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The Role of Biorock Artificial Coral Reefs in the Sustainable Governance of Marine Protected Areas: A Case Study of Pemuteran, Bali.

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For more information on Biorock please visit: www.globalcoral.org

Abstract

Coral reefs are complex, diverse ecosystems that are the storehouses of much of the world's marine biodiversity and the source of many socio-economic benefits (Bell et al., 2006; Yeemin et al., 2006). In recent decades coral reef degradation has occurred due to two broad categories of stress: 1) global scale climate change leading to increased water temperatures and coral 'bleaching' 2) local-scale impacts associated with destructive fishing methods and the overdevelopment of tourism (Yeemin et al., 2006). Consequently, coral reef restoration projects are required to protect the livelihoods of coastal communities in developing tropical countries such as Indonesia. However, the installation of artificial coral reefs can have a variety of secondary benefits for coastal communities that have previously received little attention in the academic literature. This is particularly the case with 'third generation' Biorock artificial reefs that utilise electricity to stimulate the growth of coral (Goreau & Hilbertz, 2008). Drawing on both quantitative and qualitative data, this paper will aim to show that artificial coral reefs are important not only for ecological conservation but also for the broader goals of sustainability: economic and social development. Using the case study of Pemuteran, Bali, it will be argued that artificial coral reefs can significantly contribute to a cooperative framework of coastal resource governance within marine protected areas (MPAs). By satisfying the needs and requirements of a variety of stakeholders, most notably local fishermen and the hotel industry, conflict over resource access can be reduced and tourist revenues increased.

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1.0 Introduction

Coral reefs are threatened worldwide by growing populations, tourism development and rising global temperatures. The convergence of these global pressures with local stressors such as dynamite and potassium cyanide fishing has led to a 'coral-reef crisis'. This has resulted in several problems. When coral reefs die, fish populations disappear due to lack of habitat. Beaches and shorelines are also damaged. Unprotected by breakwaters, fragile land areas become vulnerable to erosion, saltwater intrusion and destruction from waves (Goreau, 2008). This is especially problematic for a country such as Indonesia which consists of 17,500 islands and whose population frequently rely on the sale of fish and marine products to support their families. Indeed, over 60% of Indonesia's population live within coastal areas, many of whom are subsistence fishers (Elliott et al., 2001).

However, despite the severe degradation of Indonesia's coral reefs, national management objectives have tended to emphasise economic development through tourism. This has impacted negatively on host destinations in a number of ways. Firstly, though reef-based tourism is typically less destructive than other activities such as coral mining or dynamite fishing, it still has a largely detrimental effect upon reef ecosystems. This is especially the case if divers and snorkelers are uneducated in the ways of sustainable diving; trampling over large areas of coral or removing pieces for souvenirs. Secondly, tourism development initiatives frequently fail to address the socio-economic and cultural aspects of fisheries management, with the result that they tend to neglect the needs of the local fishing communities (Pomeroy, 1995). This is problematic because the available literature suggests that for effective governance to occur at the local level, the needs of all local stakeholders must be incorporated into the decision making process (Elliott et al., 2001; Cole, 2006). Biorock reefs help arbitrate conflicts between the fishing community and tourist industry by increasing fish numbers whilst simultaneously providing a tourist attraction.

Biorock Ecosystem Restoration Technology (Hilbertz & Goreau, 1996) is the only coral reef restoration method that increases coral growth rates and coral survival from lethal conditions such as high temperatures. It is therefore particularly effective in helping to restore fish habitats. By using low voltage currents, an electrolytic reaction occurs, causing limestone to form. In time, these structures build up and function as effective off shore breakwaters. Furthermore, due to the innovative technology utilised and the interesting appearance of the reefs, tourists have been attracted to them and Biorock has won numerous ecotourism awards. A picture of one of Pemuteran's 50 artificial reefs (the so-called 'Wolf Crown') is shown below:

Fig. 1 (Photograph by Wolf Hilbertz) Wolf Crown

Central to this paper will be the argument that Biorock artificial coral reefs can significantly contribute to the sustainable governance of marine resources by:

1) Increasing coral cover and fish stock for local fisherman.
2) Providing an off-shore breakwater.
3) Providing an ecotourism attraction and so increase tourist revenues.
4) Educating both tourists and local communities regarding the fragility of coral reefs.
5) Facilitating a 'win-win' solution for both the fishing and tourism industry leading to improved communication and cooperation between different stakeholder groups.
6) Implementing the 'precautionary principle'.

2.0 The Study Area – Pemuteran, Bali, Indonesia

Fig. 2 Map of Bali

Pemuteran is located along Bali's north-western coast just beyond the confines of the Bali Barat National Park. Tourists are drawn to Pemuteran's picturesque setting as a small fishing village that has managed to escape the congestion and overdevelopment of the south. The shallow offshore banks nearby have the largest area of coral reef in Bali, offering some of the best dive sites on the island (Goreau & Hilbertz, 2008). The Bali Barat National Park, famous for its diving and nature treks is only 15 minutes away.

Since Pemuteran lies in the most remote corner of Bali away from the tourist entry points of the south, it was the last coastal area to develop tourism. Consequently, the village's culture and traditions remain largely intact (Goreau & Hilbertz, 2001). It is also one of the poorest areas in Bali. Pemuteran is in the shadow of mountains and so gets less rainfall during rainy season. As it is too dry for rice cultivation, the local population has traditionally relied on the sea for both food and income.

However, in 1998 Pemuteran's coral reef fisheries were in crisis due to a combination of destructive overharvesting and El Nino linked to global warming. The 1998 Asian economic crisis resulted in millions of displaced workers and farmers who looked to fishing as a means of survival. In attempts to capitalise on these resources, fishermen turned to bombs and poisons that resulted in

damaging the very source of capital they relied upon: the coral reef ecosystem. Negative economic conditions coincided with damaging environmental weather patterns, namely El Nino which resulted in high ocean temperatures and 'coral bleaching'. This is an extreme stress response which causes the tissues of coral to lose their colour, resulting in starvation, failure to grow or reproduce, and to death of the coral if sufficiently severe (Goreau, 2008). The combination of regional economic stressors combined with global environmental impacts resulted in the near complete collapse of Pemuteran's fisheries in 1998. Photographs taken by Rani E. Morrow-Wuigk clearly document the changes that took place to the reef, from one lushly covered with corals and teeming with life, to barren rubble virtually devoid of fish:

Fig. 3 (Photograph by Rani E. Morrow-Wuigk) Taken From the *Reef Reborn* DVD.)

Fig. 4 (Photograph by Rani E. Morrow-Wuigk) Taken From the *Reef Reborn* DVD.)

The scale of destruction was so great and the use of bombs so prevalent that reef based tourism in Pemuteran became neither desirable nor safe. Valuable revenue from tourism was consequently lost, further increasing the financial strain on the village. The community responded by establishing a marine protected area (MPA) where destructive fishing methods were banned. Methods that were outlawed included dynamite fishing, potassium cyanide (*potas*) fishing (for catching highly priced aquarium fish) and *muro-ami* (drive-net fishing). A no-take zone was established in front of the main hotels such as the Taman Sari and Pondok Sari, though fishermen are still allowed to fish in zones designated toward the east of the bay and beyond:

Fig. 5 Map of North-west Bali

Hotels and dive shops arranged with the village to organise boats and personnel for the village Pecalang Laut (Sea Guardians) to monitor fishing activity and enforce village laws (Goreau & Hilbertz, 2008). If fishermen are found to use banned methods, their boats and equipment are seized and they can receive a jail sentence. Although this is achieved by traditional village (*Adat*) law, Indonesian legal authorities recognise the arrests and prosecute the cases. As a result of the MPA and zoning management, the conditions were in place for the Biorock coral reef restoration project to succeed. Biorock artificial reefs are unique from other artificial reefs in that they use electrical currents to actively grow coral at 3-5 times their normal rate (Goreau & Hilbertz, 2008). Biorock corals are also 16-50 times more resistant to stress than 'normal' corals (Goreau, 2007).

At this juncture, it is perhaps worth noting that it is not the contention of this paper to suggest that the installation of Biorock artificial reefs are in themselves sufficient to ensure the sustainable

governance of marine resources. Indeed, it is vital that certain conditions are in place such as community support, effective zoning and regulation to ensure the long term success of artificial reefs. Yet, with these important preconditions in mind, it will be argued that artificial reefs can improve the governance of marine resources by both accelerating the recovery of fish stocks and acting as an important ecotourism attraction. This is what happened in Pemuteran. In 1998, the Global Coral Reef Alliance, an NGO headed by coral reef scientist and Biorock creator Tom Goreau, began working with local dive operators and hotels to restore the biodiversity of Pemuteran's reefs. As a result of the installation of over half a kilometre of Biorock artificial reefs, coral growth increased, fish populations bounced back and the reefs began attracting tourists. In Pemuteran, the majority of reefs are located approximately 30 metres from the near shore. These reefs are powered by electricity provided by nearby hotels such as the Taman sari. Whilst the artificial reefs themselves are not visible from the shore, some of the cables become exposed at low tide. This is shown in the image below:

Fig. 6 (Photograph by Author) Biorock Cables

Since Tom Goreau's initial work, further artificial reefs utilising Biorock technology have been installed further off shore and are powered by solar panels. Although these newer reefs are managed by a different organisation, the Reef Gardeners, for ease of reference all artificial reefs will be referred to as Biorock for the remainder of this study. Pemuteran has since won Indonesia's most prestigious environmental award, the Kalpataru/ Adiputra Prize, the KONAS Award for best community-based coastal zone management project in Indonesia and the SKAL Award for best Underwater Ecotourism Project in the World (Ibid).

3.0 Literature Review

This paper incorporates a number of theoretical concepts pertaining to issues such as conflicts over common pool resources, governance and sustainable tourism. It also relies on the science of coral reef degradation and potential solutions to this environmental problem, most notably artificial coral reefs and marine protected areas (MPAs). Whilst the literature surrounding these topics is substantial, specific articles relating these issues to Indonesia, and in particular Bali, are more limited. This section will aim to outline the leading literature on each topic thematically before reviewing material that specifically relates to Bali and Pemuteran.

3.1 Governance

Of particular importance to this paper is the concept of governance. Governance is "an organising framework that represents a 'paradigm shift' from science based environmental management by experts towards wider involvement in policy creation and implementation" (Dengler, 2007: 426). Governance is ultimately concerned with creating the conditions for ordered rule and collective action (Stoker, 1998). Whereas government is understood to narrowly refer to the formal and institutional processes which operate at the level of the nation state, governance recognises the legitimate claim of a number of different actors and institutions to be involved in the management process that extend beyond the traditional confines of government. The concept of governance recognises that society is complex, pluralistic, socially unequal, and is comprised of different types of knowledge, experience and communicative rationalities that can be expressed through both formal and informal social networks (Dengler, 2007) The governance of common pool resources such as coral reefs is often problematic because of the range of stakeholder groups with competing interests. These groups frequently do not have either the technology or appropriate institutional mechanisms to govern resources sustainably. Central to this paper will be the argument that Biorock artificial reefs can help facilitate the transition towards the sustainable governance of coastal areas where resource extraction does not exceed the renewal rate and where interaction between different stakeholder groups is characterised by co-operation and collaboration rather than conflict.

The physical features which Pemuteran has traditionally relied upon to generate income (namely its beach and coral reefs) can be characterised as common pool resources. The term common pool resource (CPR) refers to "natural or man-made resource systems that are large enough to make costly the exclusion of potential users from obtaining benefits from its use, and the benefits obtained from its consumption by one individual user are subtractable from those available to other potential

users" (Yetim, 2002: 307). CPRs are not private property but are municipal and so have 'open access'. As such, they are vulnerable to overexploitation, a notion Hardin (1968) refers to as the 'Tragedy of the Commons'. Hardin explains that in the short-term, the individual advantage of over using shared resources is thought of as being greater than the potential long-term shared losses. Hardin provides the classic example of common land with 12 cows, one owned by each of 12 farmers. Each of the farmers would benefit personally from the decision to place an extra cow on the land, and so pursue his own interests, by being able to share the costs of the extra cow (damage to the land, reduction in grass available, etc.) amongst his colleagues. Thus benefits are concentrated, costs are shared and a self interested approach which takes little account of the physical resource is perpetuated (Miller & Twining-Ward, 2005). By 1998, Pemuteran bay had in many ways become a classic 'Tragedy of the Commons': destructive fishing methods were designed to catch maximum yields in the short-term with apparent little regard for the highly detrimental impact they were having on the source of capital, the coral reef ecosystem.

The literature features a number of examples of building collaborative frameworks for common pool resources (Ostrom, 1990; Dengler, 2007). Ostrom (1990) confronts the application of Hardin's 'Tragedy of the Commons' and contends that long-lasting co-operation may be achieved by establishing CPR institutions. Ostrom's research has shown that these institutions should be based on several design principles including the maintenance of clearly defined boundaries, collective choice arrangements allowing for the participation of different stakeholders and conflict resolution mechanisms that are cheap and easy to access (Ostrom, 1990). Incentives and sanctions are also identified by Ostrom, asserting that rational and self-interested actors will respond appropriately to protect the environment. Whilst Dengler's (2007) study of the Everglades was situated within the US and so subject to both US law and socio-cultural systems, it too outlines some of the principles necessary for collaborative environmental governance. Specifically, Dengler highlights three design principles: 1) incorporating multiple ad hoc organisations that involve different types of knowledges; 2) involving wider ranging stakeholders; and 3) the presence of some common good actors who are interested in the achievement of a collaborative agreement serving in leadership roles, rather than allowing actors beholden to furthering individual competing sectional interests to dominate the process (Dengler, 2007: 451). This paper proposes that Biorock technology for artificial coral reefs can greatly aid the transition from a system of governance characterised by Hardin's 'Tragedy of the Commons' to one where collaboration is the defining feature. Providing a number of the design principles outlined by Dengler and Ostrom are implemented, Biorock artificial reefs can facilitate the

sustainable governance of CPRs by helping to meet the requirements and align the interests of different stakeholders.

3.2 Sustainable Development

This study is couched in the concept of sustainable development, a discourse that has arguably come to dominate global development policy since the publication of the Bruntland report in 1987. This defined sustainable development as "development that meets the goals of the present without compromising the ability of future generations to meet their own needs or aspirations" (WCED, 1987: 43). The support for the concept was highlighted by Agenda 21, the 40 chapter action plan, agreed by all nations participating in the 1992 Rio 'Earth Summit' that provided the blue-print for implementing sustainable practices in the 21st century. Whilst Agenda 21 is a huge document that has attracted much commentary, it is important to note that the agreement rests on the assumption that sustainable development can be broken down into three dimensions: environmental, economic and social (Cicin-Sain, 1993; Elkington, 1999). Though recognising that these facets are inextricably linked, they will later serve as the foundational framework to this study.

Whilst a vast amount has been written about sustainable development that is beyond the scope of this research project, Chapter 17 of Agenda 21 is of the utmost relevance to both Bali and Pemuteran. Chapter 17 focuses on two program areas for the sustainable development of coastal areas within small island developing states (SIDS): integrated management and the 'precautionary principle'. It states that the management of coasts and oceans should be "integrated in content and anticipatory in gambit" (Cicin-Sain, 1993: 11). Chapter 17 recognises that the coastal zones of SIDS such as Bali are usually diverse and productive habitats for which these states depend on for their economic development (Griffith & Ashe, 1993). However, in addition, the coastal zones in most SIDS are the location of the vast majority of population and numerous spheres of economic activity including fisheries, tourism development, human settlement and commerce. Coastal management problems are therefore exacerbated and magnified in these areas (Ibid). The reality of these multiple uses thus necessitates a degree of integration between environment and development. As the Bruntlund report states:

> "The world is facing an interlocking crisis...until recently, the planet was a place where human activities and their effects were neatly compartmentalised within nations, within sectors (energy, trade, etc.), and within broad areas of concern (environmental, economic, social). This is no longer tenable..." (WCED, 1987: 4)

By preserving coral reef ecosystems (environment) and attracting tourists (economic) Biorock technology helps to bring the different constituent elements of sustainable development together into one unifying conception.

The second main tenet of Chapter 17 of Agenda 21 addresses the 'precautionary principle' (Cicin-Sain, 1993). This is applied to circumstances "where there are threats of serious or irreversible damage" and where "lack of full scientific certainty should not be used as a reason for postponing cost-effective measures to prevent environmental degradation.' (Principle 15, Agenda 21). The 'precautionary principle' is extremely important to SIDS such as Bali because of their inherent vulnerability to climate change. The small size and limited resources of many SIDS combined with the fact that they tend to rely on their coastal environment as an economic resource means sea level rise associated with global warming poses a serious risk to their continued development (Griffith & Ashe, 1993). Biorock artificial coral reefs implement the 'precautionary principle' in two main ways. Firstly, they act as off-shore breakwaters, protecting the shorelines of SIDS from the worst effects of coastal erosion. Secondly, they act as 'coral arcs', providing coral nurseries. In the event of a catastrophic global coral crisis where the vast majority of coral dies, Biorock reefs would be able to maintain some degree of marine biodiversity because Biorock corals are more resistant to environmental stresses than normal corals (Goreau, 2008). It is, therefore, the contention of this study that Biorock fulfils the two main criteria of Chapter 17 making the sustainable governance of marine resources a more achievable goal.

Another feature of sustainable development that is particularly relevant to Pemuteran is education. The United Nations has dedicated 2005-2014 to be the Decade of Education for Sustainable Development. Education is essential to expand understanding, skills and motivation to shift communities towards sustainable development. The Second World Summit on Sustainable Development (WSSD) convened in Johannesburg in 2002 and recognised that education had the potential to play a fundamental role in the future realisation of a 'vision of sustainability that links economic well-being with respect for cultural diversity, the Earth and its resources' (Little et., 2009: 171). UNESCO stated the overall goal of the Decade of Education for Sustainable Development was to:

> "Integrate values, activities and principles that are inherently linked to sustainable development into all forms of education and learning and help usher in a change in attitudes, behaviour and values to ensure a more sustainable future in social environmental and economic terms" (UNESCO, 2007: 5)

It will be argued that by its very presence, Biorock is an extremely powerful educational tool that raises the awareness of both tourists and the host population regarding coral reef degradation. It will be

suggested Biorock has played a key role in the subsequent change in behaviour that has allowed Pemuteran to shift to a more sustainable system of governance.

3.3 Sustainable Tourism

Sustainable tourism is a sub-branch of sustainable development that is of particular importance to this study. Tourism is the largest single industry in Bali, accounting for nearly 60% of total economic output, generating between US$1-2 billion per year. If Bali's economy is to grow at a steady rate, the imperative to make tourism sustainable thus becomes clear. Sustainable tourism can be defined as "tourism which is economically viable but does not destroy the resources on which the future of tourism will depend, notably the physical environment and the social fabric of the host community" (Swarbrooke, 1999: 13). Sustainable Tourism, however, has been criticised as a concept by numerous commentators. Duffy (2002) has highlighted the unequal power relationships between hosts and guests and has suggested that tourism in whatever guise is frequently responsible for eroding the culture of the host community. Meanwhile, Hall (2001) has commented on the fundamental tension that exists between resource use and conservation. Because sustainable tourism is similar to conventional tourism in that it relies upon a certain degree of profitability to ensure its long term viability, many areas have emphasised development at the expense of environmental protection (Fennel, 1999; Hall, 2001). Biorock artificial reefs help to circumnavigate this problem by providing a tourist attraction whilst simultaneously restoring the marine environment. It is with regards to this point that it is perhaps useful to invoke the ideas of Muller (1994). Muller produced a pentagon to explain diagrammatically what he saw as the five main components of sustainable tourism: unspoilt nature, healthy culture, a high degree of subjective well-being, optimum satisfaction of guest requirements and economic health:

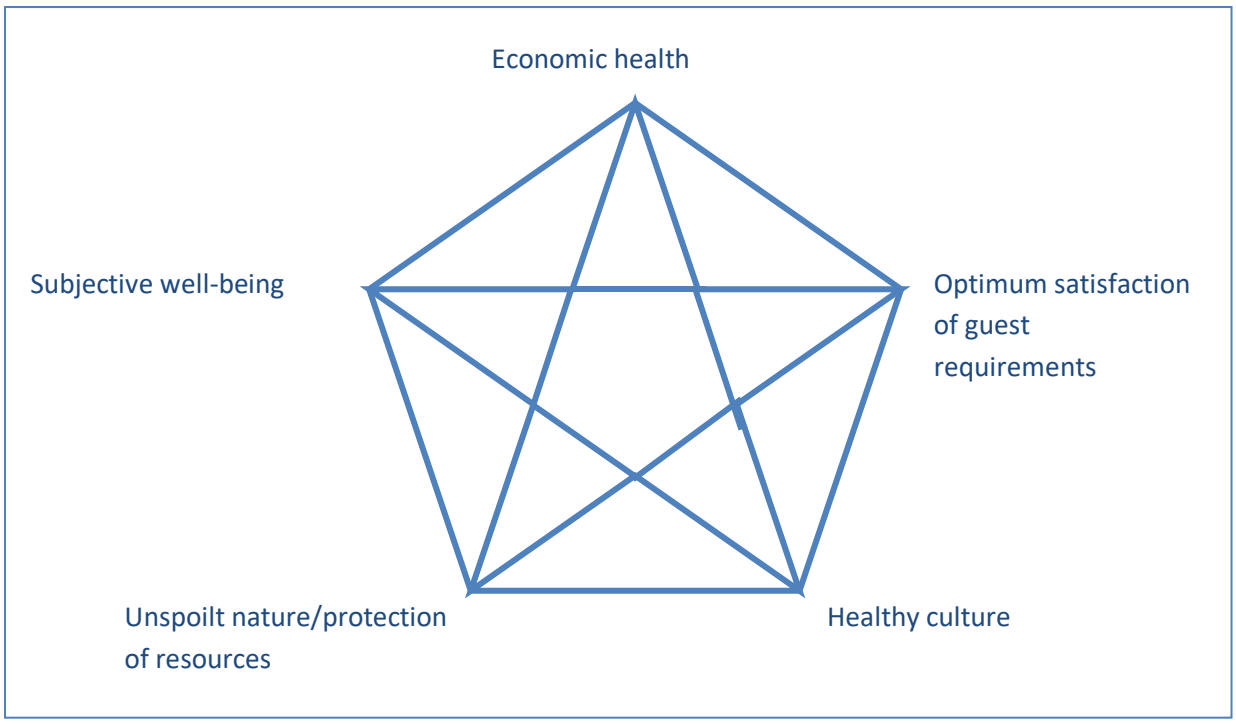

Fig. 7 Muller's Magic Pentagon

For Muller, the "target situation is balanced tourism development" and "...establishing harmony in this magic pentagon to maximise the positive relationships between all the factors" (Muller, 1994: 362). By satisfying a number of Muller's criteria, most notably economic health and protection of resources, Biorock reefs help create the conditions for a healthy equilibrium to emerge, essential for the sustainable governance of coastal areas.

However, it is important to note that for sustainable tourism to be successful, local community participation is essential (Cole, 2006, Stoker, 1998). Indeed, perhaps the main weakness to Muller's argument is the pursuit of balance ignores the host population. Hence, stakeholder theory has come to be used to promote collaboration and empowerment amongst the key players in the planning process (Miller & Twining-Ward, 2005). Bramwell and Sharmann (1999) report that a stakeholder driven approach can help avoid conflicts, resulting in policies that are more politically legitimate. Greiner & Walker (1999: 6) also comment on the intrinsic benefits of this approach: "In addition to effecting learning, stakeholder participation also builds ownership of the problems and solutions and therefore the research."Marien & Pizam (1997: 165) comment: "Sustainable tourism cannot be successfully implemented without the direct support and involvement of those who are affected by it." Clearly, then, local community participation is considered an essential step to ensure sustainable tourism development. It is for this reason that the implementation of artificial coral reefs are in themselves insufficient to ensure the sustainable governance of marine resources. Whilst it is the contention of this paper that Biorock technology can significantly improve the management of coastal

areas, this is subject to certain conditions, namely community involvement which is a prerequisite for a successful reef restoration programme. The indispensability of the host population is something that has been realised by the Global Coral Reef Alliance (GCRA), the NGO primarily responsible for the implementation of Biorock artificial reefs in Pemuteran. GCRA has trained local community members to provide the necessary maintenance to the reefs. As has been pointed out by Cole (2006), knowledge transfer is a vital initial step towards facilitating the empowerment of the local people to participate in both new technology and the planning of tourism to ensure its sustainability.

3.4 Marine Protected Areas (MPAs)

In response to the severe decline of coastal resources, marine protected areas (MPAs) have been widely adopted as a leading tool for coral reef conservation (McClanahan et al., 2006). An MPA is defined by the World Conservation Union (IUCN) as 'any area of intertidal or subtidal terrain, together with its overlying water and associated flora, fauna, historical and cultural features, which has been reserved by law or other effective means to protect part or all of the enclosed environment" (Eagles & McCool, 2002: 212). Generally, MPAs assume one of two management structures: centralised top down or community bottom-up management. When imposed by central government and outside agencies, local long-term management concerns are often overridden or ignored (Goreau & Hilbertz, 2008). Local communities are expected to comply with new external regulations, even if the regulations have an undesirable effect on their livelihood. This approach can result in conflicts over resource use and discourage local support for the MPA (Elliott et al., 2001).

Fisheries experts now recognise that resource conflicts can be decreased and resources better managed when fishers and other resource stakeholders are more involved in the management of marine reserves (Pomeroy, 2005). Community marine protected areas (CMPAs) aim to incorporate a number of partners where stakeholder participation is the norm and resources are managed on a holistic level. Whereas centralised top down MPAs tend to focus on purely ecological conservation, community MPAs incorporate social and economic considerations into their management structure (McClanahan et al., 2006). Indeed, CMPAs often rely on a model of Integrated Coastal Zone Management (ICZM) as outlined in the 1992 Rio Earth Summit. The European Commission states that the "primary role of the ICZM is to integrate economic, social cultural and recreational objectives so that conflicts amongst stakeholders living in a natural resource environment characterised by common property can be arbitrated" (Forst, 2009: 294). Management regimes that are designed to meet both economic and social community goals can achieve greater compliance and subsequent conservation success than regimes designed primarily for biodiversity conservation (Ibid). Given that Biorock

artificial coral reefs can fulfil a number of functions aside from ecological conservation including increasing tourism revenue and fish stocks, it will be argued that artificial coral reefs can act as a unifying force between different stakeholder groups. Essentially as a technology, they are capable of helping to integrate the ecological, social and economic spheres and so greatly compliment models of integrated coastal management so regularly seen in MPAs.

3.5 Coral Reefs and Coral Morbidity

As previously discussed coral reefs yield multiple benefits: they protect coastlines from erosion and shore damage, provide habitats to tens of thousands of fish and form an important role in cycling nutrients from the land to the open sea (Eagles & McCool, 2000). Nearly a third of all fish species live on coral reefs, leading Salm to state that 'coral reefs are self-perpetuating fish farms which produce high quality protein from essentially empty sea water" (Eagles & McCool: 215). However, these valuable and highly unique ecosystems are under extreme pressure and disappearing at an alarming rate. Although Indonesia still has the largest area of coral reef and highest marine biodiversity in the world (UNEP, 2001) these resources are now severely threatened. According to the Indonesian Institute of Science (LIPI), only 7% of Indonesia's reefs remain in good condition, 30% have vanished and the rest remain in critical condition (Republic of Indonesian Department of Foreign affairs, 1995). The reasons as to why coral reefs are declining worldwide are well established. Local impacts include: excess sediment delivered through rivers (from extensive land clearing for development); pollution from land, particularly excess nutrients from untreated sewage; anchor damage; and overuse through unsustainable tourism activities (Wilkinson et al., 2006). However, the most serious damage from local activity in Indonesia tends to occur as a result of destructive fishing methods including dynamite fishing and potassium cyanide fishing for catching and stunning valuable aquarium fish.

Global scale impacts include widespread coral bleaching from increased sea temperatures, linked with El Nino Southern Oscillation and global warming (Ibid). High ocean temperatures cause corals to turn white ('bleach') resulting in heat shock and death if sufficiently severe. Worryingly, corals are already towards the upper threshold of their temperature limits and it is doubtful that they will be able to survive a further global warming of one degree Celsius (IPCC, 2007). In view of the fact that the IPCC predicts global average temperatures to rise between 1 and 4 degrees Celsius in the next 30-50 years, urgent action is required. It is this fact that has no doubt prompted the Editorial of the Marine Pollution Bulletin to state: "...the time for identifying the problem of global reef decline is over and needs to be urgently replaced by an era of science and management to mitigate this" (editorial, 2005: 481).

3.6 Conventional Vs. Biorock Artificial Reefs

Conventional artificial coral reefs can be made from a number of materials including concrete rip-rap, sunken ships, tyres, natural stone, bricks and various other materials. However, these installations frequently fail to generate a typical coral reef community, the organisms being largely 'weedy' like stinging hydroids, sponges and fire coral (Goreau, 2008). Indeed, some artificial coral reefs perform so poorly that they are toxic to marine life and have to be removed at great expense. This was the case with artificial rubber tire reefs that Broward County, Florida had misguidedly installed many years previously (Ibid).

Biorock artificial reefs are unique in that they use a process called 'mineral accretion' to artificially grow coral. Developed by architect Wolf Hilbertz and marine scientist Tom Goreau, Biorock technology applies low voltage (above 1.2 volts) to a metallic structure to cause limestone to crystallize on the surface, to which coral can attach and grow. Mineral accretion causes the structures themselves to grow at a rate of up to 10 millimetres per year and corals that are transplanted onto them develop at accelerated rates 3-5 times faster than normal (Goreau & Hilbertz, 2008). Unlike conventional artificial reefs, all components of a natural coral reef migrate to them, creating the utility of a typical reef ecosystem. Moreover, by providing the optimal conditions for coral growth (namely high pH), Biorock corals are 16-50 times more resistant to physical stresses such as high ocean temperatures (Goreau, 2008). In the Maldives, during the 1998 warming, fewer than 5% of the natural reef corals survived. On Biorock reefs, however, over 80% of the corals survived (Goreau & Hilbertz, 2005).

Mineral accretion works by establishing a direct electrical current between an anode (-) and a cathode (+). The electrical current causes calcium and magnesium minerals dissolved in sea water to crystallize, forming calcium carbonate ($CaCO_3$) and magnesium hydroxide, $Mg(OH)_2$ (Hilbertz, 1979). When a positively charged anode and a negatively charged cathode are suspended in sea water with an electric current flowing between them, calcium ions combine with calcium ions to form CaCO3. This electrolytic reaction results in a hard composite of limestone and brucite with mechanical strength similar to concrete (Goreau, 2002). As a result, the structures do not rust or corrode but actively self-repair over time providing the electrical current continues to flow. They consequently offer very good shore protection as they are not so liable to collapse or damage as conventional offshore breakwaters composed of concrete or sandbags. Biorock coral reefs are also examples of the precautionary principle in action. By providing 'coral arcs' that are more resistant to stress than normal

corals, they ensure that some semblance of marine biodiversity will be maintained in the event of a catastrophic warming event.

4.0 Methodology

Analysis is based upon the data collected through the following triangulated methods: (1) semi-structural interviews, (2) questionnaires, and (3) archival research. Triangulation methods of data collection are advantageous in that they allow a mix of quantitative and qualitative data within the same dynamic model to be utilised. This allows findings to be validated and this is considered increasingly necessary to address problems of social and environmental importance (Petterson et al., 2004). Field data was collected during a five week period spanning the months June and July, 2009. A variety of stakeholder groups were consulted including local fisherman, hotel managers and dive schools as well Western ex-pats who had played a prominent role in the implementation of Biorock technology in Pemuteran. Each method of data collection will now be outlined and evaluated sequentially.

Interviewees were originally identified as a result of their public involvement in the reef restoration project, having been acknowledged on the GCRA website, *Reef Reborn* documentary or other printed media coverage. Once interviewing began and a network of key individuals had been established, a 'snowball' sample strategy was implemented. This is a process where the respondents identify other potential participants and this is especially productive in Southeast Asia where contact via means of personal introduction is customary (Sausmarez, 2007). This data gathering strategy resulted in a total of 8 interviews and one focus group involving multiple stakeholders. In 3 of the interviews, an interpreter was required. Whilst care was taken to clarify points to avoid misunderstandings, it must be duly noted a degree of meaning and nuance was inevitably lost. All interviewees agreed to be recorded and their statements attributed to their names, though some requested the digital recorder to be turned off at certain times or some comments to remain anonymous. The principle technique used to analyse the data gained from interviews was open coding. This involved identifying key themes and then collating the frequency during which certain words or themes occurred in an interview or focus group. This technique enables the data to be analysed and grounded within the context of the research (Strauss & Corbin, 1990; Spiker, 2008).

In order to explore power dynamics between different stakeholder groups, it was considered important to incorporate qualitative methods of data collection such as interviews into this research. This is because of the inherent difficulty in quantifying social systems. Miller & Twining-Ward (2005) point out that much of the literature pertaining to sustainable tourism is characterised by deterministic, cause and effect linear science. This is, however, insufficient when analysing the social component of sustainability. In light of research into complex systems such as thermodynamics (the

science of how energy can only be converted, not destroyed), global climate change and ecosystem theory, it has become increasingly accepted that all social systems, including tourism, are complex adaptive systems (Farrell & Twining-Ward, 2004). Complex adaptive systems are characterised by non-linear dynamics and complex interactions resulting in unpredictable outcomes. Social complex systems such as inter-actional relationships are, therefore, often far more effectively analysed by qualitative methods such as interviews rather than quantitative methods of data collection. In the words of Farrell and Twining Ward (2004: 277):

> "The central problem is that tourism researchers schooled in the tradition of linear, specialised, predictable, deterministic, cause-and-effect science, are working in an area that is largely nonlinear, integrative, generally unpredictable, qualitative, and characterised by causes giving rise to multiple outcomes." (Farrell & Twining-Ward, 2004: 277).

Quantitative data collection methods were used in the form of questionnaires to establish indicators of sustainability regarding the reef. Unlike direct measures which can be unambiguously counted such as household income, age or number of children, indicators are used to tap concepts that are less directly quantifiable (Bryman, 2008). Tourists were given questionnaires that used a likert scale to measure the intensity of feelings towards the Biorock reef and Pemuteran. Each respondent was asked to indicate his or her level of agreement with a statement on a seven point scale, ranging from 'strongly agree' to 'strongly disagree'. Each respondents reply on each item is scored and then the scores for each item are aggregated to form an overall score. In total, 423 questionnaires were carried out and the data collected can be used to establish various indicators regarding the reef. For example, the degree to which respondents cited the reef as a factor in their decision to visit Pemuteran is an indicator as to how important the Biorock reef is in generating tourist income and, therefore, its overall economic contribution to Pemuteran. It was not deemed appropriate to distribute questionnaires to the host population because of potential difficulties in reading and understanding written English.

A note on sample size. Using statistical theory/ means, it will now be attempted to provide an indication of the significance of the results. The responses to question 9 (see **Fig. 16**) are ordered numerically, which enables us to calculate the sample mean, $\boldsymbol{\mu}$, sample standard deviation, $\boldsymbol{\sigma}$ and the standard error of the mean given as follows:

$$\mathrm{SE}_{\mu} = \frac{\sigma}{\sqrt{n}}$$

where $\boldsymbol{n}$ is the total number of responses.

For this question we had ***n = 423*** responses where each response was a score between 1 and 7. Letting these scores represent values on a continuous distribution, the sample mean, ***μ= 4.90***, and the sample standard deviation, ***σ = 1.29*** will be calculated***.*** This gives a standard error of the mean, SE_{μ}***=0.06***. Assuming the scores approximate a normal distribution***,*** we can be 95% confident that the population mean is within the interval ***[μ±(1.96 x SEμ)]***; that is we can be 95% confident that the population mean is within the interval [4.90 ± 0.12]. This suggests that our sample size is sufficient to ensure that our results are statistically significant.

Due to the fact that many of the other questions involve non-ordered discrete variables (i.e. they cannot easily be placed on a numerical scale), it is not easy to calculate the sampling error for each question. For convenience, it is assumed that the results for question 9 are representative of the statistical significance of the responses to the other questions.

Archival data pertaining to Pemuteran and the Biorock reef was the third and final method of data collection. Articles published by the Indonesian government and WWF provided information on tourism and Pemuteran's environment whilst articles retrieved from the GCRA website offered data that was more specifically related to the Biorock reef. This was invaluable in ascertaining the role Biorock technology plays in the environmental management of Pemuteran's coral reefs. Due to time constraints as well as a lack of funding and resources, it was unrealistic to carry out any primary scientific research. As a result, it is this secondary information that is relied upon to provide scientific backing regarding the ecological viability of Biorock reefs. However, it should be noted that this data is corroborated by first hand witness accounts from local fisherman and community members. In view of the close spiritual bond the Balinese have to the ocean as well as the growing acceptance of indigenous knowledge, this information is extremely valuable even though it is not strictly quantifiable (Cinner & Aswani, 2007).

Methodologically, this study relies upon a grounded theory approach, which is to inductively develop theory based on systematic use of data (Strauss & Corbin, 1998; Dengler, 2007). Unlike a positivist deductive framework, inductive inquiry allows theory to develop from specific observations. This method was selected because it retains theoretical flexibility and allows the researcher to take advantage of emergent themes and unique case features (Eisenhardt, 1989). It also forces investigators to look beyond initial impressions and see evidence through multiple lenses (Ibid).

5.0 Results

The results have been presented in three sections that reflect the fundamental components of sustainability: Environmental, Economic, Social. Whilst it is recognised that these three dimensions are intrinsically interlinked, for the sake of both clarity and ease of analysis, they will be examined individually before exploring specific linkages and how the results relate to the wider debates surrounding the sustainable governance of marine resources.

Qualitative data in the form of interviews is presented in the table below. Here the names of the interviewees are given as well as their status as stakeholders. In the case of the focus group, three stakeholder groups were present. The quantitative data derived from questionnaires given to tourists is then presented in a series of graphs and tables.

5.1 Interviews

Name	Status Of Stakeholder (s)	Date
Putu tattoo	• Bali Barat National Park Ranger.	20th June, 2009
Rani E. Morrow-Wuigk	• Founder voluntary member of Biorock in Pemuteran. • Reef photographer. • Ongoing supervisor of Biorock.	22nd June, 2009
Duda and Hugo	• Manger and dive instructor of Pondok Sari Dive school.	23rd June, 2009
Mariciana Leotta	• Manager of Easy Diver diving school.	24th June, 2009
1. Made Grunska, Gd. Kutang, Ny Satria, Wy Wardana, Ny Sulat, Pintiil Nelayan **2. Komang Astika and Putu Catra** **3. Ny Coel Coel**	1. Pecalang Laut (Sea Guardians). 2. Biorock Project Manager and Biorock employee. 3. Diver	26th June, 2009
Wayan Landrat	• Head of Fisherman	27th June, 2009
Chris Brown	• Owner of Reef Seen Aquatics, the first dive shop in Pemuteran. • Head of Reef Gardeners. • Founder of various sustainability projects in Pemuteran such as turtle hatchery. • Owner of artificial reefs utilising mineral accretion technology that were built by Biorock. These, however, are managed independently.	4th July, 2009
Narayana Deva	• Founder member of Biorock in Pemuteran. • Ongoing supervisor of Biorock.	5th July, 2009
Agung Prana	• Owner of Taman Sari Hotel and Amertha Villas in Pemuteran. • Head of Bali Tourism board. • Community leader.	6th July, 2009

5.2 Graphs

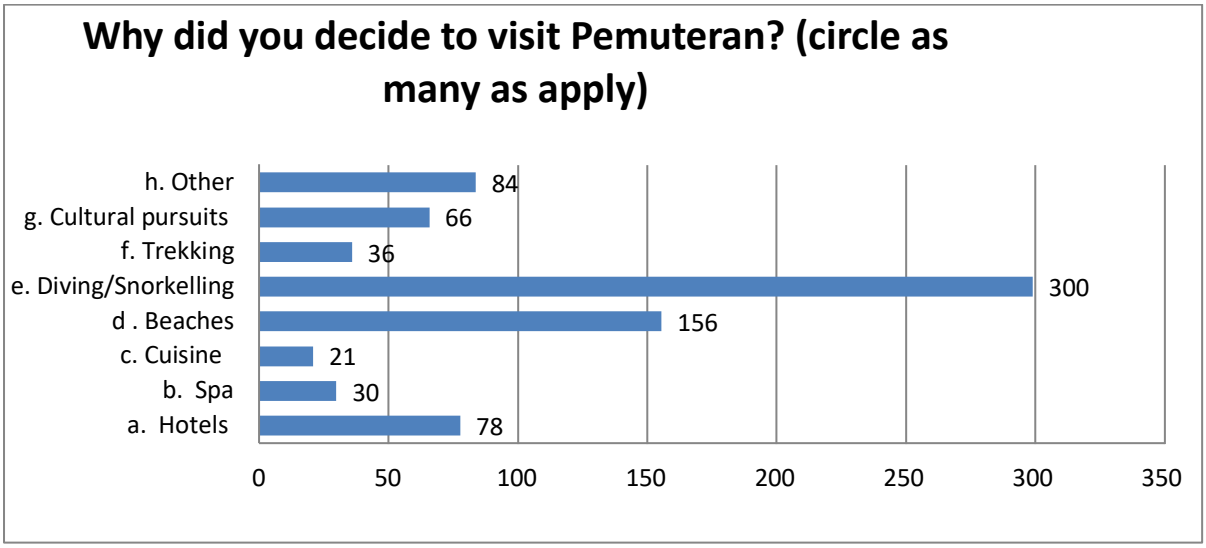

Fig. 8

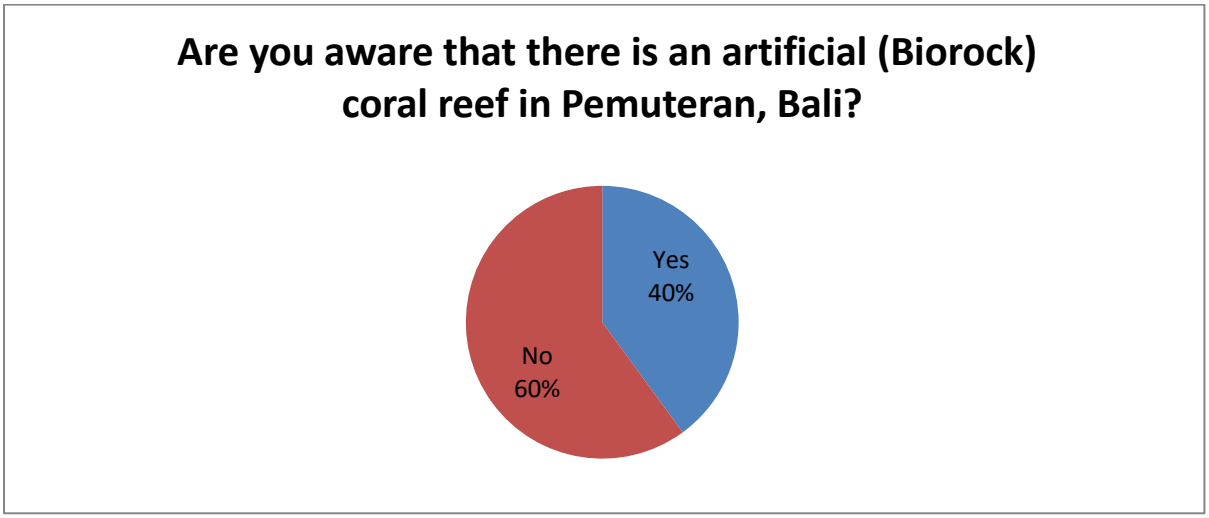

Fig. 9

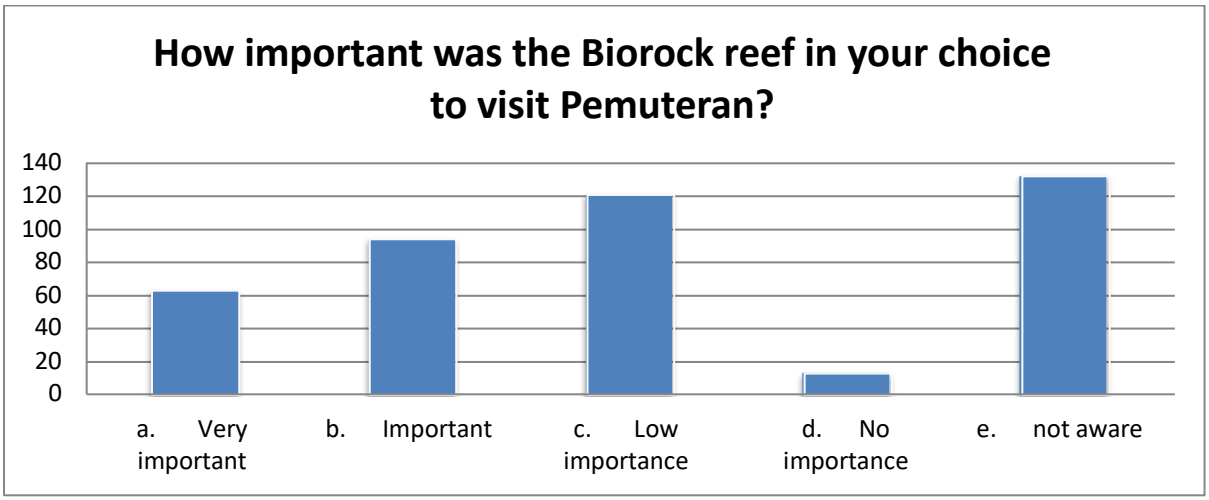

Fig. 10

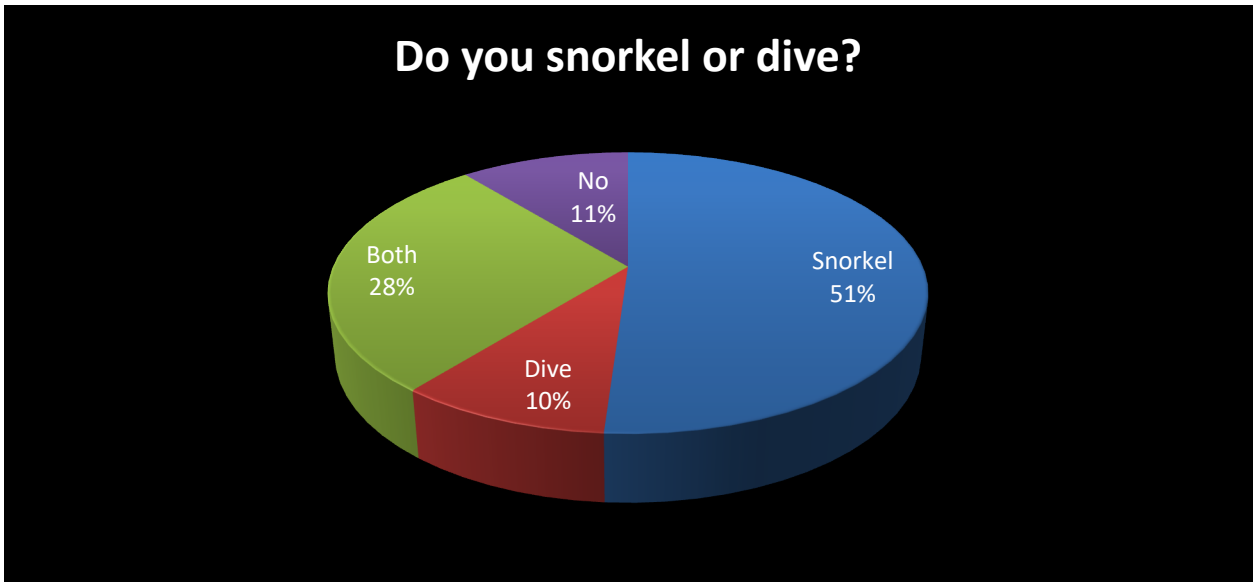

Fig. 11

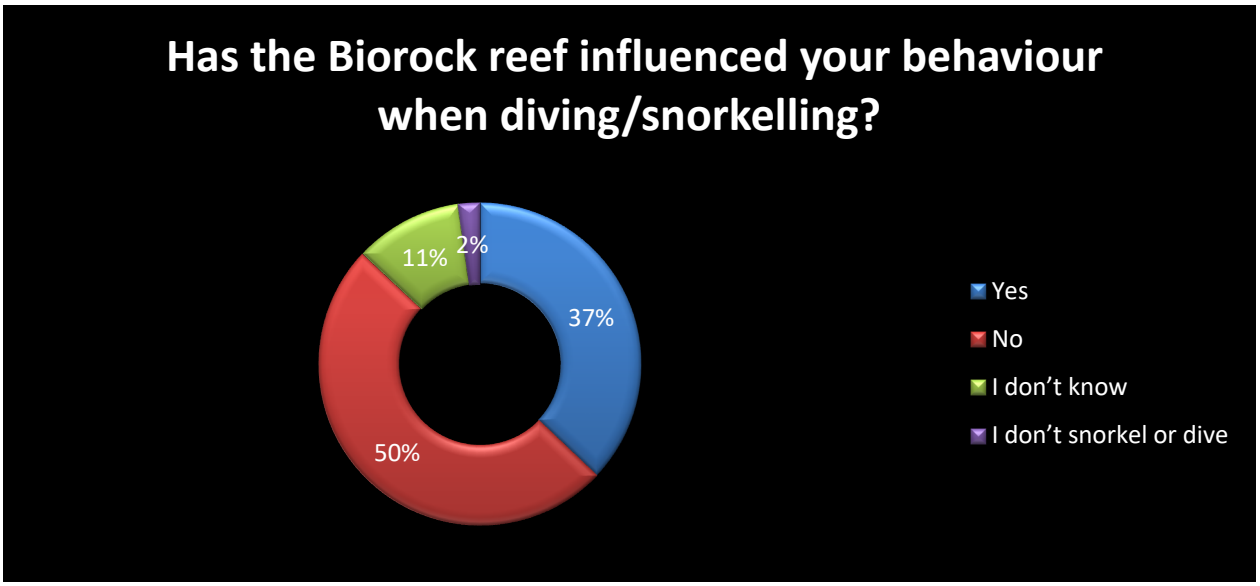

Fig. 12

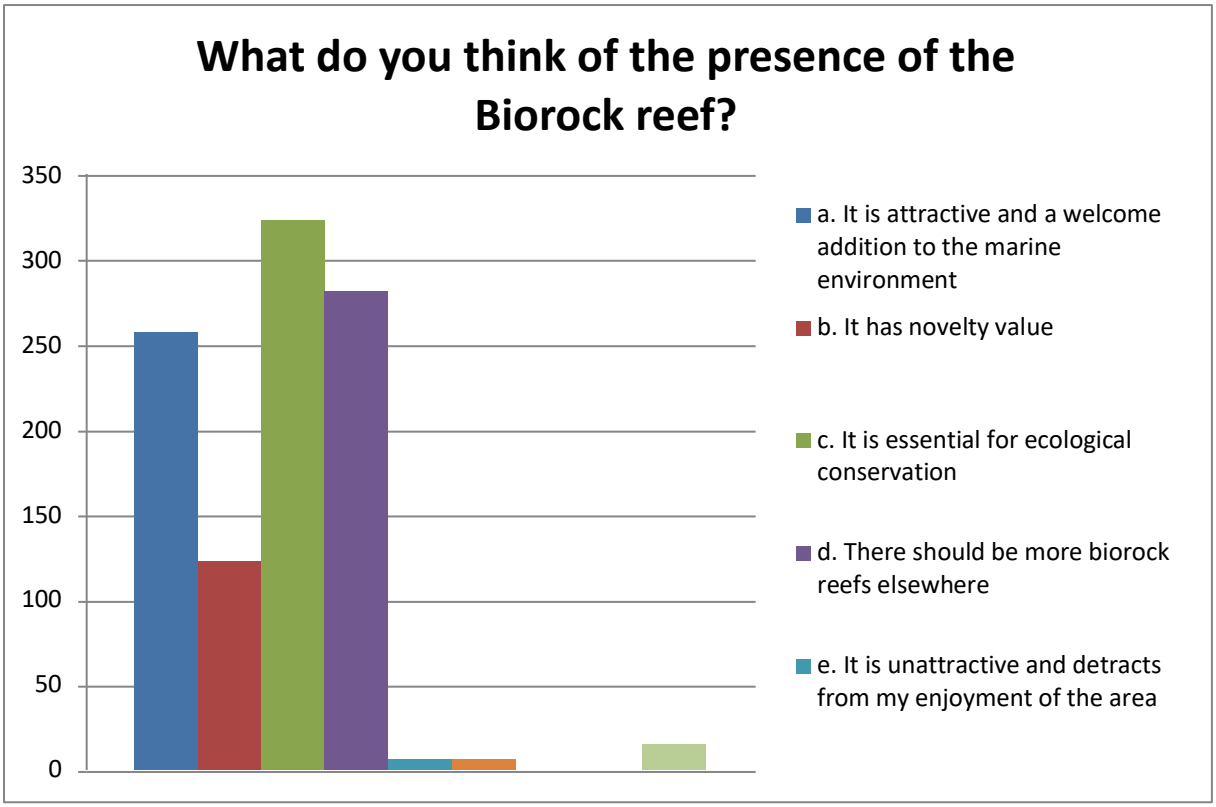
What do you think of the presence of the Biorock reef?
350
300
250
200
150
100
50
0
a. It is attractive and a welcome addition to the marine environment
b. It has novelty value
c. It is essential for ecological conservation
d. There should be more biorock reefs elsewhere
e. It is unattractive and detracts from my enjoyment of the area

Fig. 13

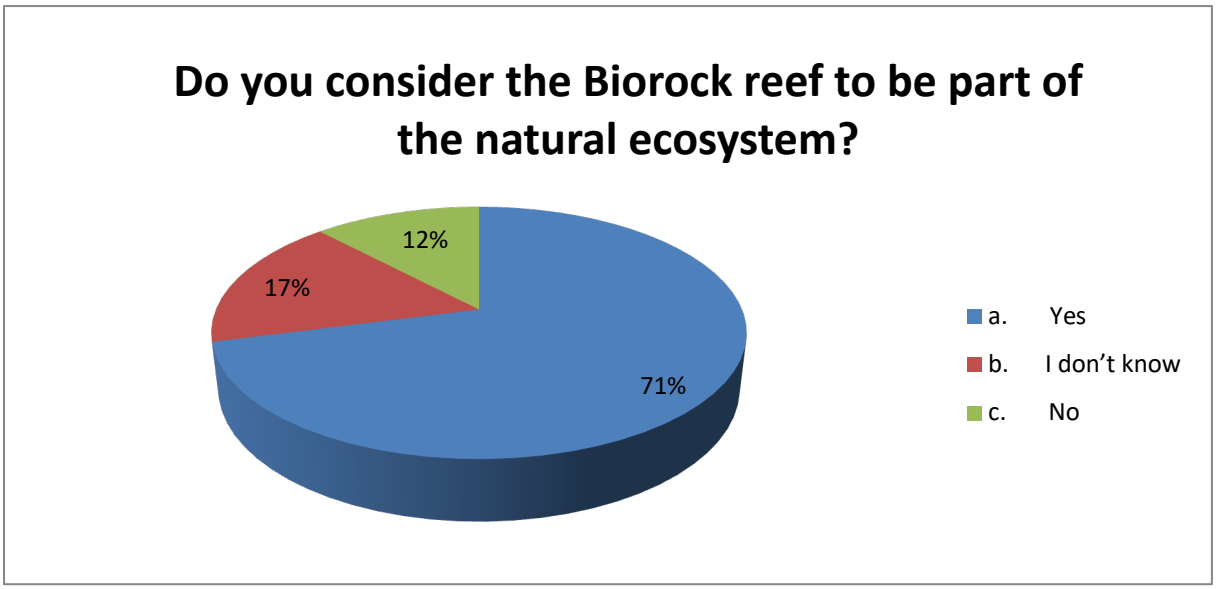
Do you consider the Biorock reef to be part of the natural ecosystem?
12%
17%
71%
a. Yes
b. I don't know
c. No

Fig. 14

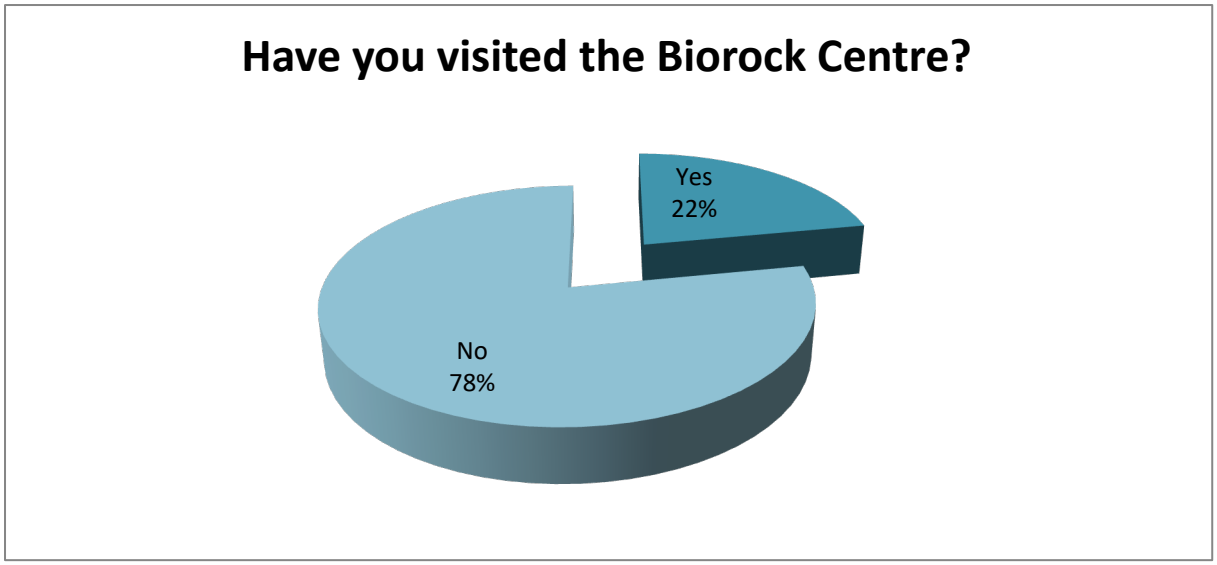

Fig. 15

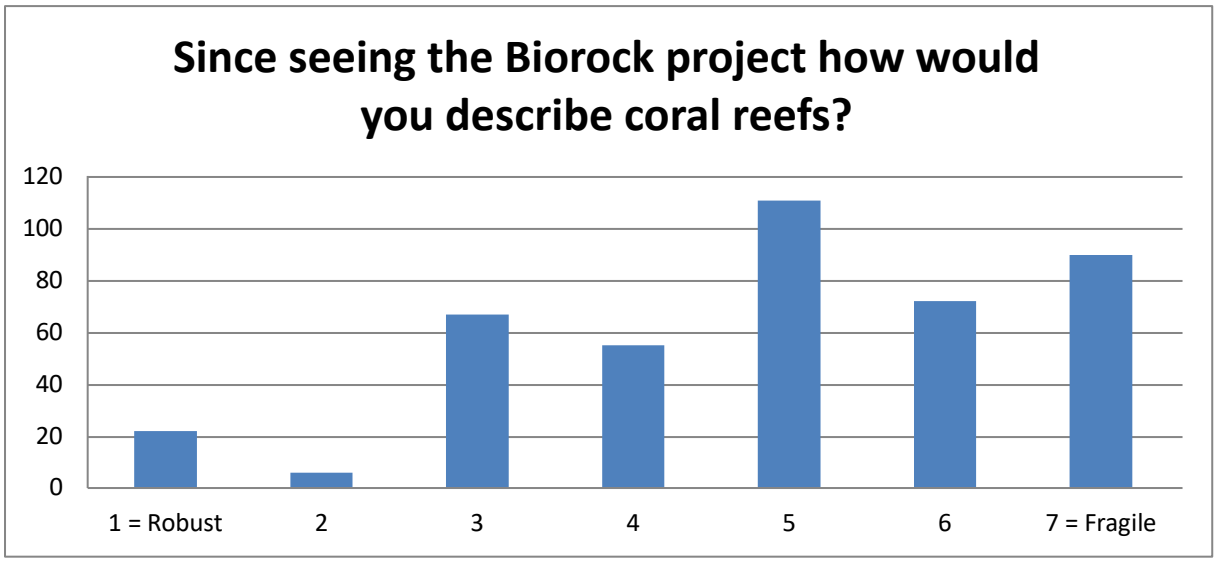

Fig. 16

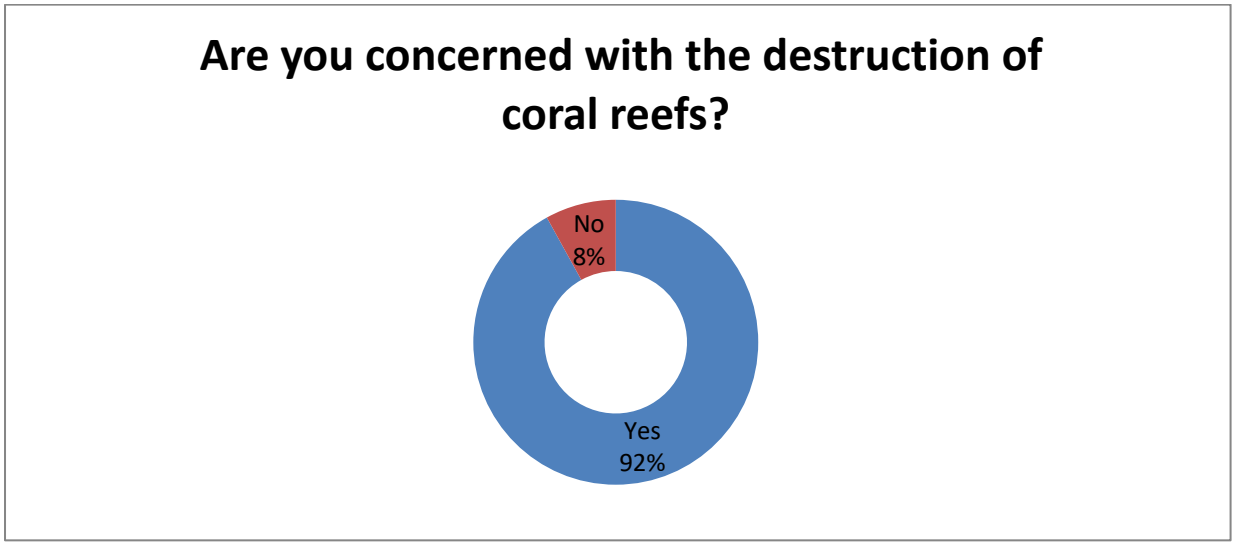

Fig. 17

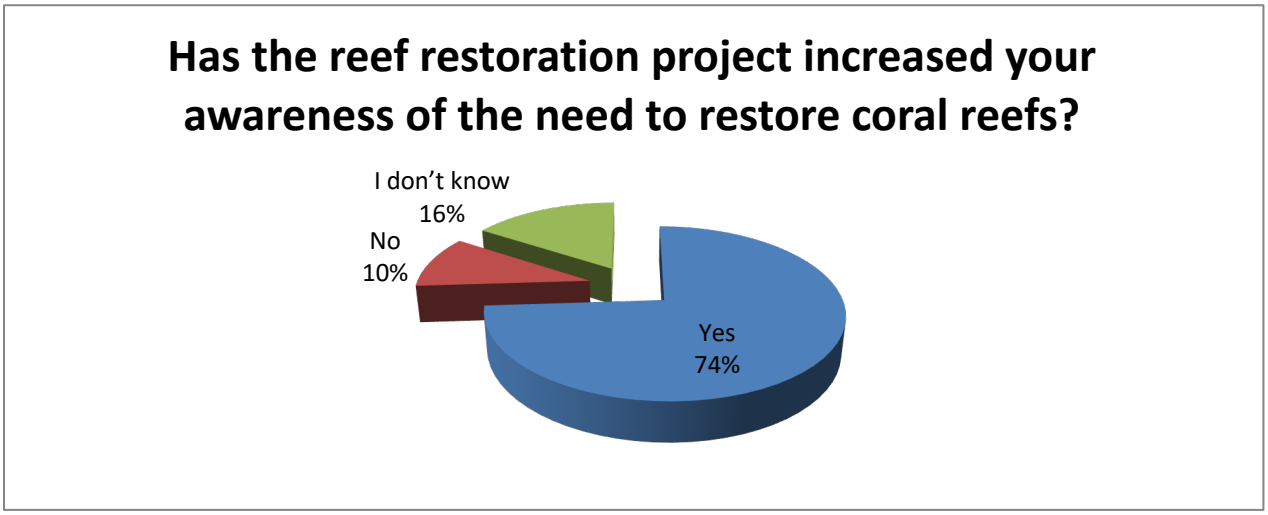

Fig. 18

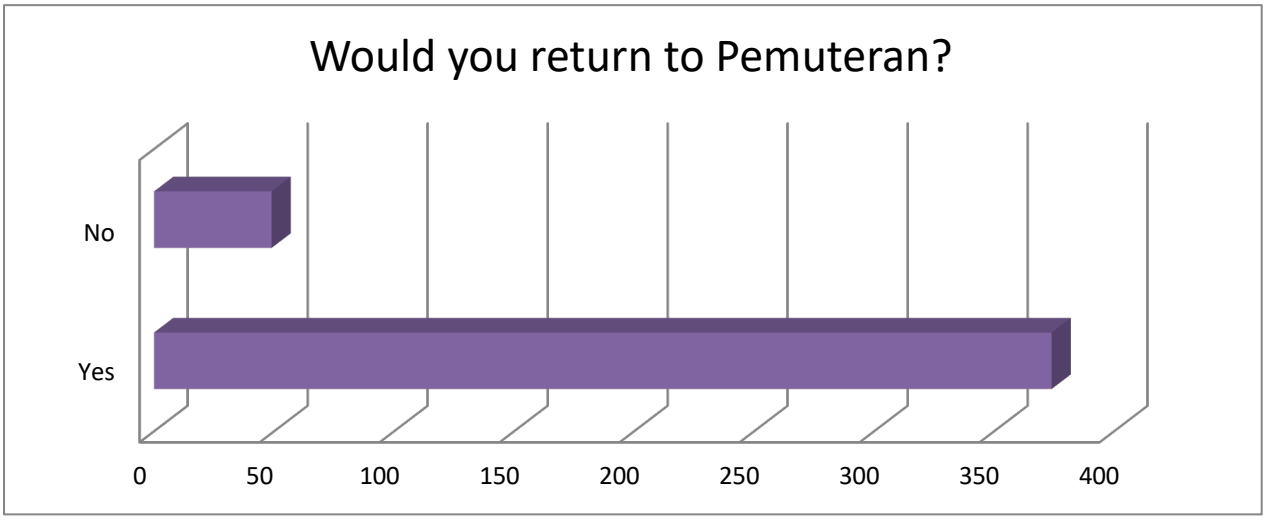

Fig. 19

Personal Data

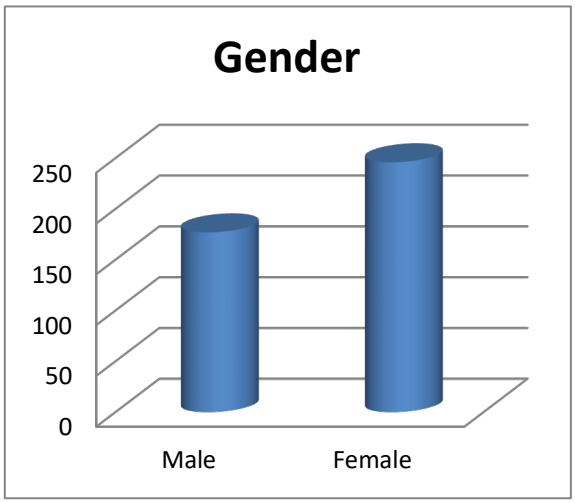

Fig. 20

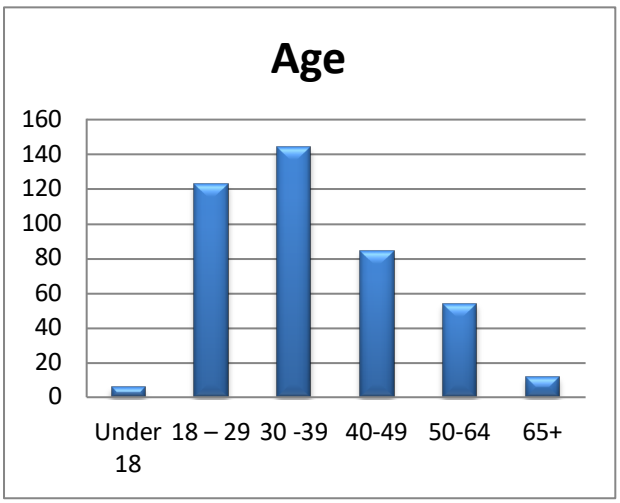

Fig. 21

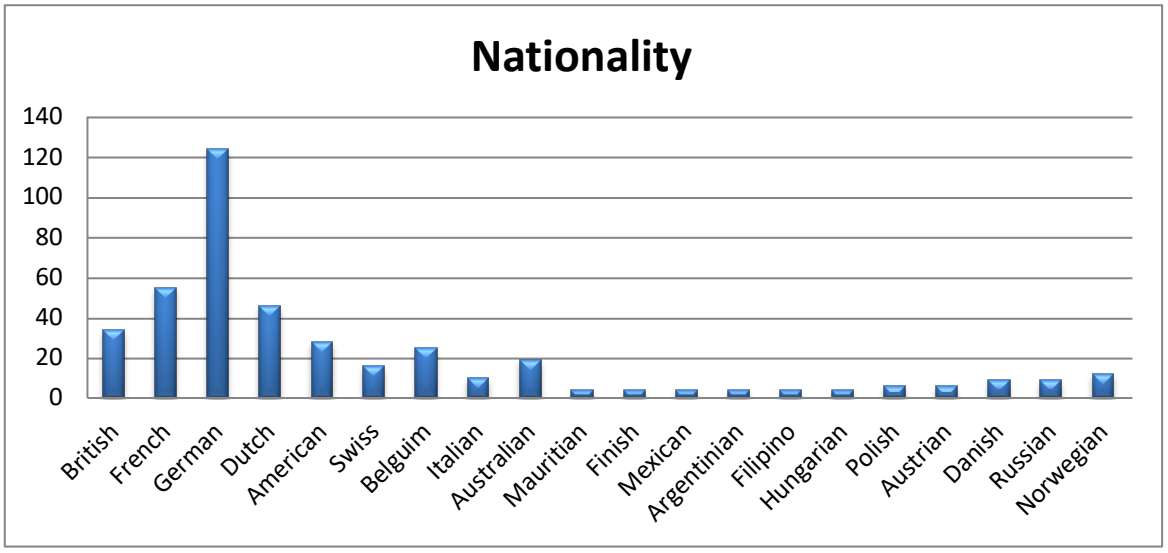

Fig. 22

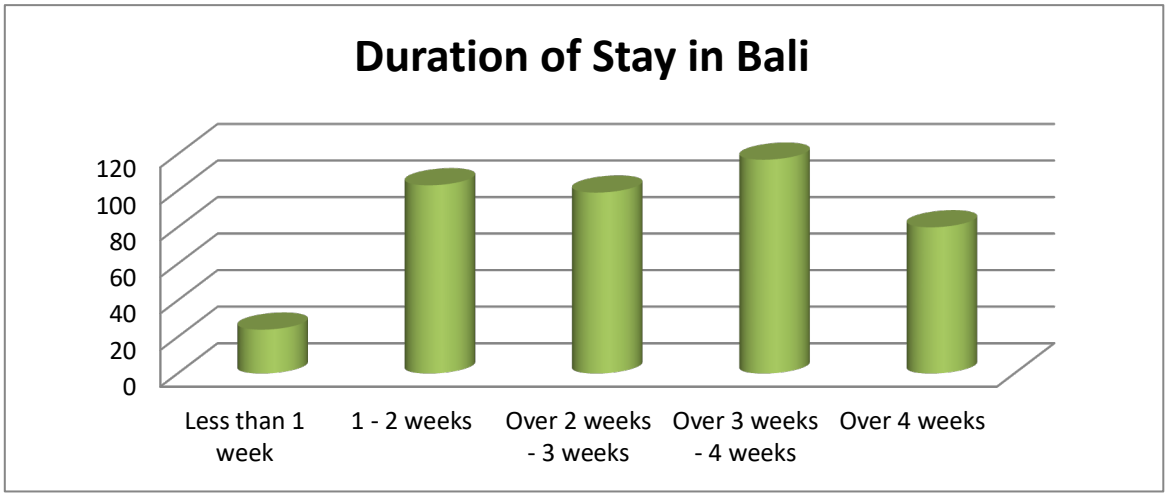

Fig. 23

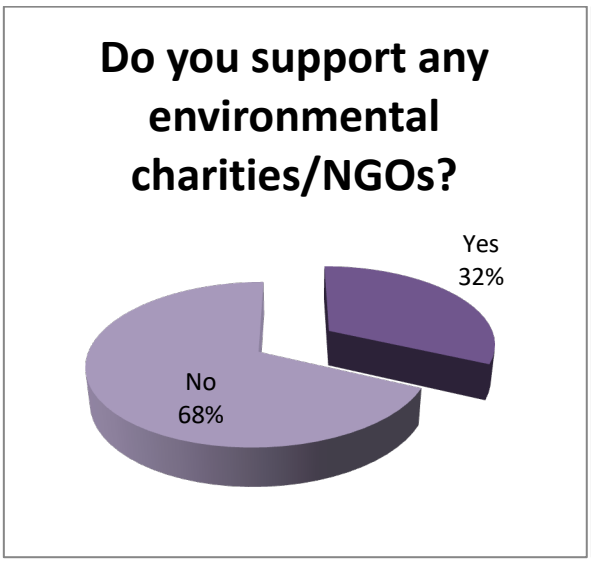

Fig. 24

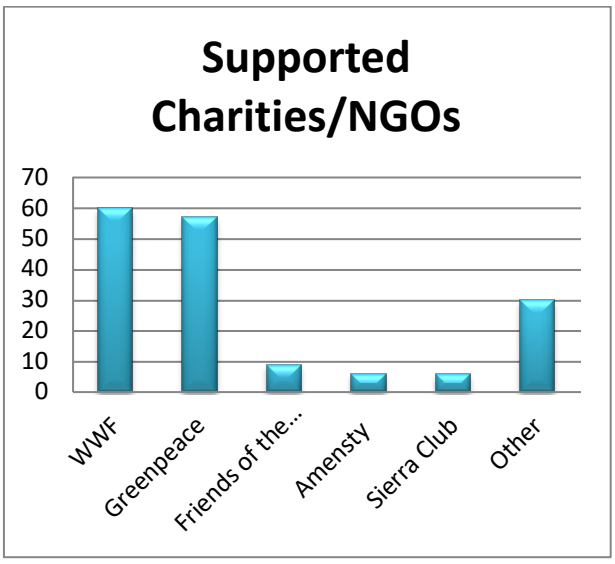

Fig. 25

5.3 Biorock and Environmental Sustainability.

The primary data gained from interviews serves to validate the information retrieved from the GCRA website and other secondary sources regarding the ecological robustness of Biorock coral reefs. Numerous articles published by Biorock creators Tom Goreau and Wolf Hilbertz as well as third parties clearly indicate that Biorock corals grow 3-5 times the normal rate as well as being 16-50 times more resistant to stress (Goreau & Hilbertz, 2005; Dwija, 2002). Interviews substantiate these articles by offering firsthand witness accounts concerning the increased growth rates of Biorock corals. Rani, who has been diving and photographing Pemuteran marine life for over 15 years, recalls when she first saw a Biorock reef:

> "So anyway I said, 'What are you doing?' It must be something for the ocean.' I had a look and went snorkelling and thought, 'it actually works. I can see it working.' One of the structures was already there for half a year. The corals looked really healthy." (Interview, Rani, 22/06/09)

Various dive operators corroborate Rani's observations and verify the successful growth of coral from Biorock structures. Duda and Hugo, for example, comment: "We have a lot of repeaters who always take pictures with the same frames. You can see from the pictures the corals have grown" (Interview, Duda & Hugo, 23/06/09).

In conjunction with increased coral cover, fish stocks were also revealed to have improved. It is this factor which has been essential in gaining the support of the local fishermen, the largest stakeholder group in Pemuteran. A spokesman for the fishermen said he "supports the Biorock because it grows coral and the coral grow fish [sic]" (Focus group, 26/06/09). Unlike conventional artificial reefs, it is the speed at which Biorock is able to replenish fish stocks that is fundamental in gaining the cooperation of the fishermen and stopping destructive fishing methods. This is an aspect that was highlighted by Nara: "The interesting thing about this project is that it is quickly (emphasised) able to show results within a few years" (Interview, Nara, 05/07/09). This is of the utmost importance when people's poverty is forcing them to act in unsustainable ways. The World Bank's *World Development Report 2003* documents the vicious circle that those deprived of adequate food and resources often find themselves: in order to survive, they are forced to degrade the environment further. For example, the search for fuel wood de-vegetates the land, making it more susceptible to erosion and fertility loss; the effort to produce more food depletes soil nutrients and leads to over grazing. In the words of Speth, the poor are forced "to eat their own seed corn, metaphorically and sometimes actually" (Speth, 2005: 132). In the case of Pemuteran, declining fish stocks forced fishermen to resort to ever more destructive fishing methods to maintain sufficient yields. This

degraded the coral reef, further reducing fish numbers as well as having a clear and obvious detrimental impact on ecological conservation. As Nara points out:

> "You're asking them to limit their fishing when they're starving, their mother needs an operation. They're looking for the fastest way to get the fish out of the water. They're not thinking about the future. So conservation and poverty bump heads in a sense" (Interview, Nara, 05/07/09).

By rapidly increasing the number of fish, Biorock reefs help stop this negative feedback loop. Fisherman no longer had to rely on destructive fishing methods to catch fish thus facilitating the sustainable governance of Pemuteran's marine resource. The Head of the Fishermen said, "The fish stock has improved. It is now easier to catch fish than cyanide fishing was" (Interview, Wayan Landrat, 27/06/09). Komang, Biorock's manager, echoes the belief that it was increasing fish numbers that led to the cooperation of the fishermen:

> "At first it was difficult to explain what we do...They (the fishermen) now know it's very important for them because they were getting more fish than before because coral grow good and now they not use cyanide [sic]. Now fishermen support us because they get more than before" (Focus group, Komang Astika, 26/06/09).

Through providing a breeding ground for fish, the support of the fisherman was gained and destructive fishing methods such as bombing and the use of potassium cyanide was dramatically reduced. This impacted positively on the marine environment, allowing neighbouring coral reefs to recover. Chris Brown, head of the Reef Gardeners, comments: "The reefs were almost totally destroyed. As we started to get them on side (the fishermen) we stopped the potassium cyanide fishing. The reefs are getting better" (Interview, Chris Brown, 04/07/09). Biorock thus facilitated the transition from a system of resource extraction that was damaging the marine environment to one which was more sustainable where the coral reefs could recover. In essence, what had been a negative feedback loop where the marine environment was becoming progressively degraded due to destructive fishing methods turned into a positive feedback loop where corals were given the opportunity to regenerate and the number of fish grew.

Another theme to have emerged from the interviews is the physical robustness of Biorock corals. This supports the scientific data that quantifies Biorock corals as being 16-50 times more resistant to stresses such as high ocean temperatures and sediment cover than natural reef corals. Duda and Hugo recall one occasion when they witnessed the durability of Biorock corals:

> "In my first season we had 9 weeks of really rough sea on the beach. The whole project was covered in sand. We went for a dive after the storm and I thought most of the corals would

> die. 3 days later we went for a dive. Everything was clear. The corals were healthy." (Interview, Duda & Hugo, 23/06/09).

It is this physical resistance to stress that is enabling the precautionary principle to be applied on a large scale in Pemuteran. In light of reports from the IPCC that global temperatures are due to rise between 1-4 degrees Celsius, the imperative to protect corals and maintain a minimum level of marine biodiversity has become increasingly pressing. Corals are already approaching the upper threshold of their limits and even a relatively small increase in temperature could prove catastrophic for coral reefs worldwide (IPCC, 2007). Nara suggests that the implementation of the precautionary principle is a fundamental tenet to the Biorock mission:

> "He's (Tom Goreau) saying that the environmental stresses are so extreme and they're rising exponentially. 100 years ago mother nature could take care of itself but it can't anymore; the corals can't take it anymore. Tom's looking at a final event scenario: that most of the corals in the world die except for small patches here and there. So his mission, and part of the Biorock mission, is to gather as many species as possible, put them on these electric grids which increase their resistance up to 50 times. He calls them 'coral arcs'." (Interview, Nara, 05/07/09).

The precautionary principle is a fundamental cornerstone to Chapter 17 of Agenda 21 and sustainable development as a paradigm in general. Its implementation, therefore, significantly contributes to the sustainable governance of Pemuteran as well as ensuring the survival of numerous coral and fish species.

A further way in which Biorock reefs contribute to the effective environmental governance of Pemuteran is to reduce soil erosion. Although Pemuteran's north-westerly position means it is not particularly prone to strong currents, many of the hotels and much of the tourist infrastructure is very close to the shoreline. Erosion, therefore, is potentially a problem. Biorock reefs help reduce the power of waves, building up the beach and so reduce the rate of erosion to the shoreline. The Global Coral Reef Alliance has implemented Biorock technology in numerous locations such as the Maldives which is specifically designed for erosion control. Whilst shore protection was not the primary intention in Pemuteran, Biorock reefs appear to have been successful in building up the beach. Nara comments:

> "Since we've put this project in here this beach has built up significantly. Last year we had to go down and repair a cable from one of the stations. We had to go down almost 2 metres to find the cable. My feeling is that the beach has significantly increased." (Interview, Nara, 05/07/09)

5.4 Biorock and Economic Sustainability

By regenerating coral and the marine environment, Biorock coral reefs contribute economically to Pemuteran by attracting tourists. Of the 423 people surveyed, 378 (88%) cited diving and snorkelling as one of the primary reasons they decided to visit Pemuteran. Indeed marine based activities are an extremely important component of Pemuteran's tourist economy. 90% of guests said they snorkelled or dived and so the protection of the marine environment is clearly very important in ensuring continued revenue streams from tourism. As Agung Prana, owner of Taman Sari and Amertha Villas, has pointed out: "If you go to a destination, would you want to go if the environment is not good? So to make you come I have to protect my environment" (Interview, Agung Prana, 06/07/09). By increasing coral cover and the number and variety of fish, Biorock has improved Pemuteran as a destination for divers and snorkelers. Mariciana, a dive instructor, states:

> "They (tourists) are saying there are more fish compared to a few years ago. So they are happy to have this (Biorock) otherwise there would be nothing. Most of the coral died because of El Nino and bombing. So there would be nothing. Now we have fish and now we have corals. I think they really enjoy and appreciate it." (Interview, Marciana, 23/06/09)

In addition to improving the environment for tourists, the artificial reefs themselves have become an ecotourism attraction. A special feature is dedicated to Biorock coral reefs in *Lonely Planet*, which is generally considered to be the travel book of choice for western tourists. Of those that were aware of the Biorock reef restoration project, 55% said Biorock was either 'important' or 'very important' in their choice to visit Pemuteran. Both Rani and Nara substantiate this data from questionnaires with observations from the ground. Rani Says:

> "Most of the tourists don't come because of that (the project) but an increasing amount do because they've heard, they've seen on the internet, in travel books, 'Yes there's something different. It's about the environment. It's about the coral.' People are becoming more aware." (Interview, Rani, 22/06/09).

Nara also sees Biorock as increasingly important in attracting tourists to Pemuteran:

> "We can see it's been an incredible attraction. It's hard to quantify the attraction because Pemuteran is a beautiful place and we have some very nice outer reefs here and we have Manjangan Island. People are coming for that. But this is a plus. This is a house reef that didn't exist before. When I got here 10 -15 years ago, this was all dead here (points to the near shore). So now we have 2 hectares of reef, lots of nice fish coming through." (Interview, Nara, 05/07/09)

Biorock is not only important in attracting tourists to Pemuteran but also in providing them with activities and enjoyment once they have arrived. Indeed, once having visited Pemuteran, the vast majority of tourists saw Biorock in a positive light. Only 1% responded negatively towards Biorock,

wrongly believing the electrified reefs to be dangerous. Yet over 98% of the tourists questioned agreed with at least one of the following statements:

1. The artificial reefs are essential for ecological conservation.
2. They are attractive and a welcome addition to the marine environment.
3. There should be more Biorock reefs elsewhere.
4. They have novelty value.

Interestingly the majority of tourists (72%) thought of Biorock coral reefs as being part of the natural ecosystem. This may seem somewhat surprising given the technical appearance of some of the reefs and their clear reliance on electricity. It does, however, strongly imply that people respond favourably towards the artificial reefs and perhaps should go some way towards dispelling any fears that Biorock would damage the tourism industry should the project be replicated elsewhere.

The fact that Biorock has become a tourist attraction is very important in enabling the reef restoration project to fulfil the economic component of sustainability. This is essential in order to ensure the sustainable governance of Pemuteran's marine resource. As Chris Brown points out: "Now days to get something running on a big scale, you've got make it economically viable for places to do it. If you put investment in anywhere, you want to see some sort of return on it" (Interview, Chris Brown, 04/07/09). That Biorock performs the dual function of both a tourist attraction as well as a tool for ecological conservation is central in gaining the support of different stakeholder groups and securing the future of the project. Biorock provides an economic incentive for both the local population and hotel industry to protect the Biorock reefs and so engage in ecological conservation. Aware that Biorock is responsible for bringing many of the dive clients to Pemuteran who stay in their hotels as guests, the hotel managers provide the project with electricity. The hotels have also been instrumental in making sure that money filters down from tourism to the local community. This has engendered support for the project. Ny Coel Coel, a local dive instructor, says:

> "The owner from the hotel try to take (one member) from each family. So that mean when they take from each family they are thinking and take care of this project [sic]. This project brings good future for next 10-15 years. And for that the people support and accept it. They never try to destroy this coral and support our friends working in Biorock here." (Focus group, Ny Coel Coel, 26/06/09).

Chris Brown echoes the belief that the financial benefits Biorock brings has been fundamental in gaining the support of the local community:

> "The only way that the village are going to continue to cooperate is that they see that all the businesses are making money out of it (Biorock). They make some money out of it as well –

> short term, long term. They see that there's better fishing out there which immediately turns around into more money for them." (Interview, Chris Brown, 04/07/09).

The support of the community is key to both the success of the Biorock project and local businesses. The local community is comprised of the largest and most powerful stakeholder groups, the fishermen and those who work within the tourism industry. Local dive shops, which are largely owned by westerners, rely on local labour and the cooperation of the local village. Agung Prana, a prominent leader in Pemuteran as well as owner of two major hotels, says: "If the community is not part of it or playing the main role, it will fail." (Interview, Agung Prana, 06/07/09).

Biorock also provides a valuable 'house reef' to the diving schools. Because Biorock is close to the shoreline and situated in calm water, diving instructors have to waste neither time nor resources taking children and learners to reefs that are less accessible. This represents a clear financial saving for Pemuteran dive schools. Duda and Hugo point out: "We sell this place to get all the dive clients here. Let's say 70-80% like it for short dives especially" (Interview, Duda & Hugo, 23/06/09) Meanwhile Mariciana observes:

> "It (Biorock) is very good because otherwise we couldn't do short dives. Without Biorock we could not take people on short dives. We would have to take the boat which would be more difficult. Without Biorock, what would we sell?" (Interview, Mariciana Leotta, 23/06/09).

Biorock, therefore, is not simply a tool for ecological conservation: it is an asset that generates income. It is the strong business case for the implementation of Biorock reefs that increases the viability of the project. Chris Brown opines:

> "By putting some structures close to the beach and, the people putting investment in it like the hotels and dive centres can then get a return on it because people come here to visit and see it so they're getting a return on it and helping to provide it. It's not just money pissed in the wind; it's an investment that they are now getting a return on." (Interview, Chris Brown, 04/07/09).

Without the financial returns, it is unlikely Biorock would have gained as much support from the dive schools or local community. As a consequence, efforts to conserve the marine environment would have suffered. However, by regenerating coral and increasing biodiversity, Biorock reefs have provided ecotourism opportunities and contributed economically to Pemuteran. This, in turn, has further contributed to ecological conservation. Putu Tattoo, a Bali Barat National Park Ranger says:

> "When people start to earn the money from tourism, they start to feel it. It's easier, much easier to tell them (to protect the environment) because they feel it but without it (money) they will never. They think it's only for the government. But when money starts to come, they realise actually it's really important for their family. (Interview, Putu Tattoo, 20/06/09).

Tourism is generally more effective at generating cash jobs than traditional uses of marine habitats such as mining or fishing. This is because tourists, who bring in high value foreign currencies, are willing to pay repeatedly to see coral and fish. Fish and coral that are seen multiple times over the course of their life assume a higher value commercially than if they were to be exploited in one off activities such as fishing and coral mining (Goreau, 2008). Therefore, by attracting tourists and adding to Pemuteran's stature as an ecotourism destination, Biorock has helped commoditise Pemuteran's marine environment as a tourism resource. As a result, the tendency in Pemuteran has increasingly been to emphasise ecological conservation in order to protect the natural environment for tourism rather than resource extraction by destructive activities such as mining. Nara comments:

> "Tourism can be the forerunner and leader in environmental programmes because it is in the interests of business and what is in the interest of business is in their (the community's) interest. So it is community and business community interested in maintaining and re-establishing and restoring the marine resource which brings the tourists." (Interview, Nara, 05/07/09).

Whereas coastal tourism has traditionally been seen to degrade the marine environment, Biorock has helped Pemuteran make the transition to a more sustainable model of tourism where a premium is placed on natural beauty. In essence, Biorock is helping tourism in Pemuteran become the leading tool for conservation. An industry that was once considered to be part of the problem is able to assume a more responsible role and become a leader in solving the problems of environmental degradation from destructive fishing practices and mining.

5.5 Biorock and Social Sustainability

In addition to enhancing Pemuteran's environment and economy, Biorock also fulfils the social component of sustainability. It contributes to the sustainable governance of Pemuteran by educating both tourists and the host population regarding the fragility of coral reefs. Both groups have modified their behaviour as a result, acting in more sustainable ways. It will also be argued that Biorock has increased social cohesion within Pemuteran by acting as a central focal point for different stakeholder groups.

One of the biggest achievements of Biorock has been to raise awareness amongst the local population regarding the degradation of the marine environment. Whilst this cannot be attributed uniquely to Biorock, the reef restoration project has played a key role in prompting local fishermen to fish in ways that are more sensitive to the environment. It has also helped concepts such as conservation, previously little known in Balinese society enter the collective consciousness and

assume a more prominent role in Pemuteran. Through Biorock, local youngsters are exposed to ideas such as sustainability and gain an informal environmental education. Nara says:

> "I've seen teachers bringing the kids to look at the project. They all understand Biorock - maybe not the technology – but that someone's growing corals. So this has never been here before. In a sense the young people are understanding that they have to take care whereas before no one knew what a coral was because they didn't go in the water. They thought they were just rocks so they blew them up or took them to build their houses with. There was no connection with ecosystems, sustainability, fish habitat. There was nothing. I think that understanding is there now. And that's in less than a generation." (Interview, Nara, 05/07/09).

As well as serving as an educational tool for children, Biorock has taught fisherman the need to conserve the marine resource. As forementioned, destructive fishing methods were commonplace in Pemuteran in the 1990s before the implementation of Biorock. Although much was done on the grassroots level to modify the behaviour of fishermen and the transition to more sustainable fishing methods is not solely due to the reef restoration programme, Biorock has strengthened the perception amongst fisherman of the need to both protect fish stocks and alter their behaviour. The Head of the Fishermen told me: "They are doing good fishing; only 1 kg, enough for eating and consumption only. They are thinking about future and not just today" (Interview, Wayan Landrat, 27/06/09). Less emphasis is placed on securing large yields and more thought is given to ensuring a sufficient number of fish for the future. Biorock has facilitated a shift in the way the fishing industry is conceptualised in Pemuteran. Whereas before fishermen aimed to 'hunt' as many fish as possible, Biorock has acted as a type of breeding ground for fish, enabling fish to be farmed in a sustainable manner. Agung Prana says:

> "We say: from hunting to farming. Before hunt, hunt, hunt but now you can make good methods not to destroy: hunting and farming. That's the fish farming here (points to the artificial reefs). And then you catch them somewhere else." (Interview, Agung Prana, 06/07/09)

As Tom Goreau, Biorock's creator, has pointed out, Biorock technology allows the Neolithic revolution to begin in the world's oceans. Just as our ancestors made the transition from hunting to organised agriculture where animals are reared for future consumption, this type of farming is now able to take place in the ocean.

Biorock also educates tourists about the fragility of coral reef ecosystems. 37% of tourists said their behaviour had changed since seeing Biorock artificial reefs. Respondents said they 'took care to no longer trample on corals' or 'take souvenirs'. Of those who said the project had not altered their behaviour, approximately 20% took care to point out that they had been diving for many years or were already 'eco-aware'. The information gained from interviews corroborates the data from the survey.

Duda and Hugo, both diving instructors said, "30-40% (of tourists) change their behaviour. We show *Reef Reborn* (a documentary about Biorock) once a week" (Interview, Duda & Hugo, 23/06/09). Mariciana also states Biorock has helped modify tourist behaviour:

> "I am a marine biologist and I organise marine biology courses so people know more about this (coral degradation) and obviously I talk about Biorock. People understand better. Once I explain the ecology of the coral reef and they see the project and I explain how a coral is made, they will never touch a coral because they understand. They have more respect for marine life." (Interview, Mariciana Leotta, 23/06/09)

By the very presence of Biorock, tourists are educated about the fragility of coral reefs. This education is then supplemented by marine biology courses such as those offered by Marciana or other major dive schools such as Reef Seen Aquatics. Products such as the DVD *Reef Reborn* (a documentary about Biorock that is sold in prominent hotels such as the Taman sari) and Biorock key rings all serve to increase awareness of coral reef degradation as well as raise valuable donations. *Biorock for Kids*, a magazine designed to educate children about Biorock and coral reefs in an engaging and easily digestible format, sells together with the *Reef Reborn* DVD in the region of 250 per month. However, whilst Biorock is clearly a very powerful educational tool, some of the data gained from the questionnaires does not indicate this fact as strongly as one might expect. Question 9, for example, suggests a significant proportion of tourists thought coral reefs to be reasonably robust, much more than expected given their fragility and susceptibility to environmental stress. I believe this was because the wording of the question was ambiguous. Question 9 (see **Fig.16**) asked respondents to rate how fragile coral reefs were on a likert scale of 1-7. Yet this question failed to distinguish between natural reefs and artificial reefs. Consequently, I believe many of the respondents believed the question was attempting to gauge their opinion towards Biorock. As such, a larger proportion of tourists indicated they believed coral reefs to be more robust than they otherwise might have done had they thought they were answering a question about natural reefs.

It is interesting to note the gender bias in this study. Approximately 60% of respondents were female and on a personal note I found women to be generally more forthcoming and inquisitive about the reef restoration project. This is an observation that was substantiated by members of the Biorock team. Rani, for instance, finds women are generally more eager to take part in Biorock's *Sponsor a Baby Coral* programme. This is where tourists make a donation of around $50 US to have their name placed on one of the Biorock reefs. The name tag is made from a conductible material such as wire and over time, it gains a calcium carbonate coating and becomes part of the structure, helping to promote coral growth. Those that partake in the programme are sent a photograph of their name tag once a year until eventually it becomes indistinguishable from the rest of the structure, having become

part of what Wolf Hilbertz refers to as 'living architecture' (Hilbertz, 1979). The idea of nurturing a baby coral is one that Rani has found to appeal to more women than men: "Women, especially, look at it and say 'oh "baby" coral' (Interview, Rani, 23/06/09)".

Perhaps one of the greatest achievements of the reef restoration project has been to improve social cohesion in Pemuteran. By benefitting each stakeholder group, communication has been increased and conflict over resource access has been reduced. Biorock is helping to restore the marine environment, an aim common to different groups in Pemuteran and so has acted as a unifying force. Meetings are held between different stakeholder groups to discuss ways to conserve the marine resource. The Head of the Pecalang Laut (sea Guardians) told me: "All the community, the marine security and hotel business, have different ideas but they make one agreement, they become one, on how to protect the coral reef" (Focus group, Made Gunaksa, 26/06/09). The view that Biorock has unified the community was echoed by other members of the focus group. Ny Satria said the need to protect the artificial reefs encouraged different stakeholder groups to come together to create the Pecalang Laut:

> "The community in Pemuteran know and support the reef because many reefs over here have already been destroyed by humans and nature also. The project time [sic]; the community here thinks the reef is not only very important for tourists but for everybody. This is why they came together to make appointment to make Pecalang Laut." (Focus group, Ny Satria, 26/06/09).

That the community is united is clearly very important for the successful governance of a marine resource. As Agung Prana has pointed out, "The ecosystem is not only nature; it is a social and cultural ecosystem" (Interview, Agung Prana, 06/07/09). By satisfying the demands of different stakeholder groups, Biorock is helping improve the health of Pemuteran's 'social ecosystem'. Nowhere is this more clearly seen than between the tourism and fishing industry. In many coastal areas, there is a fundamental conflict between fishermen who place a premium on fishing rights and the tourism industry who want to use the marine resource for leisure activities. As a technology, Biorock acts as a mediating force between these two groups by fulfilling the needs of each stakeholder group. As Mariciana says, "There can be a conflict between the fisherman and tourism. But if you deal with it in an intelligent way, maybe you can arrive at an agreement" (Interview, Mariciana, 23/06/09). By both acting as a tourist attraction and a breeding ground for fish, Biorock is uniquely placed to help facilitate an agreement between these two groups. Providing there is appropriate zoning and enforcement (which there is in Pemuteran), Biorock enables the marine resource to be utilised in a way that is mutually acceptable to both parties. This is fundamental in constructing a framework for sustainable governance within MPAs. Chris Brown adeptly sums this up by saying:

“It’s got to be a win-win situation for all. If it’s winning for the locals but not for the businesses, it’s not going to work. If it wins for the businesses but not for the locals, it won’t work. It’s got to be win for the business, win for the people, win for the tourists which translates as a win for nature.” (Interview, Chris Brown, 04/07/09).

6.0 Discussion

This section will aim to discuss how collaborative environmental governance was achieved in managing Pemuteran's highly contested common pool resource. The results focussed on Biorock's key role in facilitating the sustainable governance of Pemuteran's marine resource. By drawing on a number of key theories, it will be argued that Biorock helped draw different stakeholder groups together by not only helping to restore Pemuteran's environment but by also contributing to the area economically. It will be suggested that it is Biorock's unique ability to integrate the different spheres of sustainability (environment, economic and social) that has enabled it to play a central role in Pemuteran's governance regime. However, it will also be acknowledged that Biorock was not uniquely responsible for the progress made in Pemuteran towards good governance. Indeed, it will be demonstrated that numerous preconditions were in place that have allowed Biorock to play the successful role it has, namely strong leadership, effective zoning and law enforcement as well as the socialization of the local community. Hence, following a conceptual analysis of Biorock's prominent role in the governance of Pemuteran's coast, it will be attempted to then place this in a wider context and outline some of the challenges that still face Pemuteran.

Biorock has been instrumental in facilitating the transition from a system characterised by overexploitation of the marine resource to one that is capable of supporting a successful tourism industry and where fishermen are able to catch sufficient yields for themselves and their families. As a technology, Biorock has served the interests of two competing groups - the resorts and the fishermen - and acted as a central focal point for agreement. Increased cooperation and collaboration has allowed for a more sustainable framework of governance which in turn has benefitted the environment. The importance of collaborative action has been explored extensively by numerous authors (Ostrom, 1990; Dengler, 2007) and formed a cornerstone to WCED's (1987) *Our Common Future*. However, the role technology can play in achieving this goal has not been focussed upon so sharply. Biorock is able to perform a multiplicity of functions simultaneously and so gain the common support of different groups. It is a technology that has lubricated the wheels of agreement in Pemuteran. By regenerating coral and replenishing fish stocks, Biorock not only benefits the environment but the economic interests of the fishermen and the resorts. Its ability to educate tourists as well as the host population regarding the fragility of coral reefs helps construct a foundation for a more sustainable form of coastal tourism where there is an increased awareness of the need to protect the environment. Biorock thus plays an environmental, economic as well as social role in the governance of Pemuteran. It is through performing these different functions that has helped integrate

the three different dimensions of sustainability into one unifying conception. This is illustrated in the diagram below:

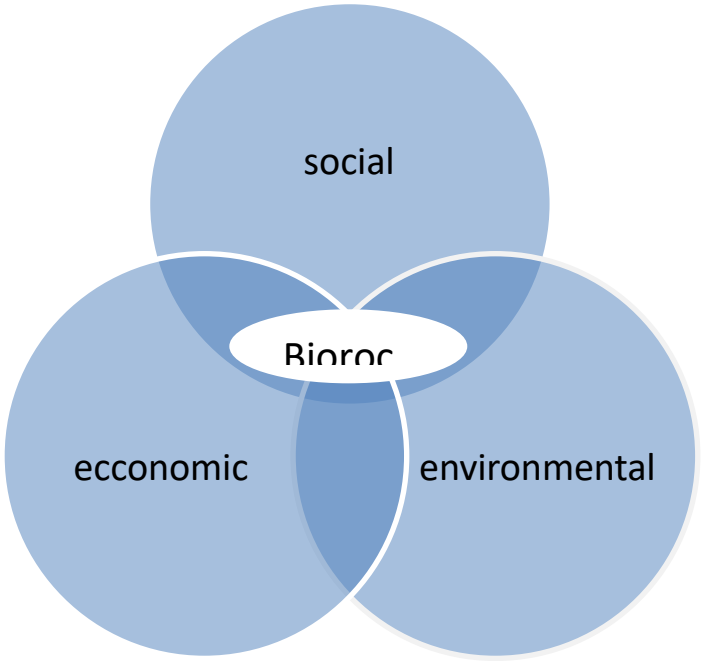

Fig. 27 (By Author) Biorock Unifying Concept

By acting as a force for unity, integration and collaboration, Biorock has played a key role in the sustainable governance of Pemuteran's common pool resources. What had been a typical 'Tragedy of the Commons' (Hardin, 1968), where the marine resource had been degraded for both tourists and fishermen has been revitalised so that both groups are able to use it. Pemuteran's system of governance has now incorporated principles of collective action and cooperation. In this regard, Pemuteran now resembles Ostrom's (1990) prescribed model for the sustainable governance of social-ecological systems much more closely than Hardin's (1968) bleak 'Tragedy of the Commons'.

Yet whilst Biorock has been instrumental in Pemuteran's transition to a more collaborative model of environmental governance, it is important to note that this was not uniquely due to the reef restoration project. Various other factors have been essential in gaining the support of different stakeholder groups. One has been the presence of a strong leader. In her study of the Everglades, Dengler (2007) highlighted how actors who inhabited multiple knowledge spaces and served in a leadership role were particularly important in shaping a cooperative framework. Dengler (2007: 30) has referred to these influential individuals as 'super-agents'. In the case of Pemuteran, Agung Prana has been particularly important in combining western scientific concepts with local indigenous knowledge and so drawing different stakeholder groups together. According to Nara:

> "There is a key factor that might not be found in other places and that is a traditional leader that understands both worlds. Pemuteran is fortunate in having Pak Prana because not only is he fluent in English and also western thinking but he's a very high cast, well respected Balinese leader whose centre of life is in the temple so he's able to talk to people who's centre of life is the temple and translate these western concepts into something that they understand." (Interview, Nara, 05/07/09).

Agung Prana is not merely translating scientific ideas literally but is able to relate them in ways that are more readily transmissible in Balinese society. Agung Prana himself says he gives 'environmental education through religion' (Interview, Agung Prana, 06/07/09). Thus it is by inhabiting both scientific and religious knowledge spaces as well as serving as a link between western and Balinese culture that Agung Prana has assumed the role of a 'super-agent'; an individual with perceived legitimacy that has been able to garner support for ecological conservation and Biorock. If the reef restoration project were to be replicated elsewhere, it is likely individuals with a similar influence to Agung Prana would need to be present in order to ensure its success.

The socialization of the local community has also been paramount in the success of the reef restoration project. Chris Brown, who could also be thought of as a 'super-agent', has spent many years in Pemuteran attempting to educate the local community about marine conservation. His own organization, the *Reef Gardeners*, owns several artificial reefs whilst his dive shop, *Reef Seen Aquatics*, runs various sustainability projects in Pemuteran such as a turtle hatchery. By holding innumerable unofficial meetings and talks with local community members, Chris Brown was able to set the foundation stones in place for Biorock to be accepted. This was vital in the project's success: Chris Brown comments:

> "A guy from UNESCO came and asked me how I have been able to do this when lots of other places haven't. I said simple: Time. I've been here 18 years and it's taken all that to get to this stage. If you do a project and its 6 months or 1 year and you spend lots of money and do lots of stuff and then walk out, you're pissing your money away because you've got to get to know the people. It takes a long time to get accepted before you can start introducing western ideas and start blending it with Balinese culture" (Interview, Agung Prana, 06/07/09).

Similarly, Nara says:

> "There's been a couple of other communities that have tried it (Biorock) and the fishermen have cut the cables and stolen the anode. The socialization process is critical in Bali. If it's not socialized and some white guy comes in and says 'here's the money to do it.' it's dead within six months." (Interview, Nara, 05/07/09)

Thus to implement Biorock reefs without having gained prior support of the community drastically increases the likelihood of failure. Indeed, it is essential to educate the local community regarding the

benefits of artificial reefs and conservation before attempting any installation. This process of socialization was well underway in Pemuteran due to important individuals such as Chris Brown and there can be little doubt that this greatly contributed to the success of the reef restoration project.

Effective zoning and regulation has also allowed for a more successful model of governance to emerge in Pemuteran. By establishing a no-take zone in front of the hotels where the majority of the reef restoration project is located, ecological conservation has been allowed to progress. Although some fishermen occasionally incur to the no-take zone, the Pecalang Laut ensure the MPA is predominantly upheld and regulated successfully. Agung Prana told me: “We need to have a master plan: zoning, regulation, commitment and policy” (Interview, Agung Prana, 06/07/09). To implement Biorock without an overriding framework of zoning and regulation would compromise the project’s safety and decrease its chances of success.

Finally, it is important to note that whilst Pemuteran has made much progress in the sustainable governance of its marine resource, it still faces several challenges. Although Biorock has played a key role in arbitrating the potential conflict between the fishermen and resorts, it has failed to completely align their interests. The fishing community dispose their waste via a river that leads to the ocean and so causes pollution. This is shown in the image below:

Fig. 28 (Photograph By Author) Waste In River In Fishermen’s Zone

Whilst this is within the fishermen's zone, the transboundary nature of pollution means that this causes a problem not only for tourism but also for ecological conservation. Mariciana told me: "The river and rubbish is a problem. They before, just a few years ago, had just natural things that they used to throw away in the street. Now they use plastic and they still throw it in the river." (Interview, Mariciana Leotta, 23/06/09). Though Biorock has increased the awareness of the local community with regards to environmental protection, it has thus far been limited in its ability to alter behaviour to the extent that rubbish is disposed of in an environmentally friendly manner.

7.0 Conclusion

Despite difficulties and limitations, Biorock has helped construct a delicate web in Pemuteran where each user of the marine resource has gained from its presence. In combination with the MPA and effective regulation from the Pecalang Laut, it has enabled a cooperative framework of governance where the marine resource is able to recover. By accelerating the recovery of fish stocks as well as providing increased coral cover and an ecotourism attraction, it has enabled a 'win-win' to occur for both the hotel and fishing industries. It is through meeting the needs of these two large stakeholder groups that conflict has been arbitrated in Pemuteran and a transition has been able to take place to a system of governance where the marine resource is not exploited beyond its ability to recover. If another mass warming event like that seen in 1998 as a result of El Nino were to occur, Biorock coral would be up to 50 times more resistant to stress than natural coral. Biorock is thus the 'precautionary principle' in action as it dramatically increases the likelihood of some coral species surviving. Indeed in the event of a complete ecosystem collapse as a result of global warming, it is feasible that Biorock reefs could become increasingly important as tourist attractions as they would represent one of the few remaining opportunities for people to see coral. It is Biorock's ability to fulfil functions within each component of sustainability (environmental, economic and social) that enables it to sit at the heart of a sustainability nexus in Pemuteran. Agung Prana said: "In Balinese culture, sea is the centre of life. Sea is the mother of purification. Sea is very important. But now the perception needs to be revitalised." Biorock is playing a key role in that revitalisation.

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Appendix

Pemuteran Questionnaire

I am a student researcher from Royal Holloway, University of London and would really appreciate it if you could take a few minutes to assist in my research project.

Why did you decide to visit Pemuteran? (circle as many as apply)

a. Hotels b. Spa c. Cuisine d . Beaches

e. Diving/Snorkelling f. Trekking g. Cultural pursuits h. Other_____

Are you aware that there is an artificial (Biorock) coral reef in Pemuteran, Bali? Yes No

How important was the Biorock reef in your choice to visit Pemuteran?

a. Very important – it is the primary reason I chose to visit.
b. Important – it is a factor that helped me decide to visit.
c. Low importance – it is of mild interest, but not a factor in my choice to visit.
d. No importance – I am aware of it, but the reef does not interest me.
e. I was not aware of the presence of the reef before my visit.

Do you snorkel or dive?

Yes, I Snorkel Yes, I Dive Yes – Both No

Has the Biorock reef influenced your behaviour when diving/snorkelling?

Yes No I don't know I don't snorkel or dive

If yes, how? _____

What do you think about the presence of the Biorock reef? (please circle all that apply)

a. It is attractive and a welcome addition to the marine environment.
b. It has novelty value.
c. It is essential for ecological conservation.
d. I think there should be more Biorock reefs elsewhere.
e. I think it is unattractive and detracts from my enjoyment of the area.
f. It is dangerous.
g. I do not think they should build any new Biorock reefs in Pemuteran or elsewhere.
h. I think they should remove the existing Biorock reef from Pemuteran.
i. Other_____

Do you consider the Biorock reef to be part of the natural ecosystem?

a. Yes, it is part of the natural ecosystem
b. I don't know
c. No, it is not part of the natural ecosystem

Have you visited the Biorock Centre? Yes No

Since seeing the Biorock project how would you describe coral reefs?

1	2	3	4	5	6	7
Robust			Stable			Fragile

Are you concerned with the destruction of coral reefs? Yes No

Why? _____

Has the reef restoration project increased your awareness of the need to restore coral reefs?

Yes No I don't know

Would you recommend the reef to others? Yes No

Why?_____

Would you return to Pemuteran? Yes No

About you

Male/Female

Age: Under 18 18 – 29 30 -39 40-49 50-64 65+

Nationality_____ **Duration of stay in Bali** _____

Do you support any environmental charities/NGOs? Yes No

If yes which one? (circle all that apply)

WWF Greenpeace Friends of the Earth Other_____

Do you have any further comments?

_____

_____

_____ _____

Thank you!

Results From Pemuteran Study, 2009

Why did you decide to visit Pemuteran? (circle as many as apply)	
a. Hotels	78
b. Spa	30
c. Cuisine	21
d . Beaches	156
e. Diving/Snorkelling	300
f. Trekking	36
g. Cultural pursuits	66
h. Other	84

Are you aware that there is an artificial (Biorock) coral reef in Pemuteran, Bali?	
Yes	169
No	254

How important was the Biorock reef in your choice to visit Pemuteran?	
a. Very important	63
b. Important	94
c. Low importance	121
d. No importance	13
e. not aware	132

Do you snorkel or dive?	
Snorkel	216
Dive	41
Both	120
No	46

Has the Biorock reef influenced your behaviour when diving/snorkelling?	
Yes	157
No	211
I don't know	46
I don't snorkel or dive	9

What do you think about the presence of the Biorock reef? (please circle all that apply)	
a. It is attractive and a welcome addition to the marine environment	258

b. It has novelty value	123
c. It is essential for ecological conservation	324
d. There should be more biorock reefs elsewhere	282
e. It is unattractive and detracts from my enjoyment of the area	6
f. It is dangerous	6
g. I do not think they should build biorock reefs elsewhere	0
h. I think they should remove the existing biorock reef from Pemuteran	0
i. Other	15

Do you consider the Biorock reef to be part of the natural ecosystem?

a. Yes	300
b. I don't know	72
c. No	51

Have you visited the Biorock Centre?

Yes	93
No	330

Since seeing the Biorock project how would you describe coral reefs? 1= Robust

1 = Robust	22
2	6
3	67
4	55
5	111
6	72
7 = Fragile	90

Are you concerned with the destruction of coral reefs?

Yes	389
No	34

Has the reef restoration project increased your awareness of the need to restore coral reefs?

Yes	313
No	43
I don't know	67

Would you recommend the reef to others?

Yes	120
No	303

Would you return to Pemuteran?

Yes	374
No	49

Gender	
Male	177
Female	246
Age	
Under 18	6
18 – 29	123
30 -39	144
40-49	84
50-64	54
65+	12
Nationality	
British	34
French	55
German	124
Dutch	46
American	28
Swiss	16
Belgium	25
Italian	10
Australian	19
Mauritian	4
Finish	4
Mexican	4
Argentinean	4
Filipino	4
Hungarian	4
Polish	6
Austrian	6
Danish	9
Russian	9
Norwegian	12
Duration of stay in Bali	
Less than 1 week	24
1 - 2 weeks	103
Over 2 weeks - 3 weeks	99
Over 3 weeks - 4 weeks	117
Over 4 weeks	80
Do you support any environmental charities/NGOs?	
Yes	135
No	288

Which?	
WWF	60
Greenpeace	57
Friends of the Earth	9
Amnesty	6
Sierra Club	6
Other	30