that each structure could be expected to support. In addition, the authors introduce a conceptual model of an artificial reef scuba dive experience to explain the relationship between the diver and the reef. Social, environmental and economic benefits are featured in the model as significant outcomes of the hypothetical dive experience.

The authors conclude by making various recommendations for future avenues of enquiry that focus on diving alongside artificial reefs. It is clear, as they rightly identify, that a paucity of information is lacking in this field of enquiry, especially within the social sciences arena. Specifically the authors suggest a greater focus on research into divers' recreational decision making behaviour and collection of data that embodies aspects of the artificial reef dive experience.

### 1.5.2 Environmental Engineering

Only one paper (van Treeck and Schuhmacher, 1999a) has been devoted to the pseudo replication of natural reef substrates for diving amenity. The authors develop a creative and innovative approach to artificial reef creation using the Biorock technology (refer to section 1.4.4.1). Although this method of artificial reef generation gives a small ecological footprint, the authors claim it provides an excellent foundation for natural coral growth and subsequent succession of species.

Using this approach, the authors propose the creation of alternative underwater attractions and present the Save Coral Reefs (SCORE) concept, designed to divert diver pressure from natural coral reefs. To illustrate the SCORE concept, van Treeck and Schuhmacher (1999a) present a hypothetical 'visionary' underwater theme park composed of a flexible system of module structures for diver training, environmental education and rehabilitation of reefs, including spawning grounds for coral larvae. The authors believe the installations can be sufficiently attractive and adequate in meeting the demands of divers and serve as acceptable recreational alternatives to vulnerable coral reefs.

Whilst this concept is an exciting and innovative application of accretion technology, to date, no such underwater park has been tested. Prior to being considered as a serious project by marine managers, it is clear that further research would be necessary to gain an understanding of the economic, social and environmental implications of a development of this nature. For example, legal studies on liabilities and property rights associated with an underwater theme park need to be understood, as do financial projections in delivering this technology to a fully functioning operation. In addition, the question of how popular this type of artificial reef would be with scuba divers needs to be fully researched to identify user numbers and patterns. Nevertheless, for future research in artificial reef development, Biorock technology represents a novel and fertile area of enquiry for interactions between engineering, biology and art.

### 1.5.3 Social Dimensions of Scuba Diving on Artificial Reefs

Several authors (Milton, 1989; Ditton *et al.*, 2002; Stolk *et al.*, 2005; Shani *et al.*, 2011; Edney, 2012) have investigated the social impacts of diving on artificial reefs using visitor surveys. A common theme binding the studies was to gain an insight into the motivations, attitudes, socio-demographic characteristics and management preferences of divers using artificial habitats. Milton (1989) pioneered such research by assessing diver (and angler) user rates of artificial reefs in Florida. Forming the basis of the study were seven large reefs consisting mainly of deployed vessels. Milton (1989) reported that by far the most important factor given by divers in choosing reef sites was their accessibility and ease of location. Of importance, travel time to the reefs was found to be significant, with a clear preference noted for reefs located relatively close to shore. Divers also rated prior success as key determinants for artificial reef use.  The most popular artificial reef for divers was the oldest and most established reef that comprised the largest number of sunken vessels. In addition, an increase in the number of ‘desirable’ fish species was important to divers (and anglers), though high fish density appeared unimportant. These findings suggest that management efforts to create artificial reefs that favour fish diversity and desirable fish species would help increase the attractiveness of artificial reefs to divers.

In a later study, Ditton *et al.* (2002) investigated the demographics, attitudes and reef management preferences of divers using artificial reefs in Texas waters. Reef resources available to Texas divers include an excess of 800 oil and gas production structures. From their sample, it was noted that divers had taken one or more trips to offshore artificial reefs in the previous twelve months. Overall participants’ possessed similar demographic and social characteristics to those analyzed in comparable artificial reef diving surveys (Stolk *et al.,* 2005; Edney, 2012). A majority of the respondents were male, Anglo or white, with a mean age of 39 years. Sixty four percent of divers had four or more year’s college education and over half had a median household income between US$60,000 to US$69,000. Additionally, a series of attitude statements was included in Ditton *et al.* (2002) study relating to the present and future management of local artificial reefs. Strong levels of agreement were recorded to statements; ‘mooring buoys should be provided at all artificial reef sites’, ‘more funds should be used to deploy large naval ships as reefs’ and ‘certain reefs should be designated for specific uses, such as for diving only or recreational fishing only’ When divers were asked for their preferred type of reef building material for use in future reef developments, large naval ships were clearly preferred, followed by oil production structures and small boats and barges. Stolk *et al.* (2005) and Shani *et al.* (2011) also note that deployed vessels and shipwrecks are significant attractions to divers.

Stolk *et al.* (2005) targeted Australian divers to collect survey data to help understand users' attitudes, perceptions and satisfaction levels towards artificial reefs for diving amenity. Australian waters already have many well established deployed reefs, most of which are ex-navy vessels. It was however the deliberate sinking of the *HMAS Swan* that appeared to prompt a growing interest by divers for the further development of reefs in Australian waters. In general, a high level of satisfaction was reported by Stolk *et al.* (2005) for diver experiences on artificial reefs, with shipwrecks considered to be the most favoured type of artificial reef to dive on. It was also evident from the study that respondents clearly recognized the value of artificial reefs in their role of reducing diver impacts on natural reefs, as well as strong agreement that 'artificial reefs may provide new habitat for marine species'. Many respondents also agreed that diving on an artificial reef could be more satisfying than diving on natural reef outcrops.

A plan to deploy a new reef along the northern shore of the Red Sea in Eilat, Israel, was the focus of Shani *et al.* (2011) research.  The authors suggest Eilats' coral reefs are some of the most extensively used in the world by recreational divers, and thus they argue the deployment of further artificial reefs locally would help divert diver attention from the natural coral reefs, as well as diversifying the local diving experience. Despite no specific mention of the infrastructure relating to the proposed artificial reef, a high level of support was given for the new reef among respondent divers. Interestingly, support for the proposed reef was significantly higher among males surveyed than for female divers. Overall, 90% of divers stated a new artificial reef would positively contribute to their diving experience, with a further 70% expressing the planned reef would increase their local diving frequency. Additionally, the study revealed the most favoured local dive site was the missile ship; the *Satil*, scoring higher mean values than any of the five adjacent natural reefs. Divers were also found to have an overriding preference for large naval ships, or other large 'themed' structures (e.g. large airplanes). These results lend support to Ditton *et al.* (2002) and Stolk *et al.* (2005) who also noted divers' preferences for these materials. Shani *et al.* (2011) suggest their study demonstrates the marketing potential of developing mass marine ecotourism through the deployment of recreation-orientated artificial reefs, as well as the prospect of promoting soft ecotourism in modified marine settings.

To date, only one researcher (Edney, 2012) has investigated the special interest group of wreck divers. Edney's data collection focused on Chuuk Lagoon, Micronesia. Chuuk Lagoon houses World War II relics' consisting of around 50-60 shipwrecks and 12 aircraft. The wrecks additionally form one of the largest collections of artificial reefs in the world, and are Chuuk's principal tourism attraction and source of tourism revenue. Survey data from live aboard divers was enriched using in-depth personal interviews that collectively aimed to provide an understanding of dive motivations and attitudes towards wrecks and their management controls. The socio-demographic profile from Edney's study was broadly consistent with previous findings (Ditton *et al.*, 2002; Stolk *et al.*, 2005; Shani *et al.*, 2011) with the exception that Edney's group were generally older in age and exhibited a considerable degree of diver experience. These latter characteristics may reflect the higher level of experience often required for wreck diving (Blout, 1981; Carter, 2008). Overall, divers were predominantly motivated to view historically significant shipwrecks, artifacts, marine life and to additionally embrace the peace and tranquility of the underwater environment. Moreover, a high level of support was given by participants for management controls over shipwrecks, such as penalties for extracting artifacts, permits to dive specific wrecks and underwater guides to control diver behaviour.

### 1.5.4 Socio-Economic Impacts of Artificial Reefs

A number of scholars (Brock, 1994; Wilhelmsson *et al.*, 1998; Dowling and Nichol, 2001; Pendleton, 2005; Oh *et al.*, 2008; Polak and Shashar, 2013) have focused on the economic benefits of recreation-orientated artificial reefs. Brock (1994) investigated the economic impact of a conglomerate of reefs used as submarine and dive tour sites in Hawaii. The author required data to allow for economic comparisons to be made between commercial fishing (consumptive activity) and submarine and diving tours (non-consumptive activity) at the reef. Results showed that over a one year period, diving activities centered on the Atlantis reef generated significantly greater economic return than for fishing revenues. The author estimated pre-tax profits for all fishing activity at US$59,000 compared to an estimated US$1.37 million for the submarine and diving tours. Brock highlights the incompatible nature of consumptive and non-consumptive activities based at a single reef site and recommends the designation of no-take zoned areas to control fisheries. This he suggests would help protect local ecotourism resources like the Atlantis reef. He proposes that artificial reefs designed as dive tour destinations should be established in ecologically unobjectionable areas such as degraded locations or monotonous sand flats.

Research matters addressed by Wilhelmsson *et al.* (1998) were two-fold. The authors studied the ecological communities of three artificial reefs and their comparisons with those of natural coral reefs, and additionally assessed earnings received from recreational scuba diving on the most visited artificial reef by divers. Three artificial reef sites were investigated in Eilat, Israel; two ex-navy vessels and a reef constructed of dead coral heads. Proximate natural reefs were also investigated by the authors within a 50m radius. The authors identified coral diversity and coral colony density as being significantly higher on the natural reefs compared to the artificial reefs examined. Despite this, higher concentrations of fish species were reported at the artificial reefs compared to adjacent natural reefs, with approximately 7 species of fish present on the wrecks, but reported as absent on the natural reefs. Wilhelmsson *et al.* (1998) suggests increased habitat complexity of the artificial reefs, such as hole sizing, crevices and reef height, collectively favoured specific fish species present. Inclusively, the authors propose that artificial and natural reef habitats may differ in terms of their function as shelters and producers of food. In addition, Wilhelmsson *et al.* (1998) presents an estimate of the commercial value of scuba diving tourism, based on the number of guided dives taken over a three month period (low season) on the most visited artificial reef, the *Satil* wreck. Figures were extended to a 12 month period giving a total of 16,000 guided dives per year. Overall, these estimates contributed an annual income to local diving schools of approximately US$ 368,000. The authors conclude that artificial reefs in the Gulf of Aqaba represent a significant source of income for those involved in the regions dive industry.

The *HMAS Swan*, located in coastal waters south of Perth, Southern Australia, was used as a focal point for Dowling and Nichols (2001) study. They discuss the transformation of the ex-navy vessel into an artificial reef and dive tourism attraction and report on the regional economic impact of the *Swan* over an 18 month period. Diver access to the *Swan* and user conduct is regulated closely, as only certified wreck and cave divers are permitted to penetrate the vessel, whilst divers with more basic training are restricted to the exterior. Over a six month period, the authors estimated the total economic gain from the *Swan* was approximately US$1.39 million. Based on the generation of beneficial and economic impacts to the area, Dowling and Nichol (2001) suggest the *HMAS Swan* should be considered a novel nature-based tourism activity in the region. Furthermore, they argue if environmental monitoring of the site continues to provide positive results, this 'ship to reef' site could eventually be classified as an ecotourism product.

In Pendleton's (2005) study, he discusses the potential economic value of creating 'ship to reef' sites for recreational diving. Using the ex-Canadian Destroyer Escort *Yukon* as a case study, he provides value estimates of the expenditures and non-market values associated with the *Yukon's* deployment and subsequent recreational use in California. Pendleton (2005) reports the annual expenditures by divers to the *Yukon* were in the region of US$3.5 million. Whilst these market value figures were upper bound estimates, they nonetheless greatly exceeded the overall cost of US$435,000 used to create the artificial reef. Furthermore, the author provides a non-market consumer surplus estimate of the *Yukon* that he suggests is between US$80,000 and US$1.3 million per annum. The author also reviews several papers investigating the market values and non-market values for diving at artificial reefs in general. Market value expenditures reported ranged from US$26 per person per-day to US$ 204 per person-day, while consumer surplus figures ranged from US$11 per person-day to US$339 annually, per diver. In his paper, Pendleton presents a positive perspective in the quantification of economic return from diving on artificial reefs and also provides fiscal evidence for the justification of new ships to reef sites in Californian waters.

In contrast to expenditure-driven studies, Oh *et al.* (2008) and Polak and Shashar (2013) used contingent valuation methods to appraise diver benefits relating to artificial reefs. Oh *et al.* (2008) aimed to establish whether this type of reef habitat was functionally acceptable to Texas divers by using willingness to pay as the evaluate. The authors also required data to ascertain whether consumer surplus varied between users of natural and artificial reefs. Ten bid values ranging from US$15 to US$400 were presented to discover what divers were willing to pay per trip in excess of their diving trip costs. The survey also included questions regarding respondents' commitment to diving as well as diving activities and experiences at local artificial reefs. Results showed that respondents participated in diving an average duration of 12 days (out of a twelve month period), with 7 of those days in Texas waters. Estimates of net willingness to pay (per trip) accrued from bids values were reported as; US$171 for natural reef divers and US$101 for artificial reef divers. Accordingly, divers of natural reefs likely obtained US$70 additional net benefits compared with artificial reef divers. Despite artificial reefs being valued less than the diving experiences derived from natural reefs, the authors argue that artificial reefs were assigned a substantial value for diving purposes and represent a functionally acceptable alternative to natural reefs.

Polak and Shashar (2013) are the first authors to determine divers' willingness to pay for changes in coral and fish attributes over an artificial reef. The authors aimed to establish which biological attributes were appreciated by Israeli divers and to evaluate their relative importance. To achieve this, computer generated images using a local artificial reef were used to isolate different levels of community descriptors, such as richness and abundance and biodiversity of corals and fish, and to attain a monetary value to each. Willingness to pay data revealed that participants were prepared to contribute towards all increases in reef community attributes, and were partially able to discriminate between them. Divers were willing to pay the highest sums of money for conservation efforts that protected high biodiversity (including fish species richness), and indeed high biodiversity was the most valued index, while fish abundance was the least valued scenario. Based on their findings, the authors suggest that artificial reefs deployed for diving amenity should be designed to attract high biodiversity and recommend that transplantation of corals would help achieve this goal.

### 1.5.5 Ecological Impacts of Artificial Reefs

Few studies (Leeworthy *et al.*, 2006; Polak and Shashar, 2012) have examined the effects of artificial reefs in reducing user pressures from natural reefs. Using a 'ship to reef' case study, Leeworthy *et al.* (2006) assessed the ecological (and economic) impacts associated with the sinking of the *USS Spiegel Grove* in close proximity to a series of natural reefs off the Florida coast. The strategic positioning of the vessel, they hoped, would yield ecological benefits by reducing diving and snorkelling activity at the nearby coral reefs. Estimates of total reef usage before and after deployment were compared. Following vessel deployment, results showed positive ecological benefits to the surrounding natural reefs. Across all recreational activities, a net decline of 13.7% usage was calculated on the natural reefs under study, with an associated increase of 9.3% occurring at the *Spiegel Grove*. In isolation, a 118.1% increase in the share of recreational dives was calculated for the artificial reef in contrast to a 12.7% decrease on the adjacent natural reefs. However, the share of the snorkelling market declined marginally, possibly due to the inaccessible nature of the *Spiegel Grove* for snorkelling. Furthermore, the authors demonstrated positive economic benefits to both dive charter businesses and the local economy, reporting an increase in annual income of US$961.8 thousand and the creation of 68 new jobs.

A similar line of enquiry was adopted by Polak and Shashar (2012) to assess potential changes in the diving behaviour of scuba divers following the immersion of a small artificial reef, in Eilat, Israel. Specifically, the authors aimed to establish the effects of a pre-planned 'concrete' artificial reef and the influence of coral transplantation on the diving times of individuals in and around the adjacent marine protected area, including visitation to proximate natural reefs. The reef was purposefully positioned approximately 10 m outside a local marine reserve in an area receiving high visitation by divers, and where the majority of instructional dives occurred. Of significance, Polak and Shashar (2012) observed the artificial reef was effective in changing the behaviour of in-training novice divers, but not of experienced divers. They suggest the apathy of advanced divers for the artificial reef was due to its relatively small size, its general unattractiveness and its proximate position to the natural reef outcrops. Additionally, the transplantation of corals had no effect on diver behavior. In conclusion, the authors recommend that artificial reefs should be large enough to preoccupy divers for their entire dive, as well as a reefs strategic positioning to maximize usage by divers.

### 1.5.6 Summary of Reviewed Literature

A selection of papers concerned with scuba diving use of artificial reefs has been reviewed, revealing diversity in approaches, aims, methodology and structure employed. Table 1.2 summarizes the general themes relating to each paper, habitat type, geographical coverage and key findings of the reviewed literature. It is clear that the majority of papers are related to North American research which reflects the prevailing worldwide trend of published research effort reported for artificial reefs in general (Baine, 2001). Greater consideration appears to have been devoted to socio-economic aspects in this field of enquiry. However, upon examination of the literature it is clear that reported data needs to be more directly comparable, thus greater parity in reporting values (e.g. person/day, person/trip) for economic studies are required. With just fifteen published papers devoted to the use of artificial reefs as diving resources, progress is slow in gathering a valuable archive of information in this scientific arena. With such a dearth of information, it is important that future avenues of enquiry in need and worthy of additional study are clearly identified.

**Table 1.2** Reviewed literature: artificial reefs and scuba diving research.

| Author(s) (year) | Theme | Location | Habitat Type | Principal Findings |
|---|---|---|---|---|
| Stolk and Markwell (2007) | General review and theory | Worldwide | Various types of artificial reefs | Six research papers were reviewed with three thematic subject categories defined. An AR model is offered outlining a hypothetical dive experience. Research priorities are identified. |
| van Treeck and Schuhmacher (1999a) | Environmental engineering | Jordan, Israel | Biorock; accretion of calcium minerals *in situ* | Mineral accretion is a suitable technology to create AR modules to support environmental education, recreation and diver training. |
| Milton (1989) | Social dimensions | Florida, USA | Vessels and steel pipes | Several AR features are important to divers; the reefs size, structure, location, access, depth and presence of desirable fish species, *inter alia*. |
| Ditton *et al*. (2002) | Social dimensions | Texas, USA | Various types of artificial reef , predominantly oil and gas production structures | Materials of choice for future AR deployment are large naval vessels and oil production structures. Divers preferred depth of deployed reef ranged between 18 and 27 metres. |
| Stolk *et al*. (2005) | Social dimensions | Australia | Various types of artificial reefs | ARs hold significant attraction to divers having the potential to broaden the diving resource base and range of diving experiences. ARs are viewed as effective conservation tools for NRs. |
| Shani *et al*. (2011) | Social dimensions | Eliat, Israel | Ex-missile ship and pyramid structure | Divers prefer large ‘themed’ ARs especially wrecks. Participants supported a new AR in Eilat that would increase their diving frequency. |
| Edney (2012) | Social dimensions | Chuuk Lagoon, Micronesia | World War II ship-wrecks and aircraft | Motivations to dive on wrecks included their historical significance, artifacts, marine life and photographic opportunities. Divers supported management controls over shipwrecks. |

| | | | | |
|---|---|---|---|---|
| Brock (1994) | Socio-economic impacts | Hawaii, USA | Yard oiler, aircraft, concrete modules and concrete terraces | Reef deployment for diving can yield greater economic returns than when used for commercial fisheries. No-take zones for ARs may be needed. |
| Wilhelmsson *et al.* (1998) | Socio-economic impacts | Eliat, Israel | Two ex-Navy ships, dead coral heads and natural reefs | Biological assessment of ARs and NRs produced variations in species composition. ARs provide a good source of income to the local dive industry. |
| Dowling and Nichol (2001) | Socio-economic impacts | Perth, Australia | Ex-Navy ship | The *HMAS Swan* is a nature-based tourism resource that should be classified as an ecotourism product. Annual income from the *Swan* was US$1.39 million. |
| Pendleton (2005) | Socio-economic impacts | California, USA | Ex-Navy ships | Creating a 'ships to reef' is costly, though benefits to the economy are significant. Annual expenditures of divers to the '*Yukon*' ship were estimated at US$3.5 million and non-market value ~US$1.3 million/year. |
| Oh *et al.* (2008) | Socio-economic impacts | Texas, USA | Various artificial and natural reefs | Divers using natural reef value their diving experiences significantly more highly than those using artificial reef habitats. In relative terms, ARs were substantially valued also. |
| Polak and Shashar (2013) | Socio-economic impacts | Eliat, Israel | Image manipulation of a small concrete and metal artificial reef | Divers are willing to pay the highest sums of money for conservation efforts that protect high biodiversity. Fish abundance was the least valued reef feature. |
| Leeworthy *et al.* (2006) | Ecological impacts | Southwest Florida, USA | Ex-Navy ship and natural reefs | Following the deployment of the *Spiegel Grove*, recreational use of the surrounding natural reefs decreased. Local income and employment grew. |
| Polak and Shashar (2012) | Ecological impacts | Eliat, Israel | Six concrete units ($24m^2$) and natural reef outcrops | The AR was effective in changing the diving behaviour of in-training novice divers but not of experienced scuba divers. Coral transplants had no effect on diver behavior. |

**Note:** AR = Artificial reef, NR = Natural reef.

## 1.6 Future Research

Two of the many benefits of conducting a literature review are the opportunities to identify gaps in knowledge and to also establish future research priorities in the given field. The studies reviewed in this chapter have demonstrated the potential of artificial reefs to mimic natural reef habitats (Wilhelmsson *et al.,* 1998; van Treeck and Schuhmacher, 1999a), to act as successful habitat substitutes for recreational divers (Ditton *et al.,* 2002; Stolk *et al.,* 2005; Leeworthy *et al.,* 2006; Shani *et al.,* 2011), to generate significant economic benefits (Brock, 1994; Wilhelmsson *et al.,* 1998; Dowling and Nichol, 2001; Pendleton, 2005; Oh *et al.,* 2008; Polak and Shashar, 2013) and to alleviate scuba diving pressure to nearby natural reefs (Leeworthy *et al.,* 2006; Polak and Shashar, 2012). However, a greater depth of scientific knowledge and understanding is still required if artificial reefs are to be used as effective tools in the sustainable management of diving tourism globally. Accordingly, directions for future research are presented.

### 1.6.1 Economic Valuation of Artificial Reefs

The majority of papers reviewed in this chapter focus on valuing the economic amenity of artificial reefs. Valuation studies are important for a number of reasons. They can provide additional insight into whether artificial reefs are a viable recreational substitute for natural coral reefs (Leeworthy *et al.,* 2006; Polak and Shashar, 2012), as well as reporting important welfare values associated with their recreational use (Leeworthy *et al.,* 2006; Oh *et al.,* 2008). Furthermore, by combining valuation studies, important explanatory factors that determine variations in reef value (e.g. number of divers on a reef and reef habitat area) can be determined (Brander *et al.,* 2007). Collectively, information yielded from valuation studies are important in the decision making process relating to the physical planning and use of artificial reefs for recreation, and may also provide information for policy makers, including the setting of marine park user fees. At present, the economic valuation literature relating to artificial reefs appears to have matured sufficiently where a meta-analysis or systematic review would synthesize the existing knowledge base. Moreover, this type of study would be more robust if un-published valuation studies were included to help capture the recreational value of artificial reefs. To the author's knowledge, no meta-analysis or synthesis of data relating to artificial reef amenity valuation has previously been undertaken.

### 1.6.2 Attitudes to and Preferences for Artificial Reefs

In the past, artificial reefs designed to meet the requirements of recreational divers have been produced, in some instances, with compromising results (Personal observation). However, if scuba divers are to be attracted to recreation-orientated artificial reefs, they need to have characteristics that deliver acceptable experiences which are stimulating, challenging and unique to users. This is especially true of divers with an ecocentric orientation towards natural reefs, who may need a great deal of encouragement to shift their diving time to artificial habitats. With this in mind, data collection revealing desirable reef characteristics that positively influence divers' choices such as material type, complexity, age and size of reef, are required. In addition, a greater understanding of scuba divers' behaviours, motivations and attitudes needs to be clarified. Being equipped with a definitive understanding of what divers require from their recreational experiences hosted by artificial reefs, and indeed their reef habitat preference between natural and artificial reefs, will assist planners and resource managers to ensure that recreational diving becomes a positive force for coastal areas.

### 1.6.3 Ecological Impacts of Artificial Reefs: Diverting Pressure from Coral Reefs

Despite the reported ecological benefits associated with changes in diving habits of scuba divers following artificial reef deployment (Leeworthy *et al.*, 2006; Polak and Shashar, 2012), the ecological impacts of artificial reefs on surrounding natural reefs warrant investigation. For example, research to elucidate whether heavily marketed and high profile reefs may indeed cause an increase in nearby natural reef usage by divers (due to an influx of tourists), needs exploring fully. The latter point is of relevance to the natural reefs fringing Key West, where the world's second-largest artificial reef, the *USS Vandenberg*, was deployed in a relatively small marine sanctuary (Adams *et al.*, 2011), and due to the reefs deployment, resulted in a net increase of natural reef tourism at the time (Office of National Marine Sanctuaries, 2011). In addition, follow-up studies of the aforementioned investigations (Leeworthy *et al.,* 2006; Polak and Shashar, 2012), may reveal interesting changes in diver patterns over time.

### 1.6.4 Artificial Reefs and Marine Protected Areas

If scuba diving participation continues to increase, coupled with the susceptibility of coral reefs to degradation from diver impacts and natural climatic events (especially bleaching), new dive management approaches combining artificial reefs may become increasingly important to the diving tourism industry. With this in mind, very little research effort (if any), has been devoted to investigate the use of artificial reefs within marine protected areas as a means of managing recreational diving and other leisure activities such as snorkelling. This latter combination represents an innovative management tool to help control diver as well as snokeller impacts to natural reefs, by increasing the availability and accessibility of alternative reef resources in a managed environment. However, research to understand if visitors would be willing to pay marine park user fees to contribute towards the management and protection of artificial reefs, and indeed if they wish to use artificial reefs within a marine reserve, needs to be established. Overall, the deployment of artificial reefs to expand existing reef resources within marine protected areas, represents an interesting conservation and marine management strategy that is worthy of investigation.

## 1.7 Summary

A considerable challenge exists for marine resource managers to provide diving opportunities that are stimulating, challenging and enjoyable, but at the same time aim to protect natural coral reefs from diver impacts. This predicament becomes even more taxing as the number of participants learning to dive and visiting dive sites continues to grow, year by year (Garrod and Gössling, 2008; Musa and Dimmock, 2013; PADI Worldwide Certification, 2013). Inclusively, artificial reefs offer tremendous potential to manage divers by augmenting and expanding the supply of natural reef habitats. Consequently, artificial reefs should be given serious consideration as effective measures to assist in the sustainable management of recreational scuba diving in the future.

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# Chapter 2

## *Measuring the Recreational Value of Artificial Reefs through a Synthesis of Data*

### 2.1 Abstract

Artificial reefs are created to serve a variety of purposes within the marine environment including the provision of recreational benefits for scuba diving, sport fishing and snorkelling. Alongside the recent growth in popularity of marine recreation hosted by artificial reefs, a paralleled emergence of the economic valuation literature has occurred. To assess the results of the current literature base, a synthesis of numbers is warranted to provide a more comprehensive insight into the potential economic benefits (or not) of recreation-orientated artificial reefs. This knowledge can provide important information for policy makers in marine resource management including the charging of marine reserve user fees. In this investigation, 20 artificial reef valuation studies were considered for inclusion, yielding a total of 57 separate recreation value observations for analysis. Artificial reef values in US$ per person-visit (2010 prices) were reported by; recreational activity, valuation methodology and region. Overall, a mean value of US$122 (± 154 s.d.) per person-visit for artificial reef recreation, and a median value of US$68, were reported. In addition, comparisons of artificial reef recreation values were made with values obtained by Brander *et al.* (2007) in a meta-analysis for world coral reef values. From their data set, a mean recreation value per person-visit of US$233 was reported and a median value of US$21.50. Between reef types, significant differences in mean value estimations for scuba diving and marine viewing were observed, with coral reefs yielding higher values for both activities. I conclude by recommending more detailed and rigorous analyses are required to increase the understanding of the economic value of artificial reefs that host marine recreation. I suggest increased use of the contingent valuation method would reduce heterogeneity and increase welfare consistency of future artificial reef valuation studies.

## 2.2 Introduction

Artificial reefs are created to serve a variety of purposes within the marine environment. Examples include; coastal protection (Harris, 2003; Ranasinghe and Turner, 2006; Christie, 2009), increase in fish biomass (Bohnsack and Sutherland, 1985; Ambrose and Swarbrick, 1989) and the protection of marine reserves (Harmelin, 2000; Claudet and Pelletier, 2004). Increasingly, artificial reefs are being used for the provision and enhancement of recreational opportunities for scuba diving (e.g. Bell *et al.*, 1998; Stolk *et al.*, 2005; Shani *et al.*, 2011) and sport fishing (e.g. Milton, 1989a; Stanley and Wilson, 1989), as well as other reef-based activities. For example, Mead and Black (1999) studied the economic and social impacts of an artificial reef program in New Zealand waters that provided amenity enhancement for diving, fishing, snorkelling and surfing. Artificial reefs are documented as being important components of the reef tourism market, from both a conservation perspective (van Treeck and Schuhmacher, 1999a, 1999b; van Treeck and Eisinger, 2008) and from an economic standpoint (e.g. Johns *et al.*, 2001; Pendleton, 2005a; Leeworthy *et al.*, 2006).

As an emerging trend; North America, Europe, Canada, Australia and the Caribbean and Pacific Islands, all employ the use of man-made reef structures to support recreation (Jensen, 2002), particularly programmes aimed at diving (e.g. Dowling and Nichol, 2001; Leeworthy *et al.*, 2006; Polak and Shashar, 2012). In the United States alone, an estimated 700 vessels to date have been purposefully sunk to create recreation-orientated artificial reefs within state coastal waters (Scuba Diving, 2011). Apart from decommissioned ships, oil and gas platforms are commonly used for recreational purposes (Stanley and Wilson, 1989; Ditton *et al.*, 2002), with the more recent use of pre-fabricated Reef Ball™ structures that provide diving and snorkelling facilities worldwide (Barber, 2000). In relation to scuba divers; studies suggest that decommissioned naval ships and shipwrecks appear to be the preferred choice of material for artificial reef amenity (Ditton *et al.*, 2002; Stolk *et al.*, 2005; Shani *et al.*, 2011; Kirkbride-Smith *et al.*, 2013).

Creating and managing artificial reefs can incur significant financial costs (Hanni and Mathews, 1977; Pendleton, 2005a). For example, Brock (1994) quoted expenditures of *circa* US$1.5 million for site preparation and development of a modest artificial reef dive site in Hawaii that consisted of a conglomerate of materials. Moreover, creating a 'ship to reef' site (often using decommissioned military ships) bears significant project expenses. Pendleton (2005a) cited ship preparation costs for deployment, ranged from US$56,000 to US$2.4 million, depending on the size of vessel (Cited in Hess *et al.*, 2001). Of a greater financial magnitude, were costs associated with the preparation and sinking in 2009 of the world's second largest artificial reef; the *USS Vandenberg* in the Florida Keys, amounting to some US$8.74 million (Leeworthy, 2011). Many of these costs are absorbed in vessel preparation for reefing that need to be meticulous and hence time consuming. For example, up to 75 man-months are typically spent on vessel preparation (Jones and Welsford, 1997). Post deployment; Sutton and Bushnell (2007) report on-going maintenance costs of vessels as being significant, quoting to the order of AU$223,000/annum over 10 years for maintaining the *HMAS* Brisbane in Australian waters (Queensland Environment Protection Agency, 2005).

Notwithstanding, the recreational value of artificial reef resources can be substantial (Pendleton, 2005a) and may contribute an important source of revenue to countries actively engaged in their development. Market value studies conducted in the United States indicate gross expenditures from divers visiting artificial reefs contribute millions of dollars annually into local economies (Pendleton, 2005a). In particular, the economic benefits associated with Florida's artificial reefs has been well documented (Adams *et al.*, 2011), with many studies attempting to address the market impact of scuba diving and other recreational activities hosted by artificial habitat (e.g. Bell *et al.*, 1998; Johns *et al.*, 2001; Johns, 2004; Leeworthy, 2011; Swett *et al.*, 2011). For example, Johns *et al.* (2001) estimated the total annual economic impact derived from artificial reef users (mostly divers and sport anglers) in southeastern Florida, as US$2.1 billion in sales and US$990 million in labour income. Additionally, Johns *et al.* (2001) reported artificial reef related expenditures generated 29,000 jobs to the region. In a more recent study, Leeworthy (2011) assessed the economic and ecological impacts of deploying the retired *USS Vandenberg* within the Florida Keys National Marine Sanctuary in 2009. Over a two year period, the author reported a net change in pre- to post-deployment expenditures by reef users (divers and snorkellers) of *circa* US$6.5 million and the creation of 105 local jobs. It appears from the literature however, that fewer economic studies for artificial reefs have been published for other countries of the world. One minor exception is in Australia where for example, the economic impact in recreational expenditures and sales associated with the deployment of the retired *HMAS Swan,* was reported to be in the region of US$1.86 million for an eighteen month period (Dowling and Nichol, 2001).

Substantial 'non-market' values have also been reported in the literature relating to artificial reef recreation. Johns *et al.* (2001) estimated the total annual use value (residents and visitors) of artificial reefs in southeastern Florida at US$34 million/year for users' willingness to pay for creating new artificial structures, and US$107 million/year for maintaining the existing artificial reefs in their current condition. Of interest, a considerably higher willingness to pay was yielded for maintaining the natural reefs at the same location, amounting to some US$288 million/year. In a separate willingness to pay study, conducted across the Florida Panhandle region, Bell *et al.* (1998) estimated the annual recreational use value of visitors and residents to pay for a new artificial reef programme. The authors used dichotomous choice (yes-no) questioning aimed at divers and fishers, and reported a total consumer surplus value of US$32 million/year. Finally, as part of a larger survey, the 'existence' value of artificial reefs was estimated by Milton (1988a) for Dade County, Florida. He surveyed user and non-user respondents (fishers and divers) for their willingness to pay for an artificial reef program and reported a value of US$1.43 million/year, with non-users of the reef, representing the largest component of this annual figure.

Many researchers have developed survey instruments to measure specifically the recreational value (both market and non-market value) derived from artificial reef users (e.g. Bell *et al.*, 1998; Ditton *et al.*, 2002; Oh *et al.*, 2008). One of the main purposes of these analyses is to provide 'some numbers' for government policy discussion for current and future reef investments and to provide data on the potential benefits of artificial reefs to those using them. User values may also help guide the setting of visitor entrance fees and raising of revenues for reef conservation within marine protected areas (Brander *et al.*, 2007; Chapter 5) and provide important 'benefit transfer' data used by economists to price unvalued 'policy sites' (Cesar, 2000; Pendleton, 2005a).

Whilst artificial reefs may be valued for other goods and services provided, such as coastal protection (Christie, 2009) and habitat for fisheries (Milton, 1989b, Kasim *et al.*, 2013), this paper focuses solely on the valuation literature concerned with the recreational value of artificial reefs. The rationale for this restriction relates to the availability of relevant literature (very few studies appear to exist on other economic benefits of artificial reefs). Furthermore, the recreational values associated with artificial reefs are arguably the most important 'economic' measure of their performance (presently), due to divers and fishers appearing to be the main user groups (e.g. Milton, 1989a; Stanley and Wilson, 1989; Brock, 1994; Johns *et al.*, 2001; Sutton and Bushnell, 2007; Swett *et al.*, 2011; Chapter 3). To date, the recreation-based literature pertaining to artificial reef valuation appears to have matured sufficiently, where a meta-analysis or systematic review would synthesize the existing knowledge base. To the author's knowledge, these results represent the first synthesis of data of artificial reef valuation results reported.

The purposes of this chapter were as follows. To first provide an overview of appropriate economic valuation techniques commonly used to measure 'ecosystem' resources, including artificial reefs. This is followed by a brief review of the valuation literature concerned with the recreational value of artificial reefs. I then report on the data for recreation value observations extracted from the literature and present the resulting statistics. Finally, direct comparisons of artificial reef recreation values are made with value estimates presented by Brander *et al.* (2007) in their meta-analysis reviewing natural coral reef recreation. I discuss my results, and conclude the study by making several recommendations to help improve future reef valuation studies.

## 2.3 How Artificial Reef Values are Measured

An artificial reef defined as "a submerged structure placed on the substratum (seabed) deliberately, to mimic some characteristics of a natural reef" (Jensen, 1997, p.505), generates economic benefits by providing users with recreational opportunities such as scuba diving, snorkelling and fishing. However, Pendleton (2005a) explains that in many instances, the values of these leisure based benefits are difficult to quantify, because measurements involve both market values and non-market values.

### 2.3.1 Market Impact of Artificial Reefs

Market impact studies concerned with artificial reefs (represented by the majority of studies included in this analysis), typically measure the financial contribution that users make when paying to engage in activities on the reef. Market impacts relating to marine recreation are derived from transactions on items including charter boat fees, fuel, equipment rental, air refills, marina fees and lodgings/food; collectively forming the basis of an economic impact analysis. While market transactions cannot be counted on to provide a complete measure of value (Schelling, 1968), gross expenditure studies, as Pendleton (2005a) asserted, do capture the measure of significance that artificial reefs may contribute to the local economy generally. Moreover, economic studies detailing gross expenditures may provide vital information to help justify future public investments for artificial reef creation. Of significance, recreational expenditures associated with artificial reef use help support local economies by stimulating employment, sales, income and generation of tax incomes (Johns *et al.*, 2001), with user expenditures measured at a local, regional or state level (Milton *et al.*, 2000). Johns *et al.* (2001) emphasized the importance of artificial reefs, stating their existence helps retain money within the local economy. Non-locals visiting an area are of special interest, as their reef-related expenditures inject cash into the economy, creating multiplier effects. This effect creates additional income and employment for local industries and businesses, with monies earned re-spent within the area (Johns *et al.*, 2001). However, this valuation method does not measure the true net economic value derived from individuals using a resource including artificial reefs. Non-market valuation approaches are required.

### 2.3.2 Non-Market Impact of Artificial Reefs

In a majority of cases, artificial reefs are ‘common property’, being owned by society in general, with their range of goods (products) and services (functions) un-priced or non-traded in the marketplace. Thus in the absence of market prices, techniques to measure non-market value, that in fact represents the true net economic value of reefs to users (Pendleton, 2005a), are adopted. The non-market impact of an artificial reef captures the value that reef users place on the experiences and opportunities offered, beyond what individuals would be paying to use the reef. In essence, this measures the additional satisfaction and welfare gained by visitors using the artificial reef (or any ecosystem resource); as a consumer surplus value with no actual cash transactions associated. Non-market valuation approaches are often crucial in the policy evaluation process so that reasonable market-equivalent comparisons can be made for goods and services between for example, artificial and natural reef habitats (Oh *et al*, 2008). Two principal valuation methods, described in the literature, are used to stimulate consumer surplus (Spurgeon, 1992); the travel cost method and the contingent valuation method.

The travel cost method, or revealed preference methodology, is used to assess 'indirectly' the non-market value of recreational resources, where the values of travel time and/or travel cost to a reef are aggregated to trace a demand curve (Boyle, 2003a). In essence, actual human behavior is used to estimate the consumer surplus of the resource in question. From the demand curve, the associated 'Hicksian' consumer surplus is determined, reflecting the amenity value of the reef to the visitor (Bell *et al.*, 1998). This method assumes that the value to the user is proportionate to the costs in reaching the reef, therefore the further the distance traveled, the higher the cost and related consumer surplus. Morgan *et al.* (2009) suggest the travel cost model exploits the tradeoffs recreators make between visitation costs and site quality when choosing where to recreate. Drawbacks of this method relates to its limitations in being appropriate for surveying non-residents only and for its inability to estimate values for levels of quality that have not been necessarily experienced (Boyle, 2003a).

In contrast, the contingent valuation method or stated preference approach is a 'direct' attempt to survey people's willingness to pay for a public good, such as coral reefs, by presenting individuals with a hypothetical market or set of circumstances to obtain data on consumer values. Direct questions are posed to elicit responses aimed at an increase (benefit) or decrease (loss/compensation) in the quantity and/or quality of goods (Cesar, 2000; Champ *et al.*, 2003). Examples of willingness to pay questions used in previous reef studies that valued recreation, are presented in Table 2.1.

**Table 2.1** Willingness to pay questions reported in previous studies aimed at valuing reef recreation for artificial and natural reef habitats.

| Author(s) (year) | Willingness to pay question | Bid values proposed | Contingent valuation method |
|---|---|---|---|
| Hargreaves-Allen (2010) | Entrance fees, including any paid by you, are used to help pay for all reef management activities. The current fee is US$10. I am going to show you a set of numbers in US$. Please tell me what is the maximum total you would be willing to pay as a **daily entrance fee to enter the reserve**? | Ten values: range $10 to $100 or more | PC |
| Johns (2004) | If your total cost for this day would have been $__ higher, would you have been willing to pay this amount to maintain the (insert kind of reef – artificial, natural or both) in their existing condition? | Five values: range $2 to $50 | S-BDC [a] |
| Oh *et al.* (2008) | If the price of goods and services were to change, causing a trip to Texas gulf waters to cost $__ more than this trip (refer to the total cost of this trip), would you have cancelled this diving trip in Texas gulf waters? | Ten values: range $15 to $400 | S-BDC |
| Tapsuwan (2005) | According to Thai regulations, you will be charged a diving fee to dive in Similan Islands. Are you willing to pay 200 baht/day to dive in Similan Islands? | No bids reported | D-BDC [b] |
| Uyarra (2009) | Is the Marine Park fee for Bonaire (divers $25, others $10) reasonable? What would your maximum willingness to pay be for this fee as a diver?___US$, others?___US$. | $10 and $25 | O-EQ |

**Notes:** PC: Payment card, S-BDC: Single-bounded dichotomous choice, O-EQ: Open-ended questioning, D-BDC: Double-bounded dichotomous choice.

[a] In a single-bounded dichotomous choice, the bid given (inserted in the space provided) is either accepted or rejected and no further bid is offered. [b] In double-bounded, negative responses are followed with the offer of a lower bid, and positive bids with a higher option (Peters and Hawkins, 2009).

Studies designed to measure willingness to pay concerned with artificial reefs, often measure values relating to the management and protection of existing reefs or payment towards new artificial reefs (e.g. Johns *et al.,* 2001, Johns, 2004; Chapter 5). These personal welfare values are expressed as the amount a visitor is willing to pay in excess of actual trip expenditures, producing estimates of 'Marshalian' consumer surplus (Boyle, 2003a). Overall, the contingent valuation method emerges as being the most conservative method to value environmental goods and services (Champ, *et al.,* 2003; Brander *et al.,* 2007). However, the hypothetical nature and behavioral intention of the contingent valuation method has, in the past, been a source of criticism (Roberts *et al.,* 1985; Hausman, 1993; Taylor, 2006), especially due to several biases associated with the methodology (Barton, 1994). Biases include; starting point and range bias, the anchoring effect on bid amounts, 'yea saying' and behavioural intention bias (Mitchell and Carson, 1989; Boyle, 2003b). Nonetheless, in isolation, the contingent valuation method if planned and conducted with care provides the most technically precise welfare measure of consumer surplus (Carson, 1989; Brander *et al.,* 2007). Three discrete methods attempting to capture the welfare value of marine recreation using contingent valuation are employed (Table 2.1). These are dichotomous choice (single-bounded and double-bounded), open-ended questioning and the payment card method, all described in detail by Mitchell and Carson (1989) and Champ *et al.* (2003) (refer to Table 2.1 legend, for details of single- and double-bounded dichotomous choice methods). Interested readers are also directed to Getzner *et al.* (2005), Bockstael and McConnell (2010) and Bennett (2011), for specific information detailing the development and application of non-market environmental valuation techniques.

## 2.4 Methods

### 2.4.1 Valuation Literature and Acquisition of Data

The valuation literature relating to the recreational value of artificial reefs has emerged steadily over the past two decades, alongside the growth in popularity in marine recreation hosted by artificial reefs. Milton published a number of studies in the late 1980's (e.g. Milton, 1988a, 1989a, 1989b) to quantify the economic performance of artificial reefs aimed at divers and fishers. More recently, a study conducted by Leeworthy *et al.* (2006), assessed the economic contribution of the *US Spiegel Grove* in Florida. However, the latter study is not included in this present analysis, as the authors used price transfer data derived from Johns *et al.* (2001) (Table 2.3) to calculate recreational expenditures. At a similar point in time, Pendleton (2005a) contributed a significant paper detailing the potential economic impacts of sinking ships for scuba diving recreation in the United States, using a price transfer methodology to estimate the value of a 'ship to reef' site. Indeed, the majority of the literature examined for this present study appears to focus on areas of the United States (Table 2.2), particularly Florida (e.g. Bell *et al.,* 1998; Johns *et al.,* 2001; Swett *et al.,* 2011) where a strong commitment to artificial reef creation is evident; notably as purposefully deployed vessels and Reef Balls™. The remaining papers selected for this study appear to focus on the recreational use of disused oil rigs (e.g. Ditton and Baker, 1999; McGinnis *et al.,* 2001; Ditton *et al.,* 2002) and pre-fabricated concrete modules (Brock, 1994; Bell *et al.,* 1998; Johns *et al.,* 2001).

I obtained data from a number of sources including electronic bibliographic databases (Scopus and Science Direct) and via direct contact with relevant researchers. In addition, three important Web sites relevant to the valuation of artificial reefs (and other marine resources) were used. The Florida Sea Grant website (www.flseagrant.org), the National Oceanic and Atmospheric Administration (NOAA) website (www.marineeconomics.noaa.org) and the National Ocean Economics Program (www.oceaneconomics.org). Searches were conducted for dates 1970 to 2011, inclusive, and studies from both the peer reviewed and gray literatures were sought to avoid publication bias (Littell *et al.,* 2008). Key words used to search within databases included; artificial reef, recreational values, economic valuation, scuba diving, contingent valuation method, non-market value and willingness to pay. Only studies published in English were used. References cited in any relevant reports found, were also checked for suitability.

**2.4.2 Screening of Data**

From the initial 30 studies assessed as suitable, data were examined to identify a number of key variables from which value observations could be compared in a meaningful way across selected studies, and with value observations reported by

Brander *et al.* (2007). Selected variables were; artificial reef value, geographical location, valuation method, individual recreational activity being valued and year of valuation. For consistency, a standard reporting value of per person-visit was required across studies to represent a unit of recreational activity. Additionally, value estimates taken from the literature were converted to a standard metric of US$ in 2010 prices using the Consumer Price Index – Purchasing Power (www.measuringworth.com). All monetary values including those reported in the introduction and discussion are in 2010 US dollars. (Note – bid values quoted in Table 2.1 are in year of report). Purchasing Power Parity conversions were not made due to a general lack of information in studies (i.e. country of origin for tourist participants). Upon preliminary examination of the literature, it was evident that a large body of the valuation research had been published in the 'gray' literature; as reports. Stoeckl *et al.* (2011) suggests this situation is in some ways of benefit, since reports are typically written in a language that is more accessible to managers in contrast to the scientific dialogue found in journals. Moreover, such reports are often commissioned by management authorities, and thus feed directly into decision-making institutions (Stoeckl *et al.,* 2011).

Figure 2.1 displays a flow diagram detailing the identification process for suitable valuation studies. From the initial 30 studies located, 10 studies were excluded from the analysis due to; use of price transfer data (Leeworthy *et al.*, 2006; Leeworthy, 2011), no standard reporting unit, or unit of per person-visit (McGurrin and Fedler, 1989; Murray and Betz, 1994; Schaffer and Lawley, 2008), annual values quoted (Roberts *et al.*, 1985; Milton, 1988b; Milton, 1989c; Morgan *et al.*, 2007) and duplicated research (Milton, 1988a). The remaining 20 studies, listed in Table 2.2, consist of 9 peer reviewed papers and 11 gray literature reports. Details of omitted studies are presented in Appendix 1 of this chapter. Due to a general lack of basic information in the valuation studies collected, including an absence of reported standard error values, I was unable to perform any robust meta-regression analysis in this study. Despite this, I report data in the form of a narrative synthesis, and include the mean and median for artificial reef values by; recreational activity, valuation methodology and by region. Where appropriate, levels of statistical significance are computed between artificial reef values and natural reef values (Brander *et al.,* 2007), using the one-sample (goodness of fit) chi square test.

**Table 2.2** Studies included in the meta analysis.

| Author(s) (year) | Location | Activity | Habitat | Valuation method |
|---|---|---|---|---|
| Bell *et al.* (1998) [R] | Florida | D, F | Sunk vessels, reef balls | MV, TCM, CVM |
| Brock (1994) [P] | Hawaii | D, MV | Pre-fabricated modules, surplus yard oiler, concrete terraces | MV |
| Crabbe & McClanahan (2006) [P] | Kenya | D | Sunk vessels, wrecks | MV, CVM |
| Ditton & Baker (1999) [R] | Texas | D | Oil and gas platforms, wrecks | CVM |
| Ditton *et al.* (2002) [P] | Texas | D | Oil and gas platforms, wrecks | MV |
| Dowling & Nichol (2001) [P] | Australia | D | Ex Navy vessel | MV |
| Hanni & Mathews (1977) [R] | Florida | D, F | Automobile tyres | MV |
| Hass Center (2007) [R] | Florida | D | Ex Navy Destroyer | MV |
| Hiett & Milton (2002) [R] | Texas | D, F | Oil and gas structures | MV |
| Holecek & Lothrop (1980) [R] | Michigan | D | Ship wrecks | MV |
| Hushak *et al.* (1999) [P] | Ohio | F | Sandstone material, concrete, brick rubble | TCM |
| Johns *et al*. (2001) [R] | Florida | D, F, S, MV | Sunk vessels, reef balls | MV, CVM |
| Johns (2004) [R] | Florida | D, F, S | Various artificial reefs | MV, CVM |
| McGinnis *et al.* (2001) [R] | California | D | Oil rig platforms | TCM |
| Milton (1989a) [P] | Florida | D, F | Sunk vessels, various wrecks, steel pipes | TCM |
| Morgan *et al.* (2009) [P] | Florida | D | Ex Navy destroyer | MV, TCM |
| Oh *et al.* (2008) [P] | Texas | D | Wrecks, various types of artificial reefs | CVM |
| Pendleton (2005b) [R] | California | D | Ex Navy destroyer | MV, TCM |
| Swett *et al.* (2011) [R] | Florida | D, F, S | Various artificial reefs | MV |
| Wilhelmsson *et al.* (1998) [P] | Israel | D | Ex Navy vessel | MV |

**Notes:** R: Report; P: Paper; D: Diving; F: Fishing; S: Snorkelling; MV: Marine viewing; MV: Market value; TCM: Travel cost method; CVM: Contingent valuation method

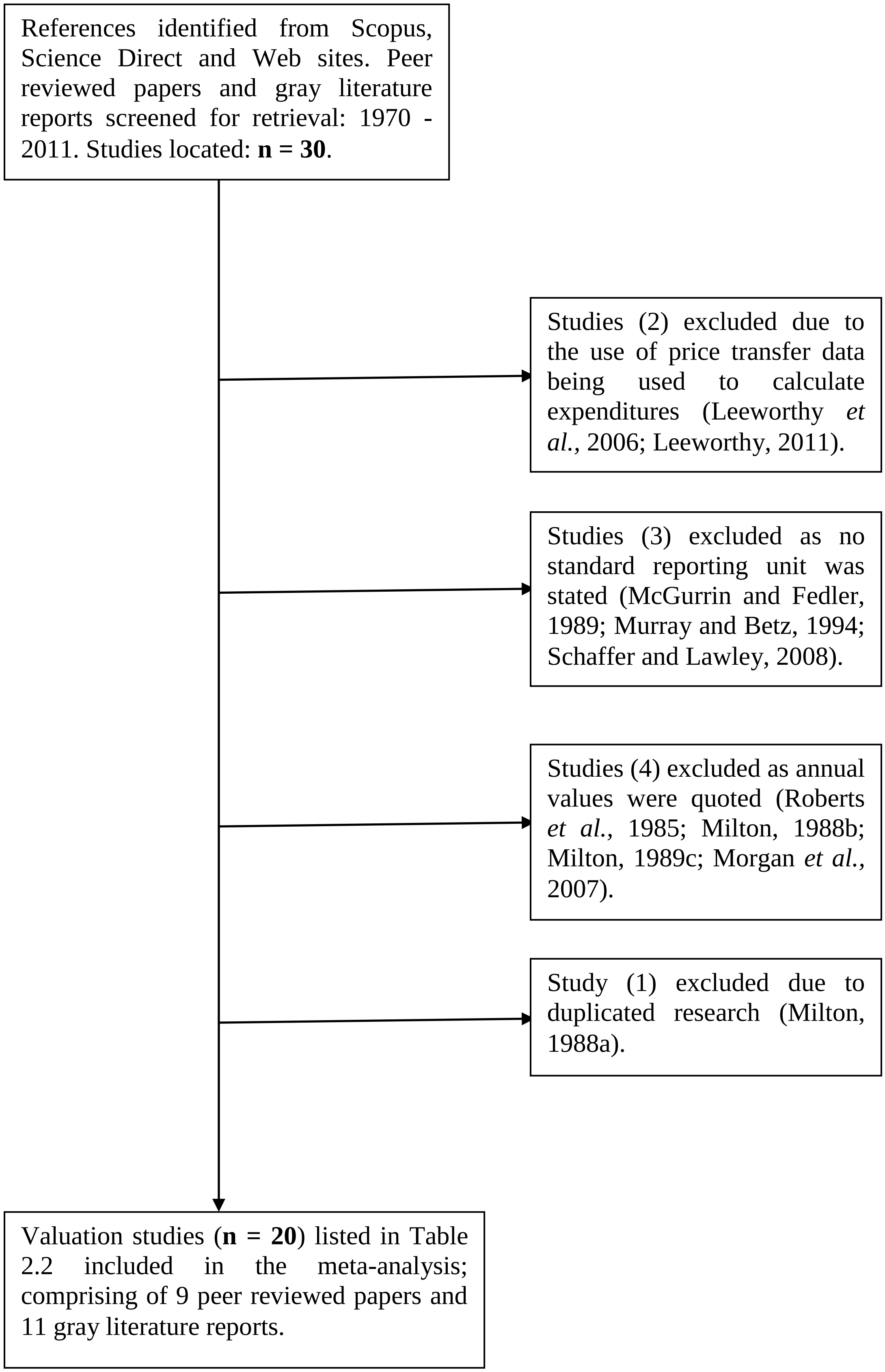


**Figure 2.1 Valuation studies.** The identification process of individual artificial reef valuation studies for inclusion in the analysis.

## 2.5 Results

### 2.5.1 Literature Overview and Recreation Value Observations

The majority of studies used in the analysis surveyed a combination of resident and visitor respondents, with the exception of Milton (1989a) and Morgan *et al.* (2009), who questioned residents or visitors only for each respective study. A combination of valuation techniques were additionally employed across studies (Table 2.2). In total 9 investigations used expenditure-driven market valuations to estimate the contribution of respective recreational activities. In contrast, 3 studies employed the travel cost approach; whilst Ditton and Baker (1999) and Oh *et al.* (2008) used contingent valuation methods of divers' willingness to pay for scuba diver benefits. Overall, 6 studies used a mixture of valuation techniques to stimulate and measure recreational amenity values relating to artificial reefs. From the 20 artificial reef valuation studies; a total of 57 separate recreation value observations were yielded (Table 2.3). These observations consisted of valuation method and activity being valued for resident and/or visitor responses. Most of these observations were for scuba diving (29 observations) followed by fishing (13 observations). Moreover, multiple observations were extracted from individual studies, with a mean of 2.85 ($\pm$ 3.05 s.d.) observations, and a median of 2 observations obtained from the 20 studies. One individual paper (Johns *et al.*, 2001) yielded a total of 13 separate value observations.

### 2.5.2 Artificial Reef Value by; Recreational Activity, Valuation Method and Region

Figure 2.2 presents mean artificial reef value estimates calculated by (*a*) recreational activity, (*b*) valuation method and (*c*) region. From the complete data set for artificial reef recreation, a mean value of US$122 ($\pm$ 154 s.d.) per person-visit was calculated and a median value of US$68. Immediately apparent from the results for artificial reef value by valuation method, is the mean estimate yielded from the contingent valuation method of US$35 ($\pm$ 67 s.d.), was considerably lower in comparison to mean values produced from the market value and travel cost methods, the latter two methods each reporting US$150 ($\pm$ 155 and $\pm$ 215 respectively, s.d.) per person-visit. These differences between valuation methods were found to be significant ($p \leq 0.001$).

**Table 2.3** Recreational values in US$ (2010 prices) reported by activity for per person-visit.

| Author(s) (year) | Diving | Fishing | Snorkelling | Marine viewing | Diving, fishing and snorkelling | Diving and fishing | Diving and snorkelling |
|---|---|---|---|---|---|---|---|
| Bell *et al.* (1998) | 67.70 **104.00** **(12.20)** | 67.60 **159.00** **(13.60)** | | | | (3.48) **(8.07)** | |
| Brock (1994) | 101.00 § | | | 44.80 **118.00** | | | |
| Crabbe & McClanahan (2006) | 49.10 (15.00) § | | | | | | |
| Ditton & Baker (1999) | (250.00) § | | | | | | |
| Ditton *et al.* (2002) | 220.00 **231.00** | | | | | | |
| Dowling & Nichol (2001) | 47.30 **55.00** | | | | | | |
| Hanni & Mathews (1977) | 72.00 § | 88.10 § | | | | | |
| Hass Center (2007) | 371.00 **487.00** | | | | | | |
| Hiett & Milton (2002) | 206.00 § | 46.50 § | | | | | |
| Holecek & Lothrop (1980) | 391.00 § | | | | | | |
| Hushak *et al.* (1999) | | (155.00) § | | | | | |
| Johns et al. (2001) | 88.50 (4.55) **(14.80)** | 82.40 **239.00** (3.75) **(16.10)** | 49.50 (3.58) **(14.50)** | **25.30** **(16.30)** | | | **190.00** |
| Johns (2004) | 23.50 | 44.40 **59.20** | 17.90 | | (6.90) **(28.30)** | | **63.20** |
| McGinnis *et al.* (2001) | (76.00) § | | | | | | |
| Milton (1989a) | (103.00) | (39.60) | | | | | |
| Morgan *et al.* (2009) | **574.00 (665.00)** | | | | | | |
| Oh et al. (2008) | (113.00) § | | | | | | |
| Pendleton (2005b) | 113.00 **596.00** **(133.00)** | | | | | | |
| Swett *et al*. (2011) | | | | | 124.00 § | | |
| Wilhelmsson (1998) | **32.00** § | | | | | | |

**Notes:** recreational values reported in parentheses indicate non-use values (derived from contingent valuation and travel cost methods). Values reported outside parentheses are market values. Values emboldened indicate estimates for visitors. Normal font indicates estimates for residents. § indicates visitor and resident estimates combined.

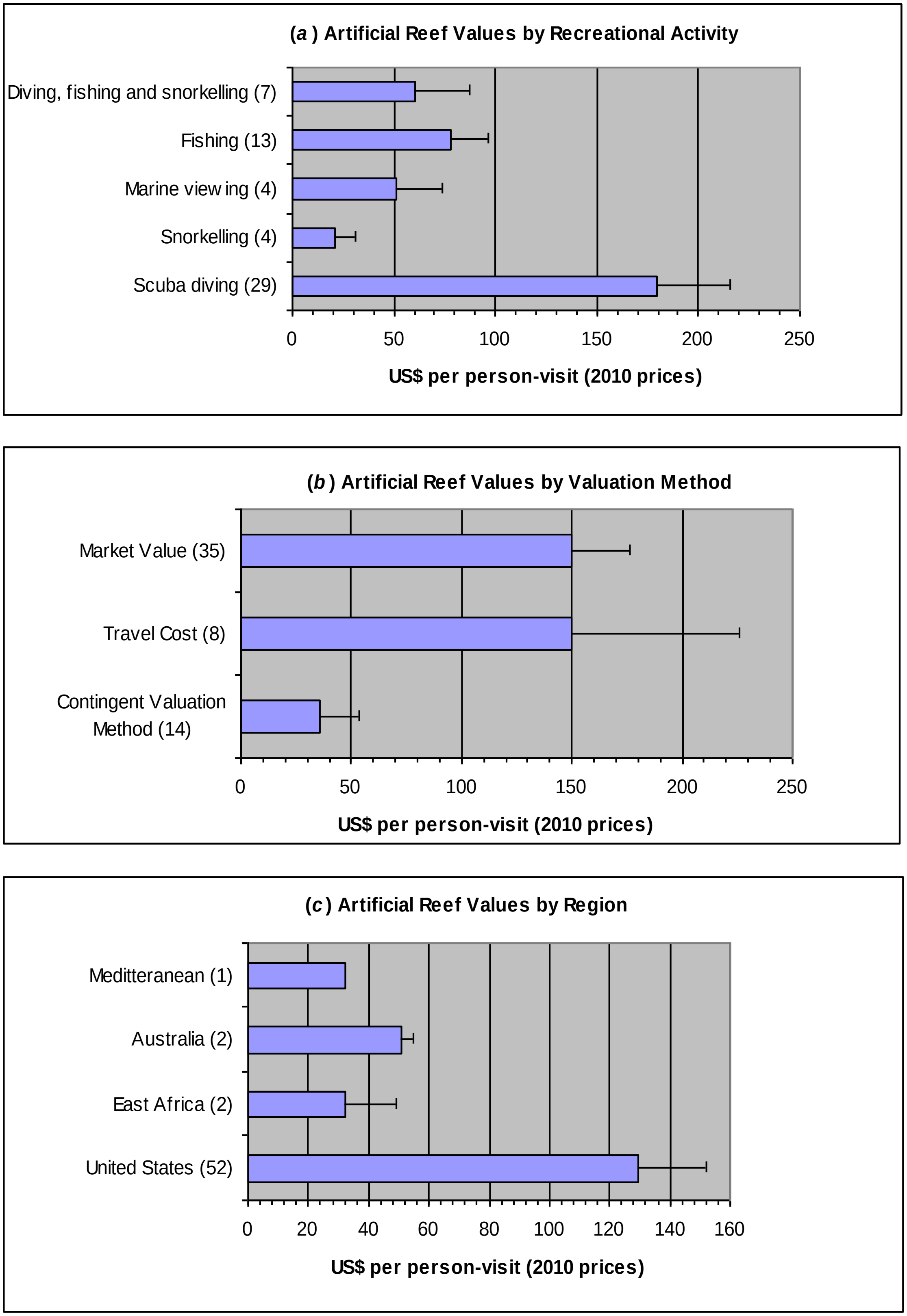


**Figure 2.2 Mean values for artificial reef recreation by; (*a*) recreational activity, (*b*) valuation method and (*c*) region.** The numbers in parentheses are the number of observations for each category.

In respect of recreational activities hosted by artificial reefs, a total of 7 categories valuing a diversity of activities were identified (Table 2.3; Figure 2.2*a*). These consisted of four individual reef-based activities (diving, fishing, snorkelling and marine viewing) and three categories using a combination of the latter. However for the purpose of calculating the mean and median for the final three categories listed in Table 2.3 (i.e. three combinations of diving, fishing and/or snorkelling), these are treated as one 'activity' group due to insufficient data obtained. Mean values per person-visit for the various recreational activities differ widely depending on the activity being valued. Snorkelling for example, yielded the lowest mean value of US$21 ($\pm$ 19 s.d.), compared to the highest mean value of US$180 ($\pm$ 191 s.d.) for diving ($p \leq 0.001$) (Figure 2.2*a*). In contrast, the value for fishing had a mean value of US$78 ($\pm$ 68 s.d.) (the second highest value reported after scuba diving) whilst I report a mean value of $51 ($\pm$ 46 s.d.) for marine viewing ($p \leq 0.022$). However, for the combined activities relating to diving, fishing and snorkelling, a relatively low mean value of US$61 ($\pm$ 71 s.d.) was yielded. This resulting estimate was skewed due to the contingent valuation method being used to measure four of the seven value observations. As previously noted, the contingent valuation method generated the lowest value estimates in the present study and in Branders *et al.* (2007) analyses.

The most widely used method for assessing the value of artificial reef recreation was the market value approach yielding 35 value observations (Figure 2.2*b*), followed by the contingent valuation method (14 value observations), with the travel cost method yielding the least with 8 observations. It is clear from Table 2.2; the various valuation methods employed by researchers to measure reef recreation differ considerably across the valuation literature. Even within individual reports, multiple valuation methods are used (e.g. Bell *et al.,* 1998; Johns *et al.,* 2001). Whilst the market valuation method based on direct and indirect expenditures for goods and services is useful for assessing artificial reef recreation value (reviewed in section: 2.3.1), contingent valuation, Brander *et al.* (2007) explain, provides estimates of the technically precise welfare measures of consumer surplus (i.e. non-market values) (reviewed in section 2.3.2). Hence the average value yielded from the contingent valuation method of US$35, reflects a reasonably accurate estimate of the net economic value of artificial reefs to users.

The studies inspected came from four areas of the world; the Mediterranean, Australia, East Africa and the United States (Figure 2.2*c*). By region, artificial reef recreation is dominated by studies conducted in the United States amounting to 85% of the 20 studies used in this analysis (Table 2.2). This relatively high number of published papers and reports reflects the prevailing commitment of the United States to artificial reef deployment and marine habitat expansion and their scientific study (Baine, 2001; Oh *et al.*, 2008). Fifty two separate value observations were identified for the United States amounting to the highest mean recreation value recorded of US$130 ($\pm$ 159 s.d.), followed by Australia with a mean value of US$51 ($\pm$ 5 s.d.) ($p \leq 0.001$). In comparison, East Africa and the Mediterranean appear to have the same mean recreation value attached to them of US$32 ($\pm$ 24 s.d.) per person-visit (Figure 2.2*c*).

### 2.5.3 Artificial Reef Value by Annual Number of Visitors

To investigate if the annual number of visitors to artificial reef sites influences recreation value, a correlation analysis was performed. To promote welfare consistency, data was drawn from estimates derived from the travel cost or contingent valuation methods only. However, by limiting this analysis to consumer surplus values, only 16 data points were used. The analysis (Figure 2.3) reveals a negative relationship between the two variables ($R^2$ = 0.521) that is found to be statistically significant; Spearman's rho (2-tailed); $p \leq 0.026$.

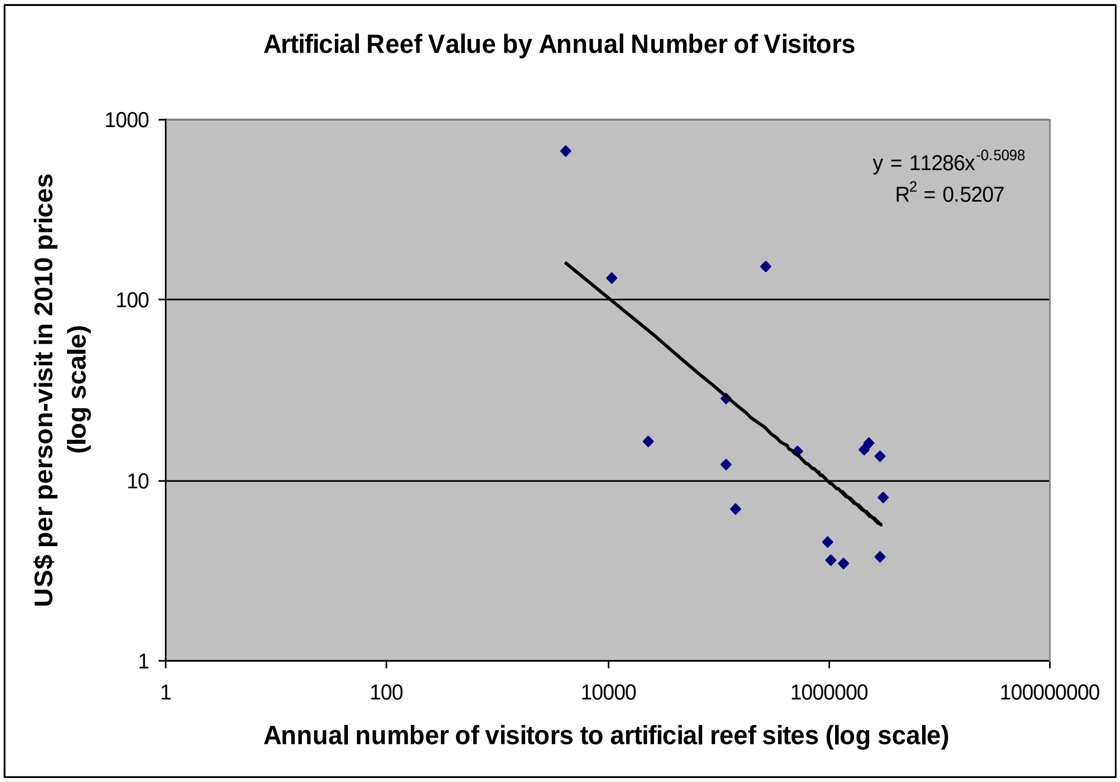


**Figure 2.3 Annual numbers of visitors to artificial reef sites vs. artificial reef values for welfare measures of recreational use using the travel cost or contingent valuation methods.** Data is presented on a log scale.

### 2.5.4 Recreation Value: A Comparison of Artificial Reef and Natural Reef Habitats

The values for artificial and natural reef habitats by recreational activity and valuation method were compared (Figures 2.4*a* and 2.4*b*). Data for natural reef recreation values were derived from Brander *et al.* (2007) coral reef meta-analysis. Values quoted in the study (year 2000) were converted to 2010 prices (www.measuringworth.com). From Brander *et al.* (2007) data set, an average coral reef recreation value per person-visit of US$233 was reported and a median value of US$21.50. This compares to a mean value of US$122 per person-visit and a median value of US$68 for recreating on artificial reefs. This difference in mean values between reef habitat types was statistically significant; $\chi^2$ (1) = 34.08, $p \leq 0.001$. Overall, value estimates reported for artificial reef recreation were more evenly distributed, in contrast to coral reef values having a skewed distribution leading to a long tail of high values.

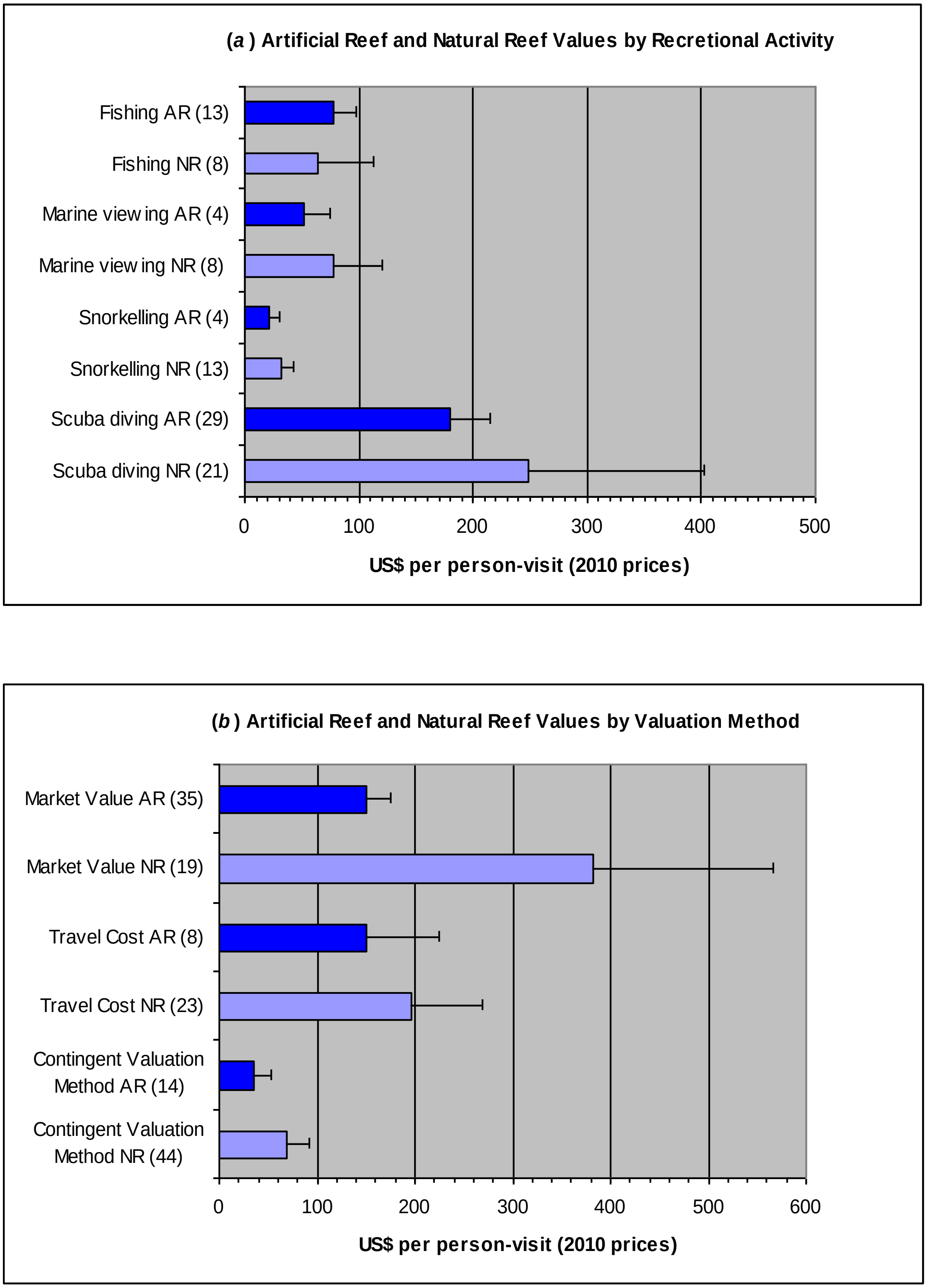


**Figure 2.4 Mean values for artificial reef (AR) recreation and natural reef (NR) recreation by; (*a*) recreational activity and (*b*) valuation method.** The numbers in parentheses are the number of observations for each category.

Four categories of reef-based activity (fishing, marine viewing, snorkelling and scuba diving) were compared between reef habitat types (Figure 2.4*a*). With the exception of a higher mean value per person-visit obtained for fishing at artificial reefs (US$78) compared with natural reefs (US$63), each of the remaining three activities had higher mean recreational values recorded for coral reefs. Congruent with Brander *et al.* (2007) results, recreation values produced for artificial reef and natural reef habitats for snorkelling received the lowest mean values of US$21 and US$32 respectively; $x^2$ (1) = 1.88, $p \geq 0.169$, and diving the highest mean values per person-visit of US$180 and US$ 249 respectively; $x^2$ (1) = 10.77, $p \leq 0.001$. Marine viewing estimates for artificial and natural reefs; US$51 and US$78 respectively; $x^2$ (1) = 5.24, $p \leq 0.022$, and fishing; US$78 and US$63 respectively; $x^2$ (1) = 1.39, $p \geq 0.238$, appeared to be broadly similar in values obtained for each reef type. Statistically significant differences in values for scuba diving and marine viewing were thus observed, with coral reefs yielding higher amounts. Overall, estimates for each individual leisure activity had a 'mirrored similarity' (Figure 2.4*a*) in recreation value assigned, regardless of reef habitat investigated.

In respect of valuation method, Figure 2.4*b* reports artificial reef and natural reef recreation values. Three techniques to value recreation hosted by artificial reefs were identified in the literature, with the market value approach being the most ubiquitous (35 value observations) (Figure 2.4*b*). In contrast, Brander *et al.* (2007) identified several valuation approaches employed by individual researchers to value coral reef recreation. Over and above the three methods compared in Figure 2.4*b*, production function and hedonic pricing methods were used as estimates. Despite this diversity, Brander *et al.* (2007) reported contingent valuation as being the most widely applied method (44 value observations) to value coral reefs. Overall, mean values reported were highest for natural coral reef recreation across all three valuation methods inspected. Immediately apparent from the contingent valuation method, was its emergence as the most conservative method at estimating values for both artificial and natural reef habitats of US$35 and US$68 respectively. This latter difference of US$33 per person-visit was statistically significant between reef habitats; $x^2$ (1) = 9.94, $p \leq$ 0.001. In contrast, the market valuation method produced the highest mean recreation values for both reef types of US$150 and US$382 respectively; $x^2$ (1) = 100.30, $p \leq$

0.001. The values yielded from the travel cost approach of US$150 and US$196 for artificial and natural reef recreation, respectively were also significantly higher for natural reef recreation; $\chi^2$ (1) = 0.015, $p \leq 0.013$.

## 2.6 Discussion

This analysis takes an initial step towards understanding the potential economic benefits of recreation-orientated artificial reefs. It demonstrates that artificial reefs have a substantial economic value as a result of individuals participating in marine recreation on human-made reefs. Moreover, by examining closely the artificial reef valuation literature, significant non-market values capturing the enhanced welfare benefits and experiences visitors enjoy from artificial reefs, are clearly recognized. Finally, by making a comparison of recreation value observations between artificial and natural reef habitats, the relative importance of values relating to artificial reef recreation are more accurately appraised.

Clearly, the most highly valued recreational activity conducted at artificial reefs is scuba diving. Research suggests a variety of factors appear to contribute to their popularity as amenity resources among divers. For example, artificial reefs may provide a focused and guaranteed diving experience, convenience of access, and in some instances, all weather diving sites (Milton, 1989a, Pears and Williams, 2005; Edney, 2012; Kirkbride-Smith *et al.,* 2013). However, the most ubiquitous reason for their use by divers appears to be their ability to harbour and concentrate marine life, especially fishes (Milton, 1989a; Stolk *et al.,* 2005; Edney, 2012; Kirkbride-Smith *et al.,* 2013). My results thus indicate scuba divers will pay significantly for these accrued benefits derived from artificial reef diving sites. As divers are an important source of tourism revenue, spending approximately three times more money per day than general tourists (Dearden *et al.,* 2006), the deployment of recreation-orientated artificial reefs have the potential to make a viable fiscal contribution (and welfare benefit) to people and local host economies (see for example; Johns *et al.,* 2001; Oh *et al.,* 2008). Indeed, Brock (1994) provides evidence that artificial reefs for non-consumptive diving can yield significantly greater economic return than when used for commercial fishery purposes.

Artificial reefs as natural fish aggregators (Bohnsack, 1989; Arena *et al.*, 2007), are not only popular with divers, but typically attract a high level of interest from sport anglers/fishers (Milton, 1989a; Stanley and Wilson, 1989; Murray and Betz, 1994). This is likely due to higher catch rates of economically important species normally present around deployed reefs (Brock, 1994; Grossman *et al.*, 1997) compared to less superior fishing on natural reef and seabed locations (McGlennon and Branden, 1994). Despite the prevailing dichotomy of opinion among scientists regarding the artificial reef fisheries 'attraction versus production' debate (e.g. Lindberg, 1997; Pickering and Whitmarsh, 1997), my findings revealed sport anglers paid on average $15 per person-visit more for fishing at artificial habitats than at natural reefs. This monetary difference is quite considerable and supports the tenet that anglers view artificial reef as being productive in their requirements (Grossman *et al.*, 1997). Further, in terms of welfare benefits gained from artificial reef use (i.e. through contingent valuation), visitors surveyed by Bell *et al.* (1998) and Johns *et al.* (2001) were willing to pay a marginally higher dollar value per person-visit (~ $1 - $1.30) to fish on artificial reefs than to dive on artificial habitat (Table 2.3). Moreover, Murray and Betz (1994) noted that significantly more anglers in Florida favoured the purchase of a stamp than scuba divers did to use the same artificial reef location for their respective sport. These studies thus suggest anglers' derived greater welfare benefits from artificial reefs than divers did. In general terms however, angling and diving are viewed as incompatible activities at a single artificial reef location (Murray and Betz, 1994) as each interferes with the goals of the other, i.e. removal of fish by anglers in contrast to the viewing of marine life by divers, thus measures to manage potential conflicts (and congestion) are important from an economic standpoint. Several control measures around artificial reefs have been proposed by researchers, including selective access (Brock, 1994) that may involve user fees and/or limited licensing to use popular reefs (Sutton and Bushnell, 2007).

Whilst market impact studies based on gross expenditure are an important economic measure of a reef resource, non-market values represent a true net economic 'welfare' value of artificial reefs to users (Pendleton, 2005a). Two valuation methods to stimulate the consumer surplus of artificial reefs were adopted in the artificial reef valuation literature, with the contingent valuation method more widely used than the travel cost method. A number of authors (e.g. Milton, 1988a; Bell *et al.*, 1998; Ditton and Baker, 1999; Johns *et al.,* 2001; Johns, 2004) report substantial non-market consumer surplus values relating to users willingness to pay for maintaining existing artificial reefs and proposed new artificial reefs. Collectively, these non-market values suggest a wealth of untapped consumer surplus of millions of dollars annually. Thus in terms of managing coral reef recreation, a vast body of consumer surplus could be potentially exploited generating substantial revenue to help conserve reefs. This is especially relevant for marine protected areas that have not as yet fully utilized artificial reefs as a recreation management tool (Oh *et al.*, 2008; Chapter 5). Notwithstanding, an interest in creating substitute sites for marine recreation amenity is gradually developing (e.g. van Treeck and Schuhmacher, 1999a; Leeworthy *et al.*, 2006; Shani *et al.*, 2011; Polak and Shashar, 2012) with sacrificial sites successfully redistributing visitors away from natural reef habitats (Leeworthy *et al.,* 2006; Polak and Shashar, 2012; Kirkbride-Smith *et al.*, 2013). As divers (principally) and snorkellers have previously shown willingness to pay for recreational opportunities at artificial reefs (Murray and Betz, 1994; Bell *et al.*, 1998; Johns *et al.*, 2001; Johns, 2004; Oh *et al.,* 2008) investigating specifically visitors' willingness to pay marine protected area user fees to access artificial reefs (as well as natural reefs), is an interesting management option for marine reserves who may wish to expand their resource base and at the same time protect natural reef assets. As far as I am aware, a reef management strategy of using visitor access fees to help fund and/or maintain artificial reefs within formally protected areas, has not been fully investigated to date (Chapter 5).

One outcome of this study suggests that high visitor numbers to an artificial reef site may potentially depress the recreation value of the reef. This indicates that visitors to high-density sites may be negatively affected by the number of additional people present, suggesting a user preference for less crowded reefs. A number of studies investigating crowding in marine recreation settings suggest congestion affects visitor satisfaction (Shafer and Inglis, 2000; Musa, 2002), depresses resource values (Rudd and Tupper, 2002; Schuhmann *et al.,* 2013) and affects preferences at either dive or snorkel sites (Inglis *et al.*, 1999; Musa, 2002). Moreover, results of Brander *et al.* (2007) meta-analysis investigating the recreational value of coral reefs indicate high visitor numbers reduces recreation values. This additionally suggests visitors to a reef site prefer an unfettered and un-crowded experience. According to Davis and Tisdell (1996), a significant proportion of the amenity values associated with scuba diving relate to the wilderness experience realized, thus a feeling of solitude appears to be an important component of the marine recreation experience. This observation has important implications for the siting and management of artificial reefs relating to their accessibility, and also in defining socially acceptable standards for visitors using artificial reefs (i.e. visitor numbers). It also follows that the price of accessing a reef site for recreation, whether natural or artificial, may need to increase in response to the effects of over-crowding. This practice would also help preserve the biological integrity of reefs, though Davis and Tisdell (1996) suggest this may be difficult to achieve due to the open access nature of reefs generally.

To further understand the relative economic importance of values obtained for artificial reef recreation, a comparison of values with those reported by Brander *et al.* (2007) for natural coral reefs, were made (Figure 2.4). Despite the valuation estimates produced for recreating on artificial habitats being less than those documented for natural reefs (with the exception of fishing), artificial reefs nonetheless appear to be highly valued especially by scuba divers and anglers. Indeed, I am aware of at least three studies (Johns *et al.*, 2001; Johns, 2004; Oh *et al.*, 2008) that specifically compare recreation values from both reef habitats existing in the same location, all with encouraging results. For example, Johns *et al.* (2001) revealed users of artificial reefs in Florida were willing to pay an average consumer surplus of $10.51 per person-day compared to an average value of $15.33 per person-day for natural reef recreation. Moreover, Oh *et al.* (2008) found divers in Texas were willing to pay $113 per trip for artificial reef use and $183 for diving in a natural reef setting. Whilst divers surveyed in Texas clearly had a preference for natural reefs, and accordingly obtained $70 more net benefits than artificial reef divers, collectively these results challenge conventional attitudes that natural coral reefs are valuable and artificial reefs are not (Oh *et al.*, 2008; Chapter 4).

In order to promote a theoretical relationship between artificial and natural reef recreation values, the same valuation construct that Brander *et al.* (2007) adopted was used in this study. However, a limitation of my research needs consideration as a result of this. As monetary measures for artificial reef values were derived from various valuation methods (i.e. market valuation, travel cost and contingent valuation), a lack of welfare consistency is evident. According to Londoňo and Johnson (2012), this pooling of data would generate theoretically non-compatible measures of value for artificial reef amenity; as it did also in Brander *et al.* (2007) study investigating coral reef recreation. Indeed, Londoňo and Johnson provide some insight into the importance and relevance of welfare consistency in coral reef meta-analysis. They challenge the Brander *et al.* (2007) study, and suggest their lack of theoretical inconsistency led to reliability concerns over reported results. In contrast, Londoňo and Johnson (2012) focus purely on consumer surplus methodologies such as the travel cost and contingent valuation methods, to measure coral reef recreation values, and rightly claim enhanced reliability of results over the Brander *et al.* (2007) study. However, unlike the ubiquitous nature of the coral reef valuation literature (Cesar, 2000), the current sparseness of consumer surplus studies aimed at artificial reef recreation, restricts this type of meta-analytical treatment at present. For example, just 9 studies measuring consumer surplus values for diving, and 4 studies valuing fishing at artificial reefs, were evident in the literature. Despite this, data derived solely from consumer surplus estimates were used to investigate the influence of visitor numbers on artificial reef recreation values (Figure 2.3).

## 2.7 Conclusions

Important lessons are yielded from this study that closely reflect those reported by Brander *et al.* (2007) and Londoňo and Johnson (2012). Specifically; substantial improvements to the artificial reef valuation literature would be made by ensuring basic information is included in primary studies. For example; reef site attributes (size, geographical location, age and biotic index), methodological characteristics (payment vehicle, sample method, sample size and country of origin) and noting deployment of artificial reefs in exiting or proposed marine protected areas. Moreover, studies should aim to use a standard reporting format in their methodology (e.g. per person-day/visit). There is also a clear need for further valuation studies that focus on consumer surpluses associated with recreation-orientated artificial reefs. Of significance is the contingent valuation method, as it represents the only technically precise means of estimating non-market values through willingness to pay or willingness to accept (Mitchell and Carson, 1989; Champ *et al.*, 2003). Collectively, an improvement in uniformity, and a stricter attendance to valuation methodology, would permit reconciliation of future valuation studies that would yield a higher-quality, more robust, meta-analytical treatment of the artificial reef recreation literature. This would benefit price transfer reliability to unvalued policy sites and aid the setting of user fees to access marine protected areas (Brander *et al.*, 2007; Chapter 5).

## Acknowledgement

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**Appendix 1**: Valuation studies excluded from the analysis.

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# Chapter 3

## *The Relationship between Diver Experience Levels and Perceptions of Attractiveness o f Artificial Reefs – Examination of a Potential Management Tool*

### 3.1 Abstract

Artificial reefs are increasingly used worldwide as a method for managing recreational diving since they have the potential to satisfy both conservation goals and economic interests. In order to help maximize their utility and conservation benefits, further information is needed to drive the design of stimulating and challenging resources for scuba divers. By employing a questionnaire survey this paper reports on the perceptions of diving on artificial reefs in Barbados from a user perspective. In addition, resource substitution behaviour among scuba divers was examined. My results showed that divers expressed a clear preference for large shipwrecks or sunken vessels that provided a themed diving experience. Motives for diving on artificial reefs were varied, but were dominated by the chance of viewing concentrated marine life, increased photographic opportunities and the guarantee of a 'good dive'. Satisfaction with artificial reef diving was high amongst novices and declined with increasing experience. Experienced divers had an overwhelming preference for natural reefs. As a management strategy, these findings suggest the success of substituting natural reefs for 'sacrificial' artificial reef diving sites would likely succeed amongst novices, but may be less effective as diver experience increases. The ability of artificial reefs to divert divers from natural reef habitats was noted in the study. In conclusion, my results emphasize the capacity of well designed artificial reefs to contribute towards the management of coral reef diving sites in Barbados as well as other diving destinations harbouring coral reefs. Directions for future research are suggested.

## 3.2 Introduction

Scuba diving is a burgeoning global activity with coral reefs being a major attraction to divers. As a niche market, recreational diving is widely acknowledged as being one of the tourism industry's fastest growing markets (Tabata, 1992; Musa, *et al.*, 2006; Ong and Musa, 2011) and as a consequence many countries are establishing themselves as new international diving destinations. An increase in leisure time and overseas travel, the ease and low cost of obtaining scuba certification and advances in technical equipment, all appear to contribute to the recent strong growth witnessed in the dive market (Garrod and Wilson, 2003). Coral reefs naturally provide a diverse and stimulating setting to conduct recreational diving as well as other marine based activities. However, their ubiquitous appeal to the diving tourism industry has led to concerns of significant levels of biological damage resulting from the practice (Thurstan *et al.,* 2012). Many studies document diver impacts (e.g. Harriott *et al.,* 1997; Medio *et al.,* 1997; Rouphael and Inglis, 1997, 2001, 2002) with levels of damage to reefs often linked to intensity of use by divers (Hawkins *et al.,* 1999; Barker and Roberts, 2004; Hawkins *et al.*, 2005) and to a lack of diving experience (Roberts and Harriott, 1994; Walters and Samways, 2001; Warachananant *et al.*, 2008; Chung *et al.*, 2013). Studies report; mechanical breakage (Tratalos and Austin, 2001; Zakai and Chadwick-Furman, 2002; Warachananant *et al.,* 2008) and the resuspension of sediments (Zakai and Chadwick-Furman, 2002; Barker and Roberts, 2004; Hasler and Ott, 2008; Chung *et al.*, 2013) as problems.

Although the negative impacts associated with mass diving tourism are clearly unacceptable, scuba diving tourism has the potential to generate substantial revenues (e.g. Johns *et al.,* 2001; Pendleton, 2005; Depondt and Green, 2006; Brander *et al.*, 2007; Oh *et al.,* 2008; Burke *et al.,* 2011) especially for many tropical countries harbouring coral reefs. However, balancing the requirements of reef conservation with the needs of local host economies, some of whom are highly dependent on tourist revenues (Hodgson and Dixon, 2000; Westmacott *et al*., 2000), represents a considerable challenge to marine managers and policy makers. Various approaches for managing coral reef diving sites have emerged over the previous 20 years, such as the percentile approach and limits of acceptable change (Rouphael and Hanafy, 2007) and the concept of ecological carrying capacity (e.g. Hawkins and Roberts, 1997; Schleyer and Tomalin, 2000; Zakai and Chadwick-Furman, 2002). A drawback of these policies though, is that they may require ongoing monitoring and adjustments (McCool and Cole, 1998) and are more effective when applied within a marine park setting. Even within marine protected areas, active management is often lacking (Burke *et al.*, 2002; Burke and Maidens, 2004; Wells, 2006; Burke *et al.*, 2011). Moreover, the conceptually appealing notion of tourism 'carrying capacity' has often been misinterpreted (van Treeck and Eisinger, 2008) or neglected (McCool and Lime, 2001). Artificial reefs could provide an alternative more unconventional method to assist in the management of scuba diving impacts.

Whilst artificial reefs are not viewed as 'perfect' substitutes for natural coral reefs (Oh *et al.*, 2008), there is evidence that they are valued by scuba divers (Blout, 1981; Stolk *et al.*, 2005; Shani *et al.*, 2011), with many structures used successfully as sacrificial dive sites worldwide (e.g. Wilhelmsson *et al.*, 1998; Dowling and Nichol, 2001; Leeworthy *et al.*, 2006; Polak and Shashar, 2012). Of significance, artificial reefs have been shown to alleviate user pressure to nearby natural reefs (Leeworthy *et al.*, 2006; Polak and Shashar, 2012) and to contribute substantially to local host economies (e.g. Johns *et al.*, 2001, Pendleton, 2005; Oh *et al.*, 2008). Artificial reefs also form integral components of reef rehabilitation programs (e.g. Clark and Edwards, 1999; Jaap and Hudson, 2001) and can function as spawning grounds for fish and coral larvae (Fitzhardinge and Bailey-Brock, 1989; DeMartini *et al.*, 1994). Moreover, some 'established' artificial reefs have demonstrated their success in sustaining a greater density and/or variety of organisms (particularly fish species) than nearby natural reefs (Wilhelmsson *et al.*, 1998; Perkol-Finkel and Benayahu, 2004; Arena *et al.*, 2007). Divers appear to recognize many of the conservation benefits of artificial reefs. For example; in a study of Australian recreational scuba divers, Stolk *et al.* (2005) found a strong level of agreement elicited for the attitude statement; 'artificial reefs help to take scuba diving pressure off popular natural reefs'. In a separate study, Shani *et al.* (2011) found a high percentage of respondents expressed the belief that a new artificial reef would positively contribute to the marine environment. In general, research suggests environmental awareness and a keen interest in the underwater environment are high among scuba dives (Barker, 2003; Meisel and Cottrell. 2004), with both of these factors appearing to be among the plethora of reasons of 'why divers dive' (Carter, 2008).

From a scientific standpoint, it is advantageous to examine the factors that attract divers to reefs and the specific reasons why in fact individual's scuba dive. According to Carter (2008, p.49), "it is the highly physical and sensory nature of diving, coupled with immersion in a challenging and alien environment, independent of gravity, that represent the primary attractions of the engagement". However, it is possibly the desire to explore and experience the underwater environment, and its associated fauna and flora that is central to diving tourism. Several studies link divers' choices to potential encounters with fauna such as large or unusual fish (Williams and Polunin, 2000; Rudd and Tupper, 2002; Barker, 2003; Ramos *et al.*, 2006; Gössling *et al.*, 2008; Uyarra *et al.*, 2009), marine turtles (Uyarra *et al.*, 2005) or less common cryptic species (Williams and Polunin, 2000), as attributes that would provide the greatest diver satisfaction. In many instances, reef attributes associated with such encounters appear to be more appreciated that attributes concerned with natural reef structure and diversity of corals (Williams and Polunin, 2000; Fitzsimmons, 2009). Also, social considerations appear to be of significant importance to scuba diving participation (Ditton *et al.*, 2002; Musa, 2002; Dearden *et al.*, 2006; Fitzsimmons, 2009), as well as the benefits of updating diving skills (Ramos *et al.*, 2006) and varied topography and good sea visibility (Fitzsimmons, 2009).

Given the relative importance that some divers place on features that are not necessarily unique to natural reefs (Dearden *et al.*, 2006; Fitzsimmons, 2009), it may be possible to satisfy diver's requirements with well conceived artificial reef attractions. However, research relating to issues concerned with the recreational use of artificial habitats by divers has received scant attention to date. The few relevant published studies (Milton, 1989; Stanley and Wilson, 1989; Ditton *et al.*, 2002; Stolk *et al.*, 2005; Shani *et al.*, 2011; Edney, 2012) and principal findings are presented in Table 3.1. A majority of these works sought to gain a personal insight from divers into their motivations and perceptions of diving on artificial reefs. In spite of these works, none of these studies investigated resource substitution behaviour among scuba divers. Indeed, some individuals participating in the sport may object to the use of artificial reefs for scuba diving. Accordingly, a number of research questions need addressing to frame suitable management approaches using artificial reefs. Notably; questions aimed at achieving a greater understanding of how artificial reefs fulfill the requirements of divers, how these structures contribute to the whole diving experience, as well as their acceptance by divers and the social aspects of artificial reef usage. Such knowledge allows managers to develop new reef sites that satisfy the demands of divers, but at the same time contributes to positive regional development and the sustainability of natural reef resources and local dive industries.

### 3.2.1 Research Aims

The aim of this paper was to explore the perceptions of diving on artificial reefs in Barbados from a user perspective. Specifically, information was sought to characterize both resident and visitor scuba divers, to acquire an understanding of why individuals dive on artificial reefs and the factors that inform their choice of reef site. I report on divers use, opinions and preferences relating to artificial reefs as diving resources, as well as the environmental attributes and motivational factors that contribute to diver enjoyment and satisfaction. I additionally explore if reef habitat preference is influenced by diving experience. The results of this study are discussed within the context of scuba diving management in Barbados as well as other marine diving destinations where reef conservation is important.

**Table 3.1** Previous studies and key findings of motivational factors relating to diving on artificial reefs.

| | **Milton, 1989** | **Stanley & Wilson, 1989** | **Ditton *et al.*, 2002** | **Stolk *et al.*, 2005** | **Shani *et al.*, 2011** | **Edney, 2012** |
|---|---|---|---|---|---|---|
| **Artificial reef attributes** | Desirable fish species | Fish species (grouper and snapper) | Large Naval ships<br>Petroleum structures | Old shipwrecks<br>Diversity of species<br>Concentration of marine life | Large Naval ships<br>Airplanes<br>Themed structures | Historical shipwrecks<br>Artifacts<br>Penetrable wrecks<br>Marine life |
| **Environmental factors** | Accessibility to dive site | Underwater visibility | Mooring buoys<br>Depth of reef | Sea visibility<br>Currents<br>Reef accessibility<br>Reef location | | |
| **Social factors** | Travel time<br>Previous experience | Size of dive group | Restrictions on spear guns<br>Night diving<br>Tranquility<br>Adventure | Size of dive group<br>Safety<br>Photography | | Peace<br>Tranquility<br>Photography |

## 3.3 Methods

### 3.3.1 Study Setting

This article presents a synthesis of work that was conducted on the Caribbean island of Barbados (13°10'N, 59°32'W), West Indies (Figure 3.1), between December 2010 to January 2012. This small island prism (431 $km^2$), composed almost entirely of coral sediments (Lewis, 1960), supports a population density of 623 inhabitants $km^{-2}$ (Barbados Statistical Service, 2010). Along the protected western side of the island are complexes of fringing, patch and bank reefs (Lewis, 1960) that nourish the world famous white sand beaches (Dharmaratne and Brathwaite, 1998). These attractive characteristics form the basis of the islands tourism appeal (Uyarra *et al.*, 2005), alongside warm tropical air temperatures and clear marine waters. To complement the natural reefs, several artificial reefs consisting of sunken ships and of Reef Balls™, have been gradually deployed along the south-west coast (Figure 3.1). Barbados claims to have the best collection of wrecks in the Caribbean (Agace, 2005), six of which are situated in a dedicated marine park in Carlisle Bay. Access to the majority of the artificial reef diving sites is only possible by boat, with the exception of the Carlisle Bay wrecks that can readily be reached from the shore.

Based on figures from the Caribbean Tourism Organization (2012), it was estimated that in 2011 approximately 568,000 tourists vacated in Barbados, with a further 620,000 cruise passengers visiting. From these data it is reported that between 30,000 and 50,000 visitors participate in scuba diving (Schuhmann *et al.*, 2008). Marine protection on the island is served by one small (2.1 $km^2$) legislated marine park, Folkestone Marine Reserve (Cumberbatch, 2001), located on the sheltered west coast in the parish of St. James.

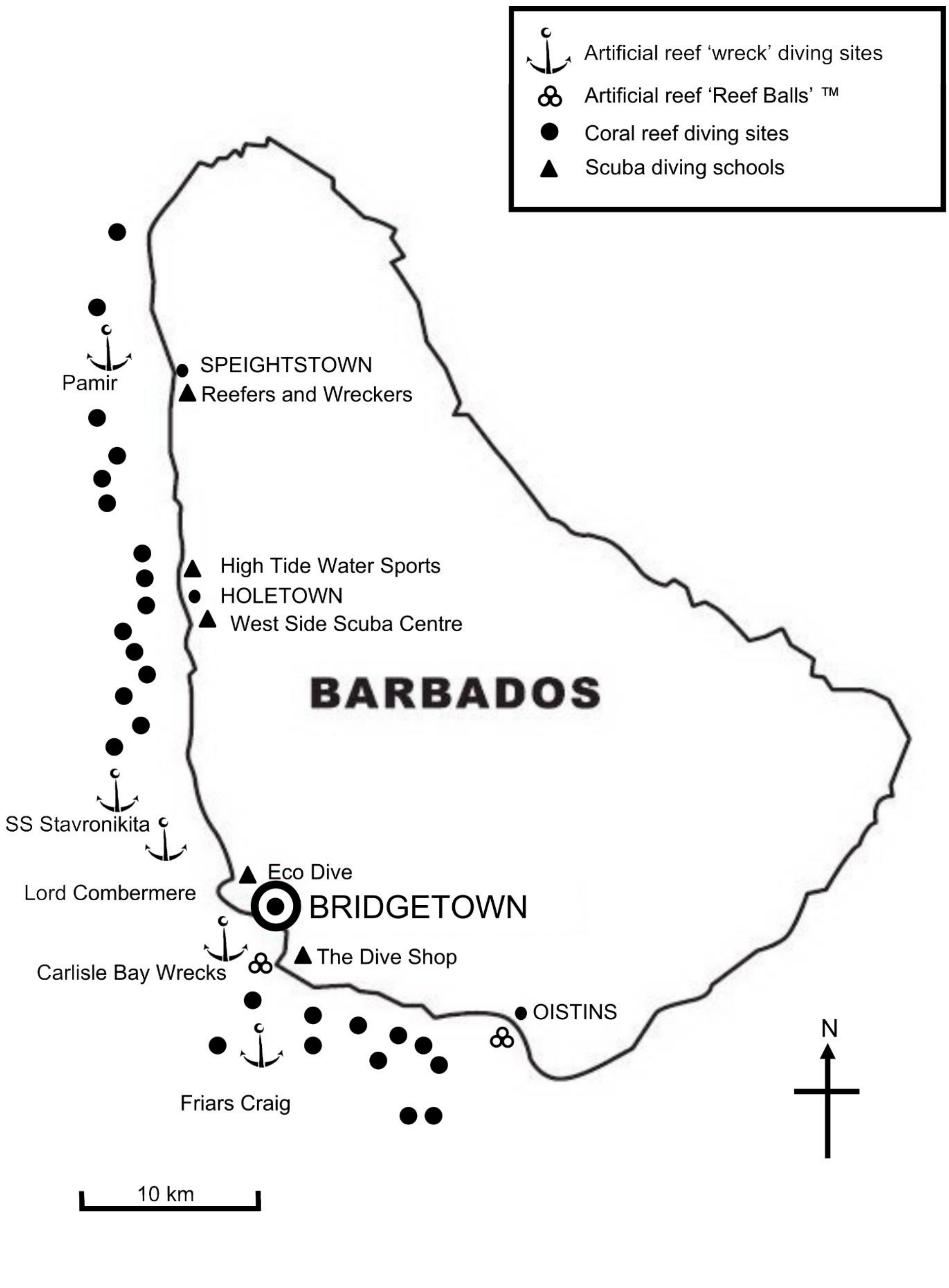


**Figure 3.1 Map of Barbados.** Locations of artificial reef and natural reef diving sites and diving schools (Adapted from: Google maps, 2012).

Barbados was well placed as a site to conduct a study of the interactions of diving tourism and artificial reefs, as the island has a well established network of artificial reefs (Agace, 2005), at various stages of maturity (A. Kirkbride-Smith, personal observation, February 2008), a diverse diving clientele (Schuhmann *et al.*, 2008) and a government that supports on-going artificial reef projects (Barbados Government Information Service, 2009).

### 3.3.2 Data Collection

Data collection was achieved through the development of a 6 page, 36 question self-administered survey (in English only) (Appendix A), using a combination of open-ended and closed questions. The questionnaire consisted of four discreet parts. The first section profiled the diving clientele of Barbados by capturing basic demographic information and diver experience, including the number of dives each participant had logged in their diving history. In the second section, information was sought on respondents' motives for diving, whether they had dived in Barbados previously, and questions relating to artificial reef awareness and local reef usage. The aim of section three was to measure the importance of specific artificial reef attributes that respondents considered contributed to their overall enjoyment and satisfaction whilst diving. In addition, personal satisfaction relating to the experience of diving on artificial reefs in Barbadian waters, were also measured. Finally, in the fourth part of the survey, attitudes towards artificial reefs were explored as well as scuba divers' reef habitat preferences between artificial reefs and natural reefs as diving sites in Barbados.

A series of Likert scales (5-point) and checklists were included in the survey design alongside 8 free-response questions that gave individuals an opportunity to express their own thoughts and feelings to a prior response. Numbered Likert scales were embedded in the survey to rate the following; satisfaction of artificial reef diving in Barbados (*1 = very dissatisfied to 5 = very satisfied*), attitude assessment statements relating to artificial reefs as diving sites (*1 = strongly disagree to 5 = strongly agree*) and diving satisfaction attributes relating to artificial reefs (*1 = not important at all to 5 = very important*). Specific questions included in the survey reflect previous works that have studied diver perceptions of artificial reefs (Ditton *et al.,* 2002; Stolk *et al.,* 2005). To assist participants; a map of Barbados was provided (Appendix A) that included a list of all artificial reef and natural reef diving sites and locations of diving schools situated along the south-west coast of the island. Respondents were given the opportunity at the conclusion of the survey to add any additional information they thought necessary/beneficial to the study or to the management of local reefs. They were also invited to provide their email address if they expressed an interest in viewing the results of the study. Prior to the main survey, the questionnaire was tested as a pilot survey ($n$ = 10) aided by a survey assessment sheet (Appendix B) that resulted in minor modifications to several of the questions.

Sampling was conducted at five of the diving companies situated along the south-west coast of Barbados at the conclusion of their dives. A twelve month period for surveying enabled me to capture one high season (November to May) and one low season (June to October) in Barbados. Selection of survey participants was randomized, based on every other individual entering a dive shop with *a priori* requirement of ≥ 10 logged dives and knowledge of local artificial reef diving. The rationale of the study was made clear to all participants prior to completion of the questionnaire, and consent was sought to use the information anonymously. All divers surveyed gave their permission to use the results. From a total of 350 survey instruments initially circulated, 200 (57%) were fully completed within the survey period.

### 3.3.3 Statistical Analysis

The Statistical Package for the Social Sciences (SPSS, Version 19) software was used to analyze relevant questionnaire data. For this study, and consistent with the methodology of Fitzsimmons (2009), a distinction was made between the experience level of divers, denoted by two categories; novice divers (< 100 logged dives) and experienced divers (≥ 100 logged dives). This was achieved by transforming the total number of dives each participant had logged to date into a categorical variable. Descriptive statistics were used to profile demographic variables and diver experience variables of survey respondents. Mean scores for factors such as age, length of diving career and frequency of diving, were calculated. To assess the importance of artificial reef diver enjoyment attributes presented in the survey, a basic ranked list of mean values were produced for both novice and experienced divers. I applied Chi-square tests (with Yate's Continuity Corrections) to categorical variables to detect differences in responses to specific questions (i.e. dichotomous choice questions) and to attitude statements. Moreover, I examined the relationship of responses to specific questions between diver experience categories and between genders.

Content analysis was employed to analyze dominant themes relating to qualitative data. Significant contributions were extracted and presented within the discussion section. As my data were not normally distributed (Kolmogorov-Smirnov Test), and remained so despite various transformations (e.g. $\log_{10}$ transformation), non-parametric statistical tests were applied. The non-parametric Kruskal-Wallis Test was used to compare diver experience in relation to artificial reef satisfaction scores. Furthermore, a Mann-Whitney U Test was employed to analyze for differences relating to the experience of divers and reef habitat preference. The data extracted from the present survey instrument, are not fully represented in this paper, but contribute towards a further study examining the enjoyment of scuba diving use of artificial and natural reef habitats (Chapter 4).

## 3.4 Results

### 3.4.1 Demographic Characteristics, Length of Stay and Reasons to Visit

Of the 200 divers surveyed, the sample included more men (60.5%) than women. Collectively respondents averaged 43 years of age ($\pm$ 13.4 s.d.), with a mode of 50 years, and an age range of 12 to 71 years (the minimum age for diver certification is 12 years of age). Fifty percent of those surveyed were British, 24.5% American, 15.5% Canadian and 6.5% resided in Barbados. The remaining 3.5% of respondents were represented by three countries; Germany, Australia and Bulgaria. Higher rates of visitation noted for the United Kingdom and the United States are consistent with figures reported in a study (Schuhmann, 2010) conducted on Barbados, and with arrival data reported for the island (Caribbean Tourism Organization, 2012). With regard to the length of stay for non-resident respondents, the majority were visiting Barbados for 7-10 days duration (43%) followed by individuals staying for a 14 day period (24.5%). Cruise/day-trippers visiting the island accounted for 2.5% of those surveyed. For non-residents, the main reasons given for visiting Barbados were either for a general holiday (50%) or for a dedicated diving holiday (39%). Only a minority were visiting for the purpose of work or business (3%) or to visit friends or relatives (3%). Content analysis revealed the 'other' category (5%) mainly consisted of individuals honeymooning (4%) or those on a golfing holiday (1%).

### 3.4.2 Scuba Diver Experience

The diving experience of respondents was found to be highly variable. A break down of diver qualification held revealed that 66.5% possessed Open Water certification (basic and advanced level, CMAS*), followed by 27% of divers with Sport or Dive Master certification (CMAS***). The remaining participants were either Instructors (5.5%) or trainee divers (1%). To help further assess each respondent's level of diving experience, individuals were questioned on the number of dives they had personally logged. From the sample of scuba divers, respondents had averaged 190 logged dives to date ($\pm$ 264 s.d.). Moreover, the study revealed novices, i.e. divers with $<$ 100 logged dives, accounted for 52% of the sample (104 individuals), compared to 48% being experienced divers (96 individuals), with $\geq$ 100 dives logged. The most frequent number of dives recorded (5% of participants), were from those respondents who had logged 1000 dives in their diving career. With regard to a diver's reported length of certified diving career, a mean of 10.75 years ($\pm$ 9.6 s.d.), a mode of 10 years and a median value of 8 years, were calculated. One individual had been diving for as long as 45 years on both reef types.

When divers were asked how frequently they scuba dived, a majority (47%) reported diving 3-6 times per year, followed by 18.5% participating in diving activity on a monthly basis, and 10% every two weeks. The remaining respondents' (24.5%) chose the option of 'other' for frequency of diving. Content analysis revealed almost half of these divers participated in scuba diving at least once per week, whilst the remaining 21 responses indicated they dived once per year on vacation. A significant proportion of non-resident divers (94 respondents) reported they had previously dived in Barbados, with the remainder not having done so (up until this visit) as it was their first experience of the Caribbean island. From the 94 returning tourists, an average of 4 previous visits were noted.

### 3.4.3 Artificial Reef Awareness, Use and Preferred Material

A number of exploratory questions were presented to participants to assess their awareness, use and *a priori* knowledge of artificial reefs. A greater proportion of divers (96%) had heard of the term ‘artificial reef’, with the remainder having not. As a reflection of this, 95% of respondents reported having previously dived on what they considered artificial habitat, whilst all 200 respondents had dived on artificial reefs in Barbados at some point in time (including this visit). To help assess the importance of established artificial reefs to individuals visiting Barbados, divers were questioned on whether their decision to visit the island was influenced by the group of six wrecks situated within Carlisle Bay. Twenty percent of individuals were found to be influenced by these reefs, and as such had chosen to visit the Caribbean island. When participants were asked if they had dived on these wrecks, 76% had done so. Respondents were also asked to state their most favoured type of artificial reef structure to conduct diving on. From a list of 9 structures; 76.5% selected shipwrecks and 15.5% sunk vessels as their most preferred material type. Figure 3.2 shows the least favoured structures consisted of rubber tyres (0%) and concrete domed modules (Reef Balls™) (0%). Despite the latter material receiving no support from divers, 12% of respondents had in fact dived on the conglomerate of Reef Balls™ deployed off the coastal area of Bridgetown (Figure 3.1). The positive comments elicited in relation to this artificial reef reinforce the ability of Reef Balls™ to attract and harbour fishes (Miller, 2006). However the most ubiquitous comments made by survey participants suggested this artificial reef is generally too small to use as a diving site *per se*, and may be more appropriate as a local in-training diving site.

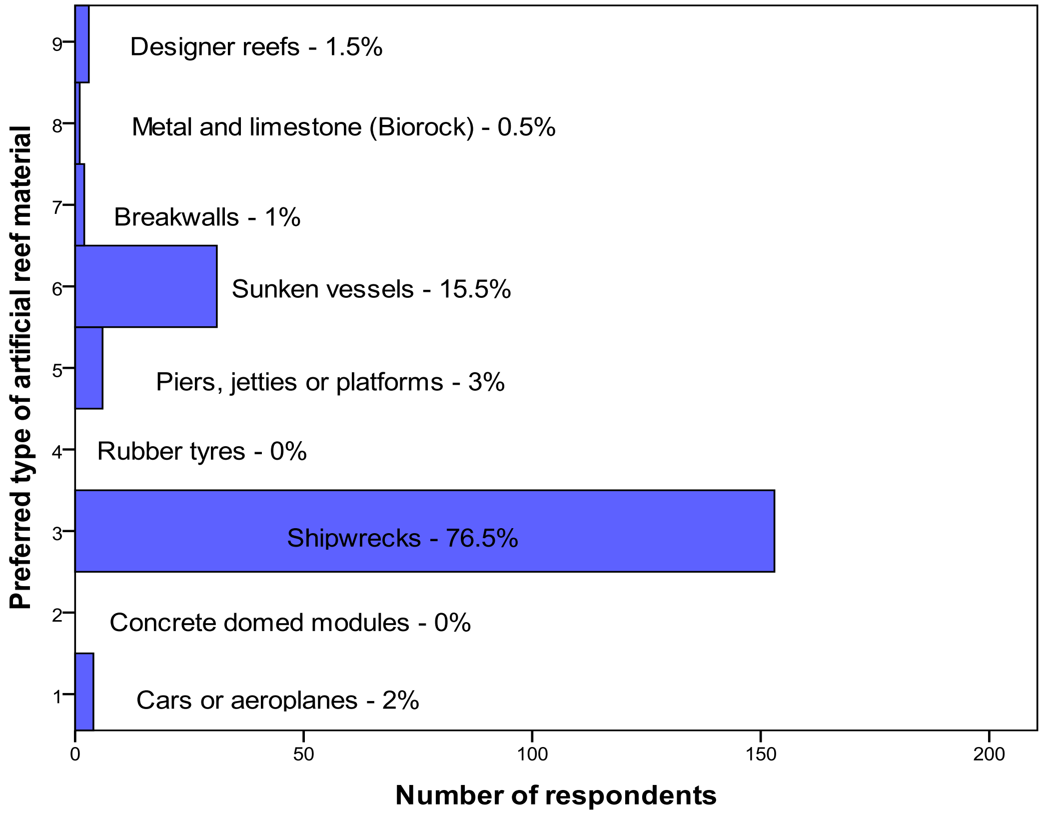


**Figure 3.2 Respondents' preferences for type of artificial reef material.** Sample size: n = 200.

Divers were also asked to state their preferred depth at which to dive on artificial habitat. This was requested in feet as Barbados currently uses imperial measurements. A majority (82%) selected having a preference for diving at less than 70 feet (21 meters) depth with only 2% of divers indicating a depth of more than 100 feet (30 meters). The most favoured category (38% of respondents) was revealed as being between 50-59 feet (15-18 meters) in depth.

### 3.4.4 Satisfaction with Artificial Reef Diving

Analysis of responses to rate divers level of satisfaction (on a Likert scale of 1 to 5) relating to the experience of artificial reef diving on the island, revealed 90% of those surveyed being either very satisfied (54%) or satisfied (36%) with the experience. This level of response suggests that divers rate the practice of artificial reef diving in the resort very highly indeed. Furthermore, none of the divers reported being 'very dissatisfied' with artificial reef diving locally. An exploratory analysis was additionally conducted to assess any relationship between diver experience and level of satisfaction according to the number of dives respondents had logged during their diving history (Figure 3.3).

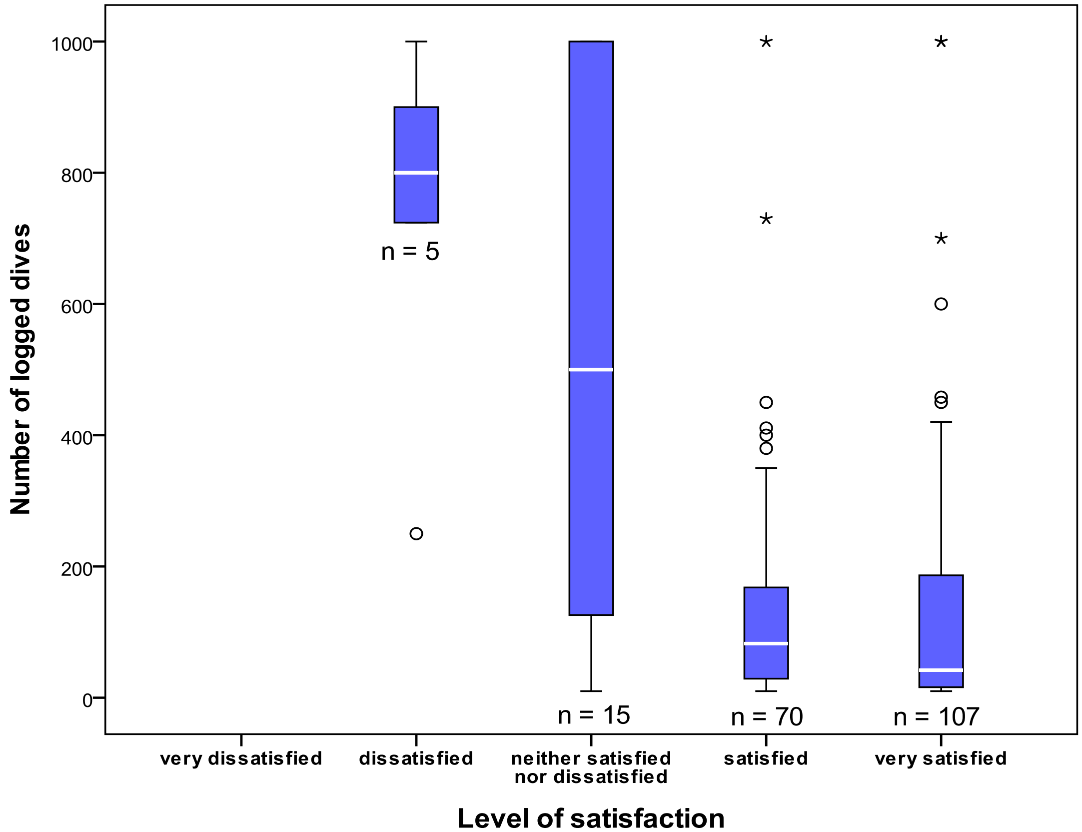


**Figure 3.3 Divers' satisfaction of artificial reef diving according to number of logged dives.** Boxes represent the inter-quartile range that contains 50% of values. The median value is represented by a line across the box. The whiskers extend to the $5^{th}$ and $95^{th}$ percentiles and circles and stars outside the box plots are outliers. Sample size is represented by numbers below each box.

A Kruskal-Wallis Test indicated a high level of association between degree of diver experience and level of satisfaction relating to artificial reef diving ($\chi^2$ (3) = 23.90, $p \leq 0.001$) (Figure 3.3). This indicates that less experienced divers with a lower number of logged dives are significantly different from their experienced counterparts in rating their satisfaction of diving on artificial reefs in Barbados. Further post hoc analysis confirmed significant differences occurring between 'very satisfied' and 'neither satisfied nor dissatisfied' responses ($U$ = 414, $z$ = -3.516, $p \leq 0.001$, $r$ = 0.30), 'satisfied' and 'neither satisfied nor dissatisfied' responses ($U$ = 325, $z$ = -2.677, $p \leq$

0.007, $r = 0.20$) and 'very satisfied' and 'dissatisfied' responses ($U = 102$, $z = -2.728$, $p \leq 0.006$, $r = 0.20$), between novice and experienced divers. It appears therefore with increasing diving experience, level of satisfaction with artificial reefs as diving sites, decreases. Conversely, novice divers appear to experience greater satisfaction with artificial reef diving on the island. Analysis was additionally conducted to assess differences in diver satisfaction between male and female divers, however no significant differences were detected between genders ($\chi^2$ (3) = 5.99, $p \geq 0.112$, *phi* = 0.174).

The next set of questions intended to explore the level of importance of 13 reef attributes that divers considered would enhance their artificial reef diving enjoyment and satisfaction. Mean scores and overall ranking of attributes are presented in Table 3.2. Regardless of diver experience, respondents appear to derive a similar level of enjoyment and satisfaction from each of the attributes listed. Ranked in the top six for both groups are fish abundance, sea visibility, coral cover, safety and reef colours. Fish abundance was significantly more highly ranked than reef complexity or reef size ($p \leq 0.004$ and $p \leq 0.001$ respectively). Location and access to artificial reefs and sea visibility for both diver groups were the most highly ranked of the environmental conditions, whereas historic value and size of reef appear to be less important to divers, being ranked towards the bottom of each group. However, closer inspection of mean scores highlighted differences in 'groups of attributes' between levels of diver experience. For example, experienced divers placed greater importance on biological attributes including coral cover, reef colours and reef complexity; whereas novices derived greater enjoyment and satisfaction from environmental conditions such as sea visibility, location and access of reef and depth of water. Whilst these latter results are not of statistical significance, further research to examine specific artificial reef attributes and their levels of importance to novice and experienced divers would be worthwhile.

**Table 3.2** Ranked mean scores relating to the importance of artificial reef attributes for novice divers and experienced divers.

| **Overall rank** | **Novice divers (n = 104)** | | **Experienced divers (n = 96)** | |
|---|---|---|---|---|
| | **Attribute** | **Mean score ± 1*SD*** | **Attribute** | **Mean score ± 1*SD*** |
| 1 | Fish abundance | 4.49 ± 0.64 | Fish abundance | 4.51 ± 0.68 |
| 2 | Sea visibility | 4.44 ± 0.75 | Sea visibility | 4.40 ± 0.77 |
| 3 | Safety | 4.28 ± 1.09 | Coral cover | 4.38 ± 0.74 |
| 4 | Coral cover | 4.11 ± 0.84 | Safety | 4.32 ± 0.97 |
| 5 | Reef colours | 4.01 ± 0.92 | Mooring buoys | 4.12 ± 0.98 |
| 6 | Location/access | 3.98 ± 0.81 | Reef colours | 4.08 ± 0.88 |
| 7 | Mooring buoys | 3.88 ± 1.06 | Location/access | 3.96 ± 0.86 |
| 8 | Currents | 3.74 ± 0.85 | Currents | 3.72 ± 0.86 |
| 9 | Travel time | 3.61 ± 0.93 | Reef complexity | 3.62 ± 0.85 |
| 10 | Historic value | 3.54 ± 1.06 | Travel time | 3.59 ± 1.03 |
| 11 | Water depth | 3.51 ± 1.05 | Water depth | 3.46 ± 1.09 |
| 12 | Reef complexity | 3.50 ± 0.96 | Historic value | 3.44 ± 1.09 |
| 13 | Size of reef | 3.34 ± 0.86 | Size of reef | 3.34 ± 0.92 |

**Notes:** novice divers' < 100 logged dives; experienced divers' ≥ 100 logged dives.
Values measured on a 1-5 point Likert scale: 1 = not important at all, 2 = not important, 3 = average, 4 = important, 5 = very important.

### 3.4.5 Attitudes towards Artificial Reefs

Respondents were presented with 8 attitude statements relating to artificial reefs that broadly addressed a number of ecological based themes. One question was specific to Barbados to allow for response in attitude towards the current number of artificial reefs deployed locally. Table 3.3 presents each statement in rank order of divers' agreement, or disagreement. A majority of respondents concurred strongly with all five positively worded statements. The highest level of agreement provided (on a Likert scale of 1-5) was for the statement 'artificial reefs provide new habitats for marine organisms' with 93% of divers either agreeing (37%) or strongly agreeing (56%). In addition, strong agreement was recorded for the statement 'artificial reefs take diver pressure off natural reefs' with 81% either agreeing or strongly agreeing.

Interestingly, it appeared that many respondents considered ‘diving on an established artificial reef’ of no special interest compared to diving on a new artificial reef, with only 64.5% either strongly agreeing or agreeing, and a further 30.5% being ambivalent towards this statement. The neutral responses recorded may suggest that new, un-established artificial reefs are sufficiently attractive to some divers.

There was a high level of disagreement (85.5%) towards the negatively worded statement ‘artificial reefs are a form of visual pollution’ (44% disagreeing and 41.5% strongly disagreeing). However, when divers were examined on their level of disagreement to the statement ‘there are currently too many artificial reef dive sites in Barbados’, a lower level of disagreement was recorded (69%) alongside a quarter of divers being ambivalent in response. In hindsight this statement was possibly difficult to answer by visiting divers, as their knowledge relating to the provision of local artificial reefs for diving may be limited, especially among first time visitors. Nonetheless, in the event only 9 individuals (4.5%) chose to agree with this latter statement. Further exploratory analysis examining responses to each of the eight attitude statements by experience level and by gender, revealed no significant differences. These probability values are listed in Table 3.3.

**Table 3.3** Divers' ranked percentage agreement/disagreement to attitude statements concerning artificial reefs, with positively worded statements positioned at the top of the table, values for the three negatively worded statements below and probability (*p*) values for responses relating to diver experience and gender.

| **Artificial reefs (AR)** | **1[a] (%)** | **2 (%)** | **3 (%)** | **4 (%)** | **5 (%)** | **Mean 1*SD*** | **Experience *p*- Value** | **Gender *p*- Value** |
|---|---|---|---|---|---|---|---|---|
| Provide new habitats for marine organisms | 0.0 | 0.5 | 6.5 | 37.0 | 56.0 | 4.49 $\pm$ 0.64 | 0.187 | 0.593 |
| Take diver pressure off natural reefs | 1.5 | 2.5 | 15.0 | 44.5 | 36.5 | 4.12 $\pm$ 0.86 | 0.533 | 0.711 |
| Attract marine life divers wish to see | 0.5 | 2.0 | 24.0 | 48.5 | 25.0 | 3.96 $\pm$ 0.79 | 0.645 | 0.520 |
| Suitable substitute for diving | 1.5 | 8.0 | 15.5 | 53.0 | 22.0 | 3.86 $\pm$ 0.90 | 0.188 | 0.547 |
| Established AR are more interesting to dive | 2.5 | 2.5 | 30.5 | 34.0 | 30.5 | 3.78 $\pm$ 0.96 | 0.946 | 0.928 |
| Form of marine visual pollution | 41.5 | 44.0 | 9.0 | 4.0 | 1.5 | 1.80 $\pm$ 0.87 | 0.869 | 0.239 |
| Disruption to the local marine ecosystem | 41.0 | 39.0 | 17.0 | 3.0 | 0.0 | 1.82 $\pm$ 0.82 | 0.495 | 0.152 |
| Too many AR in Barbados | 27.0 | 42.0 | 26.5 | 4.0 | 0.5 | 2.09 $\pm$ 0.86 | 0.823 | 0.685 |

**Notes:** [a] values measured on a 1-5 point Likert scale: 1 = strongly disagree, 2 = disagree, 3 = neither agree nor disagree, 4 = agree, 5 = strongly agree. Sample size: n = 200 for each attitude statement.

### 3.4.6 Opinions and Preferences: Artificial Reefs vs. Natural Reefs

For the final stage of the questionnaire, opinions and preferences relating to artificial reefs were sought in comparison to diving on natural reefs. Respondents were questioned on 'whether they perceived artificial reef diving to be a nature-based experience, or not'. A high level of agreement (86%) was given in support of this question, which was found to be highly significant; $x^2$ (1) = 103.68, $p \leq 0.001$. When divers were asked if they agreed or disagreed with the question; 'if there were aspects of diving on artificial reefs which are more satisfying when compared to diving on natural reefs' 58% agreed; $x^2$ (1) = 5.12, $p \leq 0.024$. The relationships of responses to questions between diver experience categories and between genders were then examined.

Both novice (88%) and experienced (83%) divers agreed strongly that 'artificial reef diving is a nature based experience' ($x^2$ (1) = 0.706, $p \geq 0.401$, *phi* = 0.074). However, the second question asking 'if there were aspects of diving on artificial reefs which are more satisfying' indicated a significant difference in attitude between novices and experienced divers, with novices tending to agree more ($x^2$ (1) = 4.24, $p \leq 0.039$, *phi* = 0.156). Moreover, there was a significant association between gender and responses to the latter two questions ($x^2$ (1) = 3.43, $p \leq 0.044$, *phi* = 0.151; $x^2$ (1) = 11.01, $p \leq 0.001$, *phi* = 0.258, respectively), with males being much more enthusiastic about artificial reefs in each case.

Respondents were also requested to state their preference for diving either on an artificial reef or on a natural reef in Barbados. Analysis revealed that a significant proportion ($x^2$ (1) = 18.00, $p \leq 0.001$) of divers chose natural reefs (65%). Differences between habitat preference and diver experience were explored. Figure 3.4 presents frequencies of responses for novice divers and experienced divers and their elected reef habitat. A Mann-Whitney U Test (2-tailed) revealed a highly significant difference in the number of dives logged and between respondents chosen habitat ($U$ = 2267, $z$ = -5.848, $p \leq 0.001$, $r$ = 0.41). It is clear from Figure 3.4, that novice divers elected artificial habitat in preference to natural reefs, though a post-hoc analysis revealed no statistical difference between habitat choice ($x^2$ (1) = 3.85, $p \geq 0.062$);

whilst experienced divers had a strong preference for natural reefs as diving sites that revealed a highly significant result ($\chi^2$ (1) = 66.66, $p \leq 0.001$). No significant gender based association between these categorical variables was indicated ($\chi^2$ (1) = 0.913, $p \geq 0.339$, *phi* = 0.078), despite females being less likely (30%) than males (38%) to choose artificial reefs for diving.

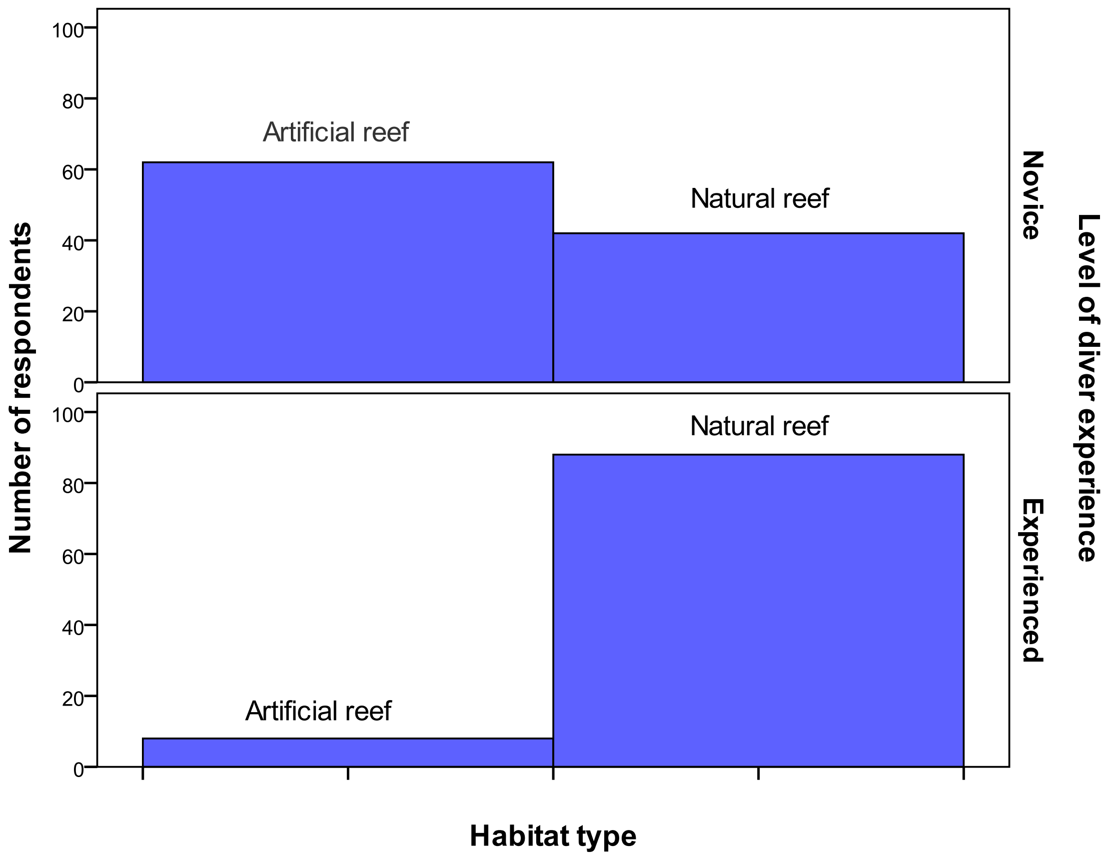


**Figure 3.4 Preferences of divers for artificial and natural reef habitat types depending on level of diver experience**. Sample size: novice divers (< 100 logged dives) n = 104, experienced divers (≥ 100 logged dives) n = 96.

Divers were additionally asked how many dives they had conducted on natural or artificial reefs during the study period. Divers were recorded as performing a total of 1,280 dives within this time. Of these dives, 57% (n = 729 dives) were conducted on natural reefs and 43% (n = 551 dives) on artificial reefs, revealing a highly significant difference between habitat use ($\chi^2$ (1) = 24.48, $p \leq 0.001$). In relation to diver experience; experienced divers performed a significantly higher percentage (56%, n =

722 dives) of these dives, in comparison to dives recorded (44%, n = 558 dives) for novices ($\chi^2$ (1) = 20.76, $p \leq 0.001$). Moreover, the percentage number of dives recorded for natural reef use was significantly higher for experienced divers (64%, n = 466 dives) than for novice divers (36%, n = 263 dives) ($\chi^2$ (1) = 55.97, $p \leq 0.001$). In contrast, no apparent differences could be detected between experienced divers (46%, n = 256 dives) and novice divers (54%, n = 295 dives) use of artificial reef habitat ($\chi^2$ (1) = 2.62, $p \geq 0.105$).

## 3.5 Discussion

In this study, the perceptions of scuba diving on artificial reefs in a tropical marine location were examined from a user perspective. The following discussion focuses on the main results and considers these findings in relation to improving and strengthening diving management and coral reef conservation.

### 3.5.1 Characteristics of the Diving Clientele of Barbados

Recreational divers in Barbados broadly mirror the demographic profile of divers studied elsewhere in the world (e.g. Ditton *et al.,* 2002; Musa *et al.,* 2006; Uyarra *et al.,* 2009). However, two points are worth noting. My results confirm a general trend emerging in female acceptance of the sport (Musa *et al.,* 2006; Sorice *et al.,* 2007; Uyarra *et al.,* 2009) with almost forty percent of divers sampled in Barbados being female. The sample of divers in this study were also older in comparison to similar studies conducted elsewhere (e.g. Musa, 2002; Stolk *et al.,* 2005), though largely consistent with the findings of Schuhmann *et al.* (2008) and Uyarra *et al.* (2009) who recently studied cohorts of divers in Barbados and Bonaire respectively. Similar to many Caribbean islands, Barbados is generally classed as a luxury holiday destination, and thus may be less affordable to younger individuals. Edney's (2012), study of wreck divers in the remote resort of Chuuk Lagoon, Micronesia, also revealed an older sample of divers. These latter differences are likely to be a function of cost.

Novice and experienced divers were evenly represented in the study providing a diversity of views relating to artificial reef diving. Indeed, over half of all nonresident divers surveyed were return visitors, with some individuals having over thirty previous visits to Barbados. The study by Schuhmann *et al.* (2008) revealed a similar trend in return visits, with half of their sample having had previous trips to the island. Measures to help attract individuals to dive locally include the provision of well conceived artificial reef diving sites such as those situated within the Carlisle Bay marine park. This group of six wrecks (Agace, 2005) appeared to influence the decision of some divers' in this present study to visit the island, with forty respondents agreeing these wrecks had a positive effect on their choice of diving destination. In general, this conglomerate of artificial reefs appears to be extensively used by divers as over three quarters of respondents had dived on them at some point.

### 3.5.2 Artificial Reef Awareness and Preferred Material

Divers' *a priori* knowledge and awareness relating to artificial reefs as diving resources was good. A greater proportion (96%) of individuals surveyed had previously heard of the term artificial reef, and when invited to give a personal description or definition of this habitat, did so with accuracy. For example: *'a structure placed on the seabed (intentionally or unintentionally) that attracts corals and associated marine species that over time appears natural'* (Participant 15), '*an object that is placed in an advantageous place that is cleansed of all environmental hazards and placed in the water to develop a habitat for underwater life'* (Participant 41), '*structures or objects deliberately placed in an accessible location for reef growth to be viewed by divers and snorkellers in the future'* (Participant 121). It was also clear that embedded within a majority of the definitions was the perception that artificial reefs provide habitat for marine fauna and flora. In addition, the word shipwreck was used frequently in the various descriptions provided by respondents.

Shipwrecks and purposefully sunken vessels were noted as the most favoured artificial reefs to dive on. Consistent with my findings, divers studied by Ditton *et al.* (2002), Stolk *et al.* (2005) and Shani *et al.* (2011) expressed an overriding preference for ex-naval ships, especially larger vessels that would absorb an entire dive. This latter point is of relevance to help ensure the ecological success of artificial reefs in managing scuba diving. One of the primary goals of recreation-orientated artificial reefs is to generate ecological benefits (Leeworthy *et al.*, 2006) by diverting diving pressure from proximate natural reefs. Polak and Shashar (2012) suggest the apathy among experienced divers to a new artificial reef in the Gulf of Eilat, Israel, was due in part to its modest size. In contrast, Dowling and Nichol (2001) and Leeworthy *et al.* (2006) reported positive environmental benefits surrounding the immersion of retired naval ships aimed at improving recreational diving in Australia and Florida, respectively. Moreover, artificial reefs need to be substantial in size to avoid congestion, as studies investigating crowding in marine recreation settings suggest congestion negatively affects visitor satisfaction (Shafer and Inglis, 2000; Musa, 2002) and depresses reef values (Rudd and Tupper, 2002).

### 3.5.3 Satisfaction with Artificial Reef Diving

In general, divers were found to derive a high level of satisfaction from artificial reef diving on this island, with very few individuals being dissatisfied or ambivalent with this type of dive experience (Figure 3.3). Stolk *et al.* (2005) additionally reported a strong level of satisfaction among a sample of Australian artificial reef divers, with their level of satisfaction changing with the type of artificial reef they dived on. Among divers in Barbados, content analysis relating to specific artificial reefs respondents had used at some point, revealed significant numbers (74 participants) visiting the *SS Stavronikita*, the most frequently dived local wreck (Agace, 2005). In addition, the group of six wrecks in Carlisle Bay, and the Pamir wreck, situated north-west of the island (Figure 3.1), had been frequently used by those surveyed (152 and 43 participants respectively).

When respondents were questioned on what they considered made one type of artificial reef more satisfying to dive on, in comparison to another artificial reef locally, many divers agreed it was the ability to penetrate the larger wrecks (e.g. the *SS Stavronikita* and the Pamir) that made a positive difference, as well as the wrecks historical connections and feelings of authenticity. A large number of divers additionally commented that bigger wrecks were preferred as they appear substantial enough to support a significant and complex ecosystem, providing diving motivation and satisfaction. Edney (2012) recently studied diving motives specific to wreck divers and recorded participants as being focused on seeking out specific experiences, notably; historically significant wrecks, artifacts, the ability to penetrate wrecks and the marine life encountered.

Despite such strong satisfaction reported for artificial reef diving, an inverse relationship was found to exist between diving experience and satisfaction with local artificial reefs. It was clear as respondents diving experience increased, level of satisfaction decreased (Figure 3.3). Conversely, my results demonstrate that novice divers appear to derive greater satisfaction with artificial reef diving on the island. Dearden *et al.* (2006) also identified a general decline in diving satisfaction with increasing dive experience, with the authors concluding more specialized divers, with a higher level of investment in the sport, tend to have more specific resource requirements than novices. Studies of other recreational activities (e.g. Bryan, 1977; Ditton *et al.,* 1992) additionally indicate a propensity for more specialized participants to have more specific resource requirements. My findings thus suggest that less experienced divers may be more willing to support the use of artificial reefs as diving attractions.

When participants were asked to rate various reef attributes considered important to their enjoyment and satisfaction of diving on contrived reef, the most valued characteristics revealed for both groups were; fish abundance, sea visibility, safety and coral cover. These results broadly reflect previous findings of attributes (Table 3.1) significant to artificial reef divers and thus additionally confirm the importance of these features in contributing to the success of recreation-orientated artificial reefs. Clearly, there is general consensus that 'fish' are highly valued components of the diving experience (e.g. Milton, 1989; Stanley and Wilson, 1989; Williams and Polunin, 2000; Musa, *et al.,* 2006; Fitzsimmons, 2009; Uyarra, *et al.,* 2009; Paterson *et al.,* 2012; Schuhmann *et al.,* 2013). Measures to therefore attract fish to reefs, either through the deployment of artificial reefs within marine protected areas, where fish abundance is often higher (Chapman and Kramer, 1999; Varkey *et al.,* 2012), or through the correct design of artificial reefs (e.g. Brock and Norris, 1989; Baine, 2001), are crucial.

### 3.5.4 Opinions and Preferences: Artificial Reefs vs. Natural Reefs

To develop a greater understanding of why divers choose artificial reefs as diving attractions, respondents' personal experiences of this type of habitat were sought relative to natural reef diving. Qualitative work by Stolk *et al.* (2005) provided a basis for this. A significant number of divers agreed 'there were aspects of diving on artificial reefs that are more satisfying when compared to diving on natural reefs'. By requesting participants to comment on these aspects, it was clear many divers used artificial reefs due to the challenging nature of the dive, the themed experiences attached to shipwrecks and airplanes and the overall guarantee of a 'good dive'. In fact several individuals commented on artificial reef dives as being their most memorable. The concentration and diversity of marine life artificial habitat attracts, was also mentioned frequently. Other salient elements of artificial reef diving discussed, revolved around their ease of access and increased photographic opportunities relative to natural reefs, the 'uniqueness' of the dive experience, the use of otherwise barren landscapes, and their ability to reduce diving pressure on natural reefs. This last point (both questionnaire and voluntary based) was made by a considerable number of respondents surveyed in Barbados, as it was by Stolk *et al.* (2005) Australian divers, thus reaffirming many divers active support of marine conservation (Dearden *et al.*, 2007).

The reefs fringing the coast of Barbados provided ideal sites to explore divers' preferences vis-à-vis natural and artificial habitats. Previous empirical works (Johns *et al.*, 2001; Johns 2004; Oh *et al.*, 2008) have demonstrated that scuba divers place a greater value on diving natural reef habitats in preference to artificial reef resources. Data from the present study supports these observations, as divers surveyed were generally found to have an overriding preference towards the use of natural reef sites for local diving participation. This result is by no means surprising, despite many divers viewing artificial habitat as a unique and stimulating type of diving experience (Blout, 1981; Stolk *et al.*, 2005; Shani *et al.*, 2011).

However, by further examining reef habitat preference in relation to diving experience, it was clear that differences existed in respondents' elected diving habitat. Whilst experienced divers chose almost unanimously, natural reefs over and above artificial habitat (Figure 3.4), novices exhibited a greater preference for artificial reefs as local diving sites. Again, my results support the tenets of Dearden *et al.* (2006) that novice divers with less developed skills and personal investment in diving, appear to have less specific resource requirements than experienced divers, who have a higher level of skill, personal attachment and commitment to their sport. These findings additionally suggest that novice divers would be more likely to accept reef habitat substitution more readily than their experienced diving counterparts. Indeed, Polak and Shashar (2012) showed a newly deployed reef was effective in changing the behaviour of in-training and novice divers (but not of advanced divers), by reducing their use of nearby natural reefs. In view of the fact that novice divers (often with poor buoyancy control) are recorded as generally causing most damage to natural reefs (Roberts and Harriott, 1994; Walters and Samways, 2001; Warachananant *et al.*, 2008; Chung *et al.*, 2013), and represent a significant market share of the dive tourism market (PADI Worldwide Certification, 2012), these results have considerable implications for the management of scuba diving tourism.

### 3.5.5 Artificial Reefs: Management Implications for Diving Tourism and Reef Conservation

Traditional practices aimed at controlling diver impacts on reefs have largely embraced the concept of ecological carrying capacity of divers (e.g. Hawkins and Roberts, 1997; Schleyer and Tomalin, 2000; Zakai and Chadwick-Furman, 2002). However the management of coral reefs necessitates more than this basic solution, it requires a range of tools, especially in non-reserve environments. Promoting artificial reefs as a diving management strategy has been proposed by several authors (e.g. Davis *et al.*, 1995; Zakai and Chadwick-Furman, 2002; Hasler and Ott, 2008; van Treeck and Eisinger, 2008) and my results suggest less experienced divers would be more likely to support a management policy using artificial reefs; at least in Barbados.

Considerable economic and ecological benefits can be achieved by developing diving destinations like Barbados, through the provision of artificial reefs for diving. In the first instance, they provide divers with a more diverse range of diving opportunities and environmental settings, essential factors in maintaining diving market interest and facilitating a competitive market edge (Dearden *et al.*, 2006). In addition, Dearden and Manopawitr (2011) predict that one possible effect of global climate change may be a reduced number of natural reefs on which to dive. A diving destination that can offer alternative artificial dive sites, again, has a competitive market advantage. Also, artificial reefs can act as dive training sites (Polak and Shashar, 2012), providing divers with the opportunity to practice and develop their skills in less ecologically sensitive and hence more relaxed surroundings. This practice in itself would reap ecological benefits, by removing more damaging in-training and novice divers (Harriott *et al.*, 1997; Rouphael and Inglis, 1997; Walters and Samways, 2001) from natural reefs. Less degraded coral reefs would in turn attract experienced divers who place greater importance on the biological characteristics of a reef site (Dearden *et al.*, 2006; Fitzsimmons, 2009). It is also increasingly appreciated that artificial reefs, as well as reducing diving pressure on natural reefs, can additionally serve as environmental educational tools as proposed by van Treeck and Eisinger (2008).

The ability to divert divers from natural reefs in Barbados was demonstrated in this study, as a substantial number (n = 551) of dives were conducted on artificial reefs. This is in comparison to 729 dives undertaken on natural coral reefs. From these figures, divers conducted an average of 2.75 dives on artificial reefs per visit. In the absence of formal statistics for diving in Barbados, data reported by Schuhmann *et al.* (2008) of between 30,000 and 50,000 divers visiting the island per year, can be used to calculate a lower bound estimate of 82,500 dives and an upper bound estimate of 1.38 million dives take place on local artificial reefs per annum. Whilst these figures are wholly encouraging, they may in part reflect the behavioral practice of local diving schools that often divide a two-tank dive between each habitat type (A. Kirkbride-Smith, personal observation, January 2010), though some divers may request specific reefs to dive on (i.e. natural reefs only). For conservation reasons, the practice of diving schools routinely visiting both reef habitats per trip should be fully encouraged, with my results suggesting that no significant loss in diver satisfaction would occur by using artificial reefs locally. Indeed, artificial reefs can in some instances be more popular than natural reefs, as other Caribbean diving destinations have recorded higher levels of artificial reef usage than for natural reef dive sites. For example, in the British Virgin Islands, Hime (2008) quoted diving figures for the Bow of the *RMS Rhone* as being 5,270 dives per year, representing four times as many dives undertaken in comparison to the busiest local natural reef.

Clearly, artificial reefs are important components in managing reef tourism in Barbados, and appear successful as indicated by their current level of use by recreational divers. For many survey participants, diving was their primary reason to visit the island, and thus efforts to maintain the islands reefs and diving attractiveness is crucial (Uyarra *et al.,* 2005), among other reasons, for returning trade. In order to enhance current dive management practices using artificial reefs, the following points are recommended for consideration by marine resource managers and policy makers in Barbados, as well as other marine diving destinations. Where artificial reefs are present: (1) transfer all introductory courses and in-training dives to artificial reef sites, (2) reinforce the environmental education of divers (Madin and Fenton, 2004) through the provision of educational materials positioned on artificial reefs, (3) during times of coral reef stress (e.g. coral bleaching), recreational dives should be conducted (ideally) on artificial reefs, and (4) use more 'in depth' conservation education dive briefings that have been shown (Camp and Fraser, 2012) to reduce damage to reefs. In addition, the following points were suggested by survey participants: (5) provide information plaques on artificial reefs detailing the wrecks history, (6) produce an information leaflet/diving map depicting the islands artificial reefs and natural reefs, (7) explore the feasibility of an artificial reef dive/snorkel trail within Barbados's marine protected area; Folkestone Marine Reserve (Chapter 5) and (8) raise the profile of Folkestone Marine Reserve, among tourists. Whilst not directly relevant to the present study, this latter point was voluntarily suggested by many divers at the conclusion of the survey.

## 3.6 Conclusions and Further Research

This study of artificial reef divers in Barbados contributes to the current body of knowledge (Milton, 1989; Stanley and Wilson, 1989; Ditton *et al.,* 2002; Stolk *et al.,* 2005; Shani *et al.,* 2011; Edney, 2012 – Table 3.1) and is useful to reef planners and marine tourism managers. Motives for diving on artificial reefs were dominated by the reliability of the diving experience, associated biodiversity viewing and wildlife photographic opportunities. Divers expressed a clear preference for themed diving experiences associated with large shipwrecks or sunken vessels.

My findings show however, that the sample of divers is not homogenous - they differ in their satisfaction of artificial reef diving and reef habitat preference. Novice divers derive greater enjoyment and show a greater preference for artificial reef diving sites than their experienced diving counterparts. These findings therefore suggest that novice divers are more likely to accept reef habitat substitution more readily than experienced divers. To my knowledge, this study is the first to reveal recreation specialization in scuba divers relative to resource substitution behavior, and these results could have significant implications for the way reef based tourism is managed.

Further studies need to establish to what extent divers would support a reef substitution policy, as well as additional research to validate my present findings in different locations. Limited work exists in the field of diver specialization (Dearden *et al.,* 2006; Paterson *et al.,* 2012) and thus more in-depth studies would further identify differences in divers' reef resource requirements using for example, a diver specialization index, such as the one constructed by Dearden *et al.* (2006).

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# Chapter 4

## *The Enjoyment of Scuba Diving Use of Artificial and Natural Reef Habitats*

### 4.1 Abstract

Despite the growth in number and popularity of artificial reefs as diving sites, it has been suggested that natural reefs are valuable and artificial reefs are not. This study investigates the value of artificial and natural reef habitats to recreational scuba divers in terms of diver enjoyment experienced from a series of 24 dive attributes. Using data drawn from a rapid survey instrument, I test the hypothesis that diving tourists derive equal enjoyment from artificial reef diving as they do from natural reef diving. In addition I; (a) identify specific attributes of the artificial reef dive experience that contribute the most to diver enjoyment, and independent of reef type (b) explore to what extent diver characteristics are influenced by potential factors present within the enjoyment data. A sample of 120 survey participants in Barbados revealed divers using artificial reefs experienced significantly higher levels of diving enjoyment than users of natural reef habitats. Further, it was shown that increased enjoyment at artificial reefs was attributed to the challenge of the dive, new experiences, photographic opportunities, water depth and reef site topography. Factor analysis reduced the enjoyment data to three major themes; social and environmental, biological and personal incentive, explaining 46% of the variance. The social and environmental factor contributed significantly more to overall diver enjoyment than either the biological or personal incentive factors. I additionally found novice divers were significantly more influenced by personal incentive attributes of the dive (e.g. updating diving skills), while biological aspects of the reef, photography and reef topography, contributed significantly more to the enjoyment of divers experienced in the sport. The results of this study may help direct reef management decisions in the design of pre-planned artificial reefs and also highlights the potential for artificial reefs to contribute towards reef conservation without reducing diving enjoyment.

## 4.2 Introduction

In recent years the diving tourism industry has expanded, being transformed from a niche market into a form of mass tourism (Garrod and Gössling, 2008). This growth presents fresh challenges for reef managers and policy makers, and it may be necessary to make better use of recreation-orientated artificial reefs; helping promote sustainable use of reefs but at the same time yielding economic benefits from recreational diving. Sustainable tourism and ecotourism are two concepts commonly associated with the diving market (Townsend, 2008). The World Tourism Organization (2001, p.8) defines sustainable tourism as being; "the environmental, economic, and socio-cultural aspects of tourism development…..and a suitable balance must be established between these three dimensions to guarantee its long-term sustainability". Fennell (2008, p.24) describes ecotourism as; "a sustainable, non-invasive form of nature-based tourism that focuses primarily on learning about nature first-hand and which is ethically managed to be low-impact, non-consumptive and locally orientated. It typically occurs in natural areas, and should contribute to the conservation of such areas".

By developing artificial habitat for diving amenity, artificial reefs are well placed to be considered part of the marine environments potential ecotourism resources (Stolk and Markwell, 2007), and if properly planned, may indeed contribute towards the principles and practices of ecotourism development (Lawton and Weaver, 2001). On environmental and fiscal grounds, the various advantages of promoting ecotourism diving activity on or around artificial reefs have been previously noted in this thesis (Chapter 1 and Chapter 3). For example, studies have demonstrated the potential of artificial reefs to; alleviate scuba diving pressure to nearby natural reefs (Leeworthy *et al.,* 2006; Polak and Shashar, 2012; Kirkbride-Smith *et al.,* 2013) mimic natural reef habitats (Wilhelmsson *et al.*, 1998; van Treeck and Schuhmacher, 1999), provide dive training sites in less ecologically sensitive areas (Polak and Shashar, 2012), furnish visitors with ease of access to diving resources (Milton, 1989; Shani *et al.*, 2011) and generate significant economic benefits to local host economies (e.g. Brock, 1994; Wilhelmsson *et al.*, 1998; Dowling and Nichol, 2001; Johns *et al.,* 2001; Johns, 2004; Pendleton, 2005; Oh *et al.*, 2008; Chapter 2). All these aforementioned benefits can make a positive contribution towards the sustainability of the diving tourism industry, in tandem with the marketing potential of ecotourism through the deployment of artificial reefs (Shani *et al.,* 2011).

Divers principal motivations to scuba dive reflect the key principles of ecotourism; the activity can provide both a nature based experience and the opportunities for environmental education (Fennell and Weaver, 2005). It is however the experience of viewing nature within its natural environment that appears to be one of the key motivational factors for the majority of divers (e.g. Barker, 2003; Musa *et al.*, 2006; Fitzsimmons, 2009; Uyarra *et al.,* 2009; Edney, 2012). The often overwhelming desire of humans to experience wildlife encounters, and to be part of nature, has been proposed by Wilson (1984) as the 'biophilia hypothesis'. The author suggests as urbanization increases and our daily lifestyles become increasingly disconnected from nature, we seek out wildlife pursuits to satisfy these shortcomings. Scuba diving tourism clearly satisfies these needs to a lesser or greater extent (Paterson *et al.,* 2012) and indeed, the engagement is thought to enhance the physical well-being of some participants (Straughan, 2012). However, it is not only the biological aspects of the diving experience that motivates divers, additional factors, including the social aspects of the engagement, play an integral role in diver enjoyment and satisfaction (Dearden *et al.,* 2006; Musa *et al.,* 2006; Fitzsimmons, 2009).

A small selection of survey-based studies has measured diver enjoyment and satisfaction as a function of specific reef attributes rated by divers. As a consequence, attributes and motivational factors associated with a natural reef dive experience are reasonably well understood both qualitatively (e.g. Williams and Polunin, 2000; Musa, 2002; Musa *et al.,* 2006; Fitzsimmons, 2009; Uyarra *et al.,* 2009; Coghlan, 2012; Paterson *et al.,* 2012) and quantitatively (e.g. Rudd and Tupper, 2002; Wielgus *et al.*, 2003; Parsons and Thur, 2007; Schuhmann *et al.,* 2008). In contrast, less work has been specifically devoted to appraise key resource attributes associated with artificial reef diving. Notwithstanding, Edney (2012) studied motivational factors of wreck divers establishing diver enjoyment was closely associated with viewing marine life and the peace and tranquility of the underwater environment. Shani *et al.* (2011) noted relaxation, special underwater features and expansion of knowledge as the main motivational drivers in their cohort of divers. Polak and Shashar (2013) examined divers' willingness to pay for changes in the biological components on a deployed artificial reef via computer assisted manipulations. They found that respondents were willing to pay the highest sums for conservation efforts that protected high biodiversity, while fish abundance was the least important.

Despite these individual works, there has been little attempt to directly evaluate the enjoyment of diving between artificial and natural reef habitats. It appears only one study (Oh *et al.,* 2008) addresses the specific question of whether artificial reefs are functionally acceptable to scuba divers, and these authors used a fiscal approach of willingness to pay to isolate diver benefits between reef habitats in the same locality. Of relevance though, Johns *et al.* (2001) and Johns (2004) studied willingness to pay for both reef types; however their comparative analyses focused on artificial and natural reef 'usage' and not on diving 'benefits'. Certainly from a reef planning and development perspective, insight into the functional acceptability of artificial reefs by divers is required, as is the relative importance of specific reef attributes that contribute to the artificial reef dive experience *per se.* This knowledge can be used to inform marine resource management decisions for the most effective provision and management of artificial reefs, not only for economic benefits but for social and ecological effectiveness also. Moreover, the intention of the Barbados government to deploy a series of tourism-orientated artificial reefs in the forthcoming years (Hoetjes *et al.,* 2002; J. Blades, personal communication, February, 2009) provided a strong incentive to understand the attributes that fundamentally attract divers to them. Whilst artificial reefs are certainly not viewed as perfect substitutes for natural coral reefs (Oh *et al.,* 2008), it has been suggested that natural reef habitats are valuable and artificial reefs are not (Bennington, 2005; cited in Oh *et al.,* 2008). Thus as a primary component of this study, I challenge this suggestion based on the extrinsic (null) hypothesis.

### 4.2.1 Research Aims

The aims of this study were threefold. First, I directly measure divers' enjoyment of artificial reef and natural reef dives conducted in Barbados to test the hypothesis that survey participants derive equal enjoyment from artificial reef diving as they do from diving on natural reefs. Second, I aim to identify specific attributes of the artificial reef dive experience that contribute significantly to diver enjoyment. Finally, I use principal components analysis to explore if certain characteristics; age, gender and diver experience, are influenced by potential factors present within the enjoyment data, and if so, to what extent. The results of this study are discussed in terms of their relevance to the planning and development of artificial reef dive sites and the feasibility of artificial reefs as substitute sites for natural reefs.

## 4.3 Methods

### 4.3.1 Study Area

For the purpose of this study I used four diving sites in Barbados (13°10'N, 59°32'W); two artificial reefs and two natural coral reefs located on the west coast (Figure 4.1). Using the same reef sites throughout the study helped minimize influencing variables that may have arisen if using for example reefs of different biological communities and topographies. Reef site selection was partially influenced by data provided by respondents from a previous questionnaire (Chapter 3 – Appendix A), identifying popular and frequently used artificial and natural reef dive sites in Barbados. As far as possible, I also selected diving sites that were of a similar age (for wrecks), water depth, travel time by boat and dive type (e.g. drift dive).

The two artificial reefs selected were the *SS Stavronikita* and the Pamir. The *SS Stavronikita*, deployed in 1978, is cited as the largest wreck in the Caribbean (Agace, 2005), receiving high numbers of tourist and local divers each year (Kirkbride-Smith *et al.*, 2013). The Parmir, situated north of the *SS Stavronikita*, was modified for diving and purposefully sunk in 1985. Whilst the Parmir is smaller (170 feet in length) that the *SS Stavronikita* (365 feet in length), it still receives a high numbers of divers on a regular basis (Kirkride-Smith *et al.*, 2013). Benthic assemblages on both artificial reefs are dominated by encrusting sponges; e.g. *Aplysina fistularis* and *Niphates erecta*, gorgonian sea fans such as *Iciligorgia schrammi* and black corals; e.g. *Antipathes caribbeana.* Both wrecks also harbour many species of reef fishes including; bluehead wrasse *Thalassoma bifasciatum*, bicolour damselfish *Stegastes partitus* (Tupper and Hunte, 1994), sergeant major fish *Abudefduf saxatilis*, trumpet fish *Aulostomus maculates* and snapper *Lutjanidae* of various species. The natural coral reefs selected for the study were Dottins reef and Bright Ledge. Dottins reef situated 7 km north of the *SS Stavronikita*, and Bright Ledge, located in close proximity to the Pamir, are both in reasonable health (approximately 30% hard and 10% soft coral cover) (Blackman and Goodridge, 2009). Moreover, both natural reefs possessed comparable fish abundance and diversity to that found on the two artificial reefs used in the study (A. Kirkbride-Smith, personal observation, January 2013).


**Figure 4.1 Map of Barbados.** Locations of the four reef diving sites and the diving schools used in the study (Adapted from: Google maps, 2012).

### 4.3.2 Data Collection

A basic, one page survey was developed (in English only) (Appendix C) to investigate the aims of the study. The survey consisted of four questions; respondent's age, gender, number of logged dives and a list of 24 enjoyment attributes relating to artificial reef and natural reef diving. The enjoyment variables were in part extracted from data derived from a previous questionnaire used in this thesis (Chapter 3 – Appendix A) that sought to identify diver enjoyment attributes (2 items) of respondents prior dive experiences on both artificial and natural reefs. To augment diver enjoyment data, high ranking dive attributes derived from Ditton *et al.* (2002), Musa *et al.* (2006) and Fitzsimmons (2009) were selected for use. Indeed, a similar methodology was used by Musa *et al.* (2006) and Fitzsimmons (2009), to assess diver enjoyment of natural reefs at eco-tourist dive resorts in Malaysia and in Fiji respectively. The selected dive attributes listed in the survey (Table 4.1) were each presented alongside a continuous enjoyment line using a percentile rating scale of 0% to 100%, with orientation markers at 0%, 25%, 50%, 75% and 100% (Uyarra *et al.*, 2009; Appendix C). The survey was initially tested as a pilot study (n = 10) on the target population of diving tourists. This resulted in modest changes being made to the final questionnaire. In general, the simplistic design of the survey allowed for a quick response by divers; eliminating confusion and minimizing respondent bias (Musa *et al.*, 2006).

The questionnaire was distributed between five of the diving companies along the south-west coast of Barbados (Figure 4.1) in January 2013, capturing the tourist high season. Conditions for diving throughout the month of January are typically favourable due to calmer weather conditions during the dry season and good underwater visibility. In general, seawater conditions appeared good and remained relatively constant (average sea surface temperature of 27$^{o}$C, underwater visibility ~ 30 m; A. Kirkbride-Smith, personal observation, January, 2013) during the study period. Due to constraints on time, I limited the sample size to 120 respondents, divided almost equally between each reef habitat type. The sampling frame for survey participants comprised of adult certified scuba divers, between the ages of 18 and 70 years, and with an *a priori* requirement of ≥ 10 logged dives conducted on both reef types. Each participant was surveyed once at either a natural reef or an artificial reef diving site (Figure 4.1), with all surveys being self-administered. Participants were requested at the conclusion of their dive, to indicate how much each one of the 24 attributes had contributed to their diving enjoyment, by marking each attribute with a tick along the enjoyment line (0% → increasing enjoyment → 100%). The purpose of the study was made clear to all participants prior to completion of the survey, with all 120 survey instruments fully completed during the month of January 2013. Consent was granted by all divers to use the information provided on an anonymous basis.

### 4.3.3 Statistical Analysis

An exploratory analysis of the survey data was conducted using the Statistical Package for the Social Sciences (SPSS, Version 19) software. Consistent with the method adopted in Chapter 3 of this thesis, and with Fitzsimmons (2009), the number of dives that respondents had logged was transformed into a categorical variable; novice (< 100 logged dives) and experienced (≥ 100 logged dives) categories. I also transformed age into a categorical variable consisting of two classifications; 18–40 and 41–67, years of age. To assess data for normality, all data were analyzed (Kolmogorov-Smirnov Test). With the exception of the variable age, no other data fulfilled the assumptions of parametric testing and thus non-parametric statistical tests were adopted. This was despite various attempts to transform data.

Initially, each of the 24 enjoyment scales was tested for their internal consistency reliability using Cronbach's alpha coefficient (Cronbach, 1951). Pallant (2010) suggests the coefficient value of a scale should be ≥ 0.70 in order to be acceptable. To test the null hypothesis of whether divers derived equal enjoyment from artificial reef diving as they did from natural reef diving, a Mann-Whitney U Test (two-tailed) was performed to analyze for differences between total enjoyment scores for each attribute presented. To identify the relative importance of each individual attribute on diver enjoyment, basic ranked lists of mean values were produced for each reef type. I then explored differences in diver enjoyment derived from each attribute presented in the survey, between artificial and natural reef dives. To do this, multiple pair-wise comparisons were conducted using the Mann-Whitney U Test (two-tailed) to detect levels of significance between each pair of variables.

Data was then inspected independent of reef habitat type. To explore whether diver characteristics (i.e. age, gender and diver experience) were influenced by potential factors present within the enjoyment data, principal component analysis (with Oblimin rotation) was conducted. Both Wang and Du (2000) and Shlens (2005) support the application of principal component analysis with non-parametric data. The relative importance of each identifiable factor on diver enjoyment was investigated using the Wilcoxon test (two-tailed). To explore differences in diver enjoyment for age categories, gender and diver experience, pair-wise comparisons (Mann-Whitney, two-tailed) were performed for each of the discrete attributes. A *p*-value of $\leq 0.05$ was accepted as statistically significant for all tests.

## 4.4 Results

### 4.4.1 Demographic Characteristics and Diving Experience

From the 120 divers sampled, more males (61%) than females were recorded. The age structure of respondents ranged from 18 to 67 years, with the median and mean age recorded as being 40 ($\pm$ 13.6 s.d.) years. Fifty-three percent of divers (n = 63) were categorized as novices, whilst the remaining 47% (n = 57) of respondents with $\geq 100$ logged dives, represented those experienced in the sport. A median of 90 logged dives were recorded for survey participants [interquartile range: 31-210]. Figure 4.2 shows the distribution of values for the variable number of logged dives and clearly displays a positive skew with a long tail of high values present.

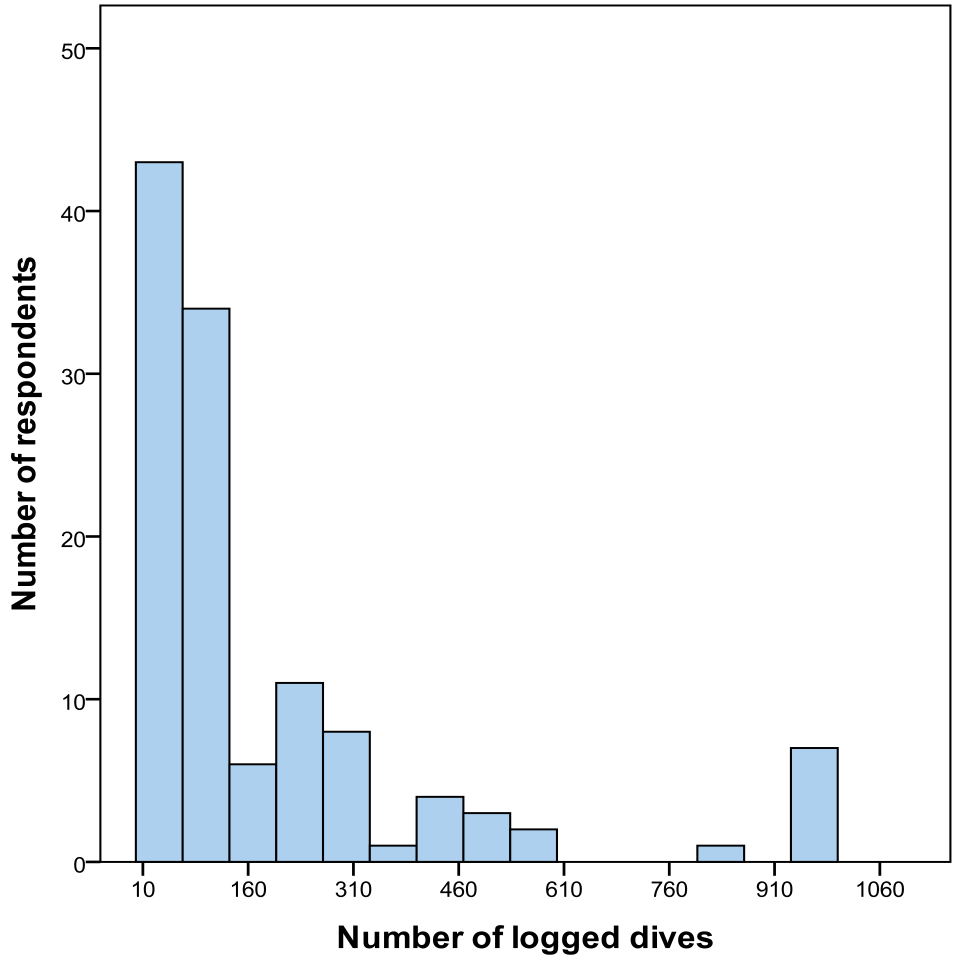


**Figure 4.2 A histogram recording the number of dives survey participants had personally logged in their diving history.**

### 4.4.2 Diver Enjoyment of Artificial Reef and Natural Reef Diving Sites

The Cronbach alpha coefficient reported a very good internal consistency for each of the 24 scales used to measure diver enjoyment (range: 0.83 – 0.85). In many instances, scores for individual attributes clustered at either the extreme positive of the scale (e.g. safety and a good buddy), or at the extreme negative of the scale (e.g. new species and large fish). Differences in diver enjoyment between reef habitat types were explored. Mean total (%) enjoyment scores for the 24 attributes offered in the survey revealed combined scores being significantly higher for dives conducted at artificial reefs than at natural reef sites. Median [interquartile range]: artificial reef sites, 69% [1535-1796], versus natural reef sites, 64% [1298-1766]; Mann-Whitney, two-tailed: $U = 1315$, $z = -2.537$, $p \leq 0.011$, $r = 0.23$ (Figure 4.3). The null hypothesis that dive tourists in Barbados derive equal enjoyment from artificial reef diving as they do from natural reef diving was thus rejected in favour of artificial reefs.

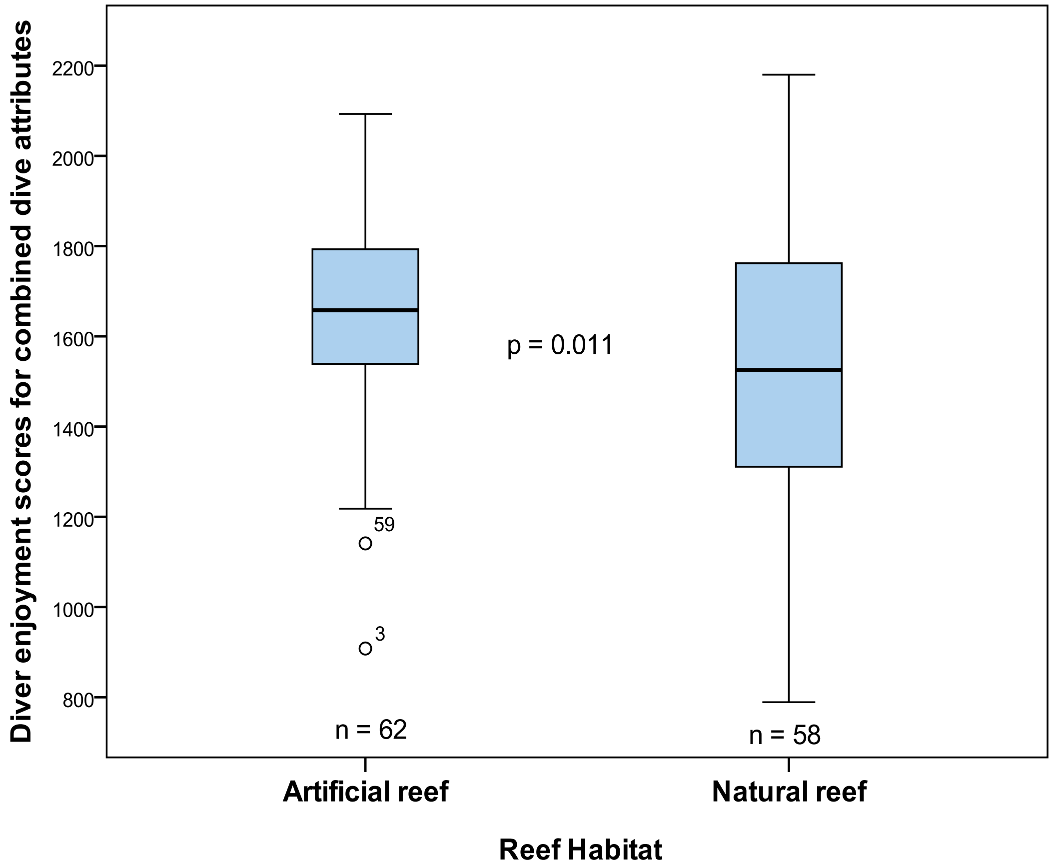


**Figure 4.3 Diver enjoyment scores for combined dive attributes for artificial reef and natural reef habitats.** Boxes represent the inter-quartile range that contains 50% of values. The median value is represented by a line across the box. The whiskers extend to the $5^{th}$ and $95^{th}$ percentiles and circles outside the box plots are outliers. Sample size is represented by numbers below each box.

To detect significant differences between the contribution of artificial reef and natural reef dive attributes to the enjoyment of divers, pair-wise comparisons (Mann-Whitney, two-tailed) were conducted. Several attributes were found to be of particular importance in determining dive site enjoyment at artificial reefs (Table 4.1). Notably; new experiences, photography, water depth, topography of reef site and challenge of the dive, were all of statistical significance in comparison to enjoyment scores for natural reef dives. Indeed, Table 4.1 shows the attribute ‘challenge of the dive’ produced a highly significant result ($p \leq 0.001$) between reef types. Significant enjoyment of artificial reef dive sites was also attributed to; overall safety, a good buddy, numbers of divers, underwater sensation and equipment.

**Table 4.1** Significant differences between the contribution of artificial reef and natural reef dive attributes to the enjoyment of divers.

| **Dive attribute feature** | **Habitat enjoyment score** | ***p*- Value** |
|---|---|---|
| Large fish | No significant difference | 0.795 |
| Water depth | Artificial reef > natural reef | **0.006** |
| Numbers of fishes | No significant difference | 0.551 |
| Location travel time | No significant difference | 0.095 |
| Overall safety | Artificial reef > natural reef | **0.001** |
| Sea visibility | No significant difference | 0.158 |
| Up-dating diving skills | No significant differences | 0.570 |
| Unusual/rare species | No significant difference | 0.538 |
| New experiences | Artificial reef > natural reef | **0.033** |
| Access to reef | No significant difference | 0.115 |
| Photography | Artificial reef > natural reef | **0.024** |
| Good buddy | Artificial reef > natural reef | **0.002** |
| Variety of corals | No significant difference | 0.062 |
| Numbers of divers | Artificial reef > natural reef | **0.006** |
| Warm water | No significant difference | 0.080 |
| Topography of reef site | Artificial reef > natural reef | **0.003** |
| Underwater sensation | Artificial reef > natural reef | **0.003** |
| Diversity of fish species | No significant difference | 0.530 |
| Challenge of dive | Artificial reef > natural reef | **0.001** |
| Coral cover | No significant difference | 0.267 |
| Equipment | Artificial reef > natural reef | **0.015** |
| Sharing enjoyment | No significant difference | 0.125 |
| New species | No significant difference | 0.117 |
| Currents | No significant difference | 0.553 |
| Total enjoyment | Artificial reef > natural reef | **0.011** |

**Note:** *p*- Values emboldened are of statistical significance (Mann-Whitney U Test, two-tailed), n = 120.

### 4.4.3 Dive Site Attributes and Impact on Diver Enjoyment

To assess the relative importance of each individual attribute on diver enjoyment, ranked lists of mean percentage values for each reef type were produced (Table 4.2).

**Table 4.2** Dive enjoyment attributes ranked by mean for artificial reef and natural reef diving sites.

| Rank | Artificial reef (n = 62) | | Natural reef (n = 58) | |
|---|---|---|---|---|
| | **Dive attribute feature** | **Mean score [a] ± 1*SD*** | **Dive attribute feature** | **Mean score ± 1*SD*** |
| 1 | Overall safety | 91.76 ± 11.15 | Overall safety | 84.22 ± 15.04 |
| 2 | Good buddy | 89.61 ± 19.39 | Good buddy | 81.66 ± 20.48 |
| 3 | Sharing enjoyment | 86.63 ± 17.38 | Sharing enjoyment | 81.03 ± 19.88 |
| 4 | Warm water | 86.16 ± 17.00 | Warm water | 80.78 ± 16.82 |
| 5 | Underwater sensation | 84.79 ± 18.97 | Access to reef | 79.43 ± 17.01 |
| 6 | Numbers of divers | 84.03 ± 21.22 | Underwater sensation | 78.16 ± 15.42 |
| 7 | Location travel time | 82.77 ± 18.69 | Location travel time | 77.98 ± 18.96 |
| 8 | Access to reef | 82.63 ± 19.68 | Water depth | 74.02 ± 16.00 |
| 9 | Water depth | 80.76 ± 18.50 | Numbers of divers | 73.47 ± 24.74 |
| 10 | Equipment | 79.53 ± 26.86 | Equipment | 71.00 ± 27.21 |
| 11 | Reef topography | 79.11 ± 20.79 | Reef topography | 70.81 ± 19.93 |
| 12 | Sea visibility | 70.87 ± 19.99 | Sea visibility | 67.10 ± 18.06 |
| 13 | Challenge of dive | 70.08 ± 27.30 | Currents | 65.93 ± 24.41 |
| 14 | Numbers of fish | 66.81 ± 24.66 | Numbers of fish | 64.62 ± 24.62 |
| 15 | Variety of corals | 64.73 ± 27.62 | Up-dating dive skills | 61.95 ± 23.40 |
| 16 | Currents | 63.63 ± 25.46 | Coral cover | 56.55 ± 27.14 |
| 17 | Coral cover | 61.89 ± 25.99 | Challenge of dive | 55.88 ± 26.99 |
| 18 | Photography | 60.87 ± 35.28 | Variety of corals | 54.59 ± 29.93 |
| 19 | New Experiences | 60.60 ± 34.31 | Diversity of fish | 52.81 ± 30.19 |
| 20 | Up-dating dive skills | 60.58 ± 35.43 | New experiences | 46.84 ± 31.52 |
| 21 | Diversity of fish | 56.23 ± 24.98 | Photography | 46.22 ± 38.24 |
| 22 | New species | 28.37 ± 27.56 | New species | 38.76 ± 34.70 |
| 23 | Unusual/rare species | 27.74 ± 22.89 | Unusual /rare specie | 31.45 ± 25.34 |
| 24 | Large fish | 26.00 ± 24.76 | Large fish | 25.95 ± 21.68 |

**Note:** [a] values measured on a percentile rating scale of 0% - 100 % of maximum enjoyment.

It is apparent from the features listed in Table 4.2, that overall safety, a good buddy, sharing enjoyment, warm water and underwater sensation, are all ranked in the top six attributes for both reef habitats. Closer inspection of attributes established that sharing enjoyment and a good buddy were significantly more highly ranked than the nearest fish or coral reef attribute ($p \leq 0.001$ all items). Warm water conditions were also greatly appreciated by divers, being the highest ranked environmental attribute influencing diver enjoyment. Attributes of moderate importance to divers were for example; photography and up-dating diving skills. Conversely, diversity of fish, new species, unusual/rare species and large fish all appear to contribute little to diver enjoyment, being ranked at the bottom of the table for both marine habitats.

### 4.4.4 The Influence of Factors on Diver Enjoyment and Diver Characteristics

To explore the presence of potential factors existing within the enjoyment data, a principal component analysis was undertaken on the 24 dive attributes, independent of reef habitat type. The initial inspection of the correlation matrix revealed many coefficients of values of 0.4 or above (Field, 2009). The Kaiser-Meyer-Olkin value was 0.77 exceeding the acceptable value of 0.6 (Kaiser, 1970; 1974), and Bartlett's Test of Sphericity (Bartlett, 1954) was of statistical significance; $x^2$ (276) = 1094.91, $p \leq 0.001$. Both tests indicated that the correlations between attributes were suitable for principal component analysis.

Initially, six factors emerged as having eigenvalues over Kaiser's (1970; 1974) criterion of 1, explaining 63.94% of the combined variance. However, inspection of the scree plot (Appendix D – Figure 1D) showed inflexion occurring between the third and fourth components, suggesting a three component solution. To validate Catell's (1966) scree test, a parallel analysis (Monte Carlo PCA) was conducted (www.openup.co.uk/spss) revealing three components with eigenvalues exceeding the corresponding criterion values (Appendix D – Table 1D). The results of the parallel analysis thus supported the use of three components for further investigation, that when combined, explained 46.92 % of the variance (Table 4.3).

Oblimin rotation was performed to assist in the interpretation of the components. Broadly, the items clustered on each factor were identified as; 'Social and

Environmental' (Factor 1; 11 items), 'Biological' (Factor 2; 7 items) and 'Personal Incentive' (Factor 3; 4 items) (Table 4.4), revealing eigenvalues of 6.51, 2.64 and 2.12, respectively. Eigenvalues are reported in Table 4.3. Each variable loaded significantly ($\geq$ 0.420) on respective factors (Table 4.4), further supporting the internal consistency reliability of the scales used (Table 4.3).

**Table 4.3** Eigenvalues, percentages of variance and reliability coefficients (Cronbach alpha) for each factor extracted.

| **Factors** | **Eigenvalue** | **% of variance** | **Reliability coefficients** |
|---|---|---|---|
| Factor 1: Social & Environmental | 6.51 | 27.11 | 0.834 |
| Factor 2: Biological | 2.64 | 10.99 | 0.831 |
| Factor 3: Personal Incentive | 2.12 | 8.82 | 0.836 |

The extent to which the three identifiable factors influenced diver enjoyment (independent of reef type) was examined using the Wilcoxon test (two-tailed). Results revealed that the social and environmental factor contributed significantly more to diver enjoyment than either the biological or personal incentive factors (median [interquartile range]: social and environmental, [815.25-972.25], biological, [234.75-425.50], personal incentive, [250.25-375.75]; Wilcoxon $Z$ = -9.51, $n$ = 120, $p \leq 0.001$). In contrast, no significant difference occurred between biological and personal incentive factors in their contribution to overall diver enjoyment; Wilcoxon $Z$ = -1.69, $n$ = 120, $p \geq 0.092$.

**Table 4.4** Factor loadings: pattern and structure matrix for principal component analysis of three factor solution of 24 dive attributes.

| **Attribute** | **Pattern coefficients** | | | **Structure coefficients** | | | **Communalities** |
|---|---|---|---|---|---|---|---|
| | **Factor 1:** Social & Environmental | **Factor 2:** Biological | **Factor 3:** Personal Incentive | **Factor 1:** Social & Environmental | **Factor 2:** Biological | **Factor 3:** Personal Incentive | |
| Underwater sensation | **0.726** | 0.125 | 0.070 | **0.700** | -0.079 | 0.147 | 0.509 |
| Water depth | **0.702** | 0.293 | 0.144 | **0.638** | 0.093 | 0.210 | 0.506 |
| Warm water | **0.690** | 0.025 | 0.005 | **0.684** | -0.166 | 0.084 | 0.469 |
| Overall safety | **0.670** | -0.227 | 0.053 | **0.739** | **-0.414** | 0.141 | 0.596 |
| Reef topography | **0.615** | -0.029 | -0.261 | **0.593** | -0.185 | -0.189 | 0.419 |
| Numbers of divers | **0.601** | 0.068 | -0.088 | **0.572** | -0.093 | -0.022 | 0.340 |
| Location travel time | **0.586** | 0.051 | 0.133 | **0.588** | -0.117 | 0.198 | 0.365 |
| Access to reef | **0.552** | -0.335 | 0.108 | **0.657** | **-0.492** | 0.188 | 0.548 |
| Sharing enjoyment | **0.547** | -0.274 | 0.290 | **0.656** | **-0.439** | 0.367 | 0.585 |
| Good buddy | **0.454** | -0.271 | 0.152 | **0.546** | **-0.404** | 0.218 | 0.390 |
| Sea visibility | **0.444** | -0.085 | 0.053 | **0.473** | -0.210 | 0.109 | 0.233 |
| Currents | 0.270 | -0.130 | 0.244 | 0.334 | -0.217 | 0.281 | 0.187 |
| New species | -0.218 | **-0.795** | 0.151 | 0.018 | **-0.743** | 0.166 | 0.612 |
| Unusual/rare species | -0.175 | **-0.782** | 0.210 | 0.064 | **-0.745** | 0.229 | 0.620 |
| Diversity of fish | 0.255 | **-0.739** | -0.199 | **0.435** | **-0.799** | -0.132 | 0.728 |
| Numbers of fish | 0.259 | **-0.592** | -0.293 | 0.388 | **-0.648** | -0.234 | 0.552 |
| Variety of corals | 0.315 | **-0.577** | -0.351 | **0.433** | **-0.646** | -0.285 | 0.609 |
| Coral cover | 0.268 | **-0.538** | -0.030 | **0.413** | **-0.610** | 0.028 | 0.438 |
| Large fish | -0.099 | **-0.420** | 0.110 | 0.030 | **-0.400** | 0.119 | 0.178 |
| Photography | 0.137 | -0.370 | -0.317 | 0.202 | -0.391 | -0.282 | 0.262 |
| Updating diving skills | 0.029 | 0.014 | **0.799** | 0.118 | -0.035 | **0.802** | 0.644 |
| New experiences | 0.113 | -0.353 | **0.631** | 0.282 | **-0.415** | **0.661** | 0.595 |
| Challenge of dive | 0.128 | 0.097 | **0.600** | 0.171 | 0.031 | **0.610** | 0.391 |
| Equipment | 0.275 | -0.128 | **0.574** | 0.377 | -0.233 | **0.613** | 0.485 |

**Notes:** major loadings for each item (≥ .40) appear in bold. Rotation method: Direct Oblimin with Kaiser normalization, n = 120.

Diver characteristics (age, gender and diver experience) were explored (Mann-Whitney, two-tailed) to assess the contribution of attributes on diver enjoyment. No significant difference in the contribution of combined attributes to diver enjoyment between the two age groups could be detected; $U = 1553$, $z = -1.284$, $p \geq 0.199$, $r = 0.12$. Individual attributes were then inspected in relation to age. Divers in the age category 18-40 years of age, derived greater enjoyment from updating diving skills and from new experiences than divers in the 41-67 age category; Mann-Whitney, two-tailed: $U = 1241$, $z = -2.927$, $p \leq 0.003$, $r = 0.27$; $U = 1312$, $z = -2.558$, $p \leq 0.011$, $r = 0.23$, respectively. Gender was then examined. No significant difference in overall diver enjoyment were uncovered between males and females; $U = 1447$, $z = -1.441$, $p \geq 0.150$, $r = 0.13$. However, inspection of discreet attributes revealed that males enjoyed the variables large fish and access to the reef, more than females; $U = 1292$, $z = -2.279$, $p \leq 0.023$, $r = 0.21$; $U = 1283$, $z = -2.343$, $p \leq 0.019$, $r = 0.21$, respectively.

Examination of diver experience categories was investigated. Novice divers were recorded as having higher combined scores for both artificial reef and natural reef dives in comparison to scores recorded for experienced divers, though this difference was not significant; $U = 388$, $z = -1.245$, $p \geq 0.213$, $r = 0.11$; $U = 363$, $z = -0.628$, $p \geq 0.530$, $r = 0.06$, respectively. However, the contribution of discreet attributes to diver enjoyment revealed significant differences occurring for several variables. Table 4.5 shows the enjoyment of the novice group was significantly more influenced by the personal incentive factor (Factor 3, principal component analysis); updating diving skills, new experiences, challenge of the dive and equipment. This result possibly reflects divers' initial requirements to develop and consolidate their skills in the sport and general emphasis on use and familiarity with equipment. In contrast, those more experienced at scuba diving derived significantly more enjoyment from the biological aspects of the dive; i.e. variety of corals and coral cover (Factor 2, principal component analysis) and from photography and the topography of the reef site. Figure 4.4 visualizes differences in the relative importance of biological attributes and personal incentive attributes to the diving enjoyment of novice and experienced divers. Despite these differences noted above, several attributes appeared to be important to both diver groups including warm water, underwater sensation, location and travel time, overall safety, sea visibility and numbers of fishes.

**Table 4.5** Significant differences between the contribution of dive attributes to the diving enjoyment of novice and experienced divers.

| **Dive attribute feature** | **Diver enjoyment score** | ***p*- Value** |
|---|---|---|
| Large fish | No significant difference | 0.790 |
| Water depth | No significant difference | 0.216 |
| Numbers of fishes | No significant difference | 0.630 |
| Location travel time | No significant difference | 0.855 |
| Overall safety | No significant difference | 0.884 |
| Sea visibility | No significant difference | 0.601 |
| Up-dating diving skills | Novice divers > experienced divers | **0.001** |
| Unusual/rare species | No significant difference | 0.543 |
| New experiences | Novice divers > experienced divers | **0.001** |
| Access to reef | No significant difference | 0.237 |
| Photography | Experienced divers > novice divers | **0.001** |
| Good buddy | No significant difference | 0.336 |
| Variety of corals | Experienced divers > novice divers | **0.005** |
| Numbers of divers | No significant difference | 0.594 |
| Warm water | No significant difference | 0.821 |
| Topography of reef site | Experienced divers > novice divers | **0.024** |
| Underwater sensation | No significant difference | 0.830 |
| Diversity of fish species | No significant difference | 0.384 |
| Challenge of dive | Novice divers > experienced divers | **0.050** |
| Coral cover | No significant difference | 0.067 |
| Equipment | Novice divers > experienced divers | **0.001** |
| Sharing enjoyment | No significant difference | 0.270 |
| New species | No significant difference | 0.274 |
| Currents | No significant difference | 0.313 |
| Total enjoyment | No significant difference | 0.332 |

**Notes:** novice divers' < 100 logged dives (n = 63); experienced divers' ≥ 100 logged dives (n = 57).
*p*- Values emboldened are of statistical significance (Mann-Whitney U Test, two-tailed).

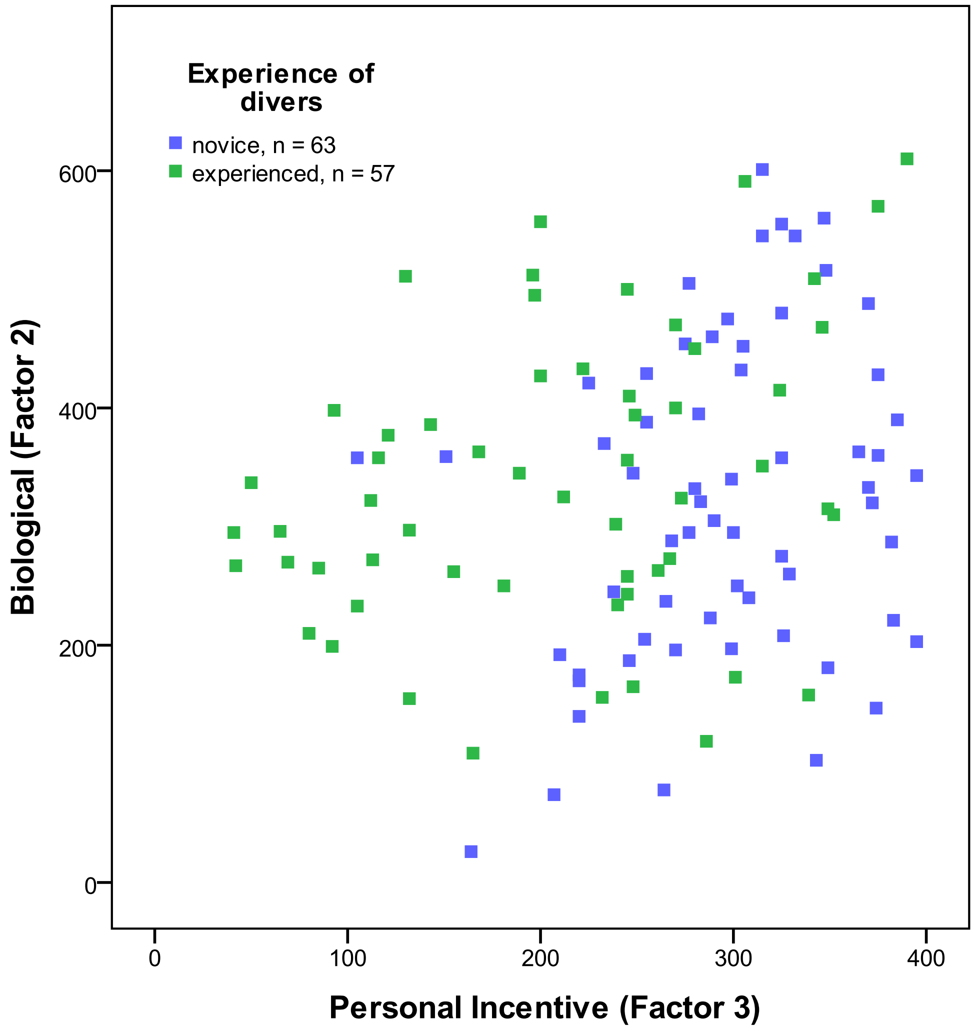


**Figure 4.4 Relative importance of biological variables (Factor 2) and personal incentive variables (Factor 3) to the diving enjoyment of novice and experienced divers.** Dots relate to mean values for combined scores of the personal incentive factor (4 items) and the biological factor (7 items).

## 4.5 Discussion

The main purpose of this study was to measure diver enjoyment between two types of reef habitat in the same locality. Studies previously conducted on scuba diver enjoyment and satisfaction have been site specific (Musa, 2002; Musa *et al.*, 2006; Fitzsimmons, 2009; Uyarra *et al.*, 2009; Shani *et al.*, 2011; Edney, 2012; Paterson *et al.*, 2012), and to the author's knowledge, this is the first investigation to explore diver enjoyment between artificial and natural reef habitats.

#### 4.5.1 Diver Enjoyment of Artificial Reef and Natural Reef Diving Sites

My results confirm that divers using artificial reefs experienced significantly higher levels of diving enjoyment than users of natural reef sites in Barbados. The notion that artificial reefs are worthless (Bennington, 2005; cited in Oh *et al.,* 2008) can therefore be dismissed, as my results show that some artificial reefs are highly valued for personal diving enjoyment. Oh *et al.* (2008) additionally rejected Bennington's (2005) claim after conducting a consumer surplus study of diving benefits associated with both marine habitats in Texas. Whilst divers in their study valued natural reefs significantly higher than artificial habitat ($171 and $101, respectively), artificial reefs nonetheless, were greatly valued by their cohort of divers. I am aware of only two other studies that compare both reef habitats that exist together. Johns *et al.* (2001) and Johns (2004) studied reefs in Florida and found consumer surplus gains from divers' use of natural reefs of around 33% more than for divers' use of artificial reefs. Both studies also showed that the greatest percentages of dives were conducted on natural reefs than dives undertaken on artificial habitat. Of interest, Johns (2004) found visitors to the region were willing to pay around three times as much for the maintenance and future development of artificial reefs, than resident divers studied.

Divers appeared to enjoy certain aspects of the artificial reef dive experience more than those appreciated on natural reefs (Table 4.1). Notably; new experiences, overall safety, photography, water depth, reef topography and the challenge of the dive, all emerged as having a positive impact on diver enjoyment at artificial reef sites. Consistent with my finding in Chapter 3 of this thesis (Kirkbride-Smith *et al.*, 2013) and with Stolk *et al.* (2005) and Edney's (2012) findings, it appears that new experiences and the challenge of the dive both provide strong incentives to dive on artificial habitat. Shipwrecks and sunken vessels are particularly favoured by divers for their new experiences and overall challenge (Edney, 2012; Chapter 3; Kirkbride-Smith *et al.,* 2013). This is due in part to the complexity and thrill of accessing the wrecks internal structure (Stolk *et al.*, 2005; Edney, 2012) and the opportunity to practice more precise diving skills (Edney, 2012). Of interest, Stolk *et al.* (2005) noted that some divers viewed a natural reef dive less challenging, due to less preparation and skill being required to navigate around natural reef habitat.

Photography is also an important motivator for divers (Meisel and Cottrell, 2004; Stolk *et al.*, 2005; Dearden *et al.*, 2006; Luna *et al.*, 2009; Ince and Bowen, 2011; Edney, 2012; Chapter 3; Kirkbride-Smith *et al.*, 2013; Lucrezi *et al.*, 2013), as it allows for identification of marine organisms and documents the whole diving experience making it more memorable. Artificial reefs are particularly good for photographic opportunities as they can concentrate marine life in small areas (Wilhelmsson *et al.*, 1998; Stolk *et al.*, 2005; Perkol-Finkel *et al.*, 2006; Arena *et al.*, 2007; Kirkbride-Smith *et al.*, 2013; Granneman and Steele, 2014), leading to longer diving times. Indeed, many wrecks are known to harbour greater fish abundance and biomass than similar sized natural reefs (e.g. Fast and Pagan, 1974; Wilhelmsson *et al.*, 1998; Arena *et al.*, 2007; Santos *et al.*, 2013). In Barbados, Tupper and Hunte (1994) reported that some artificial reefs were successful in hosting higher fish densities, especially bluehead wrasse *Thalassoma bifasciatum* and bicolour damselfish *Stegastes partitus*, than the natural reefs surveyed. Their findings thus support data gathered for the fish variable; numbers of fishes, examined in the present study (Table 4.2). Additionally, off the Cape Verde islands, Santos *et al.* (2013) observed higher fish densities present on wrecks than on the natural reefs studied. Investigations comparing artificial and natural reefs have also established wrecks and other artificial habitat have the potential to mimic local coral communities (Chou and Lim, 1986; Wilhelmsson *et al.*, 1998; Perkol-Finkel *et al.*, 2005). For example, Perkol-Finkel *et al.* (2006) reported a 119-year old shipwreck possessed a similar community structure (mainly stony and soft corals and porifera) to its adjacent natural reef. Additionally, Thanner *et al.* (2006) noted 5 years post deployment, a comparable abundance of major benthic components (principally scleractinian corals and porifera) on reef modules and boulders compared to nearby natural reef. Both authors emphasized the importance of incorporating structural complexity into artificial reef design as they believe it influences reef community structure.

### 4.5.2 Dive Site Attributes and Impact on Diver Enjoyment

Upon examination of discreet attributes (independent of reef type), overall safety, a good buddy, sharing enjoyment, warm water and underwater sensation, were all ranked in the top six attributes for both marine habitats (Table 4.2). In fact, a good buddy and sharing enjoyment were significantly more highly ranked than the nearest fish or coral reef attribute rated by divers. These five items, that appeared to have the greatest positive impact on diver enjoyment, not only serve to emphasize the social and environmental importance of diving, but collectively can be met in virtually any marine tourism setting that offers warm water conditions. Previous works have highlighted the social importance of diving. For example, Fitzsimmons (2009) studied diver enjoyment in a Fijian tourist resort and reported social attributes (i.e. a good buddy, underwater sensation and sharing enjoyment) contributed significantly more to overall diver enjoyment, than diversity and personal satisfaction items. Further, Musa (2002) identified social aspects, such as a good buddy, meeting people and making new friends, as significant contributors to satisfactory diving experiences. In contrast, he found that crowded, congested conditions, detracted from diver satisfaction. From a managerial perspective, social considerations linked to the numbers of divers at a reef site have the potential to greatly impact on diving enjoyment. Indeed, Schuhmann *et al.* (2013b) reports divers are willing to pay up to US$4.51 per dive to avoid encounters with other individuals. This reinforces the need for pre-planned artificial reefs to be sited strategically and to be large enough to help avoid diving congestion.

I found attributes that detracted the most from diver enjoyment in Barbados were all connected to the biological components of the dive. Diversity of fish, new species, unusual/rare species and large fish were all ranked at the bottom of the table for both reef environments. The item 'large fish' was highlighted as attracting the lowest mean value for diving enjoyment of $\leq$ 26% for both reef types (Table 4.2). This suggests the present quality of this specific 'fish' attribute (as well as other biological attributes) in Barbados, is generally very poor, and needs improvement. Schuhmann *et al.* (2013a) also reported the attribute 'viewing large fish' as receiving the lowest rating of all quality variables measured in a willingness to pay study conducted on the same Caribbean island. Fish attributes have often been recorded as being the most preferred biological features to view on a dive (e.g. Williams and Polunin, 2000; Rudd and Tupper, 2002; Ramos *et al.*, 2006; Paterson *et al.*, 2012; Chapter 3; Kirkbride-Smith *et al.*, 2013). Of significance, Williams and Polunin (2000) established several fish variables; 'unusual fishes', 'big fishes' and 'abundance' and 'variety of fishes', were more appreciated than those items relating to either reef benthos or structure. Moreover, Paterson *et al.* (2012) reported 'viewing large fish' as the most significant contributor to visitor satisfaction across all specialization levels of divers studied in Florida. Also, Milton (1989) and Stanley and Wilson (1989) found desirable fish species, such as grouper and snapper, as key motivators among divers using artificial reefs. Given that fish attributes (out of all the biological features) appear to have the greatest influence on divers' underwater experiences, measures to build populations and size of fishes, are clearly crucial in areas offering recreational diving opportunities. Sanctuary of fishes in marine protected areas (e.g. Williams and Polunin, 2000; Côté *et al.*, 2001; Halpern and Warner, 2002), restrictions on fishing (Varkey *et al.,* 2012) and deployment of artificial reef (e.g. Wilhelmsson *et al.,* 1998; Arena *et al.,* 2007; Santos *et al.*, 2013), would help achieve this.

The reefs in Barbados and associated fauna and flora, have deteriorated considerably over the last three decades (Burke and Maidens, 2004). Eutrophication (Tomascik and Sanders, 1985; Tomascik and Sanders, 1987a, 1987b; Tomascik, 1990; Tomascik, 1991; Lewis, 1997), bleaching (Oxenford *et al.,* 2008a, 2008b), *Diadema* mortality (Hunte *et al.,* 1986), hurricane damage (Mah and Stearn, 1986; Lewis, 2002) and sedimentation (Bell and Tomascik, 1993), have impacted the once flourishing reef system (Lewis, 1960; Stearn *et al.*, 1977). Observations (Lewis, 1960; Stearn *et al.*, 1977; Pandofi and Jackson, 2006) suggest that a phase shift from major reef building corals (e.g. *Acropora* spp.), to a dominance of slower-growing species (e.g. *Porites porites*) and macroalgal abundance, has occurred locally (Oxenford *et al.*, 2008a, 2008b; Blackman and Goodridge, 2009). Notwithstanding, recent improvements in seawater quality (Risk *et al.,* 2007) have contributed to 'some' ecosystem recovery. Blackman and Goodridge (2009) conducted a baseline survey of three fringing and three bank reefs within reserve waters and recorded up to 55% hard coral and 10% soft coral cover. Tomascik and Sander (1987a) confirmed hard coral species are dominated by mustard hill coral *Porites astreoides*, finger coral *Porites porites*, lettuce coral *Agaricia agaricites*, boulder star coral *Montastraea annularis* and the lesser starlet coral, *Siderastrea radians*. Other important fauna commonly found on the reefs (including several artificial 'wreck' reefs) are soft corals; gorgonian sea fans and whips (e.g. *Iciligorgia schrammi*, *Pterogorgia anceps*), large sponges (e.g. *Xestospongia muta* and *Niphates erecta*) and *Millepora* spp. (e.g. *M. alcicornis*) (Agace, 2005; A. Kirkbride-Smith, personal observation, January 2013). Moreover, Blackman and Goodridge (2009) observed *Diadema antillarum* as being the most abundant invertebrate on the fringing reefs, in contrast to the Caribbean spiny lobster *Panulirus argus*, noted as being absent.

A marked reduction in fish abundance has also occurred around Barbados due to historical over-fishing and poor habitat quality (Inter-American Biodiversity Information Network, 2010). Of concern, the local seine and spear fishery target reef fishes, particularly parrotfishes (Scaridae), grunts (Haemulidae) and surgeonfishes (Acanthuridae) (Maraj *et al.,* 2011; Simpson *et al.,* 2014). Blackman and Goodridge (2009) assessed the status of several indicator fish; grunts (Haemulidae), butterfly fish (Chaetodontidae), snapper (Lutjanidae), parrotfish (Scaridae), moray eel (Muraenidae), blue tangs/surgeonfish (Acanthuridae) and groupers (Serranidae), on bank and patch reefs. Parrotfish were observed as the most abundant species on bank reefs, followed by butterfly fish. In contrast, moray eels and snapper were limited at the sites. On the fringing reefs, the Haemulidae family was observed as the most abundant species, followed by parrotfish. Moray eels and snapper were scarce, whilst groupers were absent. The absence of groupers is of concern as they have been suggested as a natural predator of the invasive lionfish *Pterois volitants* (Mumby *et al.,* 2011). Lionfish were first observed in Barbados in 2006 (Schofield, 2009) and have since increased in number (R. Suckoo, personal communication, December, 2014).

The island's artificial reefs, in terms of community structure of corals and fishes, are poorly understood, and this is one area of research that needs addressing especially for coral assemblages. Two studies have investigated Barbadian fish assemblages on artificial (automobile) reefs in relation to their proximate natural reefs. Tupper and Hunte (1994) studied recruitment and population densities of fishes. Collectively, 67 species belonging to 26 families were observed on both reef habitats, with 3 common species (bluehead wrasse *Thalassoma bifasciatum,* bicolour damselfish *Stegastes partitus* and yellowhead wrasse *Halichoeres garnoti*) accounting for over 90% of all recruits. Fish recruitment rate varied little across reef types and reef locations, though recruitment of *Halichoeres garnoti* and *Stegastes partitus* were lower on an 'isolated' artificial reef.  In contrast, population densities of all species combined differed across reefs, with the artificial reef situated closer to its natural reef, supporting a higher density of combined species. Of interest, some fish species were found to be more prevalent on natural reef (*Halichoeres garnoti*) and on artificial reef (*Thalassoma bifasciatum* and *Stegastes partitus*). In a later study, Tupper and Hunte (1998) investigated fish assemblages relative to reef location and size. A total of 55 species belonging to 22 families had colonized the car reefs during the first month of deployment; this had increased to 67 species belonging to 28 families after two years. Again, the most important families recorded were Pomacentridae and Labridae, represented by two dominant species; *Stegastes partitus* and *Thalassoma bifasciatum*. The authors noted that neither reef type (artificial or natural) nor reef location appeared to have an effect on fish assemblage structure, though species richness increased with the density of fishes present on a given reef.

### 4.5.3 The Influence of Factors on Diver Enjoyment and Diver Characteristics

In this study I also considered the influence of factors on diver characteristics including diving experience. My findings suggest that the motivational drivers of diving enjoyment differ between novice and experienced divers (Table 4.5). Novices were significantly more influenced by all four attributes present within the 'personal incentive' factor (updating diving skills, new experiences, diving equipment and the challenge of the dive), more so than experienced divers were. In contrast, I established photography was very important to experienced divers, as was the 'biological' factor of the dive (variety of corals and coral cover) and reef topography. Consistent with my results, Fitzsimmons (2009) found novice diver enjoyment was significantly more influenced by equipment and personal diving skills, while divers more experienced derived significantly more enjoyment from the ecological/diversity aspects of the reef environment. Paterson *et al.* (2012) established moderate to specialized divers were satisfied after seeing live coral and a healthy reef. Meanwhile, Dearden *et al.* (2006) and Lucrezi *et al.* (2013) reported the flora and fauna aspects of diving and the opportunities for underwater photography, of growing importance as diver specialization increased. The latter two authors also noted less specialized divers placed more emphasis on non-dive characteristics such as exploring a new destination. It becomes increasingly clear from this small body of research, that novice divers are far less connected to the ecological/diversity aspects of a dive (Figure 4.4) and this offers a unique opportunity to exploit in terms of dive area management and the use of artificial reefs.

#### 4.5.4 Reef Substitution Policy as a Diving Management Strategy

Initial indications from this study suggest that a significant level of diver enjoyment can be achieved from artificial reef use and a site substitution policy may be more accepted by divers (especially by novices) than first envisaged. Additionally, results of quantitative work in Chapter 3 would support this tenet, as I demonstrated that less experienced divers were more satisfied with artificial reef diving, and had a preference for this type of reef habitat. They additionally conducted more dives on artificial reef in Barbados. This signifies that a reef substitution policy may be feasible, at least with less experienced divers.

Whilst artificial reefs may be more popular with novices (Kirkbride-Smith *et al.,* 2013), I established in Chapter 3, that experienced divers were less willing to move their diving time to artificial reef. To help encourage the use of alternative diving resources by the specialist market, features in-keeping with the motivations of experienced divers need to be carefully considered for pre-planned reefs. For example, the opportunity to view marine life appears to be of crucial importance to this group, as does underwater photography associated with biodiversity viewing (Dearden *et al.,* 2006). A selection of studies have shown (e.g. Stolk *et al.,* 2005; Shani *et al.,* 2011; Chapter 3; Kirkbride-Smith *et al.,* 2013) divers generally prefer large artificial reefs that provide themed diving experiences (ubiquitously wrecks, and to a lesser extent airplanes) as apposed to abstract, prosaic forms such as concrete pipes and blocks. According to Shani *et al.* (2011) findings, it is the very 'essence' of the artificial reef that is important to divers, especially structures that provide a type of 'environmental staging' along with attractive storylines and themes. Large shipwrecks also provide the relief and topography that experienced divers are noted as enjoying (Stolk *et al.,* 2005; Chapter 3; Kirkbride-Smith *et al.,* 2013), and offer refuge for fishes and marine biota (Arena *et al.,* 2007). Moreover, several attributes (the majority being present in Factor 1) appeared to be consistently important to both diver groups; warm water, location and travel time, overall safety, sea visibility and numbers of fishes. These features should also be given consideration in the process of reef development (refer to Gordon and Ditton, 1986; Chapter 1, section 1.4.5), as they would help enhance the success of a reef substitution policy aimed at divers of all specialization levels.

Numerous artificial reefs occur as 'sacrificial' dive sites around the world (e.g. Dowling and Nichol, 2001; Leeworthy *et al.,* 2006; Morgan *et al.,* 2009; Polak and Shashar, 2012) and several deployed reefs in Barbados were shown to be effective in redistributing visitors away from natural reef outcrops (Chapter 3; Kirkbride-Smith *et al.,* 2013). Well planned artificial reefs not only serve as natural reef substitutes, but can help maintain, and have the potential to grow, dive market shares in countries actively engaged in reef development (e.g. Dowling and Nichol, 2001; Pendleton, 2005; Leeworthy *et al.*, 2006; Adams *et al.*, 2011). In essence, 'they have the capacity to add value to the diving experiences being sold'. The coexistence of natural and man-made attractions appears to have tourism appeal within terrestrial environments. A study conducted by Reichel *et al.* (2008) on ecotourism development in a desert environment, found a high preference among potential visitors for integrated tourism sites that combined natural and artificial features and embodied environmental preservation. Reichels *et al.* (2008) study provided an indication of the economic and management potential that contrived attractions can have to support mass ecotourism, which could be effectively applied to marine protected areas (Chapter 5). Indeed, if sensitively planned, artificial reef attractions could be marketed as a true ecotourism product offering both nature-based and educational components. Moreover, promoting soft ecotourism would likely enhance the profile of a diving destination; in the same way as the presence of a marine protected area has been found to stimulate visitor interest and help increase tourism (Boo, 1990; van't Hoff, 1985; Barker, 2003; Barker and Roberts, 2008).

## 4.6 Conclusions and Further Research

This study investigated diver enjoyment using a range of resource attributes between two types of reef habitat in Barbados. My findings reveal that a significant level of diver enjoyment can be achieved from artificial reef use, providing early indications that a reef substitution policy has potential amongst divers. Indeed, previous suggestions have been made (van Treeck and Schuhmacher, 1999; Fitzsimmons, 2009) that a popular diving site does not necessarily require biological diversity or complex reef topography, and my results confirm these observations, especially among novices. In contrast, the ecocentric nature of experienced divers poses a more difficult challenge to managers, as they are clearly more motivated by natural biophysical features of the diving engagement, and this must be borne in mind by reef tourism providers.

Whilst Barbados provided an ideal location to study the enjoyment of scuba diving use of artificial and natural reef habitats, my conclusions would only be applicable to other diving locations offering a similar quality and range of attributes. However, there is considerable scope to improve and extend this study using for instance; a larger study population and a diving destination that offers more pristine coral reef conditions. Also, discrepancy levels between respondents expectations and actual dive experiences per attribute (Paterson *et al.*, 2012) could provide a finer context in understanding divers overall enjoyment in a specific area. Further, a willingness to pay study aimed at valuing dive attributes, controlling for diver characteristics (Leeworthy *et al.*, 2006) would be a useful extension to this present research. Social science studies can also serve as useful surveillance tools to help reef managers in their decision making process. For example, by repeating this present survey periodically it could provide marine managers with a basic early warning signal in dive attribute deterioration relative to baseline conditions. Overall, the results of this study are an important contribution to the artificial reef recreation literature and may help direct reef management decisions in the design of pre-planned reefs. My results also highlight the potential for artificial reefs to contribute towards reef conservation without reducing diving enjoyment.

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# Chapter 5

## *Artificial Reefs and Marine Protected Areas: A Study in Willingness to Pay to Access Folkestone Marine Reserve, Barbados, West Indies*

### 5.1 Abstract

Artificial reefs and marine protected areas offer an interesting management solution to deal with visitor impacts to coral reefs, by providing additional habitat for marine biodiversity viewing. Marine park user fees can generate substantial revenue to help manage and maintain natural and artificial reefs. Using a stated preference survey, this study investigates the present consumer surplus associated with visitor use of the marine protected area in Barbados. Two hypothetical markets were presented to differentiate between respondents use values of either: (a) natural reefs within the marine reserve or (b) future artificial reef habitat for amenity enhancement. Information was also collected on visitors' perceptions of artificial reefs, reef material preferences and reef conservation awareness. From a random sample of 250 snorkellers and divers, I estimate a mean willingness to pay of US$18.33 (median – US$15) for natural reef use and a mean value of US$17.58 (median – US$12.50) for artificial reef use. The number of marine species viewed, age of respondent, familiarity with Folkestone Marine Reserve and level of environmental concern were statistically significant in influencing willingness to pay. Of importance, regression estimates indicate visitors are willing to pay a significant dollar amount to view marine life, especially turtles. Overall, my results suggest that entrance fees could provide a considerable source of income to aid reef conservation in Barbados. In addition, the substantial use value reported for artificial reefs indicates a reef substitution policy may be supported by visitors to Folkestone Marine Reserve. I discuss my findings and highlight directions for future research that include the need to collect data to establish visitors' non-use values to fund reef management.

## 5.2 Introduction

Coral reefs are of significant economic value to the scuba diving and snorkelling industries (Brander *et al.,* 2007) and via these water-based activities, reef tourism contributes millions of dollars annually to coastal regions (Dixon *et al.,* 1993; Cesar and van Beukering, 2004; Sarkis *et al.,* 2013). A majority of reefs are located along the coastal strips of developing countries where people depend heavily on reef ecosystems for their livelihoods (Cesar, 2000; Cesar *et al.,* 2003; Burke *et al.,* 2011). In the Caribbean for example, Burke and Maidens (2004) estimated the value of goods and services derived from coral reefs in 2000 were between US$3.1 and US$6 billion, from which an annual figure of US$2.1 billion was generated from diving tourism. In St. Lucia and Tobago alone, direct spending by coral reef associated tourists in 2006 contributed an estimated US$91.6 and US$43.5 million to each respective economy (Burke *et al.*, 2008). In a more recent study, Sarkis *et al.* (2013) calculated the average total economic value of Bermuda's coral reefs was US$722 million per year, from which US$406 million was related to coral reef tourism. Despite the recognized value of coral reefs to coastal populations, not only for marine recreation, but for shoreline protection and fisheries production, among others (Moberg and Folke, 1999), global reef decline continues as a result of various anthropogenic intrusions (Halpern *et al.,* 2008).

Notwithstanding, marine protected areas have largely become an effective means of conserving reef ecosystems from human impacts (Halpern, 2003; Lester *et al.*, 2009) while still allowing for recreational use of resources including scuba diving and snorkelling (Thurstan *et al.*, 2012). Considered by some to be the 'pinnacle' in marine conservation (Thurstan *et al.,* 2012), a marine protected area is defined as "an area of sea especially dedicated to the protection and maintenance of biological diversity and of natural and associated cultural resources, and managed through legal or other effective means" (Department of the Environment, 2013, p.4). The last four decades has witnessed a proliferation of marine protected areas globally (World Data Base on Protected Areas (WDPA), 2013). As of 2006, almost a thousand marine parks and equivalent protected areas were designated covering over 98,650 $km^2$ or 18.7% of the world's coral reef habitats (Mora *et al.,* 2006). The many potential conservation benefits of marine protected areas are well documented (e.g. Gell and Roberts, 2003;

Selig and Bruno, 2010), including an increase in the diversity and abundance of numerous fish species (Mosqueira *et al.,* 2000; Halpern and Warner, 2002; McClanahan *et al.,* 2006). As a consequence, biological enhancement typically increases the attractiveness of marine parks to divers and snorkellers (Barker, 2003), though this in itself may cause a dilemma between protection and use of coral reef resources (Thurstan *et al.*, 2012).

In general, marine protected areas manage visitor use of reefs through a system of zoning (Day, 2002; Roman *et al.,* 2007) and by implementing carrying capacity measures (e.g. Hawkins and Roberts, 1997; Brylske and Flumerfelt, 2004; Ríos-Jara *et al.,* 2013). Increasingly however, marine managers are investigating other ways of reducing the impacts of underwater recreational activities. Artificial reefs and marine protected areas have been envisaged as potentially interesting management solutions to deal with visitation levels to natural reefs (Oh *et al.,* 2008), by providing additional habitat for marine biodiversity viewing (e.g. Wilhelmsson *et al.,* 1998; van Treeck and Schuhmacher, 1999; Polak and Shashar, 2012). This practice helps alleviate visitor pressures from sensitive or heavily used natural reefs (Leeworthy *et al.,* 2006; Polak and Shashar, 2012; Kirkbride-Smith *et al.*, 2013) and may contribute significant revenues to local host economies (e.g. Brock, 1994; Wilhelmsson *et al.,* 1998; Dowling and Nichol, 2001; Johns *et al.*, 2001; Johns, 2004; Pendleton, 2005; Oh *et al.,* 2008; Chapter 2). However, the use of artificial reefs for amenity enhancement, as Oh *et al.* (2008) noted, has not been without past criticism. Such condemnation has largely been due to the ubiquitous use of 'materials of opportunity' for reef creation (Stone *et al.,* 1991; Tallman, 2006), including unappealing and potentially detrimental tyre reefs (Collins *et al.,* 1995; Collins *et al.,* 2002). Nevertheless, well conceived artificial reefs may facilitate various management strategies within protected waters including influencing the location of recreational use (Leeworthy *et al.,* 2006; Polak and Shashar, 2012), as well as visitor behavior via scientifically-based interpretation materials (Rangel *et al.,* 2014).

Despite the potential efficacies of marine protected areas (Halpern and Warner 2002; Halpern, 2003; Lester *et al.,* 2009), many marine parks across the globe fail to meet management objectives (Burke *et al.,* 2002; Burke and Maidens, 2004; Wells, 2006; Burke *et al.,* 2011; De Santo, 2013), are severely under funded (e.g. Alder, 1996;

Depondt and Green, 2006) and exist as 'paper parks' only (Brandon *et al.*, 1998; Bruner *et al.*, 2001; Bonham *et al.*, 2008; Mora and Sale, 2011). Various funding mechanisms exist to help finance marine protection in reserves. These include personal donations, lottery revenues, international assistance and government taxes (Spergel and Moye, 2004). However, none of these mechanisms are wholly reliable in financing marine conservation. For instance, government taxes can be re-directed to responsibilities elsewhere (Lindberg, 2001), especially in times of economic difficulties (Spergel and Moye, 2004). Reef-based tourism is considered to be a lucrative means of financing protection of marine parks (e.g. Dharmaratne *et al.*, 2000; Depondt and Green, 2006; Peters and Hawkins, 2009), through the recovery of user fees from visitors. Techniques, including the contingent valuation method of 'willingness to pay', are used to determine the level visitors would contribute towards nature management and conservation. The procurement of fees can increase the management capacity of parks through for example; education, scientific monitoring and enforcement (Hime, 2008; Uyarra *et al.*, 2010) collectively helping sustain future conservation of reefs. However, many marine reserves remain free to use, or charge a nominal entrance fee (Terk and Knowlton, 2010; Peters and Hawkins, 2009), this is despite evidence that in some circumstances user fees could increase substantially with no apparent impact on visitor numbers (Thur, 2010).

The *Reefs at Risk* reports (Bryant *et al.*, 1998; Burke *et al.*, 2011) emphasize the need for countries harbouring coral reefs to conduct applied valuation techniques, such as contingent valuation, to help underpin decision and policy-making for reef conservation. An integral part of willingness to pay studies is to discern what motivates people to donate funds. The non-economic motives behind willingness to pay for biodiversity conservation have been explored (Martín-López *et al.*, 2007) with results proposing familiarity and biophilia aspects as having a marked effect on payment attitudes. Some papers (e.g. Cooper *et al.*, 2004; Spash, 2006) also suggest that intrinsic value is the main motivator explaining visitor's choice to contribute, as is bequest value that benefits future generations (Hargreaves-Allen, 2010). Researchers have also sought to establish what factors influence how much visitors are willing to pay. Studies indicate that users of reefs (usually divers and snorkellers surveyed) are willing to allocate more money for an increase in the abundance or quality of a specific reef attribute, such as fish, or group of attributes (e.g. Rudd and

Tupper, 2002; Schuhmann *et al.*, 2008; Polak and Shashar, 2013). Additionally, the opportunity of viewing charismatic mega-fauna including marine turtles and whale sharks is greatly valued by marine viewers as reflected in their high willingness to pay (Hargreaves-Allen, 2010; Schuhmann *et al.*, 2013; Farr *et al.*, 2014). Conversely, studies have noted losses in consumer surplus relating to the demise of coral reefs. Doshi *et al.* (2012) reported a reduction in divers' welfare identified by their decrease in willingness to pay for bleached coral reefs.

Numerous researchers (e.g. Dixon *et al.*, 2000; Arin and Kramer, 2002; Barker, 2003; Mathieu *et al.*, 2003) have undertaken contingent valuation surveys to measure visitors' willingness to pay for marine park entry. A majority of them surveyed divers and snorkellers, and a selection of papers are presented in Table 5.1. In a meta-analysis detailing 18 studies, Peters and Hawkins (2009) found an overwhelming approval of users to pay entrance fees, or an increase in fees, where charges currently existed. Additionally, there is evidence that user fees can generate sufficient funds to cover a significant share of marine park operating costs (Spergel and Moye, 2004). For example, in Australia's Great Barrier Reef Marine Park, tourist-based user fees of US$5 million contributed around 20% of the budget of the park authority in 2002/2003 (Skeat and Skeat, 2003). Moreover, on the Caribbean island of Bonaire, user fee collections of around US$1 million represented 93% of the income required to operate the Bonaire National Marine Park in 2008 (STINAPA, 2009; Uyarra *et al.*, 2010).

To date, there has been a clear emphasis on measuring the consumer surplus of visitors' recreational use of natural reefs (reviewed in Peters and Hawkins, 2009). In contrast, only a handful of contingent valuation studies appear to have measured visitors' consumer surplus relating to recreation-orientated artificial reefs (Bell *et al.*, 1998; Ditton and Baker, 1999; Johns *et al.*, 2001; Johns, 2004; Crabbe and McClanahan, 2006; Oh *et al.*, 2008; Hannak *et al.*, 2011; Chen *et al.*, 2013). However, none of the latter artificial reef studies used marine park entrance fees as the payment vehicle to estimate consumer surplus, and just three papers (Johns *et al.*, 2001; Johns, 2004; Oh *et al.*, 2008) estimated recreational values of artificial and natural reefs in the same locality. To address this dearth of information, a valuation study was developed that encompassed both artificial and natural reef habitats within a marine protected area.

### 5.2.1 Research Aims

The main purpose of this analysis was to investigate the present consumer surplus associated with visitor use of the marine protected area in Barbados, using the contingent valuation method of willingness to pay. Willingness to pay is defined as, "the maximum amount a person is willing to pay for a good or service" (Waite *et al.*, 2014, p.77). The payment vehicle used was a daily, per person entrance fee into the marine reserve. Two hypothetical markets were presented to differentiate between respondents use values of either: (a) natural reefs within the marine reserve or (b) future artificial reef habitat for amenity enhancement. Further research objectives were to establish which characteristics influenced and thus explained differences in visitor willingness to pay. Finally, data were collected on respondent preferences towards artificial reef materials that were viewed appealing for use in future artificial reef projects. I discuss my findings with relevance to visitors funding reef conservation and highlight the potential that reserves and artificial reefs have for symbiotic partnerships in coral reef management.

**Table 5.1** Selected papers and key findings of willingness to pay studies to access coral reefs in marine protected areas.

| Author(s) (year) | Location | Users surveyed | Per | Value per user [a] WTP mean | median | Suggested fee |
|---|---|---|---|---|---|---|
| Dixon *et al.* (2000) | Bonaire | Divers only | Annum | $27.40 | $20 | $10 |
| Spash (2000) | Jamaica | Locals & tourists | Annum | $25.89 | $2.87 | N/R |
| Spash (2000) | Curaçao | Locals & tourists | Annum | $25.21 | N/R | N/R |
| Arin and Kramer (2002) | Anilao, Philippines | Divers & snorkellers | Visit | $3.70 | $3 | $4 |
| Arin and Kramer (2002) | Mactan, Philippines | Divers & snorkellers | Visit | $5.50 | $5 | $5.50 |
| Arin and Kramer (2002) | Alona, Philippines | Divers & snorkellers | Visit | $3.40 | $3 | $4 |
| Mathieu *et al.* (2003) | Seychelles | Divers & snorkellers | Visit | $12.20 | N/R | $12.20 |
| Seenprachawong (2003) | Phi Phi, Thailand | Divers & snorkellers | Visit | $7.18 | N/R | $1 |

**Notes:** [a] reported in year of study in US dollars. N/R, not recorded in original paper.

## 5.3 Methods

### 5.3.1 Study Setting

This study was conducted on the west (leeward) coast of Barbados (13°10'N, 59°32'W) between the months of July to August 2013, over an 18 day period. Akin to many Caribbean islands, the basis of Barbados's tourism appeal is hinged on its coastal environmental features that attract year round tourism. In 2013, 508,000 stop-over tourists were reported to vacate on the island, with a further 570,000 cruise ship passengers visiting (Caribbean Tourism Organization, 2014). Coral reefs fringing the south-west coast (Lewis, 1960) provide a diversity of recreational opportunities including diving, snorkelling and sub-marine viewing. Schuhmann *et al.* (2008) estimates that between 30,000 and 50,000 divers visit the island per year and the Inter-American Biodiversity Information Network (2010) report a further 176,600 visitors participating in snorkel trips. As a way of diversifying the diving tourism industry, several artificial reefs have been deployed along the south-west coast (Agace, 2005).

One small marine protected area (2.1 $km^2$) Folkestone Marine Reserve, is located in the parish of St. James on the western side of the island (Cumberbatch, 2001). The reserve extends for 2.2 km along the coastal fringe and stretches outwards between 660-950 m offshore (Figure 5.1). Legislated in 1981 (Cumberbatch, 2001), the marine reserve protects 0.32 $km^2$ of accessible fringing, patch and bank reef (Inter-American Biodiversity Information Network, 2010) and supports endangered hawksbill sea turtle *Eretmochelys imbricata* nesting sites (Horrocks and Scott, 1991; Beggs *et al.*, 2007). A small artificial reef consisting of a disused barge (length ~ 8 meters), that provides a site for instructor-led dives and for snorkellers, is situated within the reserve (Figure 5.1). Encompassing just 11% of the coastline (Cumberbatch, 2001), the reserve attracts multiple stakeholders and represents the most heavily used recreational space in Barbados (Blackman and Goodridge, 2009), including approximately 7,000 scuba divers using the Folkestone reefs per year (Inter-American Biodiversity Information Network, 2010). In anticipation of potential user conflict, the reserve has been divided into four distinct zones (Cumberbatch, 2001) (Figure 5.1). The sites used for this study were located within Folkestone Marine Reserves ‘southern water sports zone’ (principally Sandy Lane patch reef – Site 1) and a site to the outside of the northern reserve boundary (Site 2), adjacent to the Lone Star reef (Figure 5.1).

### 5.3.2 Valuation Method and Related Issues

The survey adopted a payment card contingent valuation method to elicit visitors’ willingness to pay. Other common response formats used to measure demands for non-market goods, are single- and double-bounded dichotomous choice and open-ended questioning techniques. All four valuation approaches are subject to some degree of bias (Bateman *et al.,* 2002; Boyle, 2003), though this can be reduced with the careful design and pre-testing of surveys (e.g. Boyle *et al.*, 1998). Despite various biases, each of these stated preference techniques uses hypothetical market scenarios to discern a respondent’s likely behaviour under various conditions of either willingness to pay, or willingness to accept, for an increase/decrease in a public good. In the case of the payment card approach, it uses an ordered set of threshold values that respondents are asked to peruse and indicate the highest value they are willing to pay. Bateman *et al.* (2002) and Boyle (2003) outline the various advantages of payment cards including the avoidance of anchoring and ‘yea saying’ to a sole bid presented (a problem in dichotomous choice) and the avoidance of starting point bias. In addition, Mitchell and Carson (1989) suggest payment cards will assist in reducing non-response rates and eliminate the need for prompting by the interviewer. They have also been shown to yield willingness to pay estimates that are more conservative than those generated using other stated preference techniques (Champ and Bishop, 2006; Thur, 2010). Payment cards are however, subject to specific forms of bias relating to the design configuration in range of monetary values and size of intervals chosen (Bateman *et al.,* 2002). Indeed, in payment card data, the true willingness to pay value is thought to lie between the bid amount chosen and the next highest value up on the payment card (Cameron and Huppert, 1989; Bateman *et al.,* 2002; Boyle, 2003). Thus intervals rather than ‘point’ valuations are used in most statistical models.

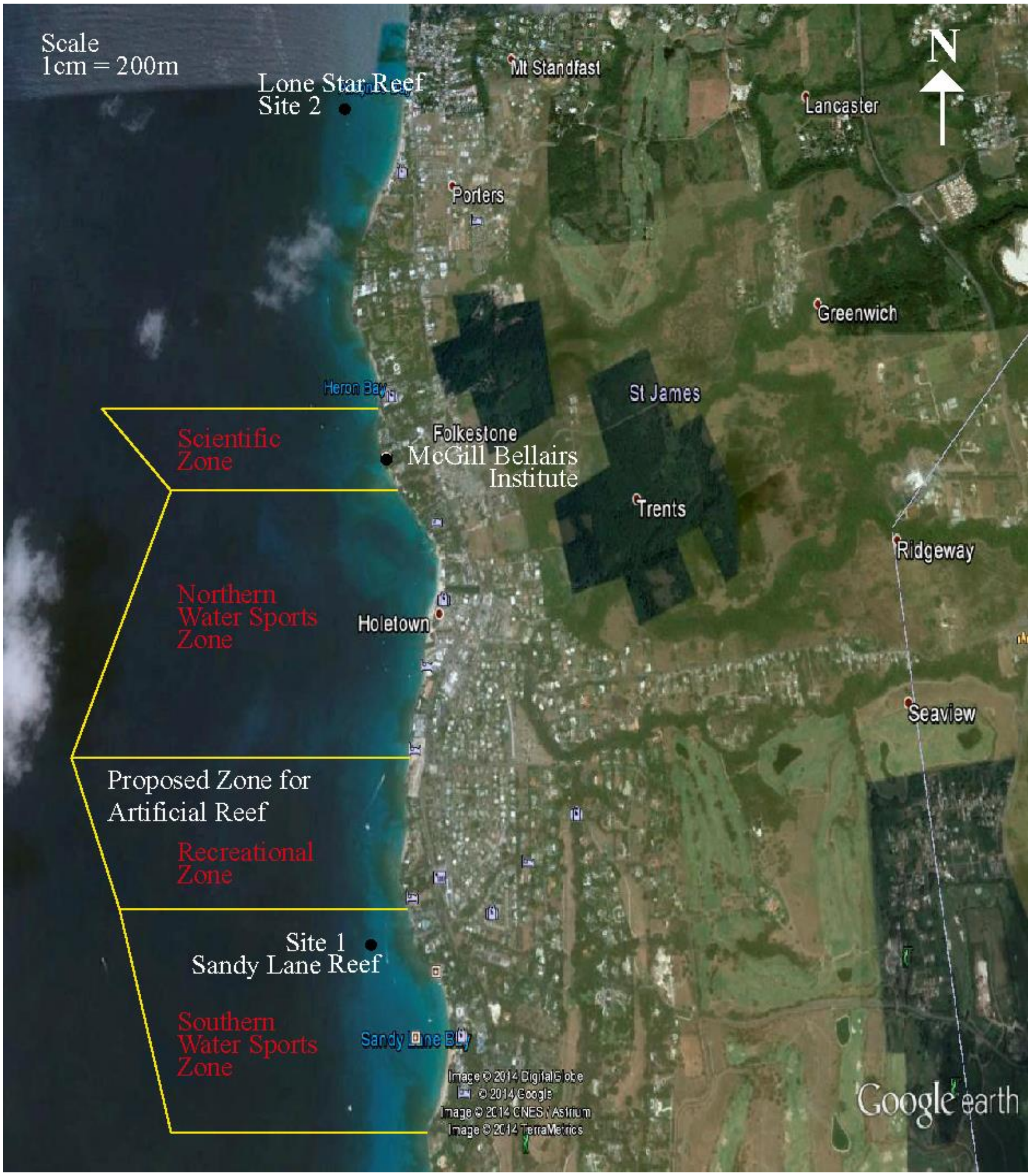


**Figure 5.1 Folkestone Marine Reserve, Barbados.** Map outlining boundary of marine protected waters and locations of study sites and proposed artificial reef (Modified from: Google earth, 2014).

### 5.3.3 Survey Design and Data Collection

To assist with the study design, an initial site visit to Folkestone Marine Reserve was conducted in 2012. This was to establish any entrance fee payment structure already in place (of which there were none) and to determine visitor trips/user patterns within the reserve. Additionally, an informal focus group consisting of divers and snorkellers was held to ascertain the range of bid values to be used in the data collection instrument. Two versions of the survey were produced; one aimed at valuing artificial reefs and the second aimed at valuing natural reefs (Appendix E). Both instruments were identical with the exception of sentence three and the wording 'artificial reef' in sentence four of the artificial reef valuation question (presented below) which were omitted from the natural reef script. The final survey consisted of 46 questions divided into five sections. A majority of the questions were closed-ended, as Champ (2003) suggests this format helps avoid respondent fatigue and simplifies statistical analysis in willingness to pay studies.

The first section explored respondents demographic characteristics that included number of years spent in education, country of residence and age. In this section also, participants were asked questions relating to their length of stay in Barbados and any previous visits to the island. In the second section, visitors were questioned about their marine recreation participation. A 5-point Likert rating scale (range: very experienced to very poor) was presented to establish their snorkelling proficiency. To gauge the experience of those who scuba dived, I asked for the number of dives they had logged in their diving history. A 5-point Likert rating scale (range: very satisfied to very dissatisfied) was used to assess visitor satisfaction with snorkelling and diving on the island. The final question in section two assessed which marine related activities respondents had undertaken during their present stay. In the third part of the survey, the hypothetical valuation scenario was presented to establish each visitor's willingness to pay bid value. The valuation script (Appendix E) contained background information pertinent to the reefs within the reserve and the challenges encountered in managing them. A laminated map of the reserve (Figure 5.1) was shown to each visitor prior to the willingness to pay question being asked, as were photos of common species found within the reserve. Additionally, in the artificial reef survey, laminated cards of popular artificial reef materials were presented (Appendix

F). The exact wording of the valuation question presented in the artificial reef survey was:

*Today, no entrance fee to visit the coral reefs and marine species within Folkestone Marine Reserve is paid by you as a visitor. All funding to conserve the reefs here is sourced elsewhere. There is a proposal to develop one or more artificial reefs within the reserve for both snorkelling and diving (show map and explain). An entrance fee into the reserve (held in a trust fund) would be used to help manage and maintain the artificial reefs within this protected area. With this in mind, I am going to show you a set of numbers in US dollars. Please consider your total trip costs for this visit and tell me; what is the maximum you would be willing to pay '**over and above your present trip costs**' as a daily entrance fee to recreate in Folkestone Marine Reserve?*

The survey presented 12 payment values in ascending order (Champ, 2003) from US$0 to US$60 (Table 5.3) from which respondents were asked to choose a value (or to specify another amount if above $60) as an indication of their willingness to pay to help manage and maintain the reefs within Folkestone. Section three of the survey also included follow-up questions exploring the rationale given for a bid value, or if a zero bid was given, the reason for that particular choice. I also asked respondents which type of organization they would prefer to manage the entrance fee revenues and enquired about any concerns relating to the management of funds raised. The fourth section of the survey was used to query respondents on their knowledge and use of artificial reefs, both in Barbados and elsewhere in the world. I included a specific question to identify respondents preferences, placed in rank order, relating to types of materials used for artificial reef creation. At this point of enquiry, three laminated cards with images of artificial reefs (Appendix F) were shown to individuals. Three questions were also embedded in section four to help capture each visitor's environmental awareness and concern for reefs and the marine environment. The final part of the survey aimed to establish respondent's prior and current experience of Folkestone Marine Reserve. I asked visitors to use a 5-point Likert rating scale (range: very good to very poor) to rate the quality of the seawater, coral and fish life encountered on their present trip. A question was also used to establish what marine life visitors had viewed whilst underwater. Finally, respondents were requested to score their overall experience of the reserve on a 4-point Likert rating scale (range: exceeded expectations to not satisfied expectations) after which visitors were asked to clarify if they had plans to return to the reserve in future.

In order to identify potential issues arising in the survey, a pre-test of the instrument (n = 20) was conducted in Barbados on the target population and changes made accordingly, prior the main data collection period. Dharmaratne and Brathwaite (1998) emphasize the importance of choosing respondents familiar with the good being valued, thus the sample frame population for this study consisted of snorkellers and/or divers with prior experience of either activity. In addition, English speaking overseas tourists of any nationality, between the ages of 18 to 70 years of age, visiting the reserve, were a requirement. As very few Barbadian residents scuba dive or snorkel (Inter-American Biodiversity Information Network, 2010), it was decided not to include them in the surveying process.

To access the defined target population, visitors to Folkestone Marine Reserve were approached on board Tiami catamaran cruise trips (www.tiamicruises.com). These five hour snorkelling trips visit the reserve on a daily basis, providing visitors with two 30 minute snorkel stops (Figure 5.1) and a beach visit for relaxation. A randomized sampling technique was chosen to sample the population by approaching every other seated tourist, moving systematically from the front to the rear of the catamaran. In view of the fact that interview context has been reported as a significant determinant of willingness to pay (Arrow *et al.*, 1993; Hime, 2008; Hargreaves-Allen, 2010) all interviews were conducted personally using the same location (i.e. on-board a Tiami catamaran) and after experiencing the reserves underwater environment. Each interview took approximately 20 minutes to complete. For consistency, the same two interviewers administered both surveys on a rotational (daily) basis, initially giving each respondent a short introduction to explain the reasons for the survey. Only one survey type was administered to each respondent. Prior to the bid valuation question being presented, it was emphasized that no entrance fee is currently imposed on visitors to the reserve. All visitors who participated in the survey gave their permission to use the results on an anonymous basis.

### 5.3.4 Data Analysis and Willingness to Pay Estimation

Visitors' demographic characteristics, trip features, willingness to pay and attitudinal responses to artificial reefs were analyzed using the Statistical Package for the Social Sciences (SPSS, Version 19) software. To investigate group differences between the responses given in survey 1 (artificial reef scenario) and survey 2 (natural reef scenario), I applied Chi-square tests with Yate's Continuity Corrections for categorical data and Mann-Whitney U tests (two-tailed) for continuous data. Variations in willingness to pay were investigated for several variables (e.g. between divers and snorkellers and for Likert scale questions) using Mann-Whitney U tests (two-tailed) and Kruskal-Wallis tests, where applicable. Consistent with the method adopted in Chapter 3 and Chapter 4 of this thesis, and with Fitzsimmons (2009), a distinction was made between the experience level of divers, denoted by two categories; novice divers (< 100 logged dives) and experienced divers (≥ 100 logged dives). Statistical significance was assumed if $p \leq 0.05$.

Data were screened for zero bids (US$0) and each individually assessed, via follow up questions, as to why the respondent was not willing to pay. Bateman *et al.* (2002) advises that zero bids are removed from the data; hence they were excluded prior to calculating mean and median willingness to pay for all models. Following the removal of non-responses from the sample, I ensured that specific characteristics of the sample (e.g. age and gender) had not been systematically biased, by testing for significant differences between the two study populations. I also calculated mean and median willingness to pay prior to and after zero bid removal for comparisons. As numerical approximation of net willingness to pay does not provide the probability distribution of the estimates (Oh *et al.*, 2008), 95% confidence intervals were calculated using bootstrapping (Kling and Sexton, 1990) to estimate the standard error of net willingness to pay measure based on 1,000 replications.

### 5.3.5 Econometric Analysis

Willingness to pay (WTP) is hypothesized to be influenced by a number of independent variables (Arin and Kramer, 2002) represented by the vector $\boldsymbol{x}$.

$$WTP_i = \beta' x_i + \varepsilon_i$$

where $\boldsymbol{\beta}$ is a vector of slope parameters and $\boldsymbol{x_i}$ is a vector of observations on the explanatory variables for individual ***i.*** The error term $\boldsymbol{\varepsilon_i}$ is presumed to be a normally distributed random variable with mean zero.

Payment card data should be analyzed using interval regression (Bateman *et al.*, 2002), as it is thought that the true payment value given lies between the value chosen and the value bounding the upper interval of that category (Cameron and Huppert, 1989). Thus for the payment card sample, a maximum likelihood estimation (MLE) procedure was used (Cameron and Huppert, 1989) that accommodates the intervals, that is the probability that WTP falls in the range defined by the lower limit $\boldsymbol{t_{li}}$ and the upper limit $\boldsymbol{t_{ui}}$, represented by the adjacent payment card value given by;

$$Pr(\log w_i \subseteq (\log t_{li}, \log t_{ui}))$$

$$= Pr\ (\log t_{li} - X'_i\beta)\ /\sigma < z_i < Pr(\log t_{ui} - X'_i\beta)\ /\sigma),$$

where $\boldsymbol{z_i}$ is the standard normal random variable. Arin and Kramer (2002) note that because the probability given by the latter equation can be written as the difference between two standard cumulative densities a likelihood function can be defined over the parameters $\boldsymbol{\beta}$ and $\boldsymbol{\sigma}$. Interval regression analysis was performed in R 3.03 (R Development Core Team, 2008) using the survival package (Therneau, 2014) to estimate the interval boundary parameters.

For comparison, an ordinary least squares regression model (using SPSS) was also applied. In the latter model, the precise mid-point of each interval category is used as the dependent variable of willingness to pay. Normality is assumed for the regression models (Cameron and Huppert, 1989), with a *lognormal* conditional distribution proposed as a first approximation. Many researchers have adopted Cameron and Hupperts methodology in willingness to pay studies using payment cards (e.g. Arin and Kramer, 2002; Blaine *et al.*, 2005; Mahieu *et al.*, 2012; Yang *et al.*, 2012), as one of the advantages is that value estimates can be interpreted in a straightforward manner (as apposed to log transformed data). Also, by using both interval regression and an ordinary least square model, it helps validate the payment card range presented and serves as an ad hoc check of the normality assumption. The stepwise backward elimination method was employed for both regression models to investigate the effects of 12 independent predictor variables (Table 5.2) on visitors' total willingness to pay. Variables that did not yield covariates significant at $\leq$ 10% level were excluded from the final model.

**Table 5.2** Descriptions of the explanatory variables.

| Variable | Description |
|---|---|
| ***Age*** | Continuous: the age of the respondent |
| ***Gender*** | Discrete: 1 = male, 0 = female |
| ***Education*** | Continuous: number of years the respondent has spent in education |
| ***Barbados_visits*** | Continuous: number of visits to Barbados |
| ***Env_concern*** | Continuous: level of environmental concern: 1 being the least concerned, 10 being the most concerned |
| ***Catamaran_cruise*** | Continuous: how many catamaran cruises undertaken in Folkestone Marine Reserve? |
| ***Dived_FMR*** | Discrete: if the respondent had dived in Folkestone Marine Reserve, 1 = yes, 0 = no |
| ***Species_view*** | Continuous: number of species mentioned in response to open ended question to the no. of species encountered |
| ***Satisfaction_trip*** | Discrete: did the snorkel trip satisfy expectations? 1 = yes, 0 = no |
| ***Fish_life*** | Discrete: if the respondent rated the fish life viewed as good, 1 = yes, 0 = no |
| ***Coral_life*** | Discrete: if the respondent rated the coral life viewed as good, 1 = yes, 0 = no |
| ***Seawater_quality*** | Discrete: if the respondent rated the seawater quality as good, 1 = yes, 0 = no |

## 5.4 Results

### 5.4.1 Visitor and Holiday Characteristics

Two hundred and fifty surveys were fully completed during the study period divided equally between the two reef scenarios ($n$ = 125 for each survey). From the total number of visitors interviewed (both surveys combined), an almost equal sex ratio was recorded with slightly more females (51%) noted. The large majority of visitors resided in the United Kingdom (72%), followed by the United States (12%), with 5 additional countries (Canada, Brazil, Norway, Italy and the Caribbean Island States) making up the sample. The mean and median age of respondents was 38 (± 13.6 s.d.) and 40 years respectively, with an age range of 18 - 69 years recorded. The total number of years visitors had spent in education ranged from 11 - 27 years with the average length being 16 (± 3.3 s.d.) years. Over a third (38%) of those surveyed, were repeat visitors to Barbados with a mean of 3 (± 3.9 s.d.) visits (including the present one). The number of nights being spent on the island ranged from 2 – 30 nights, with the majority (50%) of respondents having an average duration of 12 (± 3.9 s.d.) stop-overs. Group differences investigated between survey 1 and survey 2 identified one variable; *Age* being statistically different between the two surveys ($U$ = 6173, $z$ = -2.206, $p \leq 0.027$, $r$ = 0.14). Artificial reef survey participants were slightly older than natural reefs survey participants; means: 39 (± 14.25 s.d.) and 36 (± 12.7 s.d.) years, medians: 43 and 36 years, respectively. Data from the Caribbean Tourism Organization (2014) for visitors to Barbados in 2013 were used to assess for sample representativeness. From the limited data available, tourist stop-over arrivals for that year suggest that my sample was over-represented by UK respondents. Additionally, no cruise ship tourists were available for interview.

### 5.4.2 Marine Recreation Participation

Prior to the survey being administered, visitors had carried out a mean of 3.75 (± 0.9 s.d.) activities whilst on vacation. The majority had relaxed on the beach (85%), swam (81%), snorkelled from the shore (39%), kayaked (21%) and scuba dived (12%). To assess snorkelling proficiency amongst the sample, responses to a Likert rating scale question revealed that the majority of snorkellers described themselves as being average (50%) to very good (31%) at the sport, while 17% suggested they were poor and a further 2% very poor at snorkelling. Respondents that scuba dived (*n* = 76) had an average of 32 (± 86.81 s.d.) previously logged dives and a median of 10 dives [interquartile range: 2-25]. Almost three quarters of the sample (74%) had been given a snorkelling and/or diving briefing at some point in their life. When visitors were asked to rate their satisfactions of snorkelling on the island in general, 83% were either satisfied (41%) or very satisfied (42%) with the experience, with the remainder being ambivalent. When the same question was presented to respondents who had dived (*n* = 39) whilst visiting Barbados, all were either satisfied (66%) or very satisfied (34%) with their prior experiences.

### 5.4.3 Folkestone Marine Reserve Willingness to Pay

A total of 7 zero bids (Table 5.3) for willingness to pay were identified. Follow-up questions were asked to establish the reason why a zero bid was given. Four individuals were uncertain the money would be spent on reef conservation *per se* while the remaining respondents were unsure their contribution would make any difference to the condition of the reefs in Folkestone Marine Reserve.

**Table 5.3** Interval selection frequencies of willingness to pay bids (daily, per person).

| | Raw frequency (%) | | | | | |
|---|---|---|---|---|---|---|
| **Interval (US$)** | **All data (*n* =250)** | | **AR data (*n* = 125)** | | **NR data (*n* = 125)** | |
| 0 | 7 | (2.8) | 4 | (3.2) | 3 | (2.4) |
| 2 – 5 | 4 | (1.6) | 3 | (2.4) | 1 | (0.8) |
| 5 – 8 | 22 | (8.8) | 12 | (9.6) | 10 | (8.0) |
| 8 – 10 | 26 | (10.4) | 11 | (8.8) | 15 | (12.0) |
| 10 – 15 | 70 | (28.0) | 35 | (28.0) | 35 | (28.0) |
| 15 – 20 | 43 | (17.2) | 16 | (12.8) | 27 | (21.6) |
| 20 – 25 | 42 | (16.8) | 26 | (20.8) | 16 | (12.8) |
| 25 – 30 | 12 | (4.8) | 7 | (5.6) | 5 | (4.0) |
| 30 – 40 | 11 | (4.4) | 8 | (6.4) | 3 | (2.4) |
| 40 – 50 | 6 | (2.4) | 1 | (0.8) | 5 | (4.0) |
| 50 – 60 | 4 | (1.6) | 1 | (0.8) | 3 | (2.4) |
| > 60 | 3 | (1.2) | 1 | (0.8) | 2 | (1.6) |

**Notes:** AR = Artificial reef, NR = Natural reef. Figures in parenthesis are percentages.

Zero bids were removed and mean and median values calculated for pooled data and for each individual survey (Table 5.4). Mean values were higher than median values for all estimates calculated. This was due to positive right skews in the willingness to pay distributions. Due to the relatively few zero bids present in the sample, their removal had a meager US$0.51 impact on mean willingness to pay (Table 5.4), which did not bias my results. For pooled data, mean willingness to pay (person/day) was estimated at US$17.96 with a lower bound of US$16.62 and an upper bound of US$19.27 at a 95% confidence interval. Visitors who were asked the natural reef survey question, had a higher mean willingness to pay of US$18.33 in comparison to mean values estimated for visitors presented with the artificial reef survey; US$17.58. The median value was also higher for the natural reef scenario (US$15) than for the artificial reef scenario (US$12.50). Differences in mean willingness to pay between the two survey reef types were not found to be of statistical significance ($U$ = 7291, $z$ = -.167, $p \geq 0.867$, $r$ = .01).

**Table 5.4** Respondents' willingness to pay (WTP) to access Folkestone Marine Reserve (daily, per person) in US$.

| **WTP Scenario** | ***N*** | **Lower [a] bound CI** | **Mean $\pm$ 1*SD*** | **Upper bound CI** | **Median** |
|---|---|---|---|---|---|
| All data (zero bids in) | 250 | 15.92 | 17.45 $\pm$ 11.30 | 18.96 | 12.50 |
| All data (zero bids out) | 243 | 16.62 | 17.96 $\pm$ 11.05 | 19.27 | 12.50 |
| Artificial reef data | 121 | 15.81 | 17.58 $\pm$ 9.96 | 19.52 | 12.50 |
| Natural reef data | 122 | 16.25 | 18.33 $\pm$ 12.06 | 20.73 | 15.00 |

**Note:** [a] the lower and upper bound confidence interval was calculated from the bootstrapping approach based on 1,000 replications.

Variations in willingness to pay were investigated for several variables, and 4 were found to be of statistical significance. Females had a significantly higher ($U$ = 5921, $z$ = -2.709, $p \leq 0.007$, $r$ = 0.17) mean bid of US$19.54 ($\pm$ 11.89 s.d.) compared with a mean value of US$16.31 ($\pm$ 9.89 s.d.) estimated for males. Visitors that had viewed a turtle while snorkelling (n = 196) had a mean willingness to pay of US$19.59 ($\pm$ 11.50

s.d.) compared with a value of US$11.56 (± 5.52 s.d.) for those who had not viewed a turtle (n = 47). This latter difference of US$7.93 was highly significant ($U$ = 2232, $z$ = -5.588, $p \leq 0.001$, $r$ = 0.37). Divers who had experienced the underwater environment within the reserve prior to being interviewed (n = 24) had a lower mean willingness to pay of US$12.50 (± 5.95 s.d.) compared with divers (n = 52) visiting the reserve for the first time; US$18.55 (± 11.32 s.d.). Again, this difference in mean willingness to pay was highly significant ($U$ = 1654, $z$ = -3.036, $p \leq 0.002$, $r$ = 0.35). Finally, repeat catamaran visitors to the reserve (n = 49) had a significantly ($U$ = 3610, $z$ = -2.946, $p \leq 0.003$, $r$ = 0.19) lower mean bid value of US$13.37 (± 8.12 s.d.) compared with individuals who were first time visitors (n = 194) to the reserve of US$18.45 (± 11.74 s.d.). From a point of interest, snorkellers and divers had a very similar mean willingness to pay of US$17.89 (± 11.24 s.d.) and US$16.45 (± 11.43 s.d.), respectively. It also appeared that a higher level of experience attained in either sport did not significantly affect willingness to pay of snorkellers ($U$ = 5993, $z$ = -0.617, $p \geq 0.537$, $r$ = 0.04) or divers ($U$ = 112.500, $z$ = -1.351, $p \geq 0.190$, $r$ = 0.15).

Motivations of respondents' willingness to pay were explored via a series of follow-up questions. Most visitors (75%) reported they would donate to help preserve the reefs for future generations, followed by 10% indicating it gave them genuine pleasure to contribute towards reef conservation. A motivator of being a 'moral duty' to contribute was also important among 8% of visitors. Out of those who were willing to pay anything, 70% reported concerns over the legitimate use of monies collected for reef conservation while the remaining 30% of visitors reported no concerns. Content analyses of the follow-up question to understand these concerns revealed that most individuals were anxious that the funds raised would be spent elsewhere; typically on other government projects in Barbados. Respondents were also asked which type of organization they would prefer to manage the entrance fee revenues. An environmental non-governmental organization was clearly the most popular choice yielding 75% support, followed by the government of Barbados (13%) and public sector (3%), while 9% chose a mix of all three authorities. The question that queried respondents in relation to where they would prefer to see entrance fee revenues spent, yielded a high level of support for marine education/children's outreach programmes (47%) and for recreational artificial reefs (27%). Scientific monitoring also appeared important with 18% of respondents choosing this item. In contrast, land-based tourist facilities (1%) and marine reserve patrols (2%) seemed unimportant investments.

### 5.4.4 Perceptions and Use of Artificial Reefs and Environmental Concern

Artificial reef awareness was good amongst the population sampled with 69% having heard of the term 'artificial reef', and indeed 82 respondents (34%) had either snorkelled or dived on an artificial reef previously. When asked to rate their experience of diving and/or snorkelling on this type of reef, 79% of snorkellers and 88% of divers rated their prior experiences as good to very good. When asked if these reefs were in Barbados, 35 respondents had used artificial reefs locally, the majority ($n$ = 29) having used the conglomerate of reefs in Carlisle Bay and the remaining 6 individuals using the *SS Stavronikita*, the largest wreck to dive on in the Caribbean (Agace, 2005).

Respondents were very clear regarding their preferences relating to artificial reef materials. Three material types were presented using visual aids (Appendix F). Figure 5.2 shows that the most preferred material choice was for a purposefully sunken ship (73%), followed by Reef Balls™ (as a snorkel trail) (17%), with the most unappealing material being underwater art, chosen by 10% of those surveyed. When visitors were questioned on whether the creation of an artificial reef within Folkestone Marine Reserve would encourage them to visit the reserve again, 77% answered yes, 12% no and 11% were unsure.

To investigate respondent's environmental awareness and concern, I presented visitors with 3 questions. When asked if they were a member of an environmental group, only 10% responded positively. In contrast, 83% of visitors read or watched on television topics about marine life and marine conservation. When I asked respondents to rate their level of concern relating to coral reefs and the marine environment in general (on a scale of 1 – 10, with 1 being the least concerned), a mean and median value of 7 ($\pm$ 1.77 s.d.) was yielded.

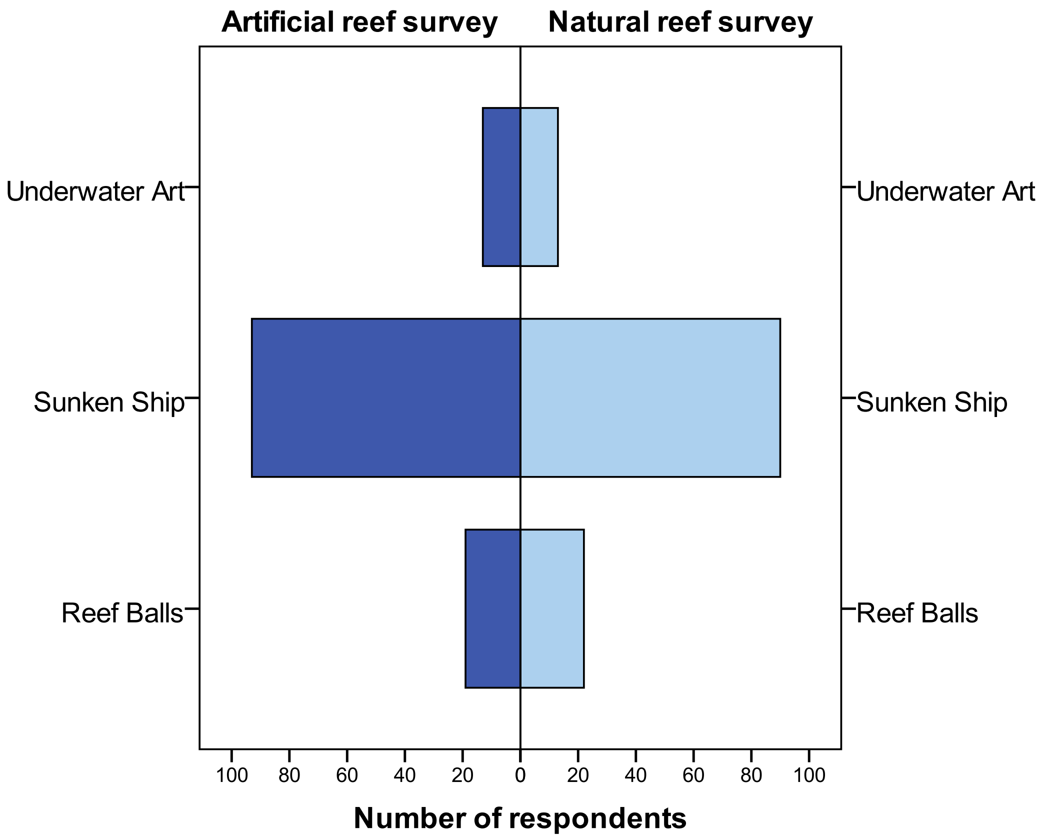


**Figure 5.2 Respondents' preferences for type of artificial reef material for future use in Folkestone Marine Reserve.** Sample size: n = 243.

### 5.4.5 Experience of Folkestone Marine Reserve

In terms of respondents prior experiences of Folkestone Marine Reserve, a fifth (n = 49) had previously visited the reserve on catamaran snorkelling cruises, with a mean of 1.84 (± 2.63 s.d.) former trips recorded. All 49 respondents said they had snorkelled during these trips. Additionally, the 24 respondents that had previously dived on reefs within reserve waters, had conducted a mean of 4.88 (± 4.31 s.d.) reserve dives.

To obtain a basic estimation of what 'marine life' visitors had encountered whilst snorkelling, they were asked to recall the number of 'species' viewed. The marine life noted in the study was; fish, coral, turtles, eels, manta rays and sea urchins. A majority of visitors recalled 3 species (mean = 3.4 (± 1.11 s.d), median and mode = 3) with a maximum of 6 species seen, with no person noted as viewing no marine life during their trip. The most common species recalled were fish, spotted by 95% of people, followed by turtles noted by 80% of visitors.

The overall experience of visitors to the reserve, in terms of their expectations being fulfilled, was very good. Thirty-two percent had their expectations exceeded and a further 55% were noted as being satisfied. Only 19 individuals said the trip had made no difference to them, while 8 visitors had not had their expectations satisfied. A significant relationship occurred between visitors' willingness to pay and their level of satisfaction with the marine park (Kruskal-Wallis test; $\chi^2$ (3) = 12.32, $p \leq 0.006$). Further post hoc analysis revealed the two groups most dissatisfied/ambivalent with the trip (when combined), had a significantly lower willingness to pay than the two 'satisfied' groups combined ($U$ = 961.500, $z$ = -1.960, $p \leq 0.050$, $r$ = 0.16). When visitors were asked if they would return to Folkestone Marine Reserve in the future, the majority (80%) said they would, while the remainder said no.

The final survey question asked respondents to rate the quality of seawater, fish and coral life they had experienced during their present visit. The overall mean ranks were calculated for each item on a scale of 1 – 5, five being the highest quality rating. Seawater (in terms of clarity) was rated highly by visitors, with a mean value of 4.48 ($\pm$ 0.43 s.d.) recorded. Fish life was rated above average with a mean of 3.80 ($\pm$ 0.88 s.d.). Coral life however, received the lowest mean rating of 3.26 ($\pm$ 0.99 s.d.). It was found that snorkellers and divers differed in their ranking of coral life, with snorkellers rating this attribute significantly higher than divers did ($U$ = 5510, $z$ = -2.196, $p \leq 0.028$, $r$ = 0.14).

### 5.4.6 Econometric Analysis

The results of the ordinary least squares and interval regression models are presented in Table 5.5. My results showed consistency in the coefficient estimations obtained between the two regression models, suggesting the payment card design used for the surveys was well ordered (Cameron and Huppert, 1989) and/or the normality assumption was well maintained by the data (Yang *et al.*, 2012).

**Table 5.5** Coefficient estimates of visitors' willingness to pay using ordinary least squares (OLS) and interval (MLE) regression models.

| **Variable** | **All data** | **All data** | **Artificial reef data** | **Artificial reef data** | **Natural reef data** | **Natural reef data** |
|---|---|---|---|---|---|---|
| **Model** | OLS | Interval (MLE) | OLS | Interval (MLE) | OLS | Interval (MLE) |
| **Intercept** | -6.542** | -5.958** | -7.719** | -7.30** | -9.401** | -8.958** |
| ***Age*** | -0.106*** | -0.103*** | - | - | -0.175*** | -0.169*** |
| | (0.040) | (0.038) | - | - | (0.059) | (0.056) |
| ***Env_concern*** | 1.264*** | 1.190*** | 1.051** | 1.00** | 1.456*** | 1.423*** |
| | (0.331) | (0.313) | (0.428) | (0.405) | (0.472) | (0.445) |
| ***Dived_FMR*** | -3.238* | -3.149* | - | - | - | - |
| | (1.771) | (1.677) | - | - | - | - |
| ***Coral_life*** | - | - | - | - | 4.368*** | 4.286*** |
| | - | - | - | - | (1.460) | (1.378) |
| ***Species_view*** | 5.806*** | 5.685*** | 5.052*** | 4.99*** | 6.573*** | 6.422*** |
| | (0.516) | (0.490) | (0.709) | (0.672) | (0.714) | (0.677) |
| **Model** | *n* = 243 | *n* = 243 | *n* = 121 | *n* = 121 | *n* = 122 | *n* = 122 |
| **parameters** | F stat: 71.43 | $Chi^2$: 167.99 | F stat: 37.56 | $Chi^2$: 61.6 | F stat: 43.04 | $Chi^2$: 112.21 |
| | *p* = 000 | *p* = 000 | *p* = 000 | *p* = 000 | *p* = 000 | *p* = 000 |
| | $R^2$: 47% | | $R^2$: 39% | | $R^2$: 59% | |

**Notes:** standard errors in parentheses. Only significant variables shown. ***, **, * Significance at the $p \leq 0.01$, $p \leq 0.05$, $p \leq 0.10$ levels, respectively.

The explanatory power of the ordinary least squares models were good, yielding $R^2$ values of 39%, or above (Table 5.5). Overall, five of the twelve estimated coefficients expected to influence willingness to pay, were statistically significant. Based on previous research (e.g. Arin and Kramer, 2002; Lindsey and Holmes, 2002; Seenprachawong, 2003; Togridou *et al.*, 2006; Hargreaves-Allen, 2010), variables expected to show significant explanatory power, but in the event did not, included number of years in education, previous catamaran trips and prior visits to Barbados. Of the variables found to be significant, three (*Age*, *Env_concern* and *Species_view*) were significant at the 1% level (*Env_concern* 5% significance level for the artificial reef survey), whilst *Dive_FMR* was marginally significant at the 10% level. Two variables (*Age* and *Dived_FMR*) had negative signs on the coefficients, implying that younger respondents and those who had not previously dived in the reserve were willing to pay more as a daily entrance fee into Folkestone Marine Reserve. The coefficients for the remaining three variables (*Env_concern, Coral_life* and *Species_view*) were positively signed.  This indicates that respondents who rated the coral life as good, reported higher levels of concern for the reefs and marine environment and viewed more marine life, had higher willingness to pay. It should be noted, the variable *Coral_life* was only significant in the natural reef entrance fee model.

The regression results indicated the variable '*Species_view*' made the largest unique contribution to the variance in willingness to pay, with a mean value of 22% noted across all data sets. Table 5.5 shows the magnitude of the coefficients for this specific variable, indicating a one unit increase elevates willingness to pay on average US$5.69 – US$5.81 for each additional species viewed (MLE and OLS models, respectively – all data).

An exploratory analysis was conducted to assess any relationship between number of species viewed and willingness to pay. A Kruskal-Wallis Test indicated a high level of association between the dependent variable and *species_view* ($\chi^2$ (5) = 133.39, $p \leq$ 0.001) (Figure 5.3). Further post hoc analysis confirmed significant differences in willingness to pay occurring between 'two and three' species viewed, 'three and four' species viewed and 'four and five' species viewed ($U$ = 1119, $z$ = -3.391, $p \leq 0.001$, $r$

= 0.30; $U = 1154$, $z = -7.380$, $p \leq 0.001$, $r = 0.58$; $U = 314$, $z = -4.703$, $p \leq 0.001$, $r = 0.47$), respectively.

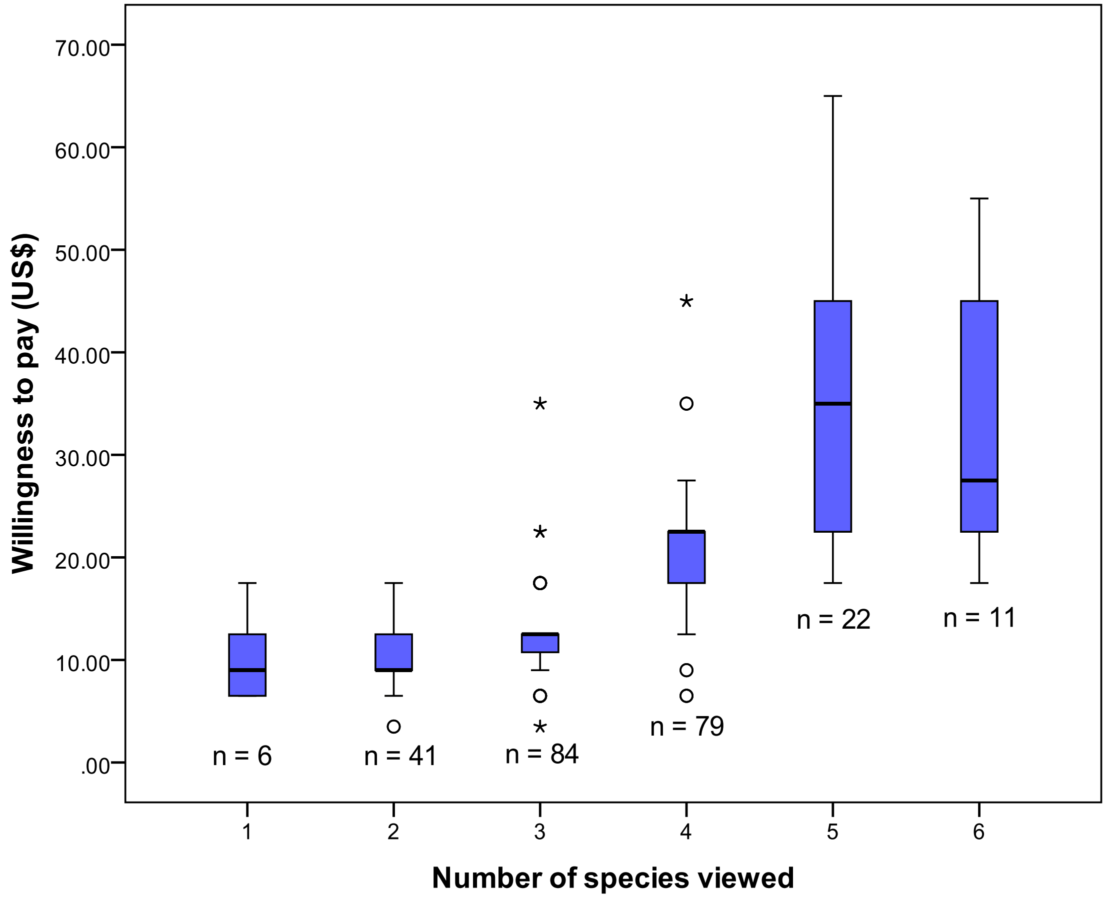


**Figure 5.3 The relationship between the number of marine species viewed and respondents' willingness to pay for reef protection in Folkestone Marine Reserve.** Boxes represent the inter-quartile range that contains 50% of values. The median value is represented by a line across the box. The whiskers extend to the 5$^{th}$ and 95$^{th}$ percentiles and circles and stars outside the box plots are outliers. Sample size is represented by numbers below each box.

## 5.5 Discussion

The principal focus of this study was to estimate visitors consumer surplus for the marine protected area in Barbados and to differentiate between visitors use value of natural and artificial reefs. As far as I am aware, it constitutes the first work to compare use values of two types of reef habitat within a reserve environment.

Upon inspection of data, it is apparent that willingness to pay for natural reefs yielded a higher mean value (US$18.33) than estimates for artificial reef use (US$17.58). Three studies (Johns *et al.,* 2001; Johns, 2004; Oh *et al.,* 2008) have reported use values relating to consumer's surplus of both reef habitats, and all three investigations yielded higher estimates for natural reef usage. Oh *et al.* (2008) estimated an average consumer surplus for diving per trip in Texas waters at US$171 for natural reef divers and US$101 for artificial reef divers; a net increase of 70% per trip for scuba diving at natural reefs. Both Johns *et al.* (2001) and Johns (2004) estimated consumer's surplus for managing and maintaining the natural and artificial reefs in southeast Florida and Martin County, Florida, respectively. Johns *et al.* (2001) reported an average use value for residents and visitors at natural reefs of US$12.74/person-day and $US$8.63/person-day for artificial reefs at the same location. In a later study, Johns (2004) estimated non-local tourists use value for diving, fishing and snorkelling combined at US$46.00/person-day at natural reefs, compared to US$23.84/person-day at artificial reefs.

Unlike the latter three studies, my results show mean willingness to pay estimates being just marginally higher for natural reef than for artificial reef habitat. Hypothetical bias linked to the 'warm glow' effect (Andreoni, 1990; Christie, 2007) may partially account for similar bid values been elicited for both reef types. Other environmental studies have identified this phenomenon of impure altruism (Nunes and Schokkaert, 2003; Polak and Shashar, 2013), which may be more prevalent among tourists on vacation (Polak and Shashar, 2013). Indeed, Kahneman and Knetsch (1992) propose that contingent valuation responses reflect people's willingness to pay for the moral satisfaction of contributing to public goods – not the economic value of the goods in question, though most (75%) visitors in this present survey exhibited the motivation of bequest value as the main driver of willingness to pay. In reality, Diamond and Hausman (1994) believe that willingness to pay would be more conservative if one were asked to pay for it during the surveying process. In spite of this, given at the time the Tiami cruise cost US$85 per person, it may be plausible that some respondents may have rounded their willingness to pay up to US$100 regardless of the reef habitat being valued. Indeed, 45% of bid values fell within the US$10-20 intervals (Table 5.3).

Several variables were significant in influencing willingness to pay. I found that as respondent's age decreased bid value increased, which is not unusual in this type of study. Arin and Kramer (2002) also noted that younger people were more willing to donate towards reef conservation and Uyarra *et al.* (2010) found younger divers had a more positive attitude towards paying higher marine park entrance fees in Bonaire. Moreover, Asafu-Adjaye and Tapsuwan (2008) reported that Thai respondents accepted the bid in a contingent valuation study more readily as the age of the diver decreased. With regard to older generations, it may be plausible that they are more skeptical about contributing towards conservation efforts in general (A. Kirkbride-Smith, personal observation, August 2013), or perhaps are more familiar and experienced with the goods being valued, thus reflecting reduced utility and diminishing marginal returns. In fact, I found divers who had previously experienced the reefs within Folkestone and repeat catamaran visitors to the reserve, had a significantly lower bid value than first-time visitors there. My results lend support to Dharmaratne *et al.* (2000) who noted repeat recreators to a terrestrial park and marine reserve in Barbados and Jamaica respectively, had a lower willingness to pay than first-time visitors. The present study also revealed that environmental awareness and concern for reefs had a positive and significant effect on willingness to pay bids, a trend confirmed in other willingness to pay reef studies (Tapsuwan, 2005; Togridou *et al.,* 2006; Casey *et al.,* 2010; Hargreaves-Allen, 2010), though not consistent with Barker's (2003) results.

Overall, the number of species viewed had the strongest effect on mean bid value for the marine park entrance fee. Collectively, the regression model estimates indicated that each additional species viewed elevated willingness to pay by approximately US$5.50 (Table 5.5). This clearly suggests visitors are willing to pay a significant dollar amount to view an abundance of wildlife within Folkestone. Indeed, marine life is regarded as one of the greatest sources of revenue for the dive and snorkel tourism industries (Barker, 2003) and viewing it has a positive impact on customer satisfaction (e.g. Musa, 2002; Musa *et al.,* 2006; Coghlan, 2012). Willingness to pay studies have shown that divers will pay significantly for conservation efforts that favour high biodiversity on artificial coral reefs (Polak and Shashar, 2013) and for greater fish abundance and fish size on natural reefs (Rudd and Tupper, 2002; Barker, 2003; Wielgus *et al.,* 2010). Individuals also hold considerable consumer surplus value for viewing large marine species such as dolphins, rays, whale sharks and turtles (Davis and Tisdell, 1999; Schuhmann *et al.,* 2008; Hargreaves-Allen, 2010; Schuhmann *et al.,* 2013; Farr *et al.,* 2014). In Barbados, marine turtles provide an additional means to attract tourists to the island (Troëng and Drews, 2004; Uyarra *et al.,* 2005) being widely promoted in various advertising campaigns. Willingness to pay to view turtles is substantial in this area of the Caribbean. Schuhmann *et al.* (2013) surveyed divers in Barbados and estimated they were willing to pay over US$57 for the first encounter with a marine turtle, and approximately US$20 per 2-tank dive for each additional encounter. I also established that turtles are a valuable resource, as they were associated with an US$8 increase in mean bid value per person, compared to divers and snorkellers who had not viewed a turtle during their trip.

An important aspect of this present research was to solicit visitors' opinions on reef material preferences for future purpose-built reef. Overwhelmingly, underwater art as sculptures was viewed as the most unappealing material choice by respondents, being selected by only 10% of people. This is despite its reported success in marine parks in Cancun, Mexico and Grenada in the Caribbean (www.underwatersculpture.com). Salient points noted as to visitors general dislike of this type of reef appeared to firmly centre on the lack of available habitat for species refuge, such as holes and crevices for fishes, and also on the 'out of context' appearance of human statues underwater as well as the small ecological footprint created. On the other hand, Reef Balls™ (www.reefball.org) presented as a snorkel trail, were viewed more favourably among 17% of individuals, especially among non-divers. Interestingly, Ramos *et al.* (2006) concluded that concrete modules were the least important choice of reef material among scuba divers in Portugal. Nevertheless, snorkel trails have been used with notable success in parts of the Caribbean. For example, in Antigua a 5-row Reef Ball™ breakwater structure also acts as a successful nature trail for divers and snorkellers (Kaufman, 2006) and in the U.S. Virgin Islands, Thorsell and Wells (1990) report nearly 90% of the 50,000 annual visitors using a managed snorkel trail. Of significance, Hannak *et al.* (2011) established that most visitors to a snorkel trail in Dahab, Egypt were willing to pay US$14-27 for a guided trip. Notwithstanding, purposefully sunken ships were found to be the most popular material choice among 73% of respondents. Divers studied previously (Ditton *et al.,* 2002; Stolk *et al.,* 2005; Shani *et al.,* 2011; Kirkbride-Smith *et al.,* 2013) have communicated an immense preference for shipwrecks and deliberately sunken vessels for artificial reef creation. Content analysis of my current data suggests the appeal of sunken ships is related to their perceived capacity to provide adequate substrate and shelter for marine species, their ‘in keeping’ generic form and visual appeal when viewed underwater and to their historical fascination.

Collectively, what are the implications of my findings in relation to reef conservation for the marine protected area in Barbados, or any other reserve? My results demonstrate that the majority (97%) of visitors would be willing to pay an entrance fee to access Folkestone Marine Reserve and this represents an unexploited revenue stream to improve reef management locally. By combining data of the artificial and natural reef models, these results indicate overseas tourists would be willing to pay almost US$18 as an entrance fee per visit to protect the reefs. This amount is broadly consistent with results of other willingness to pay studies investigating marine reserve fees for divers and snorkellers in the Caribbean (Barker 2003; Hargreaves-Allen, 2010) and elsewhere (Mathieu *et al.,* 2003; Tapsuwan, 2005).

However, US$18 would seem high to charge as a single daily fee, and indeed, to help ensure wider acceptance of marine park fees, they are typically kept low (e.g. Dixon *et al.,* 2000; Arin and Kramer, 2002; Seenprachawong, 2003; Table 5.1) with discriminatory pricing sometimes imposed on divers and snorkellers (Barker, 2003; Inter-American Biodiversity Information Network, 2010; Uyarra *et al.,* 2010). In view of this, a US$10 daily entrance fee for overseas divers and a US$5 daily entrance fee for overseas snorkellers seem fair to suggest. By using upper bound figures quoted by the Inter-American Biodiversity Information Network (2010) that indicate 7,000 scuba divers visiting Folkestone’s reefs annually and a further 176,600 visitors participating in snorkel trips, an estimated consumer surplus of US$953,000 could be generated per annum. This figure is in line with the hypothetical fee structure proposed by the Inter-American Biodiversity Information Network (2010) for the islands marine protected area. At present, it is unclear what the current operating costs are for Folkestone Marine Reserve. However as a guide, recent running costs for the Bonaire National Marine Park in the Caribbean, are in the region of US$1.1 million per year (STINAPA, 2009; Uyarra *et al.,* 2010) of which user fees contributed ~US$1 million in 2008.

Implementing a successful entrance fee system needs cooperation among visitors, tour operators and managers (Terk and Knowlton, 2010). To help achieve adoption of fees among visitors, they require clarity on how their money is used and managed (Peters and Hawkins, 2009). Studies suggest that fee acceptance improves if visitors have knowledge their funds are managed appropriately (Casey *et al.,* 2010) and specifically; that money is spent on reef protection (Casey *et al.,* 2010) and on improving park management (Yeo, 2005). In this current study, I found respondents concerned over how funds would be used and managed, and established that three quarters of visitors wanted a non-governmental organization to manage their payments. To create confidence and support in a fee system, supplying park booklets to visitors detailing the purpose and nature of fees may assist. Indeed, many participants that were interviewed requested information about the reserve and wildlife encountered, as did divers and snorkellers studied by Barker (2003) in St. Lucia. Moreover, by providing meaningful information for tourists, it helps develop place attachment and stewardship (Ham, 1992). Dive and tour operators also need encouragement to adopt fees. As an incentive to collect them, Terk and Knowlton (2010) suggest a system for compensating operators administration time, by giving them a small percentage of the fees gathered. This system was originally employed in Mexico (United Nations Environment Programme, 2003) and appears a simple but fair approach.

Visitors also need to see ‘what they are getting for their money’, and good reserve infrastructure helps justify fee payment (Sedley Associates Inc. *et al.,* 2000). This is especially relevant to repeat customers who were noted as having a lower willingness to pay. Developing eco-tourism opportunities via artificial reefs can create unique selling points in a resort (Dowling and Nichol, 2001; Leeworthy *et al.,* 2006; Shani *et al.,* 2011; Edney, 2012) and have the potential of alluring visitors to reserves. In previous research (Chapter 3; Kirkbride-Smith *et al.*, 2013) I established that artificial reefs were a prime motivator for some dive tourists to holiday on Barbados. Also, as fish abundance is often greater within protected waters (e.g. Chapman and Kramer, 1999; Varkey *et al.,* 2012) it appears a fitting environment to deploy artificial reef for amenity enhancement. Creating a new reef within Folkestone’s waters appeared to be very popular among respondents, as over three quarters of those interviewed said this type of resource would encourage repeat visitation. I also discovered that many visitors had heard of artificial reefs and over a third had either snorkelled or dived on one previously, including many deployed in Barbados. Increasingly, artificial reefs are becoming more popular, especially among scuba divers (e.g. Blout, 1981, Scuba Travel, 2006; Edney, 2012; Kirkbride-Smith *et al.,* 2013), and given the substantial use value I report for them, it suggests visitors would be willing to support a reef substitution policy in Folkestone and potentially in other reserves offering this type of amenity.

Among the recreationally used natural reefs within Folkestone, it is the fringing reefs that are the most impacted (Bell and Tomascik, 1993; Lewis, 2002; Inter-American Biodiversity Information Network, 2010) and this would appear the most appropriate zone to site underwater attractions. Several benefits could be yielded from developing artificial reefs in reserves. For example, managers may use them to influence and contain visitor use. Creating 'honey pot' sites within marine parks has been endorsed by some managers (Clark *et al.,* 2005) as a strategy to conserve other coral reefs by redirecting reef use. Such a policy would be especially useful for managing in-training and novice divers who are documented as causing substantial damage to natural reef (Roberts and Harriott, 1994; Walters and Samways, 2001; Warachananant *et al.,* 2008; Chung *et al.,* 2013). Moreover, these installations could be of great interest and value to dive shops to help sustain existing local resources. However, concentrating tourist use is open to debate as Barker (2003) found that visitors disliked the idea of being 'contained', suggesting it would lead to overcrowding and reduced naturalness of an area. In contrast, Hannak *et al.* (2011) established that a marine viewing trail would be the principal reason that their study group would choose a dive or snorkel site.

Notwithstanding, artificial reefs have been shown to offer opportunities to view interesting marine life (Wilhelmsson *et al.,* 1998; Perkol-Finkel and Benayahu, 2004; Arena *et al.,* 2007; Kirkbride-Smith *et al.,* 2013). Indeed, studies have confirmed artificial reef can support a comparable diversity and density of marine species than found on natural reef outcrops (Clark and Edwards, 1999; Perkol-Finkel and Benayahu, 2004), and this is especially true for fish abundance, where in some instances it has exceeded that present on natural reefs (Fast and Pagan, 1974; Wilhelmsson *et al.,* 1998; Arena *et al.,* 2007; Santos *et al.,* 2013; Granneman and

Steele, 2014). Clearly, creating the right type of artificial reef that encourages a diverse species community is crucial for reef tourism, as this study showed the principal driver of willingness to pay was marine life. In addition, artificial reef development allows for increased accessibility of reefs (Milton, 1989; Stolk *et al.*, 2005) and arguably, encourages the employment of more robust/resistant environments within reserves (Marion and Rogers, 1994; Claudet and Pelletier, 2004). To this end; marine protected areas provide the greatest opportunity to manage tourism use of natural reefs (Thurstan *et al.*, 2012) and environmental enhancement using 'well planned' artificial reef could potentially facilitate this (Oh *et al.*, 2008).

## 5.6 Conclusions and Further Research

This study used the marine protected area in Barbados to differentiate between respondents use value of natural and artificial reefs. My findings show that most visitors are willing to pay to support reef conservation in Folkestone and this represents an unexploited revenue stream that could be used for the day to day management of the reserve. A mean willingness to pay of US$18.33 and US$17.58 was estimated for natural and artificial reef use, respectively. This latter result thus indicates that significant use value could be gained from the provision of recreation-orientated artificial reefs within a reserve environment. Reef tourism is a valuable business in Barbados, and overall, creating substitute dive and snorkel sites have the capacity to maximize revenue without threatening natural resources.

Inclusively, this research serves as a valuable foundation for future work that should aim to uncover divers' willingness to pay for 'diving trips' within the reserve. Also, cruise trip passengers were not represented in this current study, and ideally, this omission needs addressing in future willingness to pay studies for Folkestone. Finally, research into the recovery of non-use values (i.e. not current users of the resource) to fund reef management in Folkestone, is also an area worthy of future exploration.

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# Chapter 6

## *Summary, Implications and Conclusion*

### 6.1 Discussion

In recent years, increasing affluence in the western world has led to significant changes in the scale of tourism, including the rapid growth of coral reef recreation (Garrod and Gössling, 2008; Musa and Dimmock, 2013). Many reefs are located in developing countries (Dimmock, 2007; Lew, 2013) where diving and snorkelling tourism have gained a strong and growing presence (Burke *et al.*, 2002; Barker, 2003; Burke and Maidens, 2004). However, the ramifications of increased participation in scuba diving especially, have translated into biological damage and reduced amenity values to some popular reefs (Davis and Tisdell, 1996; Rouphael and Inglis, 1997, 2001, 2002; Hawkins *et al.*, 1999; Barker, 2003; Barker and Roberts, 2004; Au *et al.*, 2014). To help serve the needs of reef conservation as well as satisfy the economic interests of coral reef tourism, new management practices are required. In this thesis I used a social science approach to examine the links between the use of recreation-orientated artificial reefs and their role in managing scuba diving and reef-based tourism. To achieve this, I addressed existing gaps in the management of coral reefs by investigating the potential economic, social and conservation impacts of artificial reefs as alternative underwater attractions in Barbados, West Indies.

In Chapter 1, I reviewed the existing literature on the use of artificial reefs as recreational diving resources. I summarized my findings and identified gaps in knowledge from which I made several recommendations for future avenues of enquiry. In Chapter 2, I conducted a meta-analysis of reported values for a suite of recreational activities performed at artificial reefs. I quantified these global values and compared them with value estimates reported by Brander *et al.* (2007) for coral reef recreation. Chapters’ 3 to 5 present field data collected in Barbados. The study methods used involved established social science techniques of survey design, interviewing and attitude measurement (Oppenheim, 2003). In Chapter 3, I explored individuals' perceptions of diving at artificial reefs and sought to establish if reef habitat preference between natural and artificial reef is influenced by diving experience. In Chapter 4, I measured divers' enjoyment of artificial and natural reef dives and also investigated which attributes of the artificial reef dive experience contributed the most to diver enjoyment. In this chapter, I additionally explored if diver characteristics such as age and dive experience, were influenced by factors present within the enjoyment data. In Chapter 5, a contingent valuation method was employed to quantify the consumer surplus of visitor use of the marine protected area in Barbados. I investigated differences between visitor use values for natural and artificial reef habitats presented in the context of a hypothetical market. I also researched tourists' reef material preferences for future artificial reef creation.

## 6.2 Summary of Results and Principal Findings

The reviewed material embodied within Chapter 1 gave me a clear insight into the content and breath of published works in relation to artificial reefs as recreational diving resources. Research grounded in environmental engineering, ecology and the social sciences were used as tools to investigate the efficacies of recreation-orientated artificial reefs. Most papers reviewed, had a strong social science-based methodology, using visitor surveys as data collection tools. In many instances, information derived from the questionnaire surveys were viewed as a valuable source of information for coral reef resource managers (Milton, 1989; Ditton *et al.,* 2002; Stolk *et al.,* 2005; Shani *et al.,* 2011; Edney, 2012). Synthesizing across the different studies, I found several motivational factors embedded in the research relating to artificial reef diving. Factors consistently important to divers included large shipwrecks and sunken vessels (Ditton *et al.,* 2002; Stolk *et al.,* 2005; Shani *et al.,* 2011; Edney, 2012), desirable fish species (Milton, 1989; Stanley and Wilson, 1989), accessibility and travel time to dive sites (Milton, 1989; Stolk *et al.,* 2005) and photographic opportunities (Stolk *et al.,* 2005; Edney, 2012). I used this line of enquiry to help develop my own research on diver's opinions and preferences (Chapter 3) and to investigate resource substitution behaviour among divers (Chapter 3). From a reef planning and management perspective, I was also aware of the importance of researching features of artificial reefs that are of interest to divers; building on previous research (e.g.

Ditton *et al.,* 2002; Stolk *et al.,* 2005; Shani *et al.,* 2011; Edney, 2012), as well as the motivational drivers of diving enjoyment between novice and experienced divers (Chapter 4). Overall, the reviewing process highlighted the positive role that artificial reefs have in maintaining the sustainability of the diving tourism market (Leeworthy *et al.,* 2006; Polak and Shashar, 2012), as well as their potential use as an ecotourism product (Brock, 1994; van Treeck and Schuhmacher, 1999; Dowling and Nichol, 2001; Shani *et al.,* 2011). In contrast, a lack of comparative works to establish the relative economic value of artificial and natural reefs to divers and other recreationists was apparent. Only one published study (Oh *et al.,* 2008) addressed this important issue, and as a consequence, I developed investigations (Chapters 2 and 5) to tackle this apparent dearth in research effort.

In this thesis I report the first results that quantify the recreational value of artificial reefs (Chapter 2) using a synthesis of data from the published and gray literatures. Using established study sources to locate metadata, a total of 57 recreation value observations from 20 studies were used for analysis. I compare my results to those of Brander *et al.* (2007) and by doing so highlight several important distinctions in recreational value between reef types. Overall, mean value estimates produced for recreating at artificial reefs (US$122 person/day) were less than those documented for natural reef use (US$233 person/day). In respect of recreational activities performed at artificial reefs, most observations made in the literature were for scuba diving and indeed, diving yielded the largest economic value (US$180 person/day) of all the activities assessed, while snorkelling was the least valued (US$21 person/day) activity. This latter result concurs with Branders *et al.* (2007) study who also found diving and snorkelling produced the highest and lowest value estimates respectively, for coral reef recreation. With the exception of fishing that yielded a higher value at artificial reefs, estimates for scuba diving, snorkelling and marine viewing were reported approximately 40% higher for natural reefs. Nonetheless, artificial reefs in relative terms appeared to be highly valued by users, especially by scuba divers and fishers.

This study (Chapter 2) also provided basic evidence of scope sensitivity and crowding-effects in marine recreation, indicating increasing numbers of visitors to artificial reefs depresses reef values. Brander *et al.* (2007) also established a similar trend for coral reef recreationists, suggesting that visitors prefer less crowded reefs. Out of all the valuation techniques used to estimate recreation values at both artificial and natural reefs, the contingent valuation method of willingness to pay emerged as the most conservative, while the market value approach was the most liberal. Of importance, this analysis highlighted the inadequacies of studies inspected to report basic information such as standard error values, reef site attributes and methodological characteristics, that if present, would not only greatly improve valuation studies, but improve any future meta-analytical treatment of the artificial reef valuation literature.

To optimize the management potential of artificial reefs, divers' opinions and reef preferences were investigated (Chapter 3). In agreement with previous studies (Ditton *et al.,* 2002; Stolk *et al.,* 2005; Shani *et al.,* 2011; Edney, 2012) the results of this investigation suggested that divers have an overwhelming preference for large shipwrecks and sunken vessels. I established major trends linking these preferences that included divers' ability to penetrate wrecks, the uniqueness of the dive experience, photographic opportunities, a large ecological footprint and the guarantee of a 'good dive'. Divers ubiquitously perceived artificial reefs (especially wrecks) as having the capacity to concentrate marine fauna and flora, especially fishes. Viewing marine life is one of the greatest motivators for most divers (e.g. Barker, 2003; Musa *et al.,* 2006; Fitzsimmons, 2009; Uyarra *et al.,* 2009; Edney, 2012) and wrecks are particularly effective at concentrating fishes (Fast and Pagan, 1974; Wilhelmsson *et al.,* 1998; Arena *et al.,* 2007; Santos *et al.,* 2013). This study also provided an indication of divers' awareness and support of marine conservation matters as respondents were particularly positive in their views relating to artificial reefs in reducing diving pressure from natural reefs. This inclination was also evident among Stolk *et al.* results for Australian divers.

The value and success of artificial reefs in Barbados was highlighted (Chapter 3). I established that many divers chose to visit the island due to the presence of several artificial reefs in Carlisle Bay (Agace, 2005) and I also presented evidence that the artificial reefs were highly effective in redistributing divers away from the naturally occurring reefs. This was especially true for novice divers, as they were found to physically use the artificial reefs more than experienced divers did. Indeed, when I moved on to explore resource substitution behaviour among my study population, I found that novices derived greater enjoyment and showed a greater preference for artificial reef diving sites than their experienced diving counterparts. These results add weight to Dearden *et al.* (2006) research of diver specialization that showed a general decline in satisfaction levels with increasing diving experience. Dearden *et al.* (2006) also suggested that more experienced divers tend to have more specific resource requirements, and my data presented supported this tendency, as experienced divers exhibited an overwhelming preference for natural reef as diving sites in Barbados. As far as I am aware, this study is the first to reveal recreation specialization in scuba divers relative to resource substitution behaviour.

To increase the attractiveness of artificial reefs it is crucial to understand the features that will attract divers to them (Polak and Shashar, 2012). I used a rapid survey instrument (Chapter 4), to specifically measure how 24 dive-related attributes contributed to diver enjoyment. My study demonstrated that dives conducted on artificial reef were enjoyed significantly more than dives conducted on natural reef in Barbados. In this particular case, the notion that artificial reefs are worthless (Bennington, 2005; cited in Oh *et al.,* 2008) can therefore dismissed, as it was in Oh *et al.* (2008) study that focused on divers willingness to pay for artificial reefs in Texas waters. In terms of discrete attributes, I found several to be of particular importance in determining dive site enjoyment at artificial reef relative to natural reef, notably; new experiences, photography, water depth and challenge of the dive. Artificial reefs as shipwrecks are particularly favoured by divers for their new experiences and challenges, as they provide the opportunity to practice more precise diving skills and offer the complexity and thrill of exploring the ships internal structure. In particular, my data showed that divers enjoyed underwater photography a great deal more on artificial reef. This is possibly due to the concentration of marine life, especially fishes, often present on simulated reef (Fast and Pagan, 1974; Wilhelmsson *et al.,* 1998; Arena *et al.,* 2007; Santos *et al.,* 2013) relative to similar sized natural reefs.

In this study (Chapter 4), I also investigated the motivational drivers of diving enjoyment in relation to each individual attribute, irrespective of reef type. Ranked in the top six attributes for both reef habitats was overall safety, a good buddy, sharing enjoyment, warm water and underwater sensation. My findings thus emphasized the social and environmental importance of diving that can be met in virtually any 'warm water' marine tourism setting and confirms results of work conducted elsewhere on diver enjoyment (Fitzsimmons, 2009; Musa, 2002). In contrast, I found the attributes that were less important were all connected to the biological components of the dive; diversity of fish, new species, unusual rare species and large fish were all ranked very low for both reef types investigated. These results are counter-intuitive to previous investigations (e.g. Musa, 2002; Musa *et al.*, 2006; Uyarra *et al.*, 2009; Polak and Shashar, 2013) that have highlighted the importance of biological attributes to divers. My results thus suggest that the present quality of these natural reef features in Barbados, especially 'large fish' (ranked the lowest for both reef habitats) is generally very poor, and needs improvement.

I also considered if certain diver characteristics such as age and diver experience, were influenced by potential factors present in the enjoyment data (Chapter 4). Factor analysis reduced the data to three identifiable factors; 'social and environmental', 'biological' and 'personal incentive'. I showed that novice divers' enjoyment appeared to be more influenced by the 'personal incentive' factor; updating diving skills, new experiences, challenge of the dive and equipment. In contrast, individuals more experienced at diving appeared to be more influenced by attributes present in the 'biological' factor; variety of corals and coral cover as well as reef topography. Moreover, analysis of discrete attributes confirmed that experienced divers gained greater enjoyment from underwater photography than novices did. My findings add support to Dearden *et al.* (2006) and Lucrezi *et al.* (2013) results who reported the biological aspects of diving and opportunities for photography of growing importance as diver specialization increased.

"Wherever there are visitors, there is opportunity" (Peters and Hawkins, 2009, p.226). The willingness to pay study (Chapter 5) highlighted that divers and snorkellers held a range of values associated with reefs within Folkestone Marine Reserve. I tested for the first time visitors' consumer surpluses between natural and artificial reefs within a reserve environment. My results demonstrated that visitors were willing to pay more as a daily entrance fee for natural reef use (US$18.33) than for artificial reef use (US$17.58). The higher value produced for natural reef is consistent with previous studies (Johns *et al.,* 2001; Johns, 2004; Oh *et al.,* 2008) that have investigated consumer surpluses of both reef types in the same location. By pooling data from both artificial and natural reef models, I estimated that overseas tourists were willing to pay an average of US$18 as a user fee to help protect Folkestones reefs. These results are broadly consistent with divers and snorkellers studied elsewhere in the Caribbean, that are willing to pay significant sums of money to protect reefs, to the order of US$25 – US$30 per trip (Dixon *et al.,* 2000; Spash, 2000; Barker 2003).

I also provided tangible evidence that viewing marine biodiversity, especially turtles, was a significant motivational factor driving willingness to pay (Chapter 5). My results indicated that a one unit increase in ‘number of species viewed’ elevated willingness to pay to the magnitude of approximately US$5.50. Schuhmann *et al.* (2013) highlighted the significance of turtles to the diving tourism industry in Barbados, reporting divers were willing to pay over US$57 for their first encounter with a marine turtle, and approximately US$20 thereafter. Additionally, I provided good evidence that younger people and individuals who are more concerned about reefs and the marine environment are, as a rule, more generous with their willingness to pay; trends consistently observed in other willingness to pay studies (Arin and Kramer, 2002; Tapsuwan, 2005; Togridou *et al.,* 2006; Asafu-Adjaye and Tapsuwan, 2008; Casey *et al.,* 2010; Hargreaves-Allen, 2010; Uyarra *et al.,* 2010).

Having the time to personally interview each visitor, I was able to establish detailed information regarding their reef material preferences. The local study showed that visitors had a general dislike of underwater art as sculptures for artificial reef creation. Salient points noted as to visitors’ overall disapproval of this type of artificial reef appeared to centre on the lack of available habitat for species refuge, the ‘out of context’ appearance of underwater statues and the small ecological footprint created. Despite this, underwater sculptures are popular tourist attractions in marine parks in Cancun, Mexico and Grenada, Caribbean (www.underwatersculpture.com). On the other hand, Reef Balls™ as a snorkel trail, were viewed more positively, especially among snorkellers that I interviewed. Consistent with my findings elsewhere in this thesis (Chapter 3), it was purposefully sunken ships that were the most popular material choice among the majority of visitors surveyed. I learnt that their appeal as an artificial reef was related to their perceived capacity in providing a significant ecological footprint for marine species colonization and refuge, their 'in keeping' generic form and visual attraction when viewed underwater and their historical appeal.

## 6.3 Implications for Reef Management

I have demonstrated throughout this thesis, that recreation-orientated artificial reefs have both an economic value (Chapters 2 and 5) and a social value (Chapters 3 and 4) to individuals participating in reef-based activities. Additionally, empirical evidence (Chapter 3) demonstrated the efficacies of artificial reefs in yielding conservation benefits by effectively diverting diving pressure from natural coral reefs.

My findings make an important contribution to the understanding of the range of economic values assigned to artificial reefs (Chapter 2) that host recreation. I also provided additional insight into the 'relative value' of artificial reefs to users, by comparing values estimates to those documented for coral reef recreation (Brander *et al.,* 2007). Overall, I found scuba diving to be the most highly valued activity occurring at artificial reefs, and this result may be useful for the design and layout of reefs and revenue generation relating to a specific recreational audience. Despite the apparent lack of welfare consistency among studies, the data I produced (Chapter 2) would be useful to marine managers and policy makers when prioritizing and targeting expenditures and also in justifying future public investments in artificial reefs. In a less formal setting, data could be used by non-economists to comprehend artificial reef values associated with the resource or policy. More specifically, contingent valuation estimates (consumers' surpluses) produced are valuable for setting (or reviewing) user entrance fees (Chapter 5) to aid raising revenues for reef management and conservation.

For practical reasons, academics need to be aware of the importance of conducting primary valuation studies that collect fundamental information relating to the characteristics of the reef and details of methods used (Chapter 5). This would lead to consistency among studies and contribute towards more robust meta-regression models generating more accurate price transfer data for 'unvalued policy sites'. This stricter attendance to methodology would ultimately save money for reef managers with budgetary constraints who wish to value sites. I also found basic evidence of scope sensitivity and crowding-effects relating to artificial reef use by visitors (Chapter 2). Indeed, it is reasonably well documented that visitor congestion at a reef site depresses reef values (Rudd and Tupper, 2002; Brander *et al.*, 2007; Schuhmann *et al.*, 2013). This observation has functional applications for artificial reefs; both in the design of pricing policies (Chapter 5) and the positioning of recreational access.

To the extent that recreation-orientated artificial reefs are substantially valued (Chapters 2 and 5) and enjoyed (Chapter 4) for their amenity enhancement, there is considerable scope for the management of divers and snorkellers through the use of contrived reef. In relation to creating new recreational opportunities, commonly held tastes for shipwrecks and sunken vessels (Chapters 3 and 4) should be upheld by marine resource managers to maximize reef use; with special emphasis on creating large ecological footprints and themed experiences (Chapter 3). My data suggests however, that divers are not homogenous (Chapters 3 and 4); they differ in their sources of satisfaction, reef preferences (Chapter 3) and motivations (Chapter 4). I demonstrated that novice divers have a preference for artificial reefs (Chapter 3) and appear to be satisfied by aspects of diving that could be met in virtually any marine tourism setting (Chapter 4). In contrast, divers with a higher level of specialization in the sport have more specific resource requirements that focus on the biological aspects of the diving experience (Chapter 4). Collectively, this information provides avenues for strategic marketing and management, and indeed there is scope to design particular reefs to cater for individuals relative to their diving preferences and abilities. For example; designing substitute reef sites to specifically accommodate in-training novice divers would reap ecological benefits by reducing diver impacts to natural reefs. Of significance, reef managers need to be aware of the ecocentric tastes of experienced divers and ensure their commonly held preferences for biodiversity viewing and photographic opportunities, among other features, are provided for.

Barbados's marine protected area is a popular attraction with visitors (Blackman and Goodridge, 2009), and these same visitors could be a source of funding for coral reef conservation via reserve entrance fees (Chapter 5). Overall, the majority of visitors that I interviewed were willing to pay to support reef conservation in Folkestone, and this represents an unexploited revenue steam to improve reef management locally. In reality, Barker (2003) suggests that charging entrance fees represents a very small fraction of tourists' total expenditures whilst on holiday, of around 1% or less, and this assessment would hold true in Barbados (A. Kirkbride-Smith, personal observation, August 2013). However, implementing a new fee system needs careful planning (Terk and Knowlton, 2010). From the standpoint of visitor acceptance, the data I presented suggests that managers need to show transparency on how user payments are spent and controlled. I established that a non-governmental organization was the most favoured body to administer funds and overall, visitors preferred to see their money used on marine education.

By exploring motivations and factors driving willingness to pay (Chapter 5) it can provide information useful to marine park managers for designing revenue raising strategies. For example, I found 'reef and marine concern' was a significant driver of bid value, thus the provision of park booklets educating visitors about the reserve may help reinforce park fees. This latter point is supported by the present study (Chapter 5) as the majority of individuals that I interviewed were very keen to learn about Folkestone and its marine life. I suggest the information (verbal and written) currently available for visitors to Folkestone is something that requires improvement. Despite this, visitors enjoyed all aspects of viewing marine life and this I found was the main influencing factor that determined their consumer surplus. This underscores the immense importance of managing reserve environments that permit a high level of marine biodiversity to flourish. In fact, the results of the local study highlight the need to examine what features of artificial reefs and the environment are attractive to charismatic megafauna such as marine turtles. Overall, I found that visitors were generally satisfied with the present qualities of seawater and fish life they encountered; however, coral life they were less satisfied with.

In this study (Chapter 5) I reported substantial use values for artificial habitat that points to reserves and artificial reefs as having potential for symbiotic partnerships in coral reef management. Dealing with high numbers of divers and snorkeller within a marine protected area is often counter-intuitive to the aims of the reserve (e.g. Thurstan *et al.*, 2012). Moreover, an emerging problem within marine protected areas is managing large numbers of cruise ship passengers that overwhelm the environment (Marion and Rogers, 1994). Deploying well conceived artificial reef could help address this issue by influencing the location of visitor use (Chapter 3). By conducting this research, I provided justification (Chapter 5) for the deployment of a disused vessel within Folkestone Marine Reserve. However, simply duplicating existing artificial reef experiences that are offered locally may not maximize benefits. In view of this, a vessel that incorporated elements of Barbados's history, such as ships cannons may be of interest, as well as ensuring attributes attractive to divers (Chapter 4) and snokellers are catered for. Furthermore, in order to deal with visitors entering reserve waters via the beach at Folkestone, I suggest a managed snorkel trail consisting of Reef Balls$^{TM}$ or a similar 'ecologically sound' material such as Biorock (Chapter 1, section 1.4.4.1). This would help divert attention away from nearby coral reefs, and if extended some distance out into reserve waters, could also benefit catamaran passengers.

Overall, I suggest that visitor surveys can be a valuable source of information to coral reef managers. I found they can provide basic information to predict likely responses to new policies, such as reef substitution (Chapter 3) and willingness of users to pay marine park entrance fees (Chapter 5). Questionnaire surveys also provide an indicator to judge resource attributes important to divers. Indeed, the straight forward method I used to measure diver enjoyment of reefs (Chapter 4) could easily be applied by marine personnel as a low cost method to monitor changes in reef attributes over time. Finally, surveys are an effective means of determining diver characteristics, preferences and behaviours (Chapter 3) that can provide an important insight into how to maintain and potentially grow dive market share; important factors in today's competitive world.

## 6.4 Limitations and Further Research

There are a number of caveats that should be noted concerning the validity of my results. The analysis of artificial reef values (Chapter 2) was constrained by the quality of current data available and the valuation methods researchers employed. The resulting lack of welfare consistency across studies led to value estimates that should be treated with caution, as should the results of Brander *et al.* (2007) who used the same methodology (refer to Londoňo and Johnston, 2012 for a discussion on this issue). Additionally, due to constraints on time and financing for data collection in Barbados (Chapters 3, 4 and 5) my results would have been improved by using larger study populations. This limitation I felt was especially relevant to the willingness to pay study (Chapter 5) as Champ (2003) suggests this method requires a considerable sample size to maintain an acceptable level of sampling error and power of statistical testing. Nonetheless, significantly smaller samples have been used in previous willingness to pay reef studies (e.g. Dixon *et al.*, 2000; Arin and Kramer, 2002; Ngazy *et al.*, 2005; Riley, 2006). While all the interviews for the willingness to pay study (Chapter 5) were carried out personally, the survey collection instruments for chapter 3 and chapter 4 were self-administered. However, in my absence, all dive school personnel were briefed consistently on providing specific information and guidance on self-completion. In terms of potential biases associated with the payment card format used to estimate consumer surplus (Chapter 5), I provided visitors with detailed information about the reserve to increase response validity and this level of communication also helped reduce hypothetical bias. I additionally used follow-up questions post bid to help minimize strategic behaviour. Nonetheless, inherent biases associated with the contingent valuation method are virtually impossible to eliminate completely (Boyle, 2003); including social desirability bias and the 'warm glow' effect that is more likely to occur with in-person interviews (Champ, 2003). Divers on diving trips were not represented in the marine park study (Chapter 5) and this omission needs addressing in future studies. Finally, whilst Barbados provided an ideal location to study the interactions of reef tourism and artificial reefs, my conclusions would only be applicable to other locations inasmuch as they offered a similar quality and range of reef-related features for users.

There is considerable scope to extend the research conducted in this thesis and I suggest that future studies should focus on the following.

- To promote welfare consistency in a future meta-analytical treatment of the artificial reef valuation literature, metadata should be drawn from methods that have known theoretical relationships that produce comparable estimates. This could be achieved by using consumer surplus data from the contingent valuation and travel cost methods only and by doing so, would improve reliability of results. However, the artificial reef valuation literature that adopts welfare methods (e.g. willingness to pay) would have to be sufficiently prevalent to make this research possible.

- More work is required to establish to what degree divers would support a management policy of reef substitution using artificial reefs. I suggest using a diver specialization index of diving commitment, investment and experience (Dearden *et al.*, 2006) (as apposed to simply using number of logged dives) to identify differences in users' reef resource requirements. This approach would provide a finer context to help understand the diversity of tastes held by subgroups of divers and provide theoretical information to underpin a policy of site substitution.

- Future studies are also needed to investigate the range of attributes that foster users' enjoyment of artificial reefs. A willingness to pay study aimed at valuing dive attributes (including transplanted corals) and controlling for diver characteristics would be a useful extension to work already undertaken (Chapter 4). This research would help elucidate ways to incorporate income-generating opportunities into artificial reefs and ultimately improve the design and attractiveness of contrived reef to recreational users.

- There is currently a lack of data that explores visitors' non-use values (individuals who do not use the resource) for artificial reefs, particularly within a marine protected area. This is despite evidence that non-use values play an important role in providing funds for reef conservation (e.g. Dharmaratne *et al.*, 2000; Subade and Francisco, 2014). To capture these values, a contingent valuation method of willingness to pay would be required, and common variables included (e.g. amount of voluntary contribution, reason to contribute, gender, age etc.) to help explain willingness to pay. Alternatively, non-use values may be measured in terms of how much time or labour an individual is willing to contribute to the cause (refer to Spash, 2000). This would eliminate the discomfort that some people experience when having to apply an instrumental monetary valuation to a pure public good (Nunes and van den Bergh, 2001; Taylor 2006).

- The potential impact of introducing new reef habitat into the marine environment on surrounding natural reefs warrants investigation. For example, research to elucidate whether heavily marketed and high profile artificial reefs may indeed cause an increase in nearby natural reef usage by divers (due to an influx of tourists), needs exploring fully. To achieve this, a similar methodology to that used by Leeworthy *et al.* (2006) should be adopted by estimating total reef usage pre- and post-deployment for the artificial reef and nearby natural reef. This would assess changes in patterns of reef use for both types of habitat in the same locality over a given period.

## 6.5 Conclusion

The work presented in this thesis has raised the profile of the importance and value of artificial reefs to recreational users and reef resource managers. Principal gaps in knowledge in the field of artificial reef research have been covered and others identified in a bid to understand the role of contrived reef in managing diving and reef-based tourism. van Treeck and Schuhmacher (1999) recently editorialized in their paper; 'Mass diving tourism – a new dimension calls for new management approaches', the need for innovative methods and techniques (i.e. artificial reefs) to help preserve the integrity of natural reef systems. Inclusively, artificial reefs offer an elegant means of contributing towards the management and sustainability of the marine tourism industries. Their use is a proactive and people friendly form of conservation that, it is hoped, will help reduce the demise of coral reefs worldwide.

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# Glossary

***Anchoring bias:*** is where a respondent is influenced by the starting values, or succeeding bids, used in elicitation of willingness to pay; for example, in a bidding game or dichotomous choice elicitation format.

***Benefit transfer:*** an approach that makes use of previous valuations of similar goods at a study site and, with any necessary adjustments, applies them to produce estimates for the same or similar good in a different context, know as the policy site. What is transferred may be a mean willingness to pay, with or without some adjustment for changed conditions.

***Bequest value:*** willingness to pay to preserve the environment for the benefit of our children and grandchildren.

***Biophilia hypothesis:*** (according to a theory of the biologist E.O. Wilson) an innate and genetically determined affinity of human beings with the natural world.

***Consumer surplus:*** the difference between the price that consumers pay and the price that consumers are willing to pay represented by the area under the ordinary (Marshallian) demand curve and above the price line.

***Contingent:*** is an acknowledgement that no market currently exists for the good or service being measured.

***Contingent valuation:*** a method to appraise the benefits a society receives from public goods.

***Contingent valuation method:*** uses surveys to simulate a market for a non-marketed good and obtain a value for that good, contingent on the hypothetical market described during the survey.

***Dichotomous choice:*** an elicitation format in which respondents are faced with only two response alternatives, such as yes/no or agree/disagree. A 'don't know' option is sometimes included to avoid forcing respondents into artificially choosing one of the answers.

***Demand curve:*** a graph showing how the demand for a commodity or service varies with changes in its price.

***Double-bounded dichotomous choice:*** the bid amount given to a participant, if rejected, is followed with the offer of a lower bid, and positive bids with a higher option offered.

***Elicitation format:*** the method whereby respondents are asked questions to determine how much they would value the good if confronted with the opportunity to obtain it. Possible formats include open-ended, dichotomous choice and payment card.

***Focus group:*** an informal discussion group consisting of a small group of respondents.

***Hedonic pricing:*** a revealed preference method of pricing based on the principle that the price of a marketed good is affected by certain external environmental or perceptual factors that can raise or lower the base price of that good. For coastal resources, the hedonic method is most commonly applied to the valuation of nearby property.

***Hicksian consumer surplus:*** ordinary demand curve measured (Marshallian) where total utility is held constant at different specified levels.

***Impure altruism:*** refer to 'warm glow effect'.

***Intrinsic value:*** refers to the value that the environment and life forms have in their own right and which is not derived from human use.

***Likert scale:*** a type of itemized rating scale where respondents are asked to indicate a degree of agreement or disagreement with statements about the subject.

***Marshalian consumer surplus:*** is the difference between the maximum amount one is willing to pay and the actual amount one pays for a good (ordinary demand curve).

***Non-market value:*** represents the true net economic value of a good or resource to a user and captures the increase in economic well-being that an individual enjoys as a result of access to that good or resource.

***Non-use value:*** the value placed on a resource by people who are not current users of that resource and who generally do not intend to use the resource themselves.

***Oblimin rotation:*** is a general form for obtaining oblique rotations used to transform vectors associated with principal component analysis or factor analysis to simple structure. Oblimin is similar to the Orthomax rotation procedures used in orthogonal rotation in that it, too, includes an arbitrary constant used to obtain different rotational properties. While most orthogonal rotations use some form of Orthomax rotation, this is no longer the case with Oblimin rotation for the oblique case.

***Open-ended format:*** a straightforward elicitation format which asks respondents to state their maximum willingness to pay (or minimum willingness to pay).

***Payment card:*** an elicitation format which presents respondents with a visual aid containing a number of monetary amounts to facilitate the visual task.

***Purchasing Power Parity (PPP):*** is an economic theory that estimates the amount of adjustment needed on the exchange rate between countries in order for the exchange to be equivalent to each currencies purchasing power.

***Revealed preference method:*** is used to identify the underlying preferences for goods and services based upon the market and non-market choices users reveal in their consumption patterns (e.g. the travel cost model).

***Single-bounded dichotomous choice:*** the bid amount given to a participant is either accepted or rejected by the individual. If rejected, no further bid is offered.

***Social desirability bias:*** occurs when respondents provide interviewers with a response that they think is socially desirable.

***Starting point bias:*** when the final valuation estimate shows dependence on the starting point used.

***Stated preference methods:*** rely on society's expressed willingness to pay for an environmental amenity. In stated preference methods, surveys are used to elicit values from people regarding their willingness to pay for environmental goods and services (or willingness to accept degradation of these resources). Typically, stated preference methods attempt to value a hypothetical provision, loss or change in a resource.

***User fee:*** a fee or tax imposed on the consumption of services or facilities.

***Use value:*** the value placed on a resource by users of that resource.

***Utility:*** an economic term referring to the total satisfaction received from consuming a good or service.

***Warm glow effect:*** is an economic phenomenon that attempts to explain why people give to charity by proposing that individuals engage in impure altruism. Instead of being motivated solely by an interest in the welfare of the recipients (or the good being valued), 'warm-glow givers' also receive utility from the act of giving. This utility is in the form of warm glow - the positive emotional feelings people get from helping others.

***Welfare:*** in the field of economics; it specifically refers to the optimal allocation of resources and goods and how this affects social welfare. Economic welfare is also called consumer surplus, and is a word used in conjunction with valuing common or public property, such as lakes, rivers, coral reefs and parks.

***Willingness to accept:*** the monetary measure of the value of forgoing an environmental (or other) gain or avoiding a loss.

***Willingness to pay:*** is a monetary indicator of the gap between a goods total utility and its actual market price. This may be elicited from stated or revealed preferences approaches via surveys.

***Yea saying:*** is the propensity of some respondents to answer yes to any bid amount presented to them in a questionnaire survey.

**Appendix A**

***Questionnaire for visitors / local residents scuba diving in Barbados***

***I am a PhD student conducting research on coral reef protection in Barbados. Please help this important cause by giving your valued opinions and time. For every questionnaire completed, $1.00 will be contributed towards reef protection in Barbados through the charity 'The Barbados Marine Trust'. Many thanks, Anne Smith.***

*If you would like to see the published results of this research, please write your email address at the end of the survey. Thank you.*

1) **Age?** ___________

2) **Male or Female?** (Please circle)

3) **Country of Residence?** _____________________________

4) **For visitors only, what is the main reason for visiting Barbados? (Please tick)**
For a diving holiday ☐ For a general holiday ☐ To visit friends or relatives ☐
For work or business ☐ Other, please specify ☐

5) **How long are you visiting Barbados for?** __________________________________

6) **What is your highest diving qualification?**
Training diver ☐ Novice/Open Water ☐ Sports Diver/Divemaster ☐ Instructor ☐

7) **What is your approximate length of your certified diving career?** _____________

8) **How many dives have you logged in your total dive history?**__________________

9) **In general, how frequently do you scuba dive?**
Two-weekly ☐ Monthly ☐ 3-6 times per year ☐ Other – please specify________

10) **What are your 3 main motives for diving in Barbados?** Choose three and place in order of: **3** = extremely important, **2** = most important, **1** = important

- To view marine life in its natural environment_____
- For the adventure/fun_____
- Sensation of being underwater________
- Photography____________
- Sharing enjoyment with others________
- For the exercise_________
- Up-date diving skills________________
- Other: please specify_____ _
  ________________________

11) **Have you dived in Barbados before?** Yes ☐ N**o** ☐ **If yes, how many times have you both visited Barbados and dived during that particular stay?______________**

12) **Have you heard of the term Artificial Reef?** Yes ☐ No ☐

13) **Have you ever dived on what you would consider an artificial reef?** Yes ☐ No ☐

14) **From the following list of nine structures which are classified as artificial reefs, which <u>one</u> would you prefer to dive on?**

Cars / Aeroplanes ☐ Concrete Domed Modules (pre-fabricated) ☐ Shipwrecks ☐
Rubber tyres ☐ Piers / jetties / platforms ☐ Sunk Vessels ☐ Breakwalls ☐
Metal frames encrusted with limestone & shaped as rocks ☐ Designer Reefs ☐

15) **In your own words, please could you give your personal description or definition of an artificial reef:**

16) **Have you dived on an artificial reef here in Barbados?** Yes ☐ No ☐

17) **If yes, please state which one(s) and briefly why? (Map of Barbados dive sites located on last page).**

18) **Was your decision to visit Barbados in any way influenced positively by the existence of the group of wrecks situated within the Carlisle Bay Marine Park?**

Yes ☐ No ☐

19) **Have you visited any wrecks within the Carlisle Bay Marine Park?** Yes ☐ No ☐

20) **Please rate your level of satisfaction with the experience of artificial reef diving in Barbados.**

| **5** very satisfied | **4** satisfied | **3** neither satisfied nor dissatisfied | **2** dissatisfied | **1** very dissatisfied |
|---|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ | ☐ |

21) **Have you dived on the artificial reef 'Reef Ball' structures (concrete domed modules), situated off the coast at Worthing?** Yes ☐ No ☐

22) **If yes, would you like to make any comment on this type of artificial reef.**

23) **Is there anything in particular that would improve your 'overall' diving experience on artificial reef diving sites in Barbados?**

24) **In your opinion, how do you rate the following points as being important while diving on an Artificial Reef in Barbados leading to overall enjoyment and satisfaction of diving?** (Please tick one box for each of the 13 points listed).

| | **5** very important | **4** important | **3** average | **2** not so important | **1** not important at all |
|---|---|---|---|---|---|
| Mooring/marker buoys…. | ☐ | ☐ | ☐ | ☐ | ☐ |
| Historic value………….. | ☐ | ☐ | ☐ | ☐ | ☐ |
| Access/location………… | ☐ | ☐ | ☐ | ☐ | ☐ |
| Travel time……………. | ☐ | ☐ | ☐ | ☐ | ☐ |
| Sea visibility…………… | ☐ | ☐ | ☐ | ☐ | ☐ |
| Currents………………… | ☐ | ☐ | ☐ | ☐ | ☐ |
| Coral cover……………. | ☐ | ☐ | ☐ | ☐ | ☐ |
| Fish abundance………… | ☐ | ☐ | ☐ | ☐ | ☐ |
| Water depth…………….. | ☐ | ☐ | ☐ | ☐ | ☐ |
| Size of Artificial Reef….. | ☐ | ☐ | ☐ | ☐ | ☐ |
| Complexity of Reef…….. | ☐ | ☐ | ☐ | ☐ | ☐ |
| Overall Safety…………. | ☐ | ☐ | ☐ | ☐ | ☐ |
| Vivid reef colours……… | ☐ | ☐ | ☐ | ☐ | ☐ |

**Please list any attribute(s) not listed above which in your opinion contributes positively to the enjoyment of your dive_______________________________**

25) Please explain in your own words, drawing from personal experience to answer the following question: **'What makes one type of artificial reef more enjoyable to dive on compared to another artificial reef in Barbados?'**

26) **What is your preferred depth to dive at on an artificial reef (in feet)?**
Less than 30feet ☐ 30-39 ☐ 40-49 ☐ 50-59 ☐ 60-69 ☐ 70-79 ☐
80-89 ☐ 90-99 ☐ 100-110 ☐ more than 110 feet ☐

27) Please read the following 8 statements which refer to artificial reefs as diving sites. Please indicate your level of agreement for each statement using the following scale: **5**=Strongly Agree, **4**=Agree, **3**=Neither Agree or Disagree, **2**=Disagree, **1**=Strongly Disagree.

Artificial reefs are suitable substitute dive sites for natural reefs.__________________
Artificial reefs are a form of underwater visual pollution.________________________
There are currently too many Artificial Reef dive sites in Barbados._______________
Artificial reefs provide new habitats for marine organisms.________________________
An established artificial reef is more interesting to dive than a new artificial reef.____
Artificial reefs attract the type of marine life scuba divers wish to see.______________
Artificial reefs help take diver pressure off natural reefs. ________________________
Artificial reefs are a serious disruption to local marine ecosystems. ________________

28) **Do you perceive diving on an artificial reef to be a nature-based experience?**
Yes ☐ No ☐

29) **Would you agree or disagree that there are aspects of diving on artificial reefs which are more satisfying when compared to diving on natural reefs?**
Agree ☐ Disagree ☐

30**) Please could you explain your response to the above question briefly?**

31) **Given a choice, would you prefer to dive on an artificial reef site or natural reef site in Barbados?**
Artificial Reef ☐ Natural Reef ☐

32) **Please give your reason(s) for your last answer.**

33) **<u>In general</u>, how often do you scuba dive artificial reef sites in Barbados compared to diving on natural reef sites here?**
Less than 10% ☐ 11% -30% ☐ 31% - 60% ☐ 61% - 90% ☐ Over 90% ☐

34) **How many dives do you plan on doing / or have done <u>on this trip</u>? On:**
Natural Reefs ____________ Artificial Reefs _____________

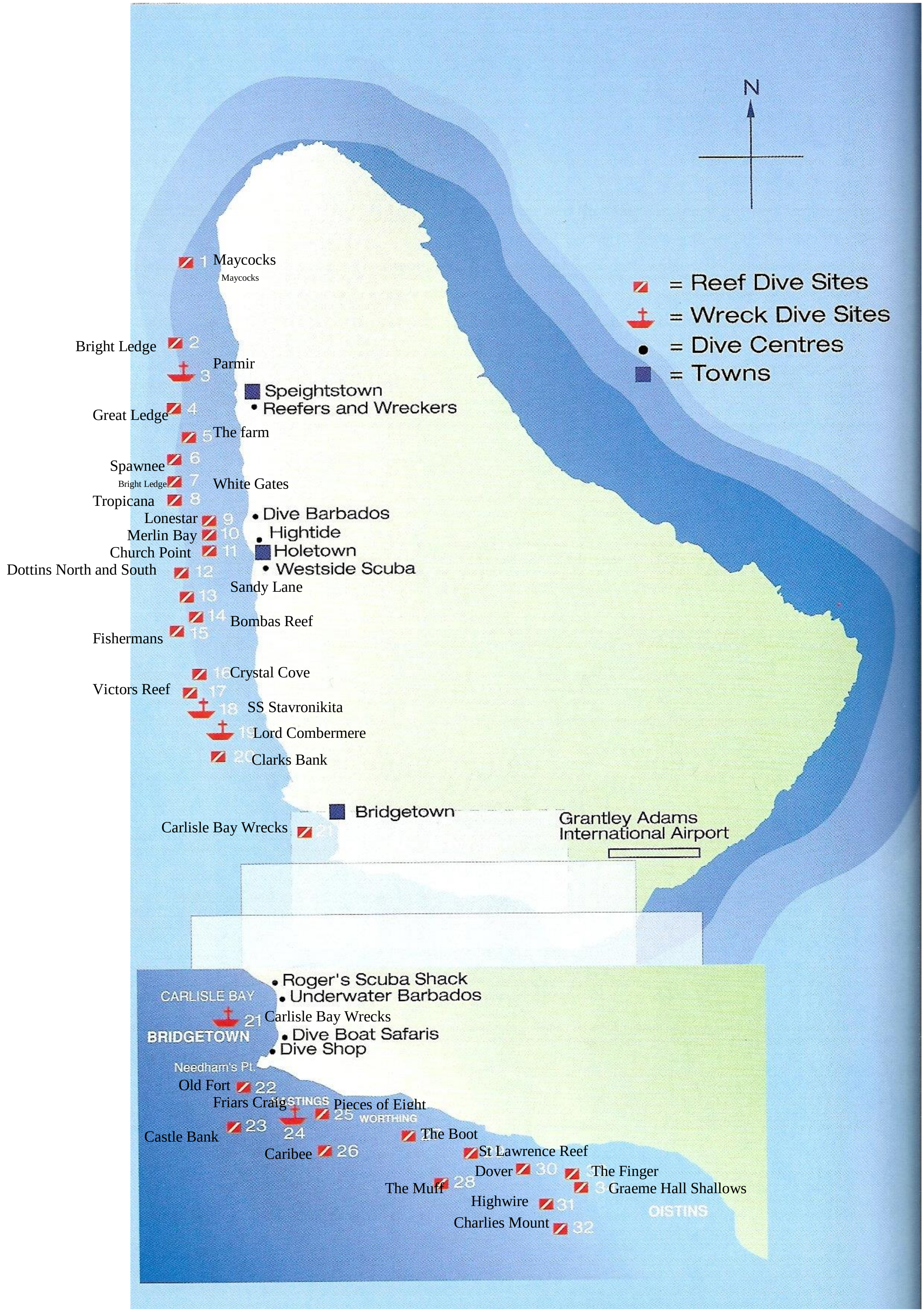
35) **Please name your two favourite <u>artificial reef</u> dive sites and your two favourite <u>natural reef</u> dive sites in Barbados, and briefly say why you favour these. (If you have only visited one, please list it). (Map of dive sites on back page).**

36) Is there anything else you would like to add or comment on?

Please leave your e-mail address if you would like the published results:

***Grateful thanks to you!***

**(Map on reverse side)**


N
= Reef Dive Sites
= Wreck Dive Sites
= Dive Centres
= Towns
1 Maycocks
Maycocks
Bright Ledge 2
3 Parmir
Speightstown
Reefers and Wreckers
Great Ledge 4
5 The farm
Spawnee 6
Bright Ledge 7
White Gates
Tropicana 8
Lonestar 9
Merlin Bay 10
Church Point 11
Dottins North and South 12
Dive Barbados
Hightide
Holetown
Westside Scuba
Sandy Lane
13
14 Bombas Reef
Fishermans 15
16 Crystal Cove
Victors Reef 17
18 SS Stavronikita
19 Lord Combermere
20 Clarks Bank
Bridgetown
Grantley Adams
International Airport
Carlisle Bay Wrecks 21
CARLISLE BAY
Roger's Scuba Shack
Underwater Barbados
21 Carlisle Bay Wrecks
BRIDGETOWN
Dive Boat Safaris
Dive Shop
Needham's Pt.
Old Fort 22
Friars Craig
HASTINGS
Pieces of Eight 25
WORTHING
Castle Bank 23
24
The Boot
Caribee 26
St Lawrence Reef
Dover 30
The Finger
The Muff 28
Graeme Hall Shallows
Highwire 31
OISTINS
Charlies Mount 32

## Appendix B

**Questionnaire Assessment Sheet**

To help ensure this questionnaire is effective in meeting its aim of gathering information on scuba divers attitudes, opinions and preferences relating to artificial reefs as diving resources, I would greatly appreciate your time to answer these important questions:

1) Do respondents have any suggestions relating to either the **addition** or **deletion** of questions?

2) Please indicate if there are any questions that you do not understand and you feel need re-wording. Please put down your suggestions.

3) Do you consider the questionnaire needs a change in the sequence of questions and any improvements in overall format?

4) Would you consider the questionnaire 'user friendly' to complete and not too exhaustive? Please comment.

5) Do you clearly understand the objectives of the questionnaire study?

***Many thanks for your participation in this important research!***

## Appendix C

**NATURAL REEF DIVE**

| Survey No |
|---|
| |

Please tell me first, a few details about yourself:

**1.** Age____________ **2.** Male or Female (Please circle)

**3.** How many dives approximately, have you logged in your total dive history? ________________

**4.** Name of Natural Reef you have dived on_______________________________________________

**5. To measure the enjoyment of your dive on a natural reef, please mark a vertical line anywhere along each of the twenty four 'enjoyment lines' to tell me how much each one of the 24 attributes listed contributed to your overall enjoyment on this dive.**
**0% = no enjoyment/satisfaction → up to 100% maximum enjoyment/satisfaction.**

| | | | | | |
|---|---|---|---|---|---|
| Large fish | 0% | 25% | 50% | 75% | 100% |
| Water depth | 0% | 25% | 50% | 75% | 100% |
| Numbers of fish | 0% | 25% | 50% | 75% | 100% |
| Location/travel time | 0% | 25% | 50% | 75% | 100% |
| Overall safety | 0% | 25% | 50% | 75% | 100% |
| Sea visibility | 0% | 25% | 50% | 75% | 100% |
| Up-dating diving skills | 0% | 25% | 50% | 75% | 100% |
| Unusual/rare species | 0% | 25% | 50% | 75% | 100% |
| New experiences | 0% | 25% | 50% | 75% | 100% |
| Access to reef | 0% | 25% | 50% | 75% | 100% |
| Photography | 0% | 25% | 50% | 75% | 100% |
| A good buddy | 0% | 25% | 50% | 75% | 100% |
| Variety of corals | 0% | 25% | 50% | 75% | 100% |
| Numbers of divers | 0% | 25% | 50% | 75% | 100% |
| Warm water | 0% | 25% | 50% | 75% | 100% |
| Topography of dive site | 0% | 25% | 50% | 75% | 100% |
| Underwater sensation | 0% | 25% | 50% | 75% | 100% |
| Diversity of fish species | 0% | 25% | 50% | 75% | 100% |
| Challenge of dive | 0% | 25% | 50% | 75% | 100% |
| Coral cover | 0% | 25% | 50% | 75% | 100% |
| Equipment | 0% | 25% | 50% | 75% | 100% |
| Sharing enjoyment | 0% | 25% | 50% | 75% | 100% |
| New species | 0% | 25% | 50% | 75% | 100% |
| Currents | 0% | 25% | 50% | 75% | 100% |

# WRECK / ARTIFICIAL REEF DIVE

Survey No

Please tell me first, a few details about yourself:

**1.** Age____________ **2.** Male or Female (Please circle)

**3.** How many dives approximately, have you logged in your total dive history? ________________

**4.** Name of Wreck/Artificial Reef you have dived on______________________________________

**5. To measure the enjoyment of your dive on an artificial reef, please mark a vertical line anywhere along each of the twenty four 'enjoyment lines' to tell me how much each one of the 24 attributes listed contributed to your overall enjoyment on this dive.**
**0% = no enjoyment/satisfaction → up to 100% maximum enjoyment/satisfaction.**

| | | | | | |
|---|---|---|---|---|---|
| Large fish | 0% | 25% | 50% | 75% | 100% |
| Water depth | 0% | 25% | 50% | 75% | 100% |
| Numbers of fish | 0% | 25% | 50% | 75% | 100% |
| Location/travel time | 0% | 25% | 50% | 75% | 100% |
| Overall safety | 0% | 25% | 50% | 75% | 100% |
| Sea visibility | 0% | 25% | 50% | 75% | 100% |
| Up-dating diving skills | 0% | 25% | 50% | 75% | 100% |
| Unusual/rare species | 0% | 25% | 50% | 75% | 100% |
| New experiences | 0% | 25% | 50% | 75% | 100% |
| Access to reef | 0% | 25% | 50% | 75% | 100% |
| Photography | 0% | 25% | 50% | 75% | 100% |
| A good buddy | 0% | 25% | 50% | 75% | 100% |
| Variety of corals | 0% | 25% | 50% | 75% | 100% |
| Numbers of divers | 0% | 25% | 50% | 75% | 100% |
| Warm water | 0% | 25% | 50% | 75% | 100% |
| Topography of dive site | 0% | 25% | 50% | 75% | 100% |
| Underwater sensation | 0% | 25% | 50% | 75% | 100% |
| Diversity of fish species | 0% | 25% | 50% | 75% | 100% |
| Challenge of dive | 0% | 25% | 50% | 75% | 100% |
| Coral cover | 0% | 25% | 50% | 75% | 100% |
| Equipment | 0% | 25% | 50% | 75% | 100% |
| Sharing enjoyment | 0% | 25% | 50% | 75% | 100% |
| New species | 0% | 25% | 50% | 75% | 100% |
| Currents | 0% | 25% | 50% | 75% | 100% |

***Grateful thanks to you for participating in this PhD research!***

## Appendix D

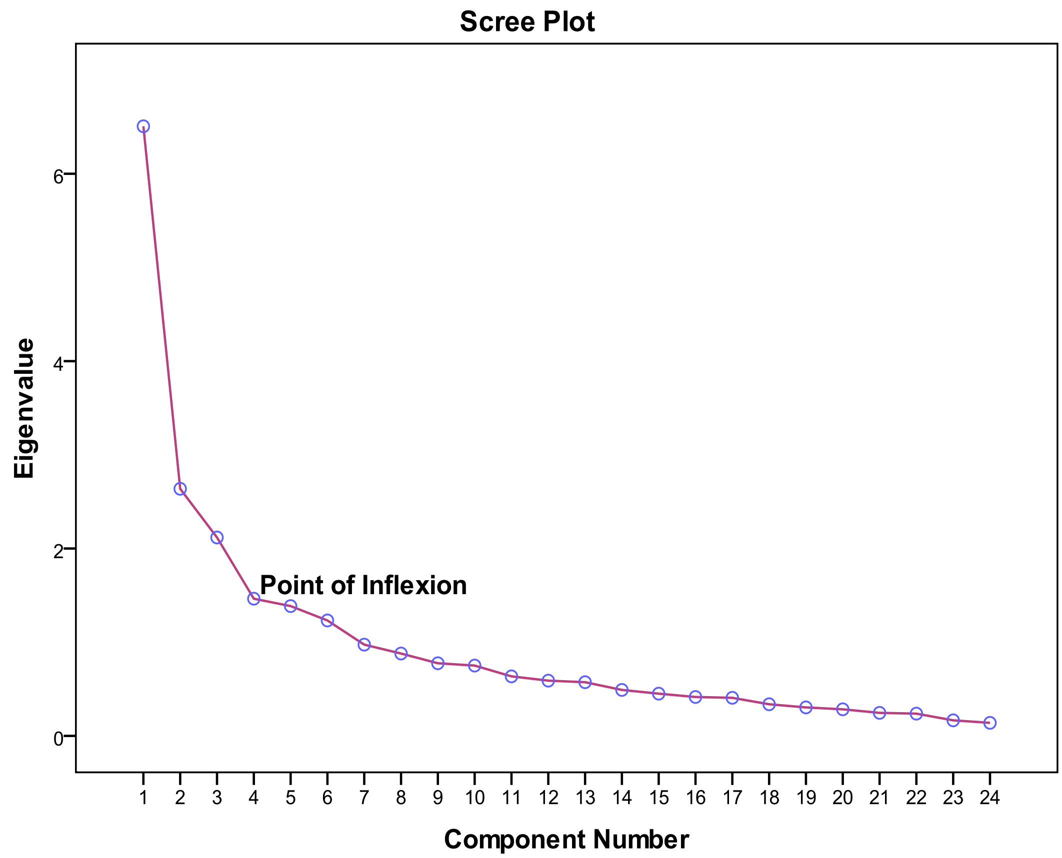



**Figure 1.D** Scree plot for 24 dive attributes showing inflexion occurring between the third and fourth components.

**Table 1.D** Comparison of eigenvalues from principal component analysis (PCA) and criterion values from parallel analysis.

| Component number | Actual eigenvalue from PCA | *Criterion value from parallel analysis | Decision |
|---|---|---|---|
| 1 | 6.507 | 1.9137 | Accept |
| 2 | 2.637 | 1.7571 | Accept |
| 3 | 2.118 | 1.6377 | Accept |
| 4 | 1.464 | 1.5382 | Reject |
| 5 | 1.386 | 1.4474 | Reject |
| 6 | 1.232 | 1.3677 | Reject |

***Note**: criterion values generated from 24 variables x 120 cases.

**Table 2.D** Component matrix listing - un-rotated loadings for 24 dive attributes.

**Component Matrix[a]**

| Dive attribute | Component | | |
|---|---|---|---|
| | 1 | 2 | 3 |
| overall safety | .751 | .088 | -.155 |
| sharing enjoyment | .740 | .174 | .084 |
| access to reef | .740 | .022 | -.028 |
| diversity of fish species | .683 | -.510 | .017 |
| good buddy | .622 | .061 | .022 |
| coral cover | .599 | -.274 | .061 |
| variety of corals | .582 | -.489 | -.176 |
| warm water | .581 | .220 | -.288 |
| numbers of fish | .559 | -.478 | -.106 |
| underwater sensation | .559 | .333 | -.293 |
| location travel time | .506 | .287 | -.163 |
| topography of reef site | .483 | -.005 | -.432 |
| equipment | .479 | .366 | .349 |
| sea visibility | .457 | .110 | -.113 |
| numbers of divers | .449 | .161 | -.335 |
| currents | .388 | .153 | .113 |
| challenge of dive | .202 | .479 | .348 |
| water depth | .440 | .478 | -.290 |
| photography | .293 | -.391 | -.153 |
| updating diving skills | .227 | .526 | .562 |
| new experiences | .510 | .216 | .538 |
| unusual rare species | .450 | -.402 | .506 |
| new species | .406 | -.460 | .485 |
| large fish | .237 | -.219 | .271 |

Extraction Method: Principal Component Analysis.

a. 3 components extracted.

## Appendix E

| Date: |
|---|
| Time: |
| Location: |

UNIVERSITY OF Hull

| Survey No. |
|---|

**Visitor Survey (AR) for snorkellers and divers recreating in Folkestone Marine Reserve, Barbados**

*Hello, my name is ___________. I am conducting research on the use of artificial coral reefs and their role in coral reef conservation here in Barbados. I would be most grateful if you would participate in this important survey by answering a few questions that should take 10-15 minutes. Your answers are greatly valued and will* ***remain anonymous and confidential****. Would you be able to help me please?*

*First, I will ask you a few details about yourself;*

**1. Demographic information and your holiday.**

Country of residence?________________________

Age? _____________________________________

Gender? 1 MALE ☐ 2 FEMALE ☐

In total, how many years have you spent in education (at school, college, university etc.)? ____________

How many times have you visited Barbados, including this visit? ________________________________

How many nights will you spend on the island on this trip? ____________________________________

**2. Marine recreation participation.**

Do you snorkel? 1 YES ☐ 2 NO ☐

If yes, are you: Very experienced ☐ Experienced ☐ Average ☐ Poor ☐ Very poor ☐

Do you scuba dive? 1 YES ☐ 2 NO ☐

If yes, how many dives have you logged to date? ____________________________________________

Before this trip, have you ever been given a snorkelling or diving briefing? 1 YES ☐ 2 NO ☐

In general, how satisfied have you been with your snorkelling and/or diving experience here on the island?

| | very satisfied | satisfied | neither satisfied nor dissatisfied | dissatisfied | very dissatisfied |
|---|---|---|---|---|---|
| Snorkelling | ☐ | ☐ | ☐ | ☐ | ☐ |
| Diving | ☐ | ☐ | ☐ | ☐ | ☐ |

What marine activities have you undertaken during your visit to Barbados? Please tick all that apply.

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Snorkelling | ☐ | Swimming | ☐ | Relaxing on the beach | ☐ | Scuba diving | ☐ |
| Jet skiing | ☐ | Surfing | ☐ | Fish feeding/viewing | ☐ | Boating/kayaking | ☐ |
| Fishing | ☐ | Glass-bottom boat trip | ☐ | Other, please specify ________________________ | | | |

**3. Folkestone Marine Reserve and valuation scenario.**

I will now give you some information about the marine reserve you are recreating in today.

***Visitor Valuation Script for Folkestone Marine Reserve, Barbados.***

Folkestone Marine Reserve is the only marine protected area in Barbados (show map). These protected waters contain a large biodiversity of corals, fishes and turtles that visitors may view and enjoy at many of the excellent dive and snorkel sites. However, like many coral reefs worldwide, these reefs are under pressure from a variety of sources, and need active conservation and management to maintain their beauty and diversity.

Efforts are in place to manage the reserve and protect its tropical species, including the creation of better tourist facilities at Folkestone Park (show map), education schemes for local and overseas visitors, plans to deploy artificial reefs, and the management of fisheries. All these management efforts require funding. For example; funds for coral reef protection programmes and for reef monitoring by scientists. However current funding is limited, and future funding for Folkestone Marine Reserve is unclear. I am now going to present a scenario to you about the marine reserve. If you have any questions about what I read, please go ahead and ask them. Please be assured I am not selling anything, nor collecting donations. I only seek your opinions.
[Ask valuation question].

***Folkestone Marine Reserve – Artificial Reef (AR) Scenario.***

Today, no entrance fee to visit the coral reefs and marine species within Folkestone Marine Reserve is paid by you as a visitor. All funding to conserve the reefs here is sourced elsewhere. There is a proposal to develop one or more artificial reefs within the reserve for both snorkelling and diving (show map and explain). An entrance fee into the reserve (held in a trust fund) would be used to help manage and maintain the artificial reefs within this protected area. With this in mind, I am going to show you a set of numbers in US dollars. Please consider your total trip costs for this visit and tell me; what is the maximum you would be willing to pay ‘over and above your present trip costs’ as a **daily entrance fee to recreate in Folkestone Marine Reserve**?

[Present cards and circle one] US$ 0, 2, 5, 8, 10, 15, 20, 25, 30, 40, 50, 60 or more_____?

If you **did not place a bid value**, or **did not answer** the last question, please go to the question marked with an * and proceed with the remainder of the survey.

If you **did place a bid value** to the last question, please tell me the letter that best explains your reason for doing so, and I will circle it. If you feel there is more than one reason, I will circle it and write next to the reason its order of importance, where 1 is 'most important', 2 is 'important', etc.

A. It gives me genuine pleasure to contribute towards reef conservation.

B. I believe reef conservation is important to help preserve coral reefs for future generations.

C. I feel artificial reefs are an effective method of conserving natural reefs from snorkeller/diver impacts.

D. I intend to visit the reefs within Folkestone Marine Reserve in the future, and wish to help conserve them.

E. I wish to contribute towards the management activities of the reserve, even though I may not visit again.

F. I feel it is a moral duty to contribute towards this good cause.   G. Other (please explain) ___________

Additionally, if you **did place a bid value**, would you have any concerns relating to the use of the money collected for reef conservation within the reserve?   1 YES ☐   2 NO ☐

If yes, please could you briefly explain those concerns? ________________________________________

________________________________________________________________________________

In your opinion, who is the most appropriate authority to administer park fees for reef conservation in Folkstone Marine Reserve? (Please circle **one** letter).

A. Non Governmental Organization (NGO) Charity   C. Public Sector (Commercial)

B. Government of Barbados   D. Other _________________________

What would you most want money raised to be used for? (please circle): scientific monitoring, children's outreach programmes, reserve patrols, recreational artificial reefs, tourist facilities, marine education, other:_________________________________________________________________________

*If you gave a **zero dollar bid** or **did not give an answer** to the valuation question, please tell me the letter that best explains your reasons for doing so, and I will circle it. If you feel there is more than one reason, I will circle it and write next to the reason its order of relevance, where 1 is 'the most relevant reason', 2 is 'less relevant', etc.

A. Reef conservation is not important to me.

B. I don't understand or like the question.

C. I do not believe my money would make any difference to the condition of the reefs.

D. I do not have confidence in a trust fund to look after my donation.

E. I do not like artificial reefs and prefer natural coral reefs.

F. It is not my responsibility to fund conservation efforts in Barbados.

G. I do not believe in being charged to access Folkestone Marine Reserve.

H. I am unsure the money would be spent on reef conservation in Folkestone Marine Reserve.

I. I already pay too may taxes on my holiday. J. Other (please explain) ___________________________

**4. Perceptions of artificial reefs and reef conservation.**

Have you heard of the term 'artificial reef'? 1YES ☐ 2 NO ☐

Have you snorkelled or dived on an artificial reef including a wreck? 1YES ☐ 2 NO ☐

If yes, how would you please rate the experience?

| | very good | good | average | not so good | poor |
|---|---|---|---|---|---|
| Snorkelling | ☐ | ☐ | ☐ | ☐ | ☐ |
| Diving | ☐ | ☐ | ☐ | ☐ | ☐ |

Was the artificial reef(s) in Barbados? 1YES ☐ 2 NO ☐

If the answer was yes, please tell me the location(s)? ___________________________________________

_____________________________________________________________________________

There is a plan to build one or more artificial reefs within the reserve for snorkellers and scuba divers. I am going to show you 3 photographs of different artificial reefs. Please can you tell me what type of artificial reef (if any) you would you like to see in Folkestone Marine Reserve? Please rate in order of preference where 1 is the most preferred, 2 is the next preferred, and 3 is the least preferred.

Reef Ball™ Snorkel Trail ☐ Underwater Art Sculptures (dive & snorkel site) ☐

Shipwreck Dive Site ☐ None ☐

If your answer was **none** to the last question, please can you give me a reason why? _________________

_____________________________________________________________________________

Would the creation of artificial reefs in Folkestone Marine Reserve encourage you to visit this reserve again?

1 YES ☐ 2 NO ☐ 3 UNSURE ☐

Are you a member of an environmental group? 1YES ☐ 2 NO ☐

Do you read or watch on TV, topics about marine life and marine conservation? 1 YES ☐ 2 NO ☐

Please rate your environmental concern about coral reefs and the marine environment, with 1 being the least concerned and 10 being the most concerned_____________________________________________

**5. Experience of Folkestone Marine Reserve.**

Have you been on a catamaran cruise to Folkestone Marine Reserve before? 1YES ☐ 2 NO ☐

If yes, how many times? _________________________________________________________________

Did you snorkel? 1 YES ☐ 2 NO ☐

Have you dived within Folkstone Marine Reserve before? 1YES ☐ 2 NO ☐

If yes approximately how many times? _____________________________________________________

What marine life have you seen today? Please list: ______________________________________________

Now that you have been in Folkestone Marine Reserve today, has your overall experience:

| Exceeded your expectations | Satisfied your expectations | Made no difference | Not satisfied your expectations |
|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ |

Do you expect to return to Folkestone Marine Reserve in the future? 1 YES ☐ 2 NO ☐

How would you rate the following attributes within the reserve?

| | Very good | Good | Average | Poor | Very poor |
|---|---|---|---|---|---|
| Fish life | ☐ | ☐ | ☐ | ☐ | ☐ |
| Coral life | ☐ | ☐ | ☐ | ☐ | ☐ |
| Quality of seawater | ☐ | ☐ | ☐ | ☐ | ☐ |

**6. Finally, can I ask you about your Tiami Cruise snorkelling experience please?**

In general, how satisfied have you been with your **snorkelling experience** today on your Tiami Cruise?

| Very satisfied | Satisfied | Neither satisfied nor dissatisfied | dissatisfied | very dissatisfied |
|---|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ | ☐ |

Please can you tell me the **most** enjoyable bit about your snorkelling today? ________________________

________________________________________________________________________________________

Please can you tell me the **least** enjoyable bit about your snorkelling today? ________________________

________________________________________________________________________________________

In order to improve Tiami's snorkelling experience for future guests, please suggest **any** improvements:

________________________________________________________________________________________

________________________________________________________________________________________

Is there anything else you would like to add about your trip today? ________________________________

________________________________________________________________________________________

## Many Thanks!

If you would like to see the results of this survey, please leave your email address with me. It will remain confidential and will be kept in a separate file away from your completed survey. After use, I will destroy it.

************************************************************************************

**For surveyor:** Time survey completed ____________ Weather/sea conditions today ________________

| Date: |
|---|
| Time: |
| Location: |

| Survey No. |
|---|
| |

**Visitor Survey (NR) for snorkellers and divers recreating in Folkestone Marine Reserve, Barbados**

*Hello, my name is ___________. I am conducting research on the use of artificial coral reefs and their role in coral reef conservation here in Barbados. I would be most grateful if you would participate in this important survey by answering a few questions that should take 10-15 minutes. Your answers are greatly valued and will* ***remain anonymous and confidential****. Would you be able to help me please?*

*First, I will ask you a few details about yourself;*

**1. Demographic information and your holiday.**

Country of residence?_________________________

Age? _______________________________________

Gender? 1 MALE ☐ 2 FEMALE ☐

In total, how many years have you spent in education (at school, college, university etc.)? ____________

How many times have you visited Barbados, including this visit? ________________________________

How many nights will you spend on the island on this trip? _____________________________________

**2. Marine recreation participation.**

Do you snorkel? 1 YES ☐ 2 NO ☐

If yes, are you: Very experienced ☐ Experienced ☐ Average ☐ Poor ☐ Very poor ☐

Do you scuba dive? 1 YES ☐ 2 NO ☐

If yes, how many dives have you logged to date? _____________________________________________

Before this trip, have you ever been given a snorkelling or diving briefing? 1 YES ☐ 2 NO ☐

In general, how satisfied have you been with your snorkelling and/or diving experience here on the island?

| | very satisfied | satisfied | neither satisfied nor dissatisfied | dissatisfied | very dissatisfied |
|---|---|---|---|---|---|
| Snorkelling | ☐ | ☐ | ☐ | ☐ | ☐ |
| Diving | ☐ | ☐ | ☐ | ☐ | ☐ |

What marine activities have you undertaken during your visit to Barbados? Please tick all that apply.

| | | | |
|---|---|---|---|
| Snorkelling ☐ | Swimming ☐ | Relaxing on the beach ☐ | Scuba diving ☐ |
| Jet skiing ☐ | Surfing ☐ | Fish feeding/viewing ☐ | Boating/kayaking ☐ |
| Fishing ☐ | Glass-bottom boat trip ☐ | Other, please specify ________________________ | |

**3. Folkestone Marine Reserve and valuation scenario.**

I will now give you some information about the marine reserve you are recreating in today.

## ***Visitor Valuation Script for Folkestone Marine Reserve, Barbados.***

Folkestone Marine Reserve is the only marine protected area in Barbados (show map). These protected waters contain a large biodiversity of corals, fishes and turtles that visitors may view and enjoy at many of the excellent dive and snorkel sites. However, like many coral reefs worldwide, these reefs are under pressure from a variety of sources, and need active conservation and management to maintain their beauty and diversity.

Efforts are in place to manage the reserve and protect its tropical species, including the creation of better tourist facilities at Folkestone Park (show map), education schemes for local and overseas visitors, plans to deploy artificial reefs, and the management of fisheries. All these management efforts require funding. For example; funds for coral reef protection programmes and for reef monitoring by scientists. However current funding is limited, and future funding for Folkestone Marine Reserve is unclear. I am now going to present a scenario to you about the marine reserve. If you have any questions about what I read, please go ahead and ask them. Please be assured I am not selling anything, nor collecting donations. I only seek your opinions.
[Ask valuation question].

## ***Folkestone Marine Reserve – Natural Reef (NR) Scenario.***

Today, no entrance fee to visit the coral reefs and marine species within Folkestone Marine Reserve is paid by you as a visitor. All funding to conserve the reefs here is sourced elsewhere (show map). An entrance fee into the reserve (held in a trust fund) would be used to help manage and conserve the natural coral reefs within this protected area. With this in mind, I am going to show you a set of numbers in US dollars. Please consider your total trip costs for this visit and tell me; what is the maximum you would be willing to pay 'over and above your present trip costs' as a **daily entrance fee to recreate in Folkestone Marine Reserve**?

[Present cards and circle one] US$ 0, 2, 5, 8, 10, 15, 20, 25, 30, 40, 50, 60 or more_____?

If you **did not place a bid value**, or **did not answer** the last question, please go to the question marked with an * and proceed with the remainder of the survey.

If you **did place a bid value** to the last question, please tell me the letter that best explains your reason for doing so, and I will circle it. If you feel there is more than one reason, I will circle it and write next to the reason its order of importance, where 1 is 'most important', 2 is 'important', etc.

A. It gives me genuine pleasure to contribute towards reef conservation.

B. I believe reef conservation is important to help preserve coral reefs for future generations.

C. I intend to visit the reefs within Folkestone Marine Reserve in the future, and wish to help conserve them.

D. I wish to contribute towards the management activities of the reserve, even though I may not visit again.

E. I feel it is a moral duty to contribute towards this good cause.   F. Other (please explain) __________

Additionally, if you **did place a bid value**, would you have any concerns relating to the use of the money collected for reef conservation within the reserve?   1 YES ☐   2 NO ☐

If yes, please could you briefly explain those concerns? ______________________________________

______________________________________________________________________________

In your opinion, who is the most appropriate authority to administer park fees for reef conservation in Folkstone Marine Reserve? (Please circle **one** letter).

A. Non Governmental Organization (NGO) Charity   C. Public Sector (Commercial)

B. Government of Barbados   D. Other _________________________

What would you most want money raised to be used for? (please circle): scientific monitoring, children's outreach programmes, reserve patrols, recreational artificial reefs, tourist facilities, marine education other:_______________________________________________________________

*If you gave a **zero dollar bid** or **did not give an answer** to the valuation question, please tell me the letter that best explains your reasons for doing so, and I will circle it. If you feel there is more than one reason, I will circle it and write next to the reason its order of relevance, where 1 is 'the most relevant reason', 2 is 'less relevant', etc.

A. Reef conservation is not important to me.

B. I don't understand or like the question.

C. I do not believe my money would make any difference to the condition of the reefs.

D. I do not have confidence in a trust fund to look after my donation.

E. I do not like artificial reefs and prefer natural coral reefs.

F. It is not my responsibility to fund conservation efforts in Barbados.

G. I do not believe in being charged to access Folkestone Marine Reserve.

H. I am unsure the money would be spent on reef conservation in Folkestone Marine Reserve.

I. I already pay too may taxes on my holiday. J. Other (please explain) ________________________

**4. Perceptions of artificial reefs and reef conservation.**

Have you heard of the term 'artificial reef'? 1YES ☐ 2 NO ☐

Have you snorkelled or dived on an artificial reef including a wreck? 1YES ☐ 2 NO ☐

If yes, how would you please rate the experience?

| | very good | good | average | not so good | poor |
|---|---|---|---|---|---|
| Snorkelling | ☐ | ☐ | ☐ | ☐ | ☐ |
| Diving | ☐ | ☐ | ☐ | ☐ | ☐ |

Was the artificial reef(s) in Barbados? 1YES ☐ 2 NO ☐

If the answer was yes, please tell me the location(s)? ________________________________________

________________________________________________________________________________

There is a plan to build one or more artificial reefs within the reserve for snorkellers and scuba divers. I am going to show you 3 photographs of different artificial reefs. Please can you tell me what type of artificial reef (if any) you would you like to see in Folkestone Marine Reserve? Please rate in order of preference where 1 is the most preferred, 2 is the next preferred, and 3 is the least preferred.

Reef Ball™ Snorkel Trail ☐ Underwater Art Sculptures (dive & snorkel site) ☐

Shipwreck Dive Site ☐ None ☐

If your answer was **none** to the last question, please can you give me a reason why? _______________

________________________________________________________________________________

Would the creation of artificial reefs in Folkestone Marine Reserve encourage you to visit this reserve again?

1 YES ☐ 2 NO ☐ 3 UNSURE ☐

Are you a member of an environmental group? 1YES ☐ 2 NO ☐

Do you read or watch on TV, topics about marine life and marine conservation? 1 YES ☐ 2 NO ☐

Please rate your environmental concern about coral reefs and the marine environment, with 1 being the least concerned and 10 being the most concerned_____________________________________________

**5. Experience of Folkestone Marine Reserve.**

Have you been on a catamaran cruise to Folkestone Marine Reserve before? 1YES ☐ 2 NO ☐

If yes, how many times? __________________________________________________________

Did you snorkel? 1 YES ☐ 2 NO ☐

Have you dived within Folkstone Marine Reserve before? 1YES ☐ 2 NO ☐

If yes approximately how many times? _____________________________________________

What marine life have you seen today? Please list: ________________________________________

________________________________________________________________________

Now that you have been in Folkestone Marine Reserve today, has your overall experience:

| Exceeded your expectations | Satisfied your expectations | Made no difference | Not satisfied your expectations |
|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ |

Do you expect to return to Folkestone Marine Reserve in the future? 1 YES ☐ 2 NO ☐

How would you rate the following attributes within the reserve?

| | Very good | Good | Average | Poor | Very poor |
|---|---|---|---|---|---|
| Fish life | ☐ | ☐ | ☐ | ☐ | ☐ |
| Coral life | ☐ | ☐ | ☐ | ☐ | ☐ |
| Quality of seawater | ☐ | ☐ | ☐ | ☐ | ☐ |

**6. Finally, can I ask you about your Tiami Cruise snorkelling experience please?**

In general, how satisfied have you been with your **snorkelling experience** today on your Tiami Cruise?

| Very satisfied | Satisfied | Neither satisfied nor dissatisfied | dissatisfied | very dissatisfied |
|---|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ | ☐ |

Please can you tell me the **most** enjoyable bit about your snorkelling today? ______________________

________________________________________________________________________

Please can you tell me the **least** enjoyable bit about your snorkelling today? ______________________

________________________________________________________________________

In order to improve Tiami's snorkelling experience for future guests, please suggest **any** improvements:

________________________________________________________________________

________________________________________________________________________

Is there anything else you would like to add about your trip today? ____________________________

________________________________________________________________________

________________________________________________________________________

## Many Thanks!

If you would like to see the results of this survey, please leave your email address with me. It will remain confidential and will be kept in a separate file away from your completed survey. After use, I will destroy it.

**********************************************************************************

**For surveyor:** Time survey completed ____________ Weather/sea conditions today _______________

## Appendix F

Aerial photograph above of a 5-row Reef Ball™ breakwater structure in Antigua that has gaps and special areas incorporated into the design to accommodate divers and snorkellers, and a standard Reef Ball™ module below, planted with propagated coral fragments. Adult reef squid are displaying mating colours (www.reefball.org).

Images of sunken vessels being inspected by scuba divers and by schools of fishes (www.forbes.com/pictures/ejef45eig/incredible-shipwrecks-around-the-world/).

Underwater sculptures by Jason de Caires-Taylor, deployed in waters off Grenada, Caribbean (top right) and Cancun, Mexico (www.underwatersculpture.com).