THE EXISTENCE VALUE OF HAWAIIAN CORAL REEFS UNDER CONDITIONS OF CLIMATE CHANGES

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ABSTRACT

Hawaii's coral reefs are highly productive ecosystems providing many valuable goods and services. However, without the necessary research into the existence value of coral reefs and the potential willingness to pay for mitigation against climate change, managers and policymakers responsible for protecting the reefs are ill equipped to properly understand the limits and options for public involvement and support for funding programs, scientific initiatives and protection efforts.

The purpose of this research is to provide tools and information beneficial for furthering the development of additional research and potential policies for climate change mitigation. To accomplish this goal, the research uses a discrete choice experiment (DCE). Results of this DCE are then used to develop a decision support system for determining public willingness to pay for climate change based on various future scenarios. Results show that there are distinct segments of the population that are divided in their climate belief. Within the segments of climate believers and climate sceptics there are further divisions of those that are willing to pay for climate change mitigation and those that are adverse to paying for mitigation. Analyses of the findings are discussed along with implications of simulations for coral reef management and climate change mitigation strategies.

Keywords: ecosystem services; climate change; existence value; willingness-to-pay; coral reef valuation

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CHAPTER 1: INTRODUCTION

1.1 Background Info and Project Rationale

Coral reefs are striking, complex, and important geological formations constructed from the accumulated skeletons of limestone-secreting animals and plants. The intimately linked plant-animal communities that create them are representative of an ecosystem that occurs in tropical and subtropical waters across the planet, most commonly in shallow oceanic water, and often close to land (Buddemeier, R., 2005). These coral reefs are highly productive ecosystems providing a variety of valuable goods and services. However, the open-access nature and public good characteristics of coral reefs often result in them being undervalued in decision making related to their use and conservation (Brander, L.M., Van Beukering, P., Cesar, H.S.J., 2006). Research on the current and future impacts of human-induced climate change on reef-building corals is causing scientists and managers to become increasingly concerned about the future of coral reefs.

Accounting for approximately 25 percent of all marine species despite covering only 0.17 percent of the ocean floor (Goudie and Viles, 1997), coral reefs provide a great number of services that benefit human populations around the globe both directly and indirectly. These services include maintenance of biodiversity, shoreline protection, tourism, fisheries, trade (aquarium and rare species), and aesthetic and cultural value. The effects of climate change and other human induced stressors will have consequences for the flow of ecosystem services from these systems.

Climate related stressors affecting coral reefs include temperature changes, solar radiation, changes in the frequency and severity of storms, sea level rise, changes in water quality, salinity fluctuations, and increasing atmospheric carbon dioxide (CO_2) levels which impacts ocean chemistry and can inhibit calcification; the deposition of the calcium carbonate minerals that are the structural building materials of coral reefs (IPCC, 2007). The major climate change factor that is becoming increasingly important for coral reefs is rising ocean temperatures, which has been implicated in chronic stress and disease epidemics, as well as in the occurrence of mass coral bleaching episodes (Buddemeier, R., 2005). In addition to the climate related stressors, several human stresses further exacerbate the conditions affecting the coral reefs: nutrient and sediment loading, direct destruction, coastal habitat modification, contamination, and the very important chronic indirect effects of overfishing.

Complex ecosystems in general provide us with numerous direct and indirect services, including waste assimilation, water purification and nutrient cycling. While ecosystems provide these services, it is extremely difficult to assess the value of a particular species within an ecosystem. Coral reefs provide protection to coastal areas and protect delicate coastal wetlands. The loss of a significant part of the coral reefs due to pollution, sedimentation, or a sea-level rise would result in a significant loss of ecosystem services and consequently a valuable loss to humankind (Hanley et al., 1997).

The economic value of a reef ecosystem can be defined as the total value of the goods and ecological services that it provides. In order to assess the value of such an ecosystem, we therefore need to know what the major goods and services of reef ecosystems are, as well as how they interact with other ecosystems. As well, the goods and services need to be quantified and evaluated in dollar terms. Unlike goods sold in the market place, whose value can simply be determined by looking at their market price, for ecological services, this is not possible. Instead, complex valuation techniques are used to determine the economic value of these services.

The goal of this study is to provide insight on public willingness to pay for mitigation efforts against the effects of climate change on coral reef ecosystem services in Hawaii. The results of this research will help establish the scientific basis for assessing the existence value of coral reefs associated with the consequences of climate change at various spatial scales. As well, it is the intention that resource managers and policy decision makers will have the opportunity to anticipate changes in ecosystem services and adapt their management practices for long-term sustainability.

1.2 Study Area

The Hawaiian Islands, which make up the State of Hawaii, are located approximately 1860 miles west of the continental USA. The islands, which comprise a total of 137 islands and atolls, can be broken into two distinct island groups, the Main Hawaiian Islands and the Northwestern Hawaiian Islands

(NWHI). The Main Hawaiian Islands consist of eight larger islands, where nearly all of the state's population, tourism and economic activities are concentrated. These islands are surrounded by about 300,000 acres of shallow water coral reef ecosystems. These coral reefs are heavily used for recreation (fishing, boating, diving and snorkeling), commercial fishing, and for cultural and religious activities by native Hawaiian people. The Northwestern Hawaiian Islands consist of many small, mostly uninhabited islands that stretch 1,500 miles northwest of the Main Hawaiian Islands and contain some of the healthiest reefs in the US. These islands are surrounded by about 400,000 acres of shallow water coral reef ecosystems. The NWHI have now been declared the Papahanaumokuakea Marine National Monument (PMNM), a marine protected area that is closed for fishing, recreation or any private use. The reef ecosystems of the NWHI are in a much more natural condition with a higher abundance and variety of fish than those of the Main Hawaiian Islands. Many large fish, seals, and other species at the top of the food chain still live here, whereas they have almost disappeared from the Main Hawaiian Islands. Only a few large coral reef ecosystems in the world remain so untouched by humans.

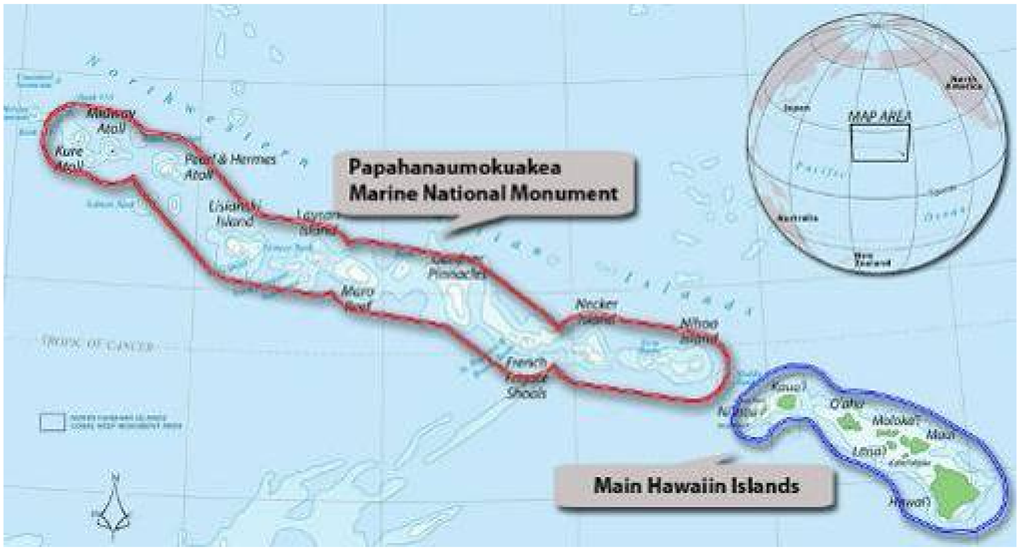

Figure 1.1: Map of the Hawaiian Islands

1.3 Research Goals

Given the potentially high use and non-use values of Hawaii's coral reefs, climate change induced coral bleaching and mortality may result in a significant economic loss for the state economy. The coral reefs of the Hawaiian archipelago are arguably important beyond the State, and are of value to the entire US population; therefore it is proposed to estimate the value of these coral reefs for both Hawaiian residents and the entire US population. This study will attempt to model the effects of projected future climate change on the existence value of Hawaii's coral reefs. The fundamental difficulty in modelling the consequences of future climate change on Hawaii's coral reefs is the uncertainty surrounding the future drivers of climate change (Hughes et al., 2003; Faucheux & Froger, 1995; Viscusi, 2006; Leiserowitz, 2006). While the occurrence of global warming can no longer be disputed, the range of possible future temperature increases laid out in the Intergovernmental Panel on Climate Change's (IPCC) Fourth Assessment Report underlines the uncertainty as to exact predictions of temperature increases. These changes depend in part on the uncertainty ranges inherent in assumptions of future global population growth, economic growth, and technological development (IPCC, 2007). While the IPCC data is global in nature, the impacts remain significant for specific locations such as the Hawaiian archipelago due to their isolated geographical location and extensive coral reef coverage.

The natural environment provides a variety of uses or benefits of value to mankind which can be separated into three main types. *Direct uses,* which include tourism and harvesting of natural resources or 'goods'; *indirect uses,* where benefit is gained indirectly from natural habitats, usually through support and protection of other economic activities and are often referred to as natural functions or environmental 'services'; and *non-uses,* such as option and existence values, whereby value can be derived without any current human use. One significant issue in dealing with Hawaiian coral reefs is the separation between the use value of the reefs for the Main Hawaiian islands and the non-use (existence) value of the Papahanaumokuakea Marine National Monument (PMNM). Both use and non-use values will be described in Chapter 2. Since the PMNM restricts access by the general public, one of the tasks within this study is to assess the value of the ecosystem services of these coral reefs in isolation from human use, therefore determining the existence value of those reefs and the services that they provide.

The intention of this research is to contribute to management and policy decision making with regards to climate change mitigation efforts for the coral reefs.

1.4 Purpose and objectives

Without the necessary research into public perception of climate change and the potential willingness to pay for mitigation, managers and policymakers responsible for protecting ecosystems such as coral reefs are ill equipped to properly understand the limits and options for public involvement and support for funding programs, scientific initiatives and protection efforts. The purpose of this research is to provide tools and information necessary for furthering the development of additional research and potential policies. Through this research, the intention is to determine the willingness of US residents to pay for efforts to mitigate against climate change impacts on Hawaiian coral reefs and to value the existence of that coral reef ecosystem.

1.5 Report organization

This document is organized into 5 chapters; Chapter one presents the rationale for the project, its goal and objectives, Chapter Two provides a review of literature relevant to this study, including coral reef and climate change literature, pertinent environmental valuation literature and more specifically the choice modelling literature. The Third Chapter presents a description of the survey design, data collection methods and analytical techniques. Chapter Four presents a description of the study participants and the results of the climate change mitigation choice experiment. Chapter Five will discuss the findings and the implications of the simulations for coral reef management and climate change mitigation strategies, and will provide an overview of this study's limitations and some suggestions for further research.

CHAPTER 2: LITERATURE REVIEW

2.1 Coral reefs and climate change

Coral reefs have the highest biodiversity of any marine ecosystem and provide important ecosystem services and direct economic benefits to the large and growing human populations in low-latitude coastal zones (Buddemeier, R., 2005). Ecosystem services can be derived from the habitat, biological or system properties or processes of ecosystems. The associated goods (such as food) and services (such as waste assimilation, or aesthetics) represent the benefits human populations derive, directly or indirectly from the ecosystems (Costanza et al., 1997). The productive capabilities of these services however are threatened globally from various human activities and especially from climate change. Increases in sea level and temperature as a result of climate change have become significant issues of concern, especially with respect to their impacts on coral reef ecosystems, as they directly affect the growing conditions of reef polyps. Eleven of the twelve years from 1995-2006 rank among the twelve warmest years in the instrumental record of global ocean surface temperature (since 1850). The linear warming trend over the 50 years from 1956 to 2005 is nearly twice that for the 100 years from 1906 to 2005 (IPCC, 2007). Observations since 1961 show that the average temperature of the global ocean has increased to depths of at least 3000m and that the ocean has so far absorbed over 80% of the heat that is added to the climate system (IPCC, 2007). Recent analyses show warming rates similar to those observed in surface temperature (IPCC, 2001). Increases in sea level are also consistent with warming sea temperatures. The global average sea level rose at an average rate of 1.8 [1.3 to 2.3] mm per year from 1961 to 2003 and at an average rate of about 3.1 [2.4 to 3.8] mm per year from 1993 to 2003 (IPCC, 2001). The predicted rise of sea level due to the combined effects of thermal expansion of ocean water and the addition of water from melting icecaps and glaciers is between 0.1 and 0.9 meter (4-36 inches) by the end of this century (Houghton et al., 2001).

In particular, warming sea temperatures have been implicated in chronic stress and disease epidemics among corals, as well as in the occurrence of mass coral bleaching episodes. "Bleaching" describes the loss of symbiotic algae by the coral host. Most of the pigments in the usually colourful corals depend on the presence of these plant cells. The living tissue of coral animals without algae is translucent, so the white calcium carbonate skeleton shows through, producing a bleached appearance. This bleaching effect is a general stress response that can be induced in both the field and the laboratory by high or low temperatures, intense light, changes in salinity, or by other physical or chemical stresses. Generally, bleaching is the extreme case of natural variation in algal population density that occurs in many corals (Fitt et al., 2000, 2001 in Buddemeier,2005). The temperature threshold for bleaching is not an absolute value, but is relative to other environmental variables (especially light) and to the duration and severity of the departure from the normal temperature conditions of a reef (Liu et al., 2003). These factors are usually affected by anthropogenic changes specific to each reef location. Slow-growing, thick-tissued, massive corals appear to be less sensitive and commonly recover from all but the most extreme episodes. Bleaching thus selectively removes certain species from reefs and can lead to major changes in the geographic distribution of coral species and reef community structures (Hughes et al., 2003).

In a study of a 1998 coral bleaching event on the Great Barrier Reef by Bellwood et al. (2006), the authors determined that these changes in community structure do indeed appear to represent a phase shift in that fish-mediated ecosystem processes have probably been modified. This event is not simply a case of functional redundancy, responding to change by replacing one species with a functional equivalent; clear evidence point to trophic simplification. Resilience would have been characterized by either no change in the community composition (resistance) or regeneration and the return to a community with similar ecological characteristics (in terms of ecosystem processes) to those exhibited by the pre-bleach community. However, the community composition and ecosystem processes both appeared to change as a result of the 1998 coral bleaching event. (Bellwood et al, 2006) This change represents evidence that coral bleaching as a result of climate change has the potential to overpower the natural resilience of coral reef ecosystems to the point where they cannot recover as a functional ecosystem that provides necessary services.

In order to assess the damages and to develop adequate mitigation strategies, it is essential to know the value of the services provided by coral reef ecosystems. Unfortunately, as mentioned earlier, valuing coral reefs is a difficult task because of their open access nature and public good characteristics (Brander, Van Beukering & Cesar, 2006).

Compounding the effects of global climate change are a number of anthropogenic practices that exacerbate the impacts of these changes. These anthropogenic stresses include increased nutrient and sediment loading, direct destruction of the reefs, coastal habitat modification, contamination from waste and run-off, and chronic indirect effects of overfishing. Further to these direct stresses, increasing global concentrations of atmospheric CO_2 will also have significant impacts on ocean chemistry and will affect reef composition and structure.

To date, limited research has been completed with the specific focus of valuing the existence of coral reefs in the context of climate change. So far, studies involving coral reefs and valuation have generally been restricted to use values. Brander et al. (2007) compiled a meta-analysis of 166 coral reef valuation studies that varied widely in terms of valuation techniques used, goods and services assessed and assumptions made. However, the impacts of climate change on those use values was underrepresented within this study. More closely related to the topic of this paper, Cesar et al. (2004) and Van Beukering and Haider (2007) have undertaken previous studies in the realm of socioeconomic impacts of climate change on coral reefs, representing a small minority of valuation studies that incorporate climate change as a key determinant of value.

This study provides a novel approach to valuing the effects of climate change on coral reefs in that it seeks to determine the existence value of those reefs in relation to potential climate change scenarios. By addressing not only coral reefs as a whole, but also the individual components that make up a coral reef, the aim is to provide more accurate assessments of value that can be transferred to a variety of reef locations and scenarios.

2.2 Environmental valuation

The emergence of the environment as a major issue facing society in recent years has had a profound implication for the decisions made by consumers, industry, government and non-government organizations. Increasingly, decision makers have also sought to quantify, in dollar terms, of the effects their choices will have on the environment (Bennet & Blamey, 2001). Resources are limited and indeed many natural environmental resources are decreasing. It is therefore desirable to assess the benefit of protecting and enhancing environmental resources compared to the opportunity costs or benefits forgone of alternative uses (Bateman & Willis, 1999).

R. Kerry Turner asks in Bateman and Willis (1999), “How much conservation should there be, and therefore what is nature’s value?” Conventional economics places its answer in terms of human individual preferences for particular things (including the environment) and the argument that something is of instrumental value to the extent that some individual is willing to pay for the satisfaction of a preference. Underlying this approach is the obvious assumption that individuals almost always make choices which benefit (directly or indirectly) themselves or enhance their welfare (Bateman & Willis, 1999).

The Total Economic Value (TEV) of a habitat (as shown below in Figure 2.1) is derived by valuing all of the values mentioned in Chapter 1; direct-use, indirect-use and non-use. (Barbier, 1989)

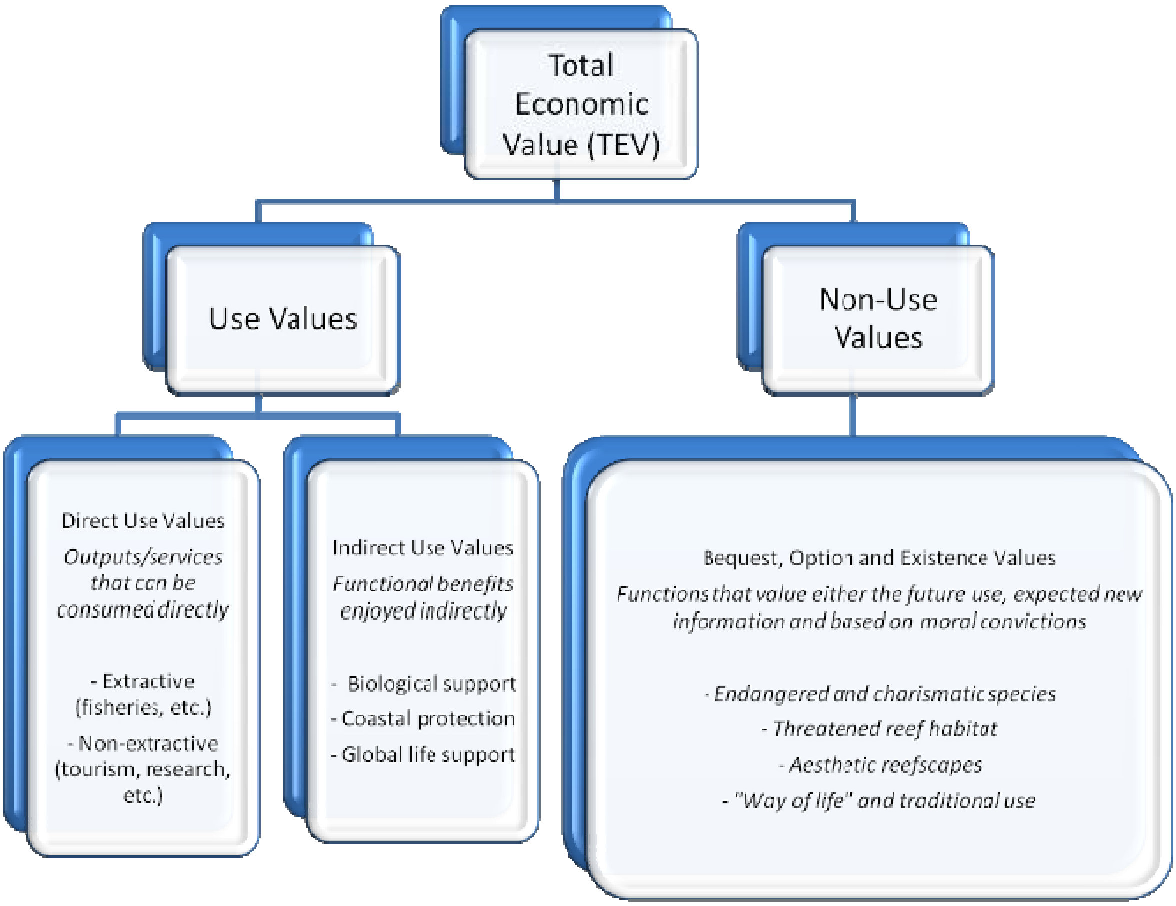

Figure 2.1: TEV from Cesar & Van Beukering (2002)

2.3 Existence Value

Krutilla first introduced the concept of non-use or existence values into economics literature in 1967, stating that the preservation and continued availability of a grand scenic wonder or a unique and fragile ecosystem would form a significant part of the real income of many individuals (Krutilla, 1967). He then noted that there were at least two reasons why people would have values unrelated to their current use of a resource – options for future use, and bequeathing natural resources to one's heirs (Freeman, 1993).

As described by Stevens et al. (1991), Loomis (1988) suggests a general form of an interdependent utility function: $U_a = F_a(f_{1a}(X_a, R_a) + f_{2a}(Q_a, (R_b, Q_b)))$ [1] where U_a is a weakly separable function relating the utility of individual a to a's own consumption of a bundle of private goods, X_a; a's use of the natural resource, R_a; knowledge that other people (represented by b) are able to use the resource, R_b; personal satisfaction from knowing that the re- source exists, Q_a; and the knowledge that others derive satisfaction from knowing that the resource exists, Q_b. The total resource value in this formulation consists of several self-interest and altruistic components which can be held simultaneously by each individual. These components can be aggregated into three main categories: (1) personal use values (including option value), (2) use by others (including bequest value), and (3) nonuse values. The condition of weak separability means that the marginal rates of substitution between goods purchased in the market, X, are independent of Q and consequently contingent valuation is the only technique capable of measuring existence values

2.4 Coral reef valuation

Coral reefs benefit society in many ways, but placing an economic value on the goods and services provided by reefs is difficult. While estimating direct economic benefits from fishing and tourism is relatively straightforward, estimating values of services such as shoreline protection, biodiversity, and aesthetic value is not (e.g., Costanza et al., 1997), and these services are often omitted from reef valuations. Nearly 40 percent of the people on Earth live within 100 km (60 mi) of the coastline, and many local and regional economies are based on goods and services provided by these coastal ecosystems (Buddemeier, R., 2005), making reef valuation a worthy and prudent venture. The goods provided by coral reefs often form an important source of income for local populations (through fishing, mariculture, etc.), and sustenance to those living at subsistence levels. Coral reefs are also a tourist attraction, contributing to local income and foreign exchange. In addition, they form a unique natural ecosystem, with important biodiversity value as well as scientific and educational values. Coral reefs also form a natural protection against wave erosion (Cesar, 2000).

The economic value of an ecosystem is often defined as the total value of its instruments, that is the goods and ecological services that an ecosystem provides. For coral reefs, we therefore need to know its major goods and services as well as their interactions with other ecosystems. Next, these goods and services need to be quantified. Complex valuation techniques are used to arrive at an economic value of these goods and services (Cesar, 2000). The economic benefits that come from reef ecosystems accrue to local economies and citizens around the globe. Locally, reefs support fisheries, attract SCUBA and snorkelling tourism, are a source of calcium carbonate, and provide important shoreline protection. Globally, coral reefs are valued for their role in the carbon cycle, their inherent existence value, and the consumer surplus enjoyed by SCUBA divers (Pendleton, 1995). Flores (2004) defines consumer or compensating surplus (CS) as the change in income that will leave an individual indifferent between the current situation and some defined alternative, given an implied right to the current situation.

Coral reef protection is usually presumed to conflict with economic development, and to require the sacrifice of economic growth. Meanwhile, some of the most important values of coral reefs, such as their value to future generations and their intrinsic values, are rarely quantified. The omission of these benefits in conventional economic analysis means that coral reefs are undervalued, which may further contribute to their unsustainable use (Seenprachawong, 2001).

In the view of some decision makers it is useful, and for some decision support tools it is necessary, to aggregate the vast number of detailed regional and sector-specific estimates to a more manageable set of numbers. Currency is the most commonly chosen numeraire for this type of aggregation exercise, partly for reasons of convenience and partly because of the internal logical consistency of monetization based on the theory of human preference measurement. Monetization also has the advantage of expressing impacts in the same units of measurement as the cost of response measures, which in turn facilitates the comparison of the costs and benefits (avoided impact) (Fankhauser et al, 1998).

As long as environmental tradeoffs are a policy reality, some common scale would seem to be useful. Monetary values such as dollars are a metric with which people have lots of practice and consequently, provide a scale with considerable psychometric power. At the same time, it would be foolish to take any monetary estimate at face value to reflect the ‘true’ price of some environmental good or service (Berk & Fovell, 1999). Much of the conventional theory and research on willingness to pay and willingness to accept payment for environmental changes has focused on non-market use values for goods and services that people experience and use directly. Other environmental goods have value to people although these goods are not directly used in any sense (Berk & Schulman, 1995).

2.5 Valuation of Climate Change Impacts

A reasonable understanding of the likely impacts of climate change on human welfare is crucial for making an informed decision about the best response strategy to the enhanced greenhouse effect.

The prospect of global warming and its possible implications for all life on the planet implies the need to value our current climate against what a future climate might be like (Berk & Schulman, 1995).

Assigning value to these non-use goods and services and then transferring that value to a position where it can be used for policy and management decisions is of utmost importance for climate change mitigation efforts.   A decrease in ecosystem services caused by climate change will affect all of the economic, social and environmental aspects of our lives.

A number of studies have attempted to compile aggregate estimates of the costs of adaptation to, and residual impacts of climate change in terms of dollar values and/or shares of GDP (Smith and Tirpak, 1989; Ayers and Walter, 1991;

Nordhaus, 1991; Cline 1992; Titus, 1992; Fankhauser, 1994; Tol, 1996, Mendelsohn et al, 1998). The general conclusion of these studies is that plausible changes in $C0_2$ and average temperature levels, would result in a reduction in GDP for present day economies (Rothman, 2000).

The willingness of the voting public to incur substantial costs in order to prevent climate change will be a key determinant of the success or failure of domestic and international climate policy (Cameron, 2005).

There is substantial academic and policy interest in the potential for, and validity of, value transfer as it offers a means of estimating monetary values for environmental resources without requiring the performing of relatively time consuming and expensive primary valuation studies (Brander et al., 2008).

2.6 Measuring Environmental Values

In order to provide a measurement of the value accrued from the environment, various methods and techniques are available.

2.6.1 Stated vs revealed preferences.

Traditional economics has long relied on 'revealed preference' methods to infer prices from observed behaviour. While revealed preference is still an adequate method for determining value in certain situations there are also many criticisms against it. These criticisms include; the failures to include any sources of value beyond direct use such as biodiversity, difficulties determining accurately the opportunity costs of on-site and travel time, and a number of thorny measurement and model specification problems (Berk & Fovell, 1999). As a result, stated preference methods have become the more popular approach in order to accurately make informed decisions regarding policy and management. Stated preference methods involve the elicitation of responses to predefined alternatives in the form of ratings, rankings or choice. Stated preference methods include both the Contingent Valuation Method (CVM) and Choice Modeling (CM), considered my most to be two distinct methods for determining respondent preferences.

2.6.2 Contingent Valuation Method (CVM)

The most common method for measuring passive use values is the Contingent Valuation Method (CVM). CVM creates a hypothetical market for a non-market good or service (i.e. a benefit associated with a natural area, or a specific environmental improvement) by asking people how much money they would be willing to pay for that particular benefit (Mitchell & Carson, 1989). Contingent valuation is a direct survey approach for estimating consumer preferences. By means of an appropriately designed questionnaire, a hypothetical market is described where the good or service in question can be traded. This contingent market defines the good itself, the institutional context in which it would be provided, and the way it would be financed. Respondents are then asked to express their maximum willingness to pay or minimum willingness to accept for a hypothetical change in the level of provision of the good (Hanley et al., 2001).The goal of contingent valuation is to elicit from people what they would be willing to pay to protect some environmental asset or what they would have to be paid to give it up (Berk & Fovell, 1999).

One of the major concerns with CVM is the embedding effect. This is the phenomenon whereby respondents provide almost the same WTP for an entire bundle of goods as they do for one of the goods in the bundle (Kahneman & Knetsch, 1992; Loomis, Lockwood, & DeLacy, 1993). It appears that respondents are willing to pay for a positive environmental change, but they are unable to make distinctions about how much change they are really willing to pay for. CVM can show support for a change, but the embedding effect raises questions about the validity of comparing WTP estimates with other economic values. Carson (1998) suggests, however, that even the embedding effect can be reduced or eliminated through careful wording of the CVM survey. A similar concern with CVM is what is known as 'yea-saying'. This is the tendency of respondents to say yes to a referendum CVM question regardless of the actual WTP amount, simply because they want to indicate support for a positive environmental policy. The result of this tendency is that CVM studies can overestimate the actual WTP, and hence overestimate the value of a particular environmental benefit.

2.6.3 Discrete Choice Experiments

CVM is now frequently replaced by stated choice surveys, which are very flexible in terms of modelling complex trade-offs between attributes (Adamowicz et al., 1994).

Discrete choice experiments (DCE) are a family of survey-based methodologies for modeling preferences for goods, where goods are described in terms of their attributes and of the varying levels that these attributes take.

Respondents are presented with various alternative descriptions of a good, differentiated by their attributes and levels, and are asked to rank the various alternatives, to rate them or to choose their most preferred. By including price or cost as one of the attributes of the good, willingness to pay can be indirectly recovered from people's rankings, ratings or choices (Hanley et al., 2001). The DCE technique is an application of the characteristics theory of value (Lancaster 1966), combined with random utility theory (Thurstone 1927; Manski 1977). It thus shares strong links with the random utility approach to recreational demand modelling using revealed preference data (Bockstaell et al. 1991).

What makes choice experiments unique is that levels of various attributes of the choice situation are varied in a systematic fashion, and that they utilize repeated measure responses from sampled individuals (Boxall et al., 1996). The repeated sampling method employed in choice experiments alleviates some concerns regarding lower informational efficiency that affect the referendum CVM model (Carson, 1991).

In choice models, alternatives are defined as combinations of attributes (Louviere et al., 2000) and choices can be modelled as a function of the attributes of the alternatives (McFadden, 1974; Ben- Akiva and Lerman, 1985).A distinction of the information presented in CM and CVM questionnaires arises in that CM seeks to communicate differences in a number of resource use options, not just the status quo and a single alternative. Whilst CVM provides an estimate of the value for only a single policy option, CM provides estimates of the value of any option that can be constructed using any combination of the attributes and attribute levels contained within the choice sets (Blamey et al., 1997).

One problem with CVM is its reliance on the accuracy of the information, and the fact that any errors in the information discovered after the fact cannot be changed. The choice experiment approach, however relies on the representation of a choice situation (rather than the specific change in the good or service) using an array of attributes. Thus, it relies less on the accuracy and completeness of one single description of the good or service, but more on the accuracy and completeness of the characteristics and features used to describe the situation (Boxall et al., 1996). Therefore, rather than being questioned about a single event in detail, as in a CVM analysis, subjects are questioned about a sample of events drawn for the universe of possible events of that type (Louviere, 1994). Discrete choice experiments are now widely used in resource management in general and for environmental valuation specifically as well as in tourism and recreation contexts (Kelly et al., 2006, Boxall et al., 1996, Cesar et al., 2002). DCEs are particularly well suited to deal with situations where changes are multi-dimensional and trade-offs between them are of particular interest because of its natural ability to separately identify the value of individual attributes of a good or programme, typically supplied in combination with one another. DCE does a better job than CVM in measuring the marginal value of changes in various characteristics of environmental programmes. This is often more useful from a management/policy perspective than focusing on either the gain or loss of the good, or on a discrete change in its attributes (Hanley et al., 2001). In many instances, DCE may be more useful in policy design than contingent valuation, since the latter does not typically involve the estimation of attribute values as constituents of the value of the whole (Hanley et al., 2001).

The DCE approach is essentially a structured method of data generation. It relies on carefully designed choice tasks that help reveal the factors influencing choice. Designing a DCE requires careful definition of the attribute space (including attribute levels and ranges) such that the attribute space includes the portion relevant for the policy questions being asked. Furthermore, the DCE approach involves the use of statistical design theory to construct choice scenarios which can yield parameter estimates that are not confounded by other factors. These orthogonal designs allow the researcher to isolate the effects of individual attributes on choice, and are an important advantage over revealed preference random utility models, where attributes in reality are often found to be highly correlated with each other (Hanley et al, 1998).

2.7 Visualization methods within DCE

Substantial, longstanding and ongoing literature in the realm of sociology and psychology shows that the presentation of information in visual form can, in many situations, greatly enhance its evaluability (Nisbett and Ross, 1980; Eagly and Chaiken, 1993; Hibbard and Peters, 2003). Early findings by MacGregor and Slovic (1986) show that visual displays outperform conventional information in terms of respondents' ability to correctly assess factual outcomes. Psychological insights therefore suggest that a strategy for addressing anomalies within nonmarket valuation studies is to use visual information to reduce uncertainty and unfamiliarity with the good concerned (Bateman et al. 2006).

The use of visualization techniques becomes of particular importance in the case of the valuation of non-market goods through hypothetical surveys such as those used in contingent valuation (CV) or discrete choice experiment (DCE) studies (Bateman et al., 2006).

A number of studies have been completed involving visualization approaches to crowding research in heavily used recreation areas (Manning et al., 1996, 1999; Behan et al., 2001). In these studies, respondents evaluated a series of images and judged either preference or acceptability of visitor numbers depicted in the various images. The application of a stated choice approach based on the visualization of the criteria under investigation results in a much more sensitive model that also includes several perfectly plausible interactions. As such, this holistic research method constitutes advancement in research compared to the classical image-based approaches, which are based on one-dimensional Likert scaling (Arnberger & Haider, 2007).

Psychological insights suggest that conventional, numeric descriptions of certain attributes featured within DCE studies of environmental goods lack evaluability (Bateman et al. 2006). In such cases survey respondents are liable to resort to heuristics, notably loss aversion, to formulate responses. This will lead to a theoretically anomalous divergence between measures of willingness to pay (WTP) for gain and equivalent loss (EL) to avoid losses. Loss aversion refers to the tendency for people to strongly prefer avoiding losses than acquiring gains Tversky and Kahneman, 1991). Visual representations of these attributes may enhance their evaluability, reducing dependency upon the loss aversion heuristic and hence reducing if not removing the asymmetry between WTP and EL measures (Bateman et al. 2006).

Visual simulation can be an important component of choice experiments involving environmental change. To address such complex decision processes, we need the ability to place people into complex decision environments that are as similar to the real decision context as possible (Bishop et al. 2009).

2.8 Issues and Assumptions with DCE

Though there are many issues relevant to the design and application of any choice experiment, this report will only touch on the assumptions and issues most relevant to this study.

2.8.1 Information Bias

An important issue in designing the survey instrument is to ensure that an adequate amount of information, pertinent to the subject, is presented without influencing the views and opinions of the respondents. Azjen, Brown and Rozenthal (1996) reported that giving respondents detailed information about the public good and about the context relevant for valuation can introduce unintended and unanticipated distortions, a process known as information bias. Given the complexities of stated preference methods, it is essential to provide respondents with sufficient information to make informed choices without forming the respondent’s choice for them. According to Spash (2002) the majority of respondents stated that the survey informed their preferences but a substantial minority of respondents stated their preferences had formed (i.e. changed) resulting from the survey. This phenomenon can result from a number of factors including; personal relevance to or prior knowledge of the good being valued, the quality of arguments used (Ajzen, Brown and Rosenthal, 1996), or the amount of information provided (Bergstrom, Stoll and Randall, 1990; Bateman and Mawby, 2004). Arguably the main disadvantage of choice modelling approaches lies with the cognitive difficulty associated with multiple complex choices, or rankings, between bundles with many attributes and levels. Both experimental economists and psychologists have frequently observed evidence of a limit to how much information respondents can meaningfully handle while making a decision (Hanley, Mourato & Wright, 2001). The challenge is to provide sufficient information for the respondents to make informed choices without causing fatigue by inundating them with too much information. It seems fair to say that it is extremely difficult, if not impossible, to design a choice model that will accurately address the preconceptions of all respondents, their prior knowledge of an issue and hold everyone's attention for a specified length of time, however those involved in environmental valuation should at least be aware of these issues in order to minimize their influence on respondents' choices.

Information biases may also occur when respondents learn (whether this learning is cognitive or not), causing them to alter their response patterns as they become more familiar with the information and the survey question format. As respondents become more familiar with the attributes involved and the changes in attribute levels, it is possible that some respondents will begin to favour certain choice set criteria over others and begin basing decisions on the newly realized information from that point forward, thereby rendering their previous decisions as less accurate depictions of their preferences. The potential for a learning effect such as this grows as the length of the survey and the amount of information provided increases.

2.8.2 Hypothetical Bias

Since DCE surveys are hypothetical in both the payment for and provision of the good in question, we do not know whether what an individual says he/she would do in a hypothetical setting matches what they will do when actually given the opportunity to do so. And, without the ability to observe the latter, it is difficult to confirm whether the values elicited from a hypothetical survey accurately reflect the real economic value of the good. Some researchers have expressed concern that this lack of a consequential economic commitment in CV surveys often leads to hypothetical bias in which economic values are overstated (Murphy and Stevens, 2004). Hypothetical bias is the difference between the hypothetical payment and the actual payment (i.e. what someone is willing to pay and what they actually pay (Hanley and Spash, 2003). According to Murphy, et al (2005) the bulk of research on hypothetical bias suggests stated preference surveys do over-estimate actual payments, but it may not be as large an issue as originally believed. Unfortunately, no consensus exists on the theoretical underpinnings of hypothetical bias or ways to calibrate welfare estimates based on this phenomenon (Murphy, *et al.* 2005).

A concern with the use of SP methods is that they are susceptible to hypothetical biases such as social desirability bias (SDB) and pro-environmental yea-saying. Yea –saying has traditionally been defined as the tendency to agree with questions regardless of content (Cronbach, 1946, 1950; Couch and Keniston 1960; Arndt and Crane 1975; Moum, 1988) and is perhaps most clearly defined in relation to this particular study as failure to attend to and process the magnitude of payment. It is unclear whether yea-sayers are also assumed to ignore other key elements of the questionnaire, such as information pertaining to the nature and magnitude of environmental improvements, although the answer is probably affirmative (Bennett and Blamey, 2001).

2.8.3 Summation of Component Values

In order to evaluate the total value of an environmental programme or good from a choice experiment, as distinct from a change in one of its attributes, it is necessary to assume that the value of the whole is equal to the sum of the parts (Hanley et al., 2001).

Hanley, Wright and Adamowicz (1998) discussed whether the essential nature of an environmental asset, such as a wetland (or in the case of this study, a coral reef), can be described in terms of its individual components. Two specific issues were addressed in relation to this problem. First, the value of the environmental good in its totality may be greater than the sum of attribute values (the value of the whole being greater than the sum of the parts). For example, hydrological and ecological integrity might be important. Second, the manner in which the experimental design treats attributes, in terms of the orthogonal, main effects design used in CE, may be at odds with ecological realities. For example, some minimum quantity of attribute *A* might need to be present before attribute *B* becomes viable. These two problems may be thought of as related to both how people perceive the environment, and how the environment itself works (Hanley, Wright & Adamowicz, 1998)

While studies have shown that this is in fact the case for conventional CV (Hoehn and Randall 1989; Hoehn and Loomis 1993), Foster and Mourato (2003) sought to determine whether the value of the whole elicited through CE is closer to the value of the whole elicited by CV, or closer to the sum of the value of the parts elicited by CV. The results indicate that CE gives significantly larger values than CV for the overall bundle and significantly smaller values for the individual components (Foster and Mourato, 2003).

2.8.4 Protest Votes

As with CVM, DCE studies are also vulnerable to protest responses in which respondents refuse to answer the question because of objections to different aspects of the valuation process (Jorgensen, Syme, Bishop, & Nancarrow, 1999). A protest voter is a respondent who does not state his/her true willingness-to-pay for the environmental good and/or service in question (Meyerhoff and Liebe, 2008). Many reasons exists for protest voting, such as, respondents who do not understand what the survey is asking of them but make choices anyway, or respondents who refuse to make choices because they disagree with some aspect of the survey (Meyerhoff and Liebe, 2008). These protest bids usually have to be excluded from the evaluation but doing so reduces the accuracy of the study. Yoo, Kwak, & Kim, (2001) used a series of follow-up questions ,with some degree of success, to determine whether zero WTP responses should be considered valid responses, or protest responses. The intention with follow-up questions is to gain a sense of the respondent's attitude towards either the good or service being valued, or the method of valuation. If the respondent clearly states that they are opposed to the valuation of the good or service in question, then their responses should be considered further as potential protest bids.

2.9 Limitations in Environmental Valuation

Despite recent advances in the use of environmental valuation techniques and the obvious advantages gained through using them, some limitations are still encountered with this technique. In order to derive an accurate depiction of an environmental value, much detailed economic and biological information is required. Even with this detailed information, some techniques still exhibit inconsistency and bias (Pearce & Turner, 1990). Inaccuracies will always exist because of incomplete understanding of complex environmental processes and inherent biological uncertainties. However, determining the relative value of the environment is a valuable first step. Ethical concerns probably create the biggest problem when valuing the environment. Many people simply believe it is immoral to place a value on the environment, especially to price individual organisms within that environment (Spurgeon, 1994).

CHAPTER 3: METHODS

For the purpose of this study, a discrete choice experiment was used as the primary analytical tool. This chapter will present the discrete choice experiment as applied to the valuation of Hawaiian coral reefs under conditions of climate change. This chapter will begin with an overview of the design of a choice experiment and then sequentially discuss the individual elements of that design in more detail.

3.1 Choice Experiment Design

Attentive and detailed design of the survey instrument is critical to the success of any choice experiment. It is imperative to consider as many issues relating to the alternatives making up the choice sets, the attributes used to describe those alternatives and the ways in which the experimental design impacts on the choice set (Blamey, Louviere & Benner, 2001).

In a choice experiment, respondents are presented with a series of choice tasks. In each choice task, the respondent is presented with a set of two or more alternative scenarios called “choice sets”, and is then required to choose their preferred scenario. Frequently, a base alternative of choosing the status quo is also presented as an option. Each alternative scenario is described in terms of a fixed number of attributes, and each attribute is in turn described in terms of several levels. Typically, the selection of appropriate attributes and levels are determined by a group of experts (researchers and managers) or focus groups who are familiar with various aspects of the situation to be studied. For this study, this group of experts included biologists, economists and sociologists who were able to provide information about the environmental attributes and human dimensions of the situation.

Statistical design theory is used to combine the levels of the various attributes into scenarios or descriptions of different choice alternatives (Veldhuisen and Timmermans, 1984; Louviere, 1988). Each combination of attribute levels is termed a “treatment” in the design literature, or a “profile” in the conjoint analysis literature. Profiles are descriptions of separate choice alternatives. These profiles are generated by applying statistical design theory to create experimental designs. Each attribute represents a factor in a statistical experiment, and each factor has levels that represent the range of values of the attributes that are of interest. Factorial designs allow one to create descriptions of choice alternatives in such a way that all of the statistical effects of the attributes that are varied can be estimated independently. Full factorial designs are rarely used, simply because the number of possible combinations would produce an unrealistic number of choice sets, even when the total number of attributes is small. As a result, fractional factorial designs are used to construct profiles. Unfortunately to use fractional designs it must be assumed that certain interaction effects among the attributes are not statistically significant. If this assumption is incorrect, the resulting utility estimates will be biased because one has omitted significant variables from the analysis (Louviere and Timmermans, 1990).

Each attribute level and, ideally, each combination of attribute levels should appear the same number of times within the Discrete Choice Experiment (DCE). Ideally the chosen levels should represent realistic states of nature, both in the current situation, and in any possible future situations. By including levels both below and above the current situation, the values of both increases and decreases can be estimated (Moore, 2002).

A main effects design only tests for the effects that each individual attribute has on a respondent's choice and does not consider interaction effects. This type of design ensures each attribute is orthogonal from one another, so as not to confound the significance of a respondent's choice for one attribute with another.

Fractional factorial, main-effects designs make the number of profiles more manageable but reduce estimation power. Although testing for all possible effects is the preferred approach, main effects explain the majority of variance in respondents' choices (approximately 70%-80% of the variance); (Louviere *et al.* 2000).

In the analysis, aggregating the responses from all respondents makes it possible to derive part worth utilities (PWUs) for each attribute. These PWUs demonstrate the importance of various attribute levels to the choice selection of an individual (Moore, 2002).

The development of a DCE should be an iterative process, involving extensive use of focus groups and pretesting to make sure that the attributes chosen are useful to managers, and at the same time it must be meaningful to the respondents, and ensure that no significant attributes are missing. Once the

DCE has been designed and refined, the analysis of the data collected is relatively straightforward (Moore, 2002).

3.2 Choice Model Design

The design of a choice model involves the following steps as adapted from Hanley et al., 2001:

1. *Characterization of decision problem*: Properly scope the research problem or environmental issue and develop specific research goals and objectives.

2. *Selection of the attributes:* Identify the relevant attributes of the good to be valued. The most relevant attributes are selected through the use of literature reviews, focus groups and expert consultations.

3. *Assignment of the levels:* Attribute levels should be feasible, realistic, non-linear and span the range of respondents' preference maps. As with the selection of attributes, levels are selected through the use of focus groups, pilot surveys, literature reviews and expert consultation.

4. *Choice of experimental design:* Statistical design theory is used to combine the levels of the attributes into a number of presentable alternative scenarios or profiles.

5. *Construction of survey:* The profiles identified by the experimental design are then grouped into choice sets to be presented to respondents. Profiles can be presented individually, in pairs or in groups.

6. *Data Collection:* Information is collected by means of mail-out, intercept or online surveys.

7. *Estimation procedure:* Determination of utility associated with different attributes through preference models.

8. *Application*: A decision support system is constructed to aid policy development and inform decision makers about public preferences.

3.2.1.1 Characterization of decision problem

The intention for this research is to value potential climate change mitigation efforts on Hawaiian coral reefs and explore their contribution to management and policy decision making. The DCE will be used to address the following overall goals of the project:

1. To determine the willingness to pay for climate change mitigation efforts by US residents;
2. To value individual components of coral reef ecosystems; and
3. To determine existence value of Hawaiian coral reefs under conditions of climate change.

3.2.2 Framing the Choice Questions

Two choice experiments were administered in the survey: one focused on a conservation fee, the other on a willingness to pay for climate change mitigation.

The first choice experiment, framed as a conservation fee question, was aimed at determining use values for the coral reefs. This choice experiment was intended as a learning procedure for respondents in order to acquaint them with the goods and services being valued. The conservation fee choice experiment consisted of choice profiles where two of the profiles described different dive/snorkel scenarios at coral reef locations representative for the Main Hawaiian Islands, and the third profile provided an “opt-out” choice, allowing respondents to choose neither of the dive/snorkel locations if they did not feel either was an acceptable choice. Respondents were informed that in order to preserve and access the reefs, each visitor would be asked to pay a daily conservation fee. The fee varied for each reef scene.

The second choice experiment focused on the core objectives of the study, existence values under the condition of climate change. Respondents were initially introduced to the concept of climate change and the potential effects on coral reefs. Following this, respondents were informed as to the nature and identity of the Papahanaumokuakea Marine National Monument, the marine protected area that encompasses the Northwest Hawaiian Islands. This was done in order to familiarize respondents with the non-use nature of the area. Once an understanding of climate change effects and the nature of the area under question was established, each choice set contained one profile of a current scenario of a coral reef location within the NWHI, and two future profiles of the same location; one with mitigation against climate change impacts, and one without. In other words, the current scenario acted as a context variable in the design, from which we were able to base the variations of changes due to climate change. The future reef scenario with mitigation included a fee in the form of a personal tax over a 30 year term. The question posed at this point was whether given the current condition of the reef, which of the future scenarios would the respondent choose.

3.2.3 Choice of experimental design

For the design of a choice experiment, attributes are combined into profiles (alternatives) and they must then be organised in a manner that allows the researcher to test for each attributes effects on respondents' choices. Ideally, respondents would see all possible combinations of attributes. Typically surveys employed a fractional factorial design in that only a selection of the total number of possible attribute combinations, determined a priori by the researchers, were used. Though orthogonality is generally sought after in a choice experiment design, this study did not employ a classical orthogonal design for the two respective scenarios. Here the orthogonal design was applied to the difference between the two profiles. This approach ensured an unbiased estimation of the difference between the two future scenarios and both the "with" and "without" scenarios were developed based on rules.

For the conservation fee task, a respondent would choose their preferred profile from the set of three and repeat this task 6 times. In total, there were 64 choice sets.

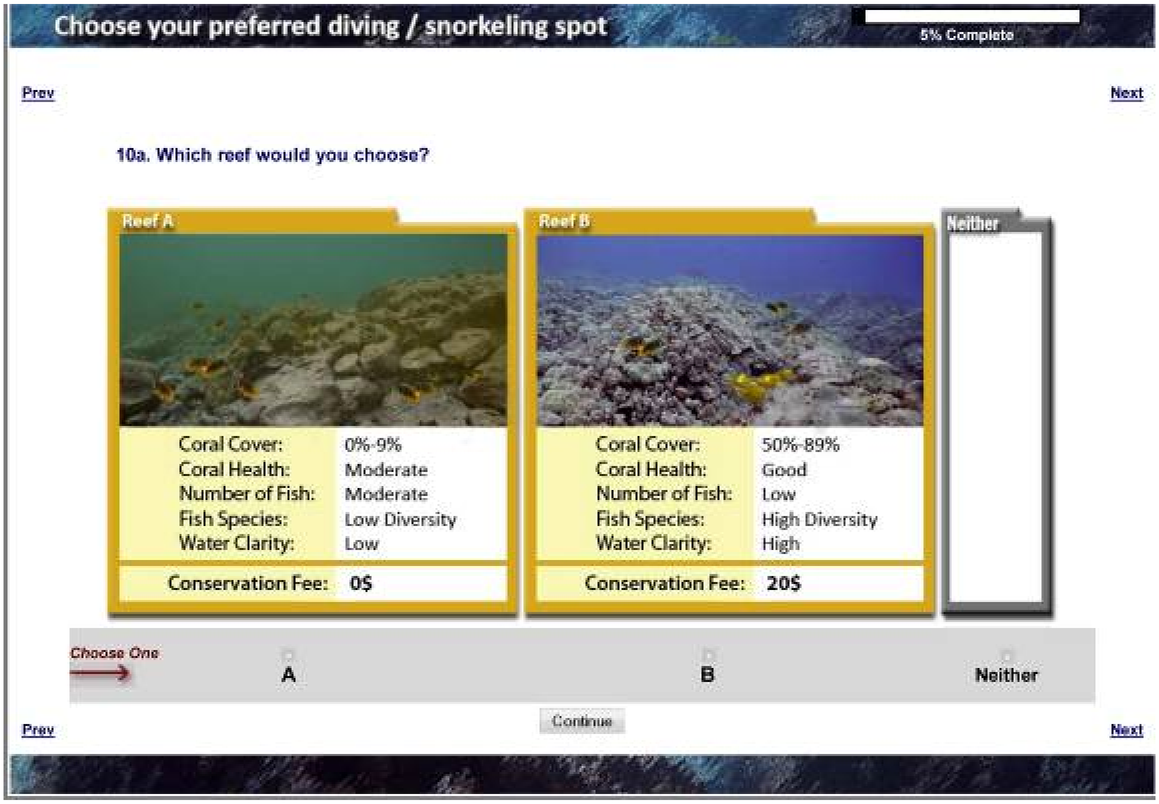

Figure 3.2: Sample of Conservation Fee choice set.

This choice experiment was primarily used as a learning task for the respondents in order to familiarize them with the structure of the choice profiles and decision making process. Results from the Conservation Fee choice task were not analyzed for this study.

The *climate change mitigation* choice task forced respondents to choose between the “with” and “without” scenarios. A neither option is not feasible in this case and therefore was not provided. Here respondents evaluated a total of 6 choice sets and the entire design consisted of 64 choice sets.

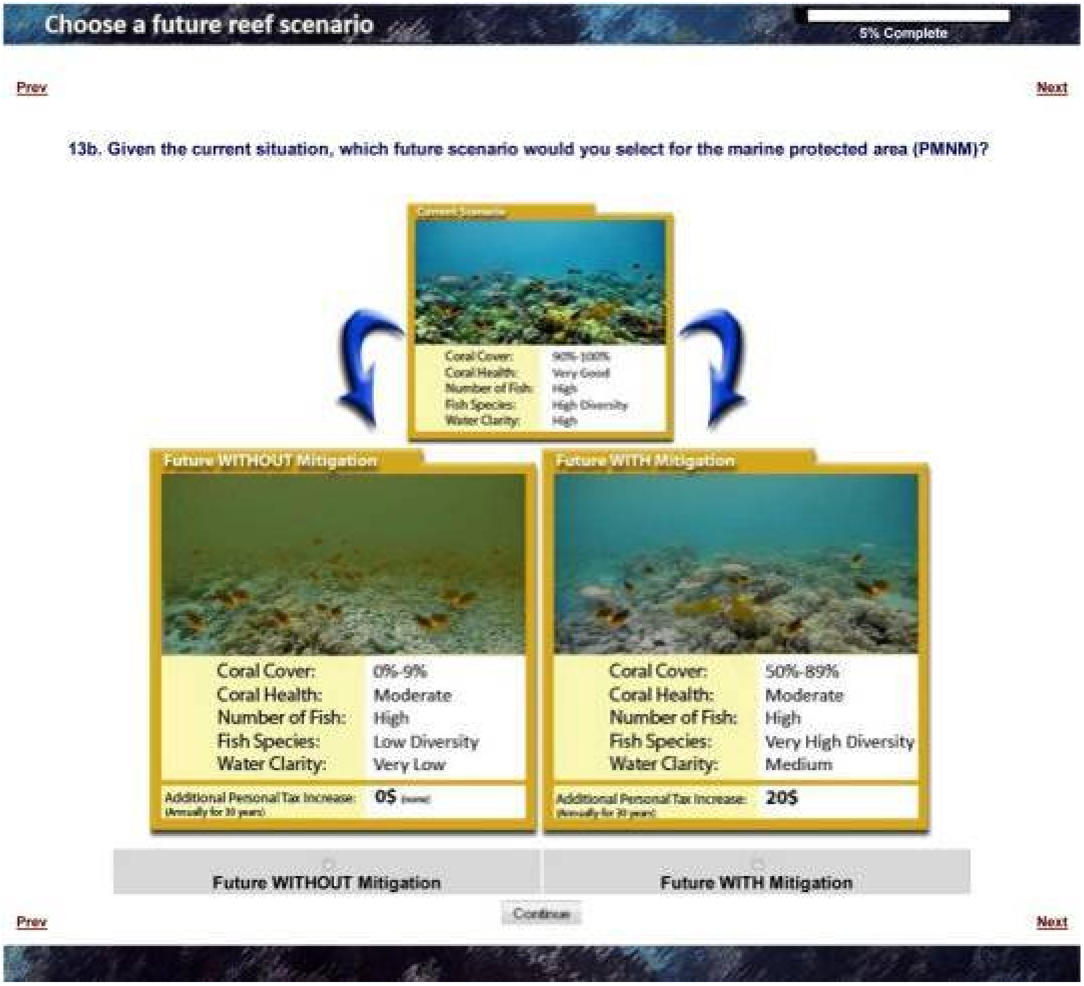

Figure 3.3: Sample of Climate Change Mitigation choice set

3.2.4 Attribute and level selection and design

In deciding on which attributes would be most suitable for addressing the issues involved in the survey, focus groups, and experts were consulted. The focus groups consisted of undergraduate students from Simon Fraser University and were used to determine which attributes of coral reefs were the most important indicators of climate change, and which held the most significance to humans. These findings were confirmed by both biological and social science experts. The chosen attributes were used to develop a series of images. For the choice model that was used in the survey, 128 images were created using Adobe Photoshop CS3. The images were based on photos of Hawaiian coral reefs provided by Dr. Paul Jokiel and his colleague Kanako Uchino. The images were then organized into 64 sets of two potential reef choices. All images contained the following attributes in a systematically varied manner: coral health, coral cover, fish numbers, species diversity (fish species) and water clarity (turbidity). See Appendix C. for examples of image modifications. Relief of the sea floor and the presence of a turtle as a charismatic species were also controlled within the images; however they were not presented as a textual choice tool for the respondents. A cost variable was included along with the textual attributes for all choice profiles.

3.2.4.1 Coral Health

According to Jokiel and Brown (1994), Coral bleaching is perhaps the most visible change to the health of coral with coral condition classified visually as ‘bleached’ (pure white), ‘pale’ (obvious pigment loss but some colour) and ‘normal’. With respect to climate change effects, changes to global carbon concentrations in the ocean will alter the rate and extent of calcification for coral species. A lowered calcification rate means that calcifying organisms extend their skeletons more slowly and/or form skeletons of lower density. Reduced skeletal density means less resistance to breakage and greater susceptibility to both physical breakdown and bio-erosion (Buddemeier et al., 2004). Based on these findings, coral health was shown in four levels: Poor (*Severely bleached,* *pure white corals, significant additional rubble present*), Moderate (*Pale corals with obvious pigment loss, some rubble*), Good (*Minimal or no pigment loss or rubble*) and Very Good (*Enhanced coral pigmentation*).

The variations in coral pigmentation were visualized with the *Selective Colour* tool in Adobe Photoshop. This tool isolates specific colours and allows you to enhance or decrease the tone, hue, and contrast. Reds, greens, yellows and blue colours were isolated on the corals and then enhanced or decreased individually. White represents severely bleached corals. Degraded coral structure was shown by cropping images of coral rubble and embedding them accordingly into the reef mother scenes.

3.2.4.2 Coral Cover

Corals with branching growth forms, rapid growth rates, and thin tissue layers appear to be most sensitive to bleaching, and usually die if seriously bleached. Slow-growing, thick-tissued, massive corals appear to be less sensitive and commonly recover from all but the most extreme episodes. Bleaching thus selectively removes certain species from reefs and can lead to major changes in the geographic distribution of coral species and reef community structures (Hughes et al., 2003). Specific coral types were targeted for each level of change for the coral cover attribute, removing the more susceptible corals first and then the more resilient corals as the level of cover worsened. The extent of coral cover has a significant impact on the ability of the reef to sustain fish populations. Specifications of the levels of coral cover followed the National

Oceanic and Atmospheric Administration (NOAA) classification maps, and relied on the following ranges; *0%-9% coral cover, 10%-49% coral cover, 50%-89% coral cover, 90%-100% coral cover.*

Again, the variations were created using Adobe Photoshop. Images of similar reef locations taken from the sample of pictures and were cropped and then manipulated with the intent of achieving photo-realism. The midpoint in the level ranges was strived for in all images used.

3.2.4.3 Numbers of Fish

The numbers of fish in each image generally correspond with the productive habitat services of the coral. The healthier and more extensive the coral cover is, the more abundant the fish should be. According to Bellwood et al. (2006) total fish numbers actually don't decline significantly as a result of coral bleaching and degradation. Species composition changes, but the numbers stay the same. Changes in the abundance of coral-associated fishes with decreasing coral cover have been recorded in a number of studies (e.g. Booth & Beretta, 2002; Jones et al., 2004). However, if herbivorous fish decline as a result of over-fishing or other events, the coral will consequentially decline as well. Therefore choice set images with low fish numbers require low coral cover or health, whereas images with low coral cover or health do not necessarily require low fish numbers. The number of fish shown represents a portion of the total fish number for that reef area. Since fish are not stationary, it is conceivable that one would not always be surrounded by fish that are in plain view (even though there may be a high number of fish present on that reef). For all levels, the number of fish was based on a range of +/- 5 from the textual numbers presented in the profiles. This was because some images required slightly more or less fish to make the numbers visible in comparison to the background. Levels for fish numbers were as follows: *Low (only a very small amount of fish will be present in the image, most likely a single school of approximately 5 in number), Moderate (a few small schools of fish approximately 15 in number), High (Larger schools of fish approximately 25 in number), Very High (multiple schools of varying sizes approximately 35 in number).*

Finding images of fish that would be easy to manipulate in Photoshop was difficult, so showing too many fish would result in a phony looking picture. As well too many fish in the image would hide the other attributes.

3.2.4.4 Species Diversity

Following the massive coral bleaching event of 1998 in Hawaii, it was found that coral associated species were still living in bleached corals through to the end of 1998 and in small remnants in 1999, but they largely disappeared thereafter. The loss of coral remnants was probably exacerbated by changes in density-dependent coral mortality rates as a result of excessive predation by the remaining fish coralivores. Most striking, apart from a decrease in species with no known association with corals, was the marked increase in abundance in the number of common, habitat and trophic generalist species (Bellwood et al.,2006). Originally, the idea was to separate species based on their relationship to coral.

This would have provided levels of coral dependant, and coral independent species. However, it was felt that respondents may not be able to understand such a detailed description and the label of "*Species Diversity*" would be more suitable for levels ranging from low to very high. Under this label, we were still able to use the coral related species levels mentioned above, however they were simply shown as levels of species diversity. Coral dependant species are species that require live coral for survival, whereas coral independent species do not specifically require coral for survival and therefore may be present in any reef situation. Levels for species diversity were as follows: *Low Diversity (single coral independent species), Moderate Diversity (coral independent species as well as one coral dependant species), High Diversity (coral independent species as well as two coral dependant species, second species being slightly larger in size), Very High Diversity (coral independent species as well as three coral dependant species, second species being slightly larger in size, and the third being slightly more charismatic in colour).*

3.2.4.5 Water Clarity

Water clarity ranges from low, to very high. As a result of overgrazing and other on-shore anthropogenic activities on many of the Hawaiian Islands, sediment run-off has resulted in quite turbid waters (specifically Molokai, Lanai, and a few placed on the Big Island). The red colour of the Hawaiian soil results in the water taking on a red/brown hue. Decreased water clarity is otherwise the result of algal bloom caused by human waste run-off. In these situations, the water takes on more of a greenish hue. In both cases visibility is diminished. In terms of the effect of turbidity on the corals themselves, the more turbid the water is, the less sunlight is able to reach the polyps, which then affects the phytoplankton. Changes to water clarity were accomplished by adding a filtered layer on top of each image in Adobe Photoshop CS3. These layers are controlled to show various depths of visibility. The hue for the filtered layers as well as the levels of visibility have been verified and were created in conjunction with Dr. Paul Jokiel, and a few of his colleagues at the University of Hawaii at Manoa (Will Smith and Ku'ulei Rodgers in particular as well as some research assistants). Levels for water clarity were as follows: *Low (0-4 feet visibility)*, *Moderate (5-14 feet visibility)*, *High (15-24 feet visibility)*, *Very High (25-35 feet visibility).*

Each level was represented by overlaying a filter layer on top of each image. This filter layer was essentially a single block of colour representing what would be seen in sediment run-off situations throughout Hawaii. The opacity of that filter layer was then altered for each level. The lowest level of water clarity utilized the filter layer at 60% opacity; moderate water clarity utilized the filter layer at 40% opacity; high water clarity utilized the filter layer at 20% opacity; and very high water clarity did not use the filter layer at all (essentially 100% opacity)

3.2.4.6 Relief

Relief was broken down into 3 levels. The levels for relief are simply: low, medium and high. The relief attribute will be controlled for, however was not presented as a decision tool in the choice profiles. 12 mother scenes were chosen, upon which the attributes and levels above were based. There were 4 scenes for each of the 3 relief levels.

Reef images in this setup were taken at standardized angles to the sea-floor. Scales were also used in some pictures to show the depth of field. The scale is 2m in length with 10cm increments.

3.2.4.7 Turtle

The final visual attribute provided was that of a turtle. The turtle represents the presence of a charismatic species and was introduced as a two level attribute: absent or present. This attribute was the only variable that was presented as strictly visual and was not mentioned I the text below the images. The intention was to assess whether the presence of a charismatic species affects the choice behaviour. The turtle images were cropped from digital photos provided by Dr. Paul Jokiel, and were then re-sized and embedded into the appropriate choice set images.

3.2.4.8 Cost

The payment vehicle varied in the two choice tasks. For the climate change mitigation task, the cost function was represented by a climate change mitigation fee. Since mitigation efforts involve research and implementation of actions, such as coral seeding, the associated costs were represented as an annual tax increase over a period of 30 years (ie. a tax of $30 per year, for 30 years). It was explained that the mitigation costs were to be paid for by all US residents (Mainland and Hawaiian), and that the annual tax would go into an earmarked fund for coral reef mitigation and research.

The cost attribute was presented as an eight level variable.

For the climate change choice task, cost levels were as follows: $10, $20, $40, $60, $80, $100, $150 and $200, and was the same in both the Mainland and Hawaiian resident surveys.

3.3 Construction of survey

Respondents were required to complete the survey in the sequence provided. In total, each respondent was required to navigate through 25 or 26 pages, depending on the survey sequence they were given. (Survey sequencing will be discussed later in the paper)

Section	Number of Pages	Description
Welcome	2	Following the cover page , this section presents the purpose of the study, instructions for the survey and required disclaimers
Introductory Questions	3	Questions regarding respondents' previous experience with diving/snorkeling, coral reefs and Hawaii. As well, the concept of climate change and specific climate change impacts on coral reefs are introduced.
Scenic Beauty Evaluation	1	Respondents are presented with 10 images of Hawaiian coral reefs and asked to rate the reefs on a scale of 1-10.
Conservation Fee ChoiceTask	7-8	Following an instruction page, respondents were presented with 6 choice sets where they were required to select their preferred diving/snorkeling location.
Climate Change Mitigation Task	8-9	An introductory page describing the NWHI, followed by an instructional page for the choice task. Respondents were then presented with 6 choice sets where they were asked to choose their preferred future coral reef scenario.
Follow-Up Questions	4	Respondents provide socio-demographics, ethnicity and answered questions relating to the design of the survey.

Table 3.1: Overall structure of the questionnaire

For detailed descriptions of the survey questions, refer to Appendix 1.

3.3.1 Survey sequencing

To investigate and possibly control for potential learning effects and biases, the survey was administered in several different sequences, to which respondents were engaged randomly.

3.3.2 Conservation Fee vs Climate Change Mitigation

Depending on the sequence, respondents were first introduced to either the conservation fee choice task or the climate change mitigation choice task. This variation in sequences allowed us to determine whether the introduction and exposure to the attributes and levels in the Conservation Fee choice task affected the respondents' choices in the climate change choice task, or whether their choices were independently affected by their prior knowledge and exposure to the effects of potential climate change.

For the Mainland survey, a total of 717 respondents were given the Conservation Fee choice task first, with 180 receiving the Climate Change choice task first.

For the Hawaiian resident survey, 224 respondents received the Conservation Fee choice task first, with 248 respondents receiving the Climate Change choice task first.

3.3.3 Sequence of alternatives within the choice set

Pre-testing showed a potential bias in favour of the choice profile on the right side of the screen. Potentially this was caused by respondents reading quickly through the survey from left to right and then simply choose whichever choice is presented on the right side of the screen. The right side bias became particularly pronounced when the choice task required respondents to scroll down in the web-browser. To control for this bias, the context of profiles A and B in the conservation fee choice task was randomly reversed between the two sides. This allowed us to determine whether the respondents were actually making choices based on the attributes and levels, or whether they were simply manoeuvring through the survey as quickly as possible while choosing the responses on the right side of the screen.

Results from respondents who answered all A, B or Neither for the conservation fee choice tasks were investigated further to determine legitimacy. It was determined that an appropriate minimum response time for the survey was 8 minutes, allowing respondents sufficient time to adequately read the instruction and respond to all of the required questions. Respondents who completed the survey in a time under 8 minutes were not considered in the analysis.
For the Mainland survey, 502 respondents received the Conservation Fee choice task in the initial format (A,B,Neither), with 395 respondents receiving the reversed Conservation Fee choice task profiles (B,A,Neither).

For the Hawaiian population survey 228 respondents received the Conservation Fee choice task in the initial format, with 244 respondents receiving the reversed Conservation Fee choice task profiles.

3.3.4 Additional Choice Set Questions

Some respondents were randomly assigned a 7th choice set which actually was identical to the 1st choice set. No additional instructions were presented as the intention was to test for consistency of responses. The results of this additional question varied substantially with many respondents making different choices for both choice sets. This may be explained as a learning effect in which respondents became more familiar with the attributes and levels therefore altering their decision making process as they went through the choice tasks. Another explanation for this discrepancy is that some respondents may have begun to simply click through the remaining choice sets due to survey fatigue.

For the Mainland survey, 426 respondents received the 7th Climate Change choice task question, with 471 respondents only receiving the initial 6 choice questions.

For the Hawaiian population survey, 227 respondents received the 7th Climate Change choice task question, with 245 respondents only receiving the initial 6 choice questions.

3.3.5 Choice set follow-up questions

Yea-saying may be particularly pertinent to this project in that it is assumed that a percentage of respondents may choose to mitigate against climate change no matter what the costs or trade-offs may be. In an attempt to control for yea-saying, a random portion of respondents were given a follow-up question to the choice task that asked how certain they were that they actually would pay the mitigation fee.

The follow-up question provided a scale of 1-10 and asked respondents how certain they were on that scale that they would actually pay either the conservation fee, or the mitigation cost respectively. The purpose for this follow-up question was to help control for yea-saying biases. Unfortunately as this follow-up question was not mandatory, the majority of respondents simply skipped it and moved on to the next choice set.

3.4 Data collection

E-rewards, a market research firm based in Houston, Texas, administered the survey. Age, place of residence and census representation formed the selection criteria for survey participation. Respondents were recruited by sending the link to the survey instrument to a random sample ensuring confidentiality of respondents and the data which was not stored in the US and therefore did not become subject to the US Patriot Act. The survey itself was hosted at Simon Fraser University. Participants were required to be older than 18 years of age and were required to be US citizens. Two surveys were administered separately. The first was targeted specifically to residents of the mainland United States, the second was targeted specifically to residents of the State of Hawaii. E-rewards agreed to deliver a minimum of 1000 completed responses and provided incentive for the clients in the form of redeemable online shopping points. Data collection occurred from Sept. 24th to Oct. 10th 2008 for the US mainland survey, while the Hawaiian resident data collection ran from Oct. 13th to Oct 23rd, 2008. Some concern was raised that global economic events occurring during that time may have affected the responses, however no such effects became apparent in our analysis. The response rate of 16.2% was well within the normal response rate for E-rewards administered surveys, given that the sample is chosen from citizens who had at one time agreed to receive emails for such surveys, but may not necessarily still use the same email, and who most likely are not directly affected by the subject of the survey.

3.5 Estimation procedure

After data collection, various statistical models estimate how the different attributes affected respondents' choices. This section provides an overview of the models this project used in measuring the different attributes described earlier.

3.5.1 Random Utility model

Based on the Random Utility Theory (Luce & Suppes, 1965), the random utility approach to modeling provides the foundation for stated preference surveys, which makes it possible to combine choice behaviour with economic valuation (Rolfe and Bennett, 2006). Historically, random utility models, a subset of the class of probabilistic choice models, were first developed by psychologists in the attempt to characterize observed inconsistencies in patterns of individual behaviour (Manski, C.F., 1977). The random utility model assumes that people are rational decision makers and that the probability that an individual will choose a certain good or service is dependent on the utility gained from that good or service relative to the utility associated with any other alternative. The formula below describes this:

$$P_{ij} = Prob(U_{ij} > U_{ih}) \quad (1)$$

Where the probability of individual 'i' choosing alternative 'j' is equal to the probability that the utility 'U' of alternative 'j' is greater than the utility of alternative 'h' (for all 'h' in a given choice set where 'j' does not equal 'h').

The assumption here is that utility is the sum of the observable and unobservable influences on choice:

$$U_{ij} = V_{ij} + \varepsilon_{ij} \qquad (2)$$

Where V_{ij} represents the observable (measurable) component of utility and ε_{ij} is the unobservable (or error) component of utility.

The observable component of utility can be further described as a function of the characteristics of a good and the characteristics of an individual, as represented below:

$$U_{ij} = (Z_{ij}+S_i) + \varepsilon_{ij} \qquad (3)$$

Where Z_{ij} represents the characteristics of the good or service, and S_i represents the characteristics of the individual. Expanding the above equation to include all attribute and socio-demographic variables produces the following:

$$V_{ij} = [\beta_{0ij}+\beta_{1ij}Z_{1ij}+ \beta_{2ij}Z_{2ij}+\ldots+\beta_{nij}Z_{nij}]+[\beta_{aij}S_{ai}+ \beta_{bij}S_{bi}+\ldots+\beta_{kij}S_{ki}] \qquad (4)$$

Z is the attribute associated with alternative 'j' that individual 'i' chose and there are '1' through to 'n' attributes (denoted by the subscripts '1' and 'n'). In addition, the socio-demographic variables of individual 'i' are represented by 'S' where there are 'a' through 'k' socio-demographic variables included as explanatory variables in this particular model. The parameter (or coefficient) β_{1ij} is associated with attribute Z_1 for alternative 'j' and individual 'i'. The β's are the weight that each attribute and socio-demographic variable has on observable utility (Hensher, Rose and Greene, 2005). β_{0ij} is not associated with any particular attribute but instead is the intercept and represents all unobserved sources of utility (Hensher, Rose and Greene, 2005). Furthermore, associating parameters with each individual (i.e. β_i) suggest that the weights are not homogenous across a population and permits the modelling of segments within the population (Hensher, Rose and Greene, 2005). The modelling of segments is possible through a latent class model approach, discussed later in this section. Equation 4 can now be substituted into equation 1, which gives a more detailed expression of the fundamental choice model (shown below):

$$P_{ij} = \text{Prob}[(\beta_{0ij}+\beta_{1ij}Z_{1ij}+\ldots+\beta_{nij}Z_{nij}+\beta_{aij}S_{ai}+\ldots+\beta_{kij}S_{ki}) + \varepsilon_{ij} > (\beta_{0ih}+\beta_{1ih}Z_{1ih}+\ldots+\beta_{nih}Z_{nih}+\beta_{aih}S_{ai}+\ldots+\beta_{kih}S_{ki}) + \varepsilon_{ih}] \quad (5)$$

Equation (β0ih+β1ihZ1ih+…+βnihZnih+βaihSai+…+βkihSki) + εih] (5 shows that a researcher can determine the probability an individual will choose a certain alternative out of a finite set of alternatives based on the individual's socio-demographic characteristics, the attributes that make up that particular good or service and other unobservable sources of utility.

3.5.2 MNL model

Typically, choice models are analysed with a multinomial logit model (MNL) to produce regression estimates, known as part-worth utility (PWU) parameters for each attribute. The assumptions made in the MNL require a restriction known as the Independence from Irrelevant Alternatives (IIA) condition, which states that the probability of a particular alternative being selected is independent of all other alternatives, and has the underlying condition that the error terms are independently and identically distributed (IID) (Rolfe and

Bennett, 2006). With this assumption, one can define a probability distribution called the multinomial logit (MNL) model which takes the general form:

$P_{ij} = \exp V_j / \sum_h \exp V_h$ (for all h in choice set C where j ≠ h) (6)

According to Rolfe and Bennett (2006) the MNL is generally preferred to other modes because it is computationally easier to use. The MNL equation shows that the probability of individual 'i' choosing alternative 'j' is equal to the components of observable utility associated with the chosen alternative (i.e. 'j') raised to the exponent divided by the sum of observable utilities associated with all other alternatives ('h') raised to the exponent. Results from the survey for this study were entered into various software packages including SPSS and Latent Gold to calculate the actual frequency that individuals 'i' choose alternative 'j' and this forms the left hand side of equation 5. With the known frequency of choice, the same software tools then used to estimate each researcher-specified parameter through maximum log-likelihood procedures. Knowing the parameters associated with various attributes allows a researcher to predict the probability that an individual will choose a particular environmental amenity as described by various combinations of the attributes. However, the predicted probability that an individual will choose a particular alternative is a relative measure, not an absolute measure of the probability (or utility) associated with that particular alternative (Hensher, Rose and Greene, 2005).

3.5.3 Measuring compensating surplus

As mentioned in Chapter 2, compensating surplus (CS) is the change in income that will leave an individual indifferent between the current situation and some defined alternative, given an implied right to the current situation.

Rolfe and Bennett (2006), describe the formula for estimating welfare change from the MNL model as:

$$CS = -1/\beta_{paymentvehicle}[\ln\Sigma \exp V_{i0} - \ln\Sigma \exp V_{i1}] \quad (7)$$

Where CS represents the compensating surplus, $\beta_{paymentvehicle}$ represents the marginal utility of income (represented by the coefficient for the monetary opportunity cost attribute in the choice experiment), and V_{i0} and V_{i1} are the indirect utility functions before and after changes to the choice profiles.

The entire equation is negative, which represents a WTP scenario; in other words, a respondent is willing to pay a certain amount for an environmental improvement. Rolfe and Bennett (2006) also explain that if the changes in the state of nature reflect an environmental loss (i.e. going from '1' to '0') then the appropriate sign for the equation 7 would be positive which implies a willingness-to-accept compensation for an environmental loss. However, what is not clear from Rolfe and Bennett's (2006) description of handling a WTA scenario is whether or not it is appropriate to apply a scaling factor that takes into account the difference between WTA and WTP estimations.

If the states described by '1' and '0' only differ in one attribute (i.e. the choice profile between two alternatives is constant with the exception of one attribute that will differ according to its levels), then equation 7 simplifies to equation 8:

$$CS = -1/\ \beta_{paymentvehicle}\ [V_{i0} - V_{i1}] \qquad (8)$$

This equation represents the amount of money an individual is willing-to-pay if faced with two alternatives that only differ by a single attribute. If V_{i0} accurately represents the status quo, and not a hypothetical alternative, then the CS estimated from equation 8 will reflect a WTP for an environmental improvement from a real situation.

In addition, if a researcher is using continuous data, then equation 8 simplifies to equation 9 below (Rolfe and Bennett, 2006):

$$W = -\beta_{attribute}\ /\ \beta_{paymentvehicle} \qquad (1)$$

Where welfare (W) is equal to the ‘utility per attribute’ divided by the ‘utility per dollar’ which provides a monetary estimation of an attribute in question. Rolfe and Bennett (2006, p41) describe equation 9 as the “…marginal rate of substitution between income change and the attribute in question.” In other words, equation 9 represents the amount of money that could be substituted (assuming weak sustainability) for any given attribute described in the choice experiment.

3.5.4 Latent class model

The latent class approach is an expanded, mixed logit form of the MNL and permits measurement of preference heterogeneity. At a broad level, the LCM assumes that the sample population is heterogeneous as a whole but is made up of ‘X’ relatively, homogenous classes, or segments (Semeniuk, et al., 2008). Where each class is a combination of invariant characteristics of the respondents such as socio-demographics, attitudinal and psychometric effects (Boxall and

Adamowicz, 2002), and each class will have different preferences or choice behaviour from one another (Train, 2003). The number of classes comprising a sample population is performed endogenously through choice patterns and sorted into 'X' groups according to statistical information criteria (a combination citation from Milon and Scrogin, 2006 and Semeniuk *et al.* 2008).

The LCM is the product of two probability distributions, where the probability 'P' of a randomly chosen individual 'i' choosing alternative 'j' is:

$P_{ij} = (P_{ix})*(P_{ij|x})$ (2)

Where P_{ix} is the probability that individual 'i' will be part of class 'x' and $P_{ij|x}$ is the probability that individual 'i' will choose alternative 'j' conditional on membership in class 'x'. As described by Boxall and Adamowicz (2002), these probability distributions (from equation 10) both follow the random utility model and assuming the error term in both of these distributions is independent and identically distributed among individuals with Type I, extreme value distribution, then they can be expressed as follows:

$$P_{ij} = \sum_{x=1}^{X}\left[\frac{\exp(\alpha_x S_i)}{\sum_{x=1}^{X}\exp(\alpha_x S_i)}\right]\left[\frac{\exp(\beta_x Z_j)}{\sum_{h\in C}\exp(\beta_x Z_h)}\right] \qquad (3)$$

Where, α_x is the parameter associated with the socio-demographics, attitudinal, or psychometric effects 'S' specific to group 'x'. β_x is the class 'x' specific parameters for alternative 'j', chosen from all alternatives 'h' in choice set 'C'. If there is only one class of respondents, then:

$$\frac{\exp(\alpha_x S_i)}{\sum_{x=1}^{X}\exp(\alpha_x S_i)} = 1 \qquad (4)$$

and equation 11 collapses to the MNL.

The advantage of the LCM is that it estimates different parameters for each specified class. These different parameters across the classes help to identify the heterogeneity of the sample population (Milon and Scrogin, 2006). In turn, accounting for respondent heterogeneity provides decision makers with a greater understanding of how one policy can have varied impacts across a range of stakeholders.

3.6 Decision support system

The parameter estimates from the survey were used to create a computerized decision support system (DSS), which predicts the likely response to any possible scenario that can be created as a combination of attribute levels. One simply needs to substitute the MNL estimates into the MNL equation (Formula (6) above) to predict the probability of choice or support. In broad terms, the DSS aids decision makers by estimating the public's support for conservation plans as described by the attributes from the survey. Specifically, the DSS shows two possible outcomes, similar in layout to the survey. The attributes of the DSS describe each outcome and the decision maker can specify the level of each attribute for either outcome. Using the parameter estimates to calculate the overall utility of the inputted levels, the decision maker can see the difference between various outcomes from the perspective of the general public. The DSS also shows market share, or the probability that an individual will choose a conservation plan based on the levels specified by a decision maker.

CHAPTER 4: RESULTS

This chapter presents the results of the climate change choice task for both the respondents of the Mainland sample and the Hawaiian resident sample. For all stages of the analysis, the Mainland and Hawaiian samples were analyzed separately. In this chapter these results will be presented side by side for comparative purposes. First the basic characteristics of the survey respondents will be presented, followed by the overall results of the choice experiments. Thereafter, the effect of climate change belief will be discussed and incorporated into the model results. Finally, the results of a latent class analysis will be explained along with their potential impacts on the overall utility of the model.

4.1 Overall characteristics of the samples

The web-based survey targeted a random sample of residents of the US Mainland, and a separate sample of the Hawaiian population. Sampling of US mainland residents took place between Sept. 24th and Oct. 10th 2008, while the survey for the Hawaiian residents took place between Oct. 13th and Oct 23rd, 2008.

4.1.1 Response rates

Survey response rates are shown in Table 4.1. In total, the number of individuals who were invited to participate in the survey was12,191 (9316 for the US Mainland survey and 2875 for the Hawaiian resident survey). Only 16.4% and 20.9% of the invitees in the two respective samples actually started the survey. Of these surveys submitted, 76.1% of the Mainland surveys were complete, and 70.8% were eventually used for the analysis. For the Hawaiian sample the rate of completion (91.8%) and rate of usable surveys (84%) was clearly higher.

	US Mainland	Hawaiian Residents
Total # of Survey requests	**9316 (100%)**	**2875 (100%)**
# of Surveys Started	1532 (16.4%)	601 (20.9%)
Of the started surveys:		
# of Surveys Completed	*1166 (76.1%)*	*552 (91.8%)*
# of Surveys Used For Analysis	*1085 (70.8%)*	*505 (84.0%*

Table 4.1: Survey Response Rates

Surveys were eliminated from analysis if any one of the following criteria applied: when surveys remained incomplete, when respondents completed the survey in what was deemed to be an insufficient (usually too short) amount of time, or when written comments that were collected at the end of the survey indicated protest behaviour or clear lack of understanding.

Suspecting that respondents are motivated predominantly by the incentives and might not take the survey very serious, completion times were monitored for each respondent, and surveys with a completion time of under eight minutes were discarded. Completion time for each individual choice task was also scrutinized and if the first two choice tasks were undertaken too quickly (under 10 seconds), a survey record was eliminated.

The additional comments which were collected throughout the survey allowed us to identify protest votes. A protest voter is a respondent who does not appear to understand, or rejects the hypothetical market described in the survey. Protest voters were deleted and excluded from the analysis.

4.1.2 Socio-demographics of study participants

The basic socio-demographic characteristics of respondents for both samples are tabulated in Table 4.2 and are also compared to the respective census data where possible. Questions included gender, age, level of education, employment status, income, place of residence, ethnicity, and place of birth.

		Survey		US Census	
				US Total	Hawaii
		Mainland Number of resp (%)	Hawaii Number of resp. (%)	%	%
Gender	Male	509 (47.44)	208 (41.19)	49.24	50.2
	Female	549 (51.16)	284 (56.24)	50.76	49.8
	Missing	15 (1.4)	13 (2.57)		
Age *	under 20	14 (1.3)	3 (0.59)		
	20 – 35	269 (25.07)	177 (35.05)	28.1	28.8
	35 – 50	235 (21.9)	168 (33.27)	30.6	41.0
	50 – 65	226 (21.06)	129 (25.54)	24.1	12.1
	over 65	324 (30.2)	27 (5.35)	17.2	18.1
	Missing	5 (0.47)	1 (0.2)		
Education	less than high school	7 (0.65)	1 (0.2)	16	15.4
	completed high school	261 (24.32)	80 (15.84)	30	28.5
	completed university	202 (18.83)	86 (17.03)	17.1	17.8
	post graduate degree	397 (37)	211 (41.78)	9.9	8.4
	trade/non-uni cert	202(18.83)	124 (24.55)	X	x
	Missing	4 (0.37)	3 (0.59)		
Employment	F/T single employer	405 (37.74)	269 (53.27)	Comparison unavailable	Comparison unavailable
	F/T self employed	43 (4.01)	40 (7.92)		
	F/T many employers	33 (3.08)	35 (6.93)		
	part time employed	110 (10.25)	43 (8.51)		
	seasonal employed	11 (1.03)	2 (0.4)		
	Unemployed	121 (11.28)	50 (9.9)		
	Retired	343 (31.97)	61 (12.08)		
	Missing	7 (0.65)	5 (0.99)		
Income	under 25000	200 (18.64)	28 (5.54)	24.5	23
	25000 – 50000	316 (29.45)	131 (25.94)	25.6	27.2
	50000 – 74999	238 (22.18)	137 (27.13)	18.8	20.6
	75000 – 99999	134 (12.49)	97 (19.21)	12.1	12.7
	100000 – 149999	91 (8.48)	76 (15.05)	11.4	11.1
	150000 – 199999	38 (3.54)	22 (4.36)	3.9	3
	over 200000	42 (3.91)	10 (1.98)	3.7	2.5
	Missing	14 (1.3)	4 (0.79)		

Table 4.2: Socio-demographic results of web survey and census data

*Note: Percentages for age classes in the US census data have been adjusted to align with age classes in the survey

The socio-demographic results show clear differences both between the two sample populations and the US Census data. These differences may help to explain certain characteristics of respondents' decision making. Specifically, differences within the categories of age, education, employment and income may assist in explaining the willingness of each respective sample to support a tax structure geared towards mitigating against effects of climate change on the coral reefs.

While the Mainland sample is fairly evenly split along gender, the Hawaiian sample contains a larger share of female respondents (56%), which stands in contrast to the Census data, where the gender proportions are very equal.

The samples contain biases with regards to age, once the age distribution for the US-Census data have been recalculated for adults only by ignoring the age class of under 20 years of age, who represented less than 1% of the sample. The Mainland sample significantly over-represents the group of 35 to 50 year olds, while it contains too few seniors over 65, The Hawaiian sample contains an over-representation of 20 to 35 year group and the 50 to 65 years of age group, while it under-represents the 35 to 50 year group and the seniors over 65 years of age.

Significant differences are also observed on education, as both samples are much better educated than the respective populations. The mainland sample is fairly similar to the US Census results on income, while the Hawaiian sample contains many fewer low income respondents (under $25,000), which leads to some differences on all the other income categories.

4.2 The US-Mainland vs Hawaiian Samples

Table 4.3 contains the results of the multinomial logit model for the two respective samples. Each of the two sub-models for the respective samples is documented with the coefficient, the standard error and the z-value (the z-value indicates if the estimate is statistically significant). The four final columns of the table contain the comparative statistics between the two samples. The Wald test indicates if the variable in itself is significant, while the Wald (=) test indicates parameters that are significantly different from each other between the two models. A quick inspection of these two test statistics indicates that all attributes except turtle, are significant in themselves, i.e. the levels within differ significantly from each other, while only a few parameters are statistically significantly different from each other. Figure 4.1. graphs all the model estimates (part-worth utilities) for the respective attributes.

The overall model fit as indicated by the R^2 statistic, is reasonable with R2=.16 for the mainland sample, and R2=.09 for the Hawaiian sample. For the interpretation of these results it is important to remember that the design underlying this study differs from a regular generic CE which usually compares two hypothetical profiles that simply differ on several attributes. Here, the two alternatives were labelled as future 'without mitigation' and future 'with mitigation', and contrary to most CEs where the attribute content within the profiles remains orthogonal, this research question lead us to keep the difference between the two scenarios orthogonal. This fundamental characteristic of the choice sets allowed us to include additional parameters into the model that accrue from these design characteristics, and will be explained below. All variables were effects coded except for the variables with reference to a linear estimate.

The constant simply explains which of the two scenarios was preferred, everything else being equal. In both samples, the option ‘with mitigation’ is preferred over ‘without mitigation’, and shows that respondents are more likely to choose mitigation with all other attributes kept at their respective means (an artefact of effects coding).

The current scenario represents a context variable indicating if the present situation influences the evaluation of the future scenarios. The four levels of this variable represent combinations of the actual variables from the scenarios below, and their levels represent combination of these attributes on the best or second best level. The context variable was not significant in the Hawaiian model, but in the Mainland model the all-levels-on-best scenario was significantly preferred over the two mixed levels, and the all-levels-on-second-best scenario was regarded as significantly worse.

The decline index measured the difference between the current situation and the ‘without mitigation’ scenario. The index was calculated by simply treating each attribute as an indicator, with the attribute levels being measured as a 1 if it was at the worst level, and a 4 if it was at the best level, and then summing these numbers for each scenario. In other words, this index documented the interaction between the current scenario and the future without mitigation, and served as a crude indicator of quality. A larger decline index led to a more negative evaluation of this difference.

The main variables of the study are discussed next. Water clarity showed a hugely significant effect, and declining water quality was evaluated as even more negative by the US Mainland sample, when compared to the Hawaiian sample. Declining coral cover was also perceived as negative and in this case no difference emerged between the two samples. The number of fish in the scenes emerged as highly significant in the Hawaiian sample, but remained insignificant in the Mainland sample.

Coral Health and Species Diversity were presented as categorical variables, and left as such for the analysis. These two variables did not show any significant results for the Hawaiian sample, while for the Mainland sample the result was somewhat counterintuitive as the moderate rather than the poor was evaluated as the most negative level for coral health, and good rather than very good was perceived as the most positive level. The same phenomenon occurred for moderate species diversity.

The WTP for climate change mitigation of coral reefs was highly significant and negative for both samples, but the slope was significantly more negative for the Mainland sample.

When the initial model was calibrated with main effect for turtle alone (without further turtle interactions), the estimate for turtle remained insignificant, but hinted into the intuitively wrong direction. This phenomenon disappeared by introducing select interaction effects with turtle, which are included in this model. For the US Mainland sample interactions between turtle and cost and with coral health respectively were significant, but the difference between the Mainland and the Hawaiian sample were not significant. These significant differences for the

Mainland sample indicated that respondents reacted negatively to a turtle if the coral health was on a poor level, while the reacted positively when coral health was better. Similarly, when the mitigation scenario contained a turtle, Mainland respondents in particular exhibited a lower willingness to pay, i.e. a decline in the utility associated with paying higher sums of money.

		Mainland Residents			Hawaii Residents						
Attributes	Levels	coeff.	s.e.	z-value	coeff.	s.e.	z-value	Wald	p	Wald(=)	p
Constants	Without Mitigation	-0.39	0.13	-3.10	-0.34	0.15	-2.22	14.5	0.001	0.07	0.800
	With Mitigation	0.39	0.13	3.10	0.34	0.15	2.22				
Current Scenario	All level 3	-0.40	0.11	-3.59	-0.12	0.13	-0.90	20.6	0.002	3.45	0.330
	Fish level 3, Coral level 4	0.04	0.08	0.49	-0.10	0.09	-1.05				
	Coral level 3, Fish level 4	-0.11	0.08	-1.41	-0.03	0.09	-0.39				
	All level 4	0.47	0.12	3.88	0.25	0.14	1.80				
Decline Index	Linear	-0.17	0.04	-4.12	-0.11	0.05	-2.20	21.85	0.000	0.96	0.330
Water Clarity	Linear	0.19	0.02	7.54	0.11	0.03	3.95	72.47	0.000	3.99	0.046
Coral Cover	Linear	0.11	0.01	7.67	0.06	0.02	3.74	72.75	0.000	4.41	0.036
Coral Health	Poor	-0.07	0.11	-0.64	-0.03	0.12	-0.22	17.90	0.007	0.75	0.860
	Moderate	-0.10	0.05	-1.88	-0.09	0.06	-1.46				
	Good	0.17	0.06	2.94	0.09	0.07	1.40				
	very good	0.00	0.09	0.00	0.02	0.11	0.21				
Fish Number	Linear	0.03	0.03	1.12	0.10	0.03	3.22	11.62	0.003	2.96	0.085
Species Diversity	Low diversity	0.09	0.10	0.90	-0.02	0.12	-0.21	12.45	0.053	2.11	0.550
	Moderate diversity	-0.15	0.05	-3.02	-0.07	0.06	-1.21				
	High diversity	0.00	0.06	0.06	0.09	0.07	1.30				
	Very High diversity	0.06	0.09	0.67	0.01	0.10	0.07				
Turtle	Absent	0.00	0.08	0.04	0.05	0.09	0.59	0.35	0.840	0.18	0.670
	Present	0.00	0.08	-0.04	-0.05	0.09	-0.59				
Mitigation Cost	Linear	-0.11	0.01	-16.05	-0.08	0.01	-9.67	351.3	0.000	9.26	0.002
Turtle X Coral Health	Linear Interaction	0.45	0.18	2.45	0.09	0.19	0.51	6.27	0.044	1.82	0.180
Turtle X Cost	Linear Interaction	-0.05	0.02	-2.71	-0.01	0.02	-0.76	7.93	0.019	1.54	0.210
Summary Statistics	$R^2(0)$	R^2	LL	BIC(LL)	AIC(LL)	AIC3(LL)	CAIC(LL)	Npar	L^2	df	p-value
Overall	0.5339	0.1361	-3995.1	8257.4	8064.17	8101.17	8294.38	37	4100.5	1332	8.60E-279
Mainland	0.5818	0.1626									
Hawaii	0.4428	0.0883									

Table 4.3: MNL model for the US Mainland and Hawaiian samples

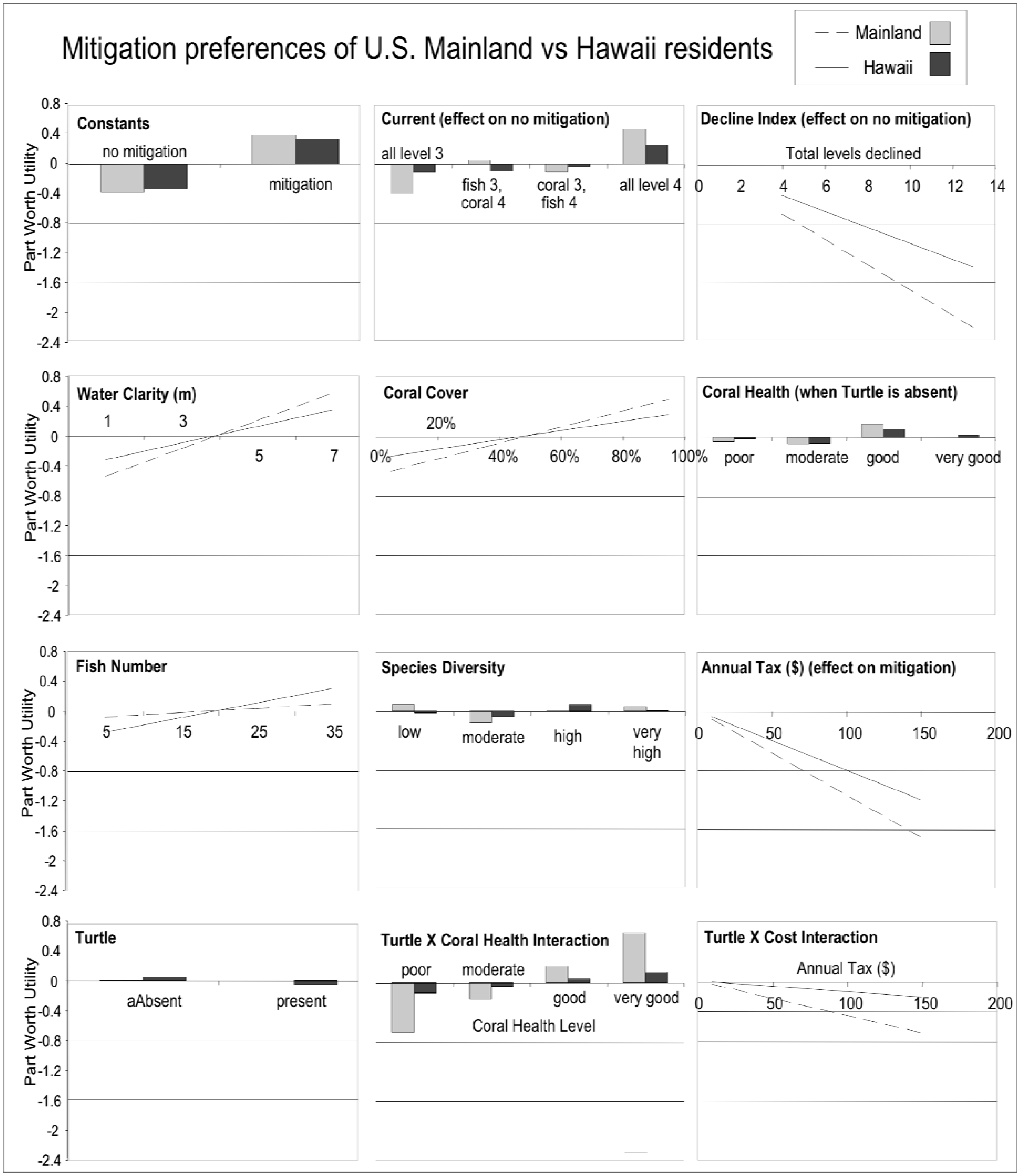

Figure 4.1: Results of the Choice Model for US-Mainland and Hawaiian samples

4.3 Climate Change Belief

As part of the survey, respondents for both samples were provided with the following question to assess their familiarity with, and belief in climate change.

Which of the following statements best reflects your opinion about climate change?

Respondents were then required to choose one of the following responses:

1. *There will be climate change, but the implications will only be noticeable later.*
2. *Climate change is a fact and the first indications are evident already.*
3. *Evidence about climate change is still too uncertain; it is too early to know what will happen.*
4. *I do not believe in climate change.*
5. *Other (please specify…)*

Mainland and Hawaiian results for this question are seen below in Figure 4.2

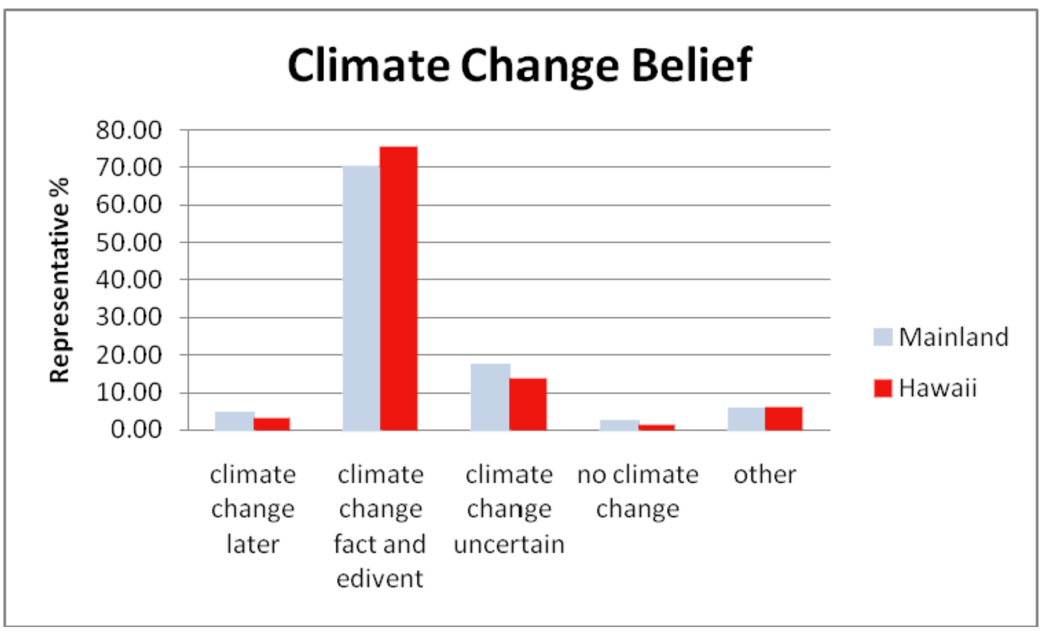

Figure 4.2: Climate change belief results

Based upon the results of this question, respondents were grouped as either climate change believers (comprised of those who chose responses 1-2 as listed above) and climate change sceptics (comprised of those who chose responses 3-4 as listed above). Responses of "other" were left out of the analysis. For the Mainland population, climate change believers represent approximately 75% of the respondents, leaving 25% as climate change sceptics. For the Hawaiian population, climate change believers represent 79% of the respondents, while 21% represent the climate change sceptics. This classification was brought into the latent model as a covariate in order to better define latent classes.

4.3.1 Climate Change Believers and Sceptics – *a priori* segmentation

When segmenting the respective samples by the belief about climate change (Table 4.3), surprisingly few differences emerged between the two samples. The only significant difference was observed on willingness to pay (WTP), as the sceptics had a steeper negative slope compared to the respondents who believe in climate change. Nevertheless, this model is regarded as important for further analysis below, and will therefore be retained in a simplified version, by collapsing all attributes between the two segments, except the WTP function. No significant differences between these two attitudinal groups emerged for the Hawaiian sample.

Further exploration of the model can be undertaken with a latent class analysis. Tables 4.5 and 4.7 will explore the results of a 2-class model and a 4-cloass model for the US-Mainland sample only. Contrary to many other latent

		Mainland Residents							Hawaii Residents						
	Attributes	Coeff	s.e.	z-value	Wald	p-value	Wald(=)	p-value	Class1	s.e.	z-value	Wald	p-value	Wald(=)	p-value
Constants	Without Mitigation	-0.3756	0.1259	-2.9827	8.8965	0.0029			-0.3082	0.1535	-2.0073	4.0293	0.045		
	With Mitigation	0.3756	0.1259	2.9827					0.3082	0.1535	2.0073				
Current	All level 3	-0.4035	0.1115	-3.6196	16.718	0.00081			-0.1323	0.1328	-0.9965	3.5736	0.31		
	Fish level 3, Coral level 4	0.0389	0.0796	0.4881					-0.0811	0.0946	-0.8572				
	Coral level 3, Fish level 4	-0.1059	0.08	-1.3243					-0.0428	0.0904	-0.4729				
	All level 4	0.4706	0.1221	3.8535					0.2561	0.1412	1.8145				
Decline Index	Lin	-0.1732	0.0417	-4.1505	17.2263	3.30E-05			-0.1138	0.0495	-2.2958	5.2706	0.022		
Water Clarity	Lin	0.1873	0.0248	7.5669	57.2578	3.80E-14			0.1175	0.0284	4.1364	17.1095	3.50E-05		
Coral Cover	Lin	0.1083	0.0141	7.689	59.1202	1.50E-14			0.063	0.0167	3.769	14.2052	0.00016		
Coral Health	poor	-0.0769	0.1093	-0.7037	13.7029	0.0033			-0.0421	0.1227	-0.3431	3.9039	0.27		
	moderate	-0.098	0.0523	-1.8726					-0.0826	0.0619	-1.3354				
	good	0.17	0.0574	2.9627					0.0954	0.0677	1.4092				
	very good	0.0049	0.0914	0.0535					0.0293	0.1073	0.2732				
Fush Number		0.0309	0.0258	1.1979	1.4349	0.23			0.0996	0.0303	3.2846	10.7889	0.001		
Species Diversity	Low diversity	0.0856	0.1006	0.8514	9.6111	0.022			-0.0018	0.1166	-0.0157	2.9183	0.4		
	Moderate diversity	-0.1571	0.0512	-3.0675					-0.0773	0.0611	-1.2654				
	High diversity	0.0055	0.0596	0.0917					0.0796	0.0703	1.1335				
	Very High diversity	0.066	0.0894	0.7389					-0.0005	0.1002	-0.0052				
Turtle	Absent	0.0143	0.0773	0.1852	0.0343	0.85			0.0488	0.0893	0.5468	0.299	0.58		
	Present	-0.0143	0.0773	-0.1852					-0.0488	0.0893	-0.5468				
Turtle X Coral Health Interaction	Lin	0.4385	0.182	2.4092	5.8043	0.016			0.0911	0.1875	0.4857	0.2359	0.63		
Turtle X Cost Interaction	Lin	-0.0436	0.0173	-2.5236	6.3685	0.012			-0.0167	0.0194	-0.8633	0.7454	0.39		
Mitigation Cost	Believers (Lin)	-0.1054	0.0075	-14.11	274.8443	2.10E-60	16.8796	4.00E-05	-0.0691	0.0088	-7.89E+00	120.6024	6.50E-27	27.5361	1.50E-07
	Skeptics (Lin)	-0.1359	0.0088	-15.3932					-0.1264	0.012	-10.5077				

Table 4.4: MNL Model for US-Mainland and Hawaiian Samples using Climate Belief as a Covariate

class models, the segmentation in this case did not result in a separation of the intercept.

4.3.2 Latent Class Models

A latent class model was used to investigate heterogeneity in the responses. Prior to running a latent class model, the overall models were run several times with various criteria as covariates based on the questions within the survey. Criteria such as "whether or not respondents had visited Hawaii previously", "whether or not respondents were divers or snorkelers", "whether or not respondents believed in climate change", and socio-demographic information attained from the survey were all assessed in order to determine if any were significant as covariates with the model.

Climate change belief was determined to be the only significant covariate and therefore was used within the latent class model.

Sample	Classes	LL	BIC(LL)	AIC(LL)	AIC3(LL)	Npar	L^2	df	p-value	Class. Err.	$R^2(0)$	R^2
Mainland	1	-1859.7	3841.8	3755.4	3773.4	18	2584.9	879	0.000	0.00	0.58	0.16
	2	-1634.4	**3527.1**	3344.7	3382.7	38	2134.2	859	0.000	0.07	0.75	0.50
	3	-1597.3	3588.9	3310.5	3368.5	58	2059.9	839	0.000	0.16	0.79	0.57
	4	-1564.7	3659.8	**3285.4**	**3363.4**	78	1994.9	819	0.000	0.17	0.81	0.63
	5	-1542.7	3751.7	3281.4	3379.4	98	1950.8	799	0.000	0.17	0.83	0.66

Table 4.5: Model statistics for latent class model with Climate Change Belief as an active covariate.

Statistical indicators such as log likelihood at convergence, Akaike Information Criterion (AIC) and Bayesian Information Criterion (BIC), among others, suggest that the additional latent classes improved the model compared with the1 class model, supporting the notion that the data is in fact heterogeneous. These indicators are not conclusive about selecting a single best model, and suggest focusing on the two class or the four class solutions instead. Upon inspection, the four class solution left two rather small classes with few significant parameters; therefore we will focus the interpretation on a two class model (Table 4.6).

Class 1 (72% of respondents) represents a very reasonable, intuitive plausible model, with the constant being significant at the 10% level, and neither the current situation nor the decline index influencing the evaluations. At the same time, the core variables of the model, i.e. water clarity, coral health, species diversity and cost all contain significant estimates in the intuitively correct direction. The fish number variable is not significant, and the presence of a turtle almost reaches the 5% level of significance. The 28% of respondents in class two on the other hand reacted significantly to the current situation and the decline index, were similar in their evaluation of water clarity and coral cover, while reacting in non-plausible ways to the quality indicators associated with coral health and species diversity. At the same time they were much less inclined to pay for mitigation, and these respondents accounted for the earlier described significant interaction between turtle and coral health.

2 Class Model	Attributes	Class1	s.e.	z-value	Class2	s.e.	z-value	Wald	p-value	Wald(=)	p-value
Constants	Without Mitigation	-0.46	0.27	-1.74	0.01	0.25	0.03	3.12	0.210	1.45	0.230
	With Mitigation	0.46	0.27	1.74	-0.01	0.25	-0.03				
Current	All level 3	-0.07	0.27	-0.27	-0.67	0.22	-3.08	15.69	0.016	2.75	0.430
	Fish level 3, Coral level 4	0.25	0.20	1.24	0.29	0.15	1.95				
	Coral level 3, Fish level 4	-0.12	0.21	-0.55	-0.21	0.15	-1.41				
	All level 4	-0.06	0.33	-0.19	0.58	0.24	2.45				
Decline index	Linear	-0.09	0.11	-0.88	-0.18	0.08	-2.40	7.60	0.022	0.39	0.530
Water Clarity	Linear	0.40	0.07	5.85	0.25	0.05	4.72	67.45	0.000	2.74	0.098
Coral Cover	Linear	0.15	0.04	3.68	0.19	0.03	6.51	69.85	0.000	0.35	0.550
Coral Health	Poor	-1.17	0.39	-3.01	-0.01	0.20	-0.07	33.57	0.000	18.27	0.000
	Moderate	-0.29	0.12	-2.31	0.11	0.10	1.03				
	Good	0.37	0.17	2.18	0.22	0.10	2.13				
	very good	1.08	0.30	3.64	-0.32	0.18	-1.74				
Fish Number	Linear	0.09	0.07	1.25	0.06	0.05	1.38	4.12	0.130	0.06	0.800
Species Diversity	Low diversity	-0.41	0.26	-1.57	0.20	0.19	1.03	24.86	0.000	11.85	0.008
	Moderate diversity	-0.51	0.12	-4.16	-0.05	0.11	-0.42				
	High diversity	0.11	0.14	0.75	0.07	0.11	0.61				
	Very High diversity	0.81	0.27	2.99	-0.22	0.17	-1.30				
Turtle	No turtle	0.38	0.20	1.92	-0.21	0.15	-1.37	5.15	0.076	5.14	0.023
	Turtle	-0.38	0.20	-1.92	0.21	0.15	1.37				
Mitigation Cost	Linear	-0.08	0.02	-4.37	-0.24	0.02	-11.40	169.11	0.000	30.58	0.000
Turtle X Coral Health		-0.06	0.56	-0.10	0.70	0.30	2.31	5.41	0.067	1.27	0.260
Turtle X Cost	Linear Interaction	0.04	0.04	0.91	-0.08	0.04	-1.76	3.77	0.150	3.46	0.063
Summary Statistics	Class Size	R^2	$R^2(0)$								
Class 1	72%	0.1805	0.8229								
Class 2	28%	0.4219	0.4548								
Overall	100%	0.5017	0.7512								

Table 4.6: Latent class model (2 classes) for Mainland respondents

4.3.3 DSS (Welfare Estimates)

A Decision Support System (DSS) was written in EXCEL and can be used to estimate the welfare measures associated with various potential future reef conditions and mitigation situations. While the welfare measure is calculated as the trade-off between the future scenario with climate change versus the future without climate change, this DSS also accommodates the context variable, which is the current scenario.

The *Current* Scenario description within the DSS provides a tab for analysts to choose between 4 options which were actually provided in the survey. These 4 options alter a select group of attributes as follows:

Current Scenario	Option 1	Option 2	Option 3	Option 4
Coral Cover	70%	95%	70%	95%
Coral Health	Good	Very Good	Good	Very Good
Fish Number	25 Fish	25 Fish	35 Fish	35 Fish
Species Diversity	High	High	Very High	Very High

Table 4.7: The four levels of the current scenario

Option 1 represents the lowest possible current scenario with all attribute (except water clarity) at their second highest levels. Options 2 and 3 altered the quality of the levels with Option 2 displaying higher quality coral attributes and Option 3 displaying higher quality fish and species attributes. Option 4 displayed the highest possible quality for all attributes.

For the scenarios in the DSS to be evaluated below, the water clarity attribute remained at the highest level, while all other attributes alternated between the highest and second highest levels. The *Current* scenario was used as a base from which to measure the difference between the future effects of climate change between the without mitigation and with mitigation alternatives. WTP values change significantly depending on which current scenario is used as the base in the DSS. It shows the support for the two respective future scenarios and can also be used to calculate the overall WTP for the scenario *with* as opposed to *without* mitigation. The share of support for each of the two scenarios and the net WTP is calculated for the two samples, and for the respective segments based on climate change belief. Figure 4.3 shows a print-screen of the user interface, in which any one of the variables can be set to other levels. Grey dialog boxes provide basic explanations. Based on this DSS, four different scenarios will be evaluated in the discussion (Chapter 5); the relevant configurations of the DSS are presented in Appendix B of Ch 7.2.

Current Scenario #	4	WITHOUT MITIGATION	WITH MITIGATION
Water Clarity	7 m	7 m	7 m
Coral Cover	95%	70 %	95 %
Coral Health	Very Good	Good	Very Good
Fish Number	35 fish	25 fish	35 fish
Species Diversity	Very High	Moderate	Low
Turtle	Absent	Absent	Absent
Mitigation Cost	No Cost	No Cost	$0.00

			Net WTP
Mainland ALL	26%	74%	$92.34
Hawaii ALL	27%	73%	$120.14

Mainland

Believers	26%	74%	$98.40
Skeptics	26%	74%	$76.32

Hawaii

Believers	28%	72%	$138.06
Skeptics	28%	72%	$75.47

Figure 4.3: The interface page of the DSS

CHAPTER 5: DISCUSSION

This chapter first summarizes the results of the DCE before it provides recommendations as to how the results may relate to climate change research, to research on existence value and specifically to research on the valuation of ecosystem services provided by coral reefs.

Throughout this paper, the following goals were addressed:

1. To determine willingness to pay for climate change mitigation efforts by US residents,
2. To value individual components of coral reef ecosystems, and
3. To determine existence value of Hawaiian coral reefs under conditions of climate change.

A survey was developed and administered online to a sample of both the Mainland US resident and Hawaiian resident populations. The use of a choice experiment was critical to the study as it allowed for the valuation specific attributes of coral reefs to be valued in the context of each other and in relation to climate change.

5.1 Summary of Results

5.1.1 Characteristics of sample populations

The US Mainland and the Hawaiian samples differed on many accounts. The Hawaiian sample contained many more female respondents compared to the Mainland (56.24% Hawaii, 51.16% Mainland). The average age of respondents of the Mainland sample was significantly older than the Hawaiian. This was particularly evident as 30.2% of Mainland respondents were over 65 years of age, as opposed to only 5.35% of Hawaiians belonged to this age group. The educational background of the two samples differed in that there were significantly more Hawaiian respondents both without a completed high school degree and without a university degree at any level. The Mainland sample contains substantially fewer respondents that fall into the full time-single employer category, with only 37.74% as opposed to 53.27% of Hawaiians, while 31.97% of Mainland respondents fall into the retired category as opposed to only 12.08% of Hawaiians. Income was generally higher for the Hawaiian sample in comparison to the Mainland sample. All of these differences may explain variations in the results and could help to potentially determine specific policy development and management plans for each sample population.

Representativeness of the sample when compared to the US census data showed several important differences. For example, survey results show a representation of 56.24% female respondents as opposed to the US Census data, which shows female representation for the State of Hawaii as 49.6%. Both samples could be separated into climate believers (approx 75%) and climate sceptic (approx 25%) categories, which formed an important backbone for the analysis, and provided an early suggestion that potential climate change mitigation policies will have to deal with varied opinions and preferences within each sample.

5.1.2 Results of the choice experiment

The main results of the study were presented separately for the US Mainland and Hawaiian residents, and they were further segmented into respondents who believe that climate change is already a fact or about to become an actual phenomenon, as opposed to respondents who deny this issue. Results from the models show that both sample populations gain varying degrees of utility from the attributes that comprise a coral reef. Understanding these variations is useful in forming meaningful and compliable policies and management plans. The results for the Climate Change Mitigation choice task attributes can be summed as follows:

Mainland residents gain greater utility than Hawaiians from water clarity on coral reefs as evidenced from the PWU values. This increased utility may be explained in that Hawaiian culture is inherently more closely related to the functional requirements and use of reefs and therefore water clarity may be viewed as secondary to the functional and productive aspects of reefs.

Both survey samples displayed increasing utility for improvements to coral cover, however the Hawaiian sample displayed a greater range in utility. This observation may be explained by the utility that increased coral cover provides for such functions as erosion control, fish habitat, (i.e. use values) and which Hawaiian residents are more aware of, as opposed to the simple concept of aesthetic beauty derived from Mainland residents most of whom would solely associate coral reefs with recreation.

Despite the fact that all these variables were shown visually in the images and also in written form in the text below the images, it is somewhat surprising that no significant differences emerged for coral health. The results for coral health did not provide an intuitive explanation for the preferences of levels. While both samples displayed similar trends with respect to PWU values, the attribute Fish Numbers was not significant for the Mainland residents, but was significant for Hawaiian residents. The significance of fish numbers may be attributed to typical Hawaiian resident use of fish not only for recreational fishing purposes, but also for cultural and subsistence purposes.

The general utility trend of species diversity suggests that PWU values increase as diversity increases, however the moderate level is an anomaly within the attribute. Similar to the coral health attribute, respondents may have been affected by the visual representation of species diversity, perhaps not picking up on the differences between the *low* and *moderate* levels. The attribute was not significant, suggesting that it was not influential in decision making. The two class latent class model provided further insights into this phenomenon, as apparently about one quarter of respondents applied a very different response strategy to these choice sets.

Though it may seem to go against intuition, the results clearly show a decline in utility when a charismatic species such as a turtle is present in the coral reef scenarios. Upon further inspection, it becomes evident that the utility from the presence of a turtle is directly affected by the relationship between the presence of a turtle and the other attributes within the choice sets. As coral cover and health decline, the utility for the turtle decreases and respondents display a higher WTP for climate change mitigation. Conversely, when coral health and cover are at their highest, the presence of a turtle is seen as an added bonus, showing increased utility for respondents, thereby resulting in a lower WTP for climate change mitigation. This shows that respondents value the overall health of the reef as more important than the presence of a charismatic species like a turtle.

The Mitigation Fee attribute was highly significant for both survey samples. PWU values clearly suggest a decline in utility as the mitigation fee increases. The Mainland sample displayed a slightly higher adversity to increases in mitigation costs, most likely due to their physical detachment from coral reef ecosystems.

In comparison, Hawaiian residents are much more likely to have direct experience with coral reefs and therefore displayed a higher willingness to pay the mitigation costs.

5.2 Willingness-To-Pay Based on Climate Change Scenarios

The construction of a Decision Support System (DSS) was crucial for understanding the public's willingness to pay for climate change mitigation, and thus the existence values derived from the Hawaiian coral reefs. The DSS is to be used as a decision making tool for policy planners and managers when making decisions regarding potential introductions of climate change taxes relating specifically to coral reefs.

According to the DSS, the results show that Willingness-To-Pay is influenced especially by the current state of the coral reefs, the magnitude of the effects of climate change (the decline in the quality of the reefs without mitigation) and the effectiveness of the mitigation. All three of the aforementioned factors work in conjunction with one another to influence respondents' willingness to pay for climate change mitigation.

5.2.1 Sensitivity Analysis for DSS scenarios

Table 5.2 presents the results for four potential future climate change scenarios as described by the DSS (specific DSS setting can be found in Appendix B of Ch 7.2). The *best-case* and *worst-case* scenarios refer to potential natural outcomes with the *best-case* representing the best possible natural climate scenario regardless of whether or not mitigation occurs, and the *worst-case* representing the worst possible outcome even with the highest possible level of mitigation. The *maximum difference* scenario is used to calculate the respondents' maximum willingness to pay, which is then followed by a *plausible* scenario.

Attribute		Best-case scenario			Worst case scenario			Maximum Difference			Plausible		
		Current	Without Mitigation	With Mitigation	Current	Without Mitigation	With Mitigation	Current	Without Mitigation	With Mitigation	Current	Without Mitigation	With Mitigation
Water Clarity		7m	7m	7m	7m	1m	1m	7m	1m	7m	7m	5m	6m
Coral Health		70%	95%	95%	95%	5%	5%	95%	5%	95%	70%	60%	75%
Coral Cover		Good	Very Good	Very Good	Very Good	Poor	Poor	Very Good	Poor	Very Good	Good	Moderate	Good
Fish Number		25 fish	35 fish	35 fish	35 fish	5 fish	5 fish	35 fish	5 fish	35 fish	25 fish	20 fish	25 fish
Species Diversity		High	Very High	Very High	Very High	Low	Low	Very High	Low	Very High	High	High	High
Turtle		No Turtle	No Turtle	No Turtle	No Turtle	No Turtle	No Turtle	No Turtle	No Turtle	No Turtle	No Turtle	Turtle	No Turtle
Mitigation Cost		0$	No Cost	0$	0$	No Cost	0$	0$	No Cost	0$	0$	No Cost	0$
Market Share	*Hawaii*		43.7%	56.3%		18.9%	81.9%		3.2%	96.8%		26.4%	73.6%
	Mainland		42.1%	57.9%		11.7%	88.3%		1.3%	98.7%		30.3%	69.7%
Net WTP	*Hawaii*			**$31.44**			**$187.43**			**$421.40**			**$126.76**
	Mainland			**$28.03**			**$177.55**			**$379.06**			**$72.89**

Table 5.2: Scenarios and results for Climate Change mitigation in DSS

5.2.2 Best Case Scenario

The Best Case Scenario represents a potential scenario in which the current coral reef conditions are of moderate quality. In this scenario, both the With Mitigation and Without Mitigation options improvements conditions to the highest possible quality. The results show WTP values of $28.03 and $31.44 respectively for the Hawaiian and Mainland samples, representing a desire by the public to pay for improvements in coral reef conditions, even if the outcome is the same as that for the without mitigation option. The fact that 57.9% (Hawaii) and 56.3% (Mainland) of the samples would still prefer to pay for mitigation even when the outcome is the same as the Without Mitigation outcome shows a "yea-sayer effect.

5.2.3 Worst Case Scenario

For the Worst Case Scenario, the current coral reef conditions are set at their highest possible quality and then deteriorate to the worst possible conditions for both the With Mitigation and Without Mitigation options. This represents a scenario in which the coral reef deteriorates to the lowest possible quality both with and without mitigation efforts. The results show a WTP of approximately $187.43 and $177.55 respectively for both Hawaiian and Mainland populations. In other words, respondents are willing to pay a fee for the mere act of attempting to mitigate, even if the mitigation efforts are ineffective. Both Mainland and Hawaiian residents strongly preferred the mitigation option given this scenario, with 88.3% of Mainlanders and 81.9% of Hawaiians opting for mitigation.

The relatively high WTP values, even in a scenario with a negative outcome, may be due to respondents feeling of guilt. Essentially, respondents would prefer to pay for mitigation efforts simply to ease their conscience and say that they at least tried to do something to help save the coral reefs.

5.2.4 Maximum Difference

For the Maximum Difference scenario, current reef conditions are set at their highest level of quality. Conditions then degrade to the worst possible quality for the Without mitigation option, however they improve (or remain at their highest levels) for the With mitigation option. This scenario shows WTP values of $421.40 and $379.06 for Hawaiian and Mainland populations respectively, clearly showing a strong desire by the public to maintain the reefs and pay for climate change mitigation. Interestingly, approximately 3.2% of Hawaiian residents still are unwilling to pay for climate change mitigation even though they are essentially assured an improvement to the coral reefs. This scenario tells us that in the event of an assured success in mitigating against climate change, the majority of the respondents are willing to pay a substantial fee. The mere act of improving a coral reef to a level of high quality from a level of low quality is sufficient enough to merit a willingness to pay from nearly all respondents.

5.2.5 Plausible Scenario

Realistically, changes to reef structures will likely not be as dramatic as those shown in the previous scenarios. The more plausible scenario shows minor decline from the current reef conditions for the without mitigation option, and only minor improvement for the with mitigation option. Also, the plausible scenario includes the presence of a turtle in the With Mitigation scenario. The results show that both Mainland and Hawaiian resident populations are in favour of mitigation with 73.6% of Hawaiian residents and 69.7% of Mainland residents supporting the option to mitigate against climate change. Of the mitigation supporters, Hawaiian residents show a net WTP of $128.76 and Mainland residents show a net WTP of $72.89. These WTP values indicate that given the above scenario, US residents are willing to pay a small fee per year to achieve the desired mitigation against climate change for Hawaiian coral reefs.

5.2.6 Willingness to pay for incremental improvements in coral reef attributes

The decision support system allows us to determine public willingness to pay for increases in coral reef attribute quality for each individual attribute. Results show WTP for both Mainland and Hawaiian residents and also for the separation between climate believers and climate sceptics for the Mainland sample. The WTP values for attribute improvements hold true for all scenarios. Changing the Current coral reef scenario, or the Future Without climate change mitigation scenario does not seem to alter public WTP values. Apparently Hawaiian residents are clearly willing to pay more for improvements to fish numbers as opposed to coral cover or health improvements. Reasons for this may include traditional Hawaiian value for fish as subsistence or for cultural purposes.

With the exception of the Fish Species attribute, the Mainland sample demonstrates that climate believers are always willing to pay higher values for improvements to coral reef attributes. However, in general, climate sceptics are still willing to pay minimal amount to improve coral reef attributes to achieve a very high level of quality.

5.3 Implications for further research and management

The results from the models provide important data for management and policy development, however further research is needed to adequately assess the best possible avenues for mitigating climate change on Hawaiian coral reefs. Specifically, this study intends to provide tools and information for climate change research in general, research into valuing ecosystem services and research on determining existence values.

5.3.1 Climate Change

The results of this study clearly show a significant willingness to pay for climate change mitigation on behalf of the US population. The fact that climate belief was the most significant covariate, could be useful in showing that there are still 25% of the population that are sceptical about climate change, and therefore more research may be required to provide concrete evidence of the causes, impacts and implications of climate change, specifically on coral reefs. As well, it is evident that there are defined segments of the population with certain beliefs of climate change and mitigation options. Understanding these population segments will be useful for policy makers and managers.

Viscusi and Zeckhauser (2006) found that respondents to their study on perception of climate change risks predominantly view the current scientific uncertainty as a rationale for greater support of policy interventions rather than for a wait-and-see approach. A factor addressed in their study that may influence WTP, holding risk estimates constant, is whether a respondent feels scientific uncertainty motivates a more or less aggressive approach to climate change policy. Environmentalists overwhelmingly preferred more aggressive climate change policies while climate change sceptics clearly preferred less aggressive approaches to climate change policy (Viscusi and Zeckhauser, 2006). Leiserowitz (2005) demonstrate that the majority of the American public does not currently consider climate change an imminent or high-priority danger. Instead, he states that most Americans currently believe that the impacts of climate change will have moderate severity and will most likely impact geographically and temporally distant people and places or non human nature. Yet, within the American public, several distinct interpretive communities were found, ranging from alarmists with extreme risk perceptions to naysayers, some of whom view climate change as a hoax perpetrated by scientists and environmentalists (Leiserowitz, 2005).

The results of our study show that climate change is obviously an important factor that influences the changes in utility derived by the taxpaying public. Leiserowitz (1995) tells us that while Americans currently demonstrate a high awareness of global climate change, a strong belief that it is real, and high levels of concern about the issue; at the same time, public opinion polls and academic studies consistently show that Americans regard both the environment and climate change as relatively low national priorities (Dunlap&Scarce, 1991; Bord *et al*., 1998, p. 77). The task for policymakers and conservationists is now to promote awareness of the necessity for dealing with climate change at a localized scale, and help the public to understand how they will personally be affected. Further longitudinal studies on changing preference values resulting from climate changes may help to shed light on specific areas of mitigation that the public may be most willing to pay for.

5.3.2 Existence value

Where an environmental resource simply exists and provides us with products and services at no cost, then it is our willingness to pay alone, which describes the value of the resource in providing such commodities, whether or not we actually make any payment (Barbier et al., 1997).

As the climate change mitigation fee question was framed using the PMNM, a marine protected area that essentially limits access to the general public, results show the majority of people are willing to pay at least some dollar value to improve reef conditions in locations that they themselves do not have access to. This shows a general WTP for the pure existence of the coral reefs, and may help to boost support for further research on various aspects of existence valuation. While existence value has been studied in the context of numerous other ecosystems (Turpie,2003; Amirnejad et al., 2006) limited research has been completed exclusively in the context of coral reefs.

In a study on the non-use values of the Tubbataha Reefs National Marine Park in the Philippines (Subade, 1995), close to 90%of respondents who were willing to pay at least some amount of money to preserve the reefs, cited their motivation behind their WTP as non-use. Among non-use motives, bequest value/motive (concern for future generations) was the highest ranked, ranging from 34% to 54% of total respondents per sub-sample. This was followed by existence value, altruistic motive and good cause (Sabade, 1995). This empirical evidence points towards the idea of existence value as a valid platform from which to base policy decisions for conservation and mitigation against climate change.

It would be beneficial to understand how US citizens value other coral reef locations worldwide in comparison to the PNMN. This may help to give insight into whether the values derived from this study were altered by a sense of nationalism, or whether these WTP measures are in fact purely derived from the existence values.

5.3.3 Ecosystem services

Ecosystem services play a crucial role in maintaining the ecological balance of our earth. By breaking down the attributes of the coral reefs and providing WTP estimates for incremental impacts of those changes in those attributes, as was done by Brauman et al (2007) in their research on the valuation of wetlands and riparian areas, connections can be made to the direct and indirect services provided by the reefs in general as well as the services provided by the individual attributes of those reefs. Barbier et al. (2007) agree that valuing the non-market benefits of ecological regulatory and habitat services is becoming increasingly important in assisting policymakers to manage critical environmental assets. If arguments can be made that the services provided by certain ecosystems (coral reefs in this case) are in fact of value to the public, especially if that value is not associated with a direct use, then there may be potential for policymakers to initiate stronger conservation and preservation measures.

Valuation provides a way for people to assess the impacts and trade-offs of ecosystem change and illuminates the accrual of gains and losses to different beneficiaries at disparate spatial and temporal scales. Monetary valuation, although not an end in itself, can be a powerful tool for decision making because it organizes information using a common metric for making comparisons. Brauman et al (2007)

5.3.4 Coral Reefs

The part worth utility estimates resulting from the latent class models show a strong utility derived from improvements to specific attributes, more so than others. In the realm of climate change research, this may be used to show that (particularly for Mainland US residents) improvements to coral attributes provide greater utility than improvements to fish attributes. While there have been a number of studies devoted to valuations of coral reefs (Cesar,2000; Cesar, Chong and Mahfuzuddin, 2005; Seenprachawong, 2004; Spash, 2002), to date, limited research has been completed on the specific ties between coral reefs and the impacts (economic and social) associated with changes resulting from climate change. While this study does begin to shed some light on potential willingness to pay for mitigation from climate change, it also highlights the need for further research into the area.

5.3.5 Policy implications

While determining the value of these reefs was indeed the focus of this study, there are still steps to be taken before the findings may be beneficial in successfully mitigating against climate change impacts. Economic valuation is a two-part process in which it is necessary to first, demonstrate and measure the economic value of environmental assets, and second, find ways to capture the value of such. The first part is called the demonstration process, while the second part is called the appropriation process (Georgiuo et al., 1997). What this study has detailed so far in the above sections is the demonstration of determining the willingness to pay for the existence value of Hawaiian coral reefs under the conditions of climate change. The appropriation of these values requires policies, rules, and regulations on the part of concerned agencies and institutions.

The results of this study have the potential to guide future location specific policy and project decision making. These findings will be useful for policy makers and managers in deciding how to secure adequate coastal zone management funding and who should pay, how much they should pay, and what they can charge for with respect to climate change mitigation. Results from this study also show that both use and non-use values should be considered when assessing the value of a given location. In other words, it is important that the concept of total economic value be applied to potential policies.

Subade (2005) suggests that the non-use values for his work on the Tubbataha Reefs National Marine Park can be captured through appropriate policy instruments such as taxes. He states that designing appropriate policy instruments is one big task in itself and there are possible options to be considered like: (a) tax attached to property value, (b) tax attached to utility bills, and, (c) voluntary contributions. While these options may not work for all classes of the study population, they are good examples of the type of policies that can be applied. Subade also suggests that since education is a determinant that increases WTP, future trust fund raising campaigns should target schools – elementary and high schools, colleges, and universities. So, while the information and education campaigns would increase people's knowledge and awareness, it would also increase people's WTP and the probability of their WTP (Subade, 2005).

Viscusi and Zeckhauser (2006) report in their study on the perception and valuation of the risks of climate change that there is a potentially substantial level of support for truly effective climate-change mitigation policies. With that in mind

Detailed location specific values should be determined based on the attributes of the coral reefs in that location. This may help inform policy development, especially for implementation of marine protected areas, since based solely on average values, the value of a given location may be significantly overestimated or underestimated

5.4 Study Limitations

The climate change scenarios were based on an assumption that each potential future outcome was assured depending on whether or not a fee was paid to mitigate against the effects on the coral reefs. One aspect that may have been helpful to the study would have been to look at the concept of risk and how the perception of risk may have affected decisions with respect to climate change. By introducing risk as an attribute, the presence of a risk function may have altered respondents' decision making in that knowing the certainty or uncertainty of a possible future coral reef scenario would ultimately affect their willingness to pay for that outcome. Leiserowitz (2006) makes an excellent case for the impact of risk perception on potential climate change policies, stating that policy support is strongly influenced by experiential factors, including affect, imagery, and values, and demonstrates that public responses to climate change are influenced by both psychological and socio-cultural factors.

Another issue that should be mentioned is that this study looked at coral reefs over a wide geographical area. Not all reef conditions should be assumed to be identical across all Hawaiian coral reefs. Braumen et al (2007) accurately states that the generic value of hydrologic services is apparent, but the functionality and value of an ecosystem is likely to be highly variable, so site-specific assessment remains important.

While the images used in the study were beneficial in aiding the decision making process and added a degree of realism to the climate change scenarios, they were amalgamated from a number of sites across the Hawaiian archipelago. Because of the amalgamated nature of the images, true photo-realism was difficult to achieve. Spending more time and effort in achieving true photo-realism may have affected the values associated with those reef locations. In the same context some of the spatial features of the images; such as fish, which are mobile and may move through the reefs in varying patterns could have been better represented through another medium such as video.

5.5 Conclusion

This study provides empirical evidence of positive non-use (existence) values for the coral reefs of the Northwestern Hawaiian Islands. An understanding of the value of ecosystem services provided by Hawaii's coral reefs will help to address the notion of placing an existence value on those reefs and thereby provide estimates for adequately funding research into climate change mitigation strategies. In order to begin understanding the values associated with ecosystem services and more specifically the existence value of Hawaiian coral reefs, analytical tools such as choice models are not only beneficial, but necessary as they are able to provide detailed descriptions of not only the values of the coral reefs as a whole, but also the specific attributes of those reefs that make them what they are.

The results from such choice models, as shown in this study, can help to define the preference values for not only entire populations such as Hawaiian or US Mainland residents, but also specific classes within those populations

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APPENDICES

Appendix A: Web-Survey Questions

1. Have you ever visited Hawaii before?

- No
- Yes → If yes, what is the approximate number of times you have visited Hawaii in your lifetime and when was the year of your most recent trip?
  Please enter your information in the boxes below..
  - Number of Visits
  - Year of last Visit

2. How likely are you to visit Hawaii in the future?

- Very Likely
- Likely
- Unlikely
- Very Unlikely
- Undecided

3. Have you ever dived or snorkelled before, either in Hawaii or elsewhere in the world?

- No
- Yes → If yes, please indicate the approximate number of dive and /or snorkel trips that you have taken during your lifetime.
  Please enter your information in the boxes below..
  - Number of Diving Trips
  - Number of Snorkelling Trips

  What is the current retail value (replacement value) of all the diving and snorkelling equipment that you own?

  $

4. How likely are you to dive or snorkel in the future?

- ☐ Very Likely
- ☐ Likely
- ☐ Unlikely
- ☐ Very Unlikely
- ☐ Uncertain

5. Have you ever visited a coral reef before?

☐ No → If no, please go to question 6.

☐ Yes → If yes, what activities have you engaged in while visiting coral reefs? Please check all that apply.

- ☐ Diving
- ☐ Snorkelling
- ☐ Glass-Bottom Boating
- ☐ Fishing
- ☐ Spear-Fishing
- ☐ Swimming
- ☐ Surfing
- Other [Please specify....]

→ Have you ever visited coral reefs in any of the following regions? If so, please rate each reef visit experience.

	No	Yes	Poor 1	2	3	4	Excellent 5
Hawaii	☐	☐	☐	☐	☐	☐	☐
Great Barrier Reef	☐	☐	☐	☐	☐	☐	☐
Caribbean	☐	☐	☐	☐	☐	☐	☐
Indian Ocean	☐	☐	☐	☐	☐	☐	☐
Red Sea	☐	☐	☐	☐	☐	☐	☐
South East Asia	☐	☐	☐	☐	☐	☐	☐
Other	☐	☐	☐	☐	☐	☐	☐

6. How attractive do you find each of the reef scenes below?

Please use the scale from 1 (= not attractive at all) to 10 (= very attractive) when evaluating each image

(Respondents were shown 12 of 128 coral reef images, 4 of which were standardized for everyone)

7. From the list of issues of national importance below, please choose the three you consider most important.

Please type 1, 2 or 3 where 1 is the most important.

☐	Aging Population	☐	AIDS
☐	Crime	☐	Drugs
☐	Economy	☐	Education
☐	Environment	☐	Foreign Policy
☐	Health Care	☐	Racism
☐	Terrorism	☐	Unemployment

8. From the list of environmental issues of national importance below, please choose the three you consider the most important.

Please type 1, 2 or 3 where 1 is the most important.

☐	Acid Rain	☐	Climate Change
☐	Deforestation	☐	Endangered Species
☐	Overpopulation	☐	Ozone Depletion
☐	Smog	☐	Toxic Waste
☐	Urban Sprawl	☐	Water Pollution

9. How familiar are you with the term 'climate change'?

○	Very Familiar
○	Somewhat Familiar
○	Completely Unfamiliar

10. Which of the following statements best reflects your opinion about climate change?

Please select one of the options listed below.

- ☐ There will be climate change, but the implications will only be noticeable later.
- ☐ Climate change is a fact and the first indications are evident already.
- ☐ Evidence about climate change is still too uncertain; it is too early to know what will happen.
- ☐ I do not believe in climate change.
- ☐ Other [Please specify....]

11. Should humans take actions to reduce climate change?

- ☐ No
- ☐ Yes → If yes, who should lead and coordinate these actions? Please check one only.
  - ☐ Federal Governments
  - ☐ State Governments
  - ☐ Local Governments
  - ☐ Private Sector
  - Other [Please specify....]

Q 12/13.

(here respondents either receive the Conservation fee choice task, or the climate change mitigation choice task depending on the sequence they are randomly chosen to complete)

14. When you made your choices, to what extent did you consider the images of the coral reefs, and to what extent the text that described the coral reefs?

- ☐ Predominantly text
- ☐ More text than images
- ☐ Equal
- ☐ More images than text
- ☐ Predominantly images

15. If you chose the `Neither` option in any of the choice sets, what was your main reason for this decision?

16. Do you agree that you and other US citizens should be asked to pay for climate change mitigation action on coral reef?

- Agree
- Disagree → If you answered "Disagree", can you briefly explain why?
- Don`t Know

17. How important is the protection of Hawaiian coral reefs to you personally?

- Not at all important
- Of minor importance
- Somewhat important
- Very Important
- No opinion

18. How important is the protection of other international coral reefs to you personally?

- Not at all important
- Of minor importance
- Somewhat important
- Very Important
- No opinion

19. What is your gender?

- Male

- Female

20. Which of the following age categories describes you?

- Under 20
- 20 to 35
- 35 to 50
- 50 to 65
- 65 and over

21. What is the highest level of education you have completed?

- Less than high school
- Completed high school
- Trades or non-university certificate or diploma
- Completed university
- Post graduate degree

22. Which of the following best describes your employment status?

- Full time employment with single employer
- Full time self employment
- Full time employment with numerous employers and/or self employment
- Part time employment
- Seasonal employment
- Currently not employed
- Retired

23. What category best describes your net annual household income level after tax?

- Under $25,000
- $25,000 to $50,000
- $50,000 to $74,999

- $75,000 to $99,999
- $100,000 to $149,999
- $150,000 to $199,999
- Over $200,000

24. Where is your main residence?

Country: United States of America

State/Province Please Select ... (only if living in the USA or Canada)

City

Hawaii Sequence: (the following questions were specific to the Hawaiian resident survey)

1. How long have you lived in Hawaii?

0-2 years 3-5 years 6-10 years 11-20 years 20+ years

2. Which of the Main Hawaiian Islands have you visited?
Please check all that apply

- Hawai'i (Big Island)
- Maui
- O'ahu
- Kaua'i
- Moloka'i
- Ni'ihau
- Lana'i

Appendix B: DSS Results

Best Case Scenario

Current Scenario #	**1**	**WITHOUT MITIGATION**	**WITH MITIGATION**
Water Clarity	**7 m**	**7 m**	**7 m**
Coral Cover	**70%**	**95 %**	**95 %**
Coral Health	**Good**	**Very Good**	**Very Good**
Fish Number	**25 fish**	**35 fish**	**35 fish**
Species Diversity	**High**	**Very High**	**Very High**
Turtle	**Absent**	**Absent**	**Absent**
Mitigation Cost	**No Cost**	**No Cost**	**$0.00**

			Net WTP
Mainland ALL	**42.1%**	**57.9%**	**$28.03**
Hawaii ALL	**43.7%**	**56.3%**	**$31.44**

Mainland

Believers	**42.8%**	**57.2%**	**$27.39**
Skeptics	**42.8%**	**57.2%**	**$21.24**

Hawaii

Believers	**45.5%**	**54.5%**	**$26.01**
Skeptics	**45.5%**	**54.5%**	**$14.22**

Worst Case scenario

Current Scenario #	4	WITHOUT MITIGATION	WITH MITIGATION
Water Clarity	7 m	1 m	1 m
Coral Cover	95%	5 %	5 %
Coral Health	Very Good	Poor	Poor
Fish Number	35 fish	5 fish	5 fish
Species Diversity	Very High	Low	Low
Turtle	Absent	Absent	Absent
Mitigation Cost	No Cost	No Cost	$0.00

			Net WTP
Mainland ALL	11.7%	88.3%	$177.55
Hawaii ALL	18.1%	81.9%	$187.43

Mainland

Believers	11.8%	88.2%	$190.95
Skeptics	11.8%	88.2%	$148.09

Hawaii

Believers	18.3%	81.7%	$216.83
Skeptics	18.3%	81.7%	$118.54

Maximum Difference

Current Scenario #	4	WITHOUT MITIGATION	WITH MITIGATION
Water Clarity	7 m	1 m	7 m
Coral Cover	95%	5 %	95 %
Coral Health	Very Good	Poor	Very Good
Fish Number	35 fish	5 fish	35 fish
Species Diversity	Very High	Low	Very High
Turtle	Absent	Absent	Absent
Mitigation Cost	No Cost	No Cost	$0.00

			Net WTP
Mainland ALL	1.3%	98.7%	$379.06
Hawaii ALL	3.2%	96.8%	$421.40

Mainland

Believers	1.3%	98.7%	$413.54
Skeptics	1.3%	98.7%	$320.73

Hawaii

Believers	3.1%	96.9%	$497.92
Skeptics	3.1%	96.9%	$272.20

Plausible Scenario

Current Scenario #	1	WITHOUT MITIGATION	WITH MITIGATION	
Water Clarity	7 m	5 m	6 m	
Coral Cover	70%	60 %	75 %	
Coral Health	Good	Moderate	Good	
Fish Number	25 fish	20 fish	25 fish	
Species Diversity	High	High	High	
Turtle	Absent	Absent	Present	
Mitigation Cost	No Cost	No Cost	$0.00	Net WTP
	Mainland ALL	30.3%	69.7%	$72.89
	Hawaii ALL	26.4%	73.6%	$126.76

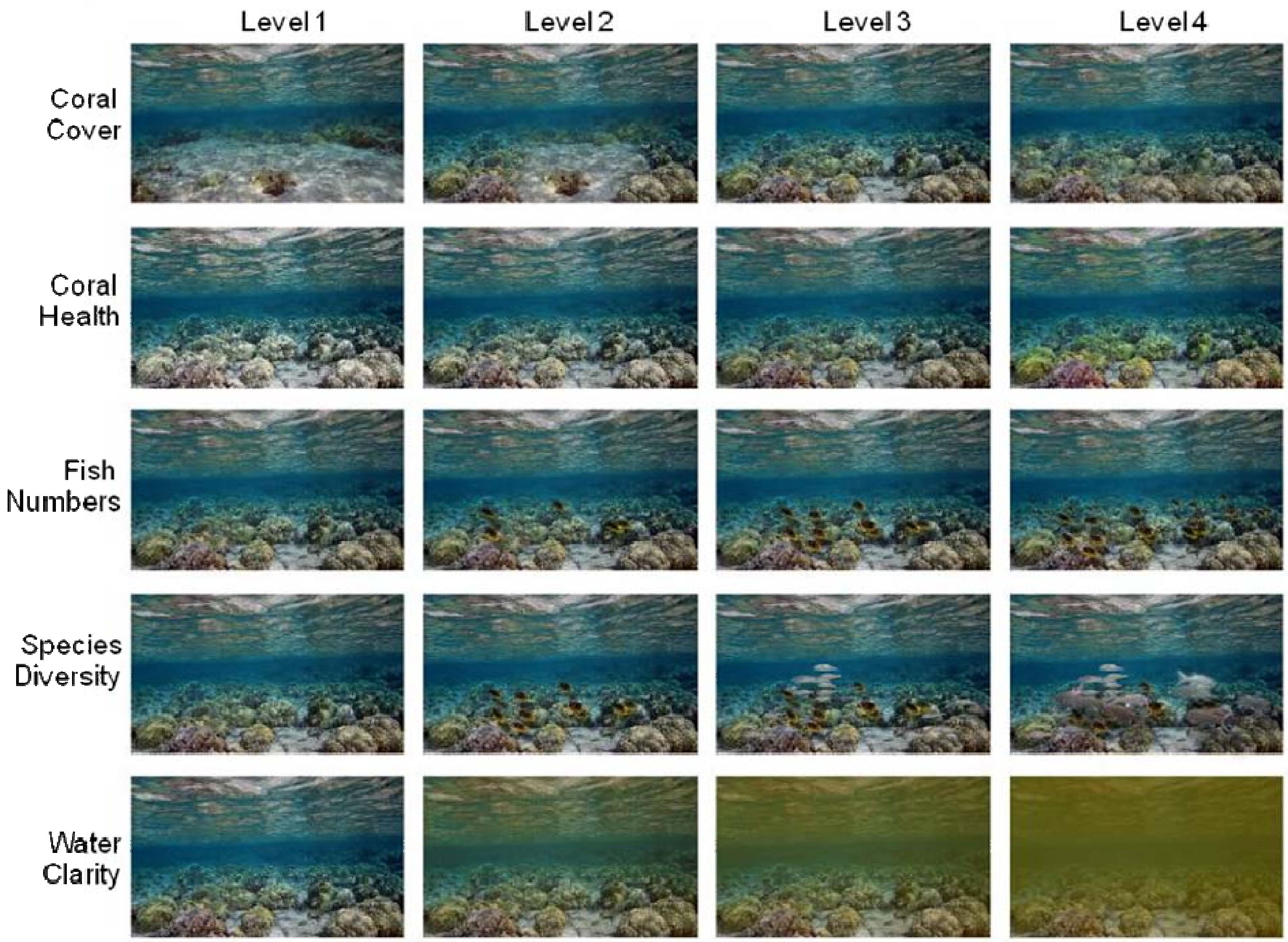
Mainland

Believers	30.8%	69.2%	$76.70
Skeptics	30.8%	69.2%	$59.48

Hawaii

Believers	26.9%	73.1%	$144.47
Skeptics	26.9%	73.1%	$78.98

Appendix C: Image Sequences (example for one mother scene)



Appendix C1 represent s one mother scene in all iterations. Layers of attribute levels were added, or removed following the fractional factorial design. In total, twelve mother scenes were chosen, with four scenes each from the three levels of topographical relief. Appendix C2 displays varying levels of reef quality for one mother scene of each type of relief.