1. Introduction

This chapter provides background information on coral reefs, including the goods and services they provide, specifics about Hawaiian coral reef ecosystems, the current risks and threats to coral reefs worldwide, and U.S. policies to protect and understand coral reefs. It also provides the primary motivation for this study: to estimate total economic values for protecting and restoring coral reefs in Hawaii. The secondary, methodological motivations for this study are also addressed and supported by two literature reviews on coral reef valuation studies and the use of internet surveys in valuation studies.

1.1 Background on Coral Reefs

Coral reef ecosystems are one of the most diverse and densely populated environments on Earth (Spalding et al., 2001). Approximately 100,000 species of plants and animals living near coral reefs have been named and described, but the total number of plant and animal species supported by the world's reefs could be close to 1 million (Reaka-Kudla, 1997). Even so, coral reefs cover only an estimated 600,000 square kilometers and only 0.1% of the Earth's surface (Reaka-Kudla, 1997). Coral reefs can be found in shallow lagoons (platform reefs), along shorelines (fringing reefs), offshore (barrier reefs), and as isolated shallow areas in the open ocean (atolls). They are generally found in warm, clear, shallow waters with few nutrients.

The ecological functioning of healthy coral reef ecosystems provides an extensive array of both economic and ecological goods and services (Table 1.1). The types and levels of these goods and services vary by their location and type. For example, an atoll hundreds of miles from shore will not provide shoreline protection services, but nitrogen fixation by such a reef may be more critical (Moberg and Folke, 1999).

1.1.1 Goods

Some goods provided by coral reefs may be renewable if utilized carefully; however, the extraction of other goods is incompatible with sustainable uses of the ecosystem. Potentially renewable resources include commercial and recreational fisheries, as well as other food sources such as seaweed (Moberg and Folke, 1999). It is estimated that 50% of all federally managed fisheries in the United States depend on coral reefs and related habitats for at least part of their lifecycle (NOAA, 2001). The catch directly from reef areas constitutes around 10% of the fish consumed by humans (Moberg and Folke, 1999).

Table 1.1. Goods and services provided by coral reef ecosystems

Goods		Services				
Renewable resources	**Nonrenewable resources**	**Physical structure**	**Biotic**	**Biogeochemical**	**Information**	**Social and cultural**
Commercial and recreational fisheries	Coral blocks and sand for building materials	Construction of complex structural base for habitat by hermatypic corals	Maintenance of coral reef habitat processes and functions	Nitrogen fixation	Historical record of contaminants	Recreation such as ecotourism, diving, and snorkeling
Pharmaceuticals and medical raw materials	Raw materials for production of lime and cement	Protection of shallow aquatic nursery and feeding habitat from severe wave action	Provision of spawning, nursery, breeding, and feeding areas for many species	Carbon cycling	Historical record of salinity	Cultural and religious values
Raw materials (primarily seaweed) for production of agar, carrageenan, and fertilizer	Mineral oil and gas	Protection of shoreline property from severe wave action and erosion	Maintenance of species and genetic diversity	Calcium sink	Historical record of sea temperature	Maintenance of traditional lifestyles
	Shells and corals for jewelry and souvenirs	Construction of new land	–	Export of dissolved organic matter, nutrients, and plankton to nearby habitats	Monitoring of environmental pollution impacts	Aesthetic values and artistic inspiration
Live fish and corals for aquariums	–	Provision of sand to tropical beaches	–	Assimilation of waste (particularly petroleum)	–	–

Source: Adapted from Moberg and Folke, 1999, Table 2.

The natural resources of coral reefs also have great potential for use by the pharmaceutical industry. Seaweeds, sponges, mollusks, soft corals, and sea anemones found on coral reefs contain substances that may be useful in development of new anti-cancer, acquired immune deficiency syndrome (AIDS)-inhibiting, antimicrobial, anti-inflammatory, and anticoagulating drugs (Moberg and Folke, 1999). Coral skeletons may also be used for bone graft operations (Moberg and Folke, 1999).

Reefs also supply other potentially renewable goods to humans such as seaweed used to produce agar, carrageenan, and fertilizer, as well as live fish and corals for aquariums (Moberg and Folke, 1999).

Nonrenewable uses of coral reefs include the extraction of carbonate structures of corals for building materials and for the production of lime, mortar, and cement (Moberg and Folke, 1999).

1.1.2 Services

The structure and functioning of coral reefs also provide many services of both ecological and human importance. These services can be categorized into physical structure, biotic, biogeochemical, information, and social and cultural services (Cesar, 2000b, Table 1).

The physical structures of coral reefs protect shallow aquatic habitats such as lagoons, mangroves, and sea grass beds from severe wave action. These habitats, in turn, provide key nursery, breeding, and feeding habitats for aquatic biota (Reaka-Kudla, 1997; Moberg and Folke, 1999). Additionally, coral reefs buffer wave action, providing important protection for shoreline property. They help to prevent loss of life, property damage, and erosion during severe storms (Reaka-Kudla, 1997; NOAA, 2001). It has been estimated that destruction of reefs in Indonesia has resulted in 0.2 meters of coastal erosion per year (Moberg and Folke, 1999).

The coral reef ecosystem provides important spawning, nursery, breeding, and feeding areas for many organisms. Its complex structure and heterogeneity of habitat facilitate niche diversification and thus the potential for evolutionary development of new species (Moberg and Folke, 1999). Coral reefs also help to maintain current biological and genetic diversity.

Coral reefs provide biogeochemical services, acting as sinks for carbon dioxide on a geologic timescale and as minor sources on human timescales (Moberg and Folke, 1999). Coral reefs also appear to support nearby habitats by exporting excess dissolved organic matter and nitrogen, as well as bacterio-, phyto-, and zooplankton (Moberg and Folke, 1999).

Microbes found in coral reefs play an important role in the assimilation of waste that enters the ocean (Moberg and Folke, 1999). Reefs can help detoxify petroleum products by converting hydrocarbons into carbon dioxide and water. They also immobilize or sequester persistent pollutants.

Reefs provide valuable information to scientists about long-term changes in the environment (Moberg and Folke, 1999). For example, reef deposits have been used to review the history of contaminant levels in seawater and to track historical variations in temperature, salinity, and flooding. Because they are highly sensitive to environmental change, coral reefs can also be used to monitor current changes in the environment and effects of human disturbance and environmental pollution.

Services provided by coral reefs extend to the cultural and spiritual realm as well. They are important for recreational activities such as ecotourism, diving, and snorkeling. Religious rituals in southern Kenya focus on the importance of reefs to the society (Moberg and Folke, 1999). Reefs are also important as a traditional source of livelihood for local communities and can maintain cultural traditions. They also offer aesthetic value and serve as artistic inspiration (Cesar, 2000b).

1.1.3 Hawaiian coral reefs

The coral reefs of the Hawaiian Islands comprise almost 10% of reefs within U.S. territorial seas and the exclusive economic zone (Rohmann et al., 2005).[1, 2]

Hawaiian coral reefs contain about 55 species of stony corals, with the majority of these species found in the Main Hawaiian Islands (MHI; Gulko et al., 2000b). About 25% to 50% of Hawaii's coral species are endemic (DeMartini and Friedlander, 2004), which is due to the islands' geographic isolation from other reef habitats (Gulko et al., 2000a). Marine invertebrate diversity is high, with more than 100 species of sponges, 1,071 species of marine mollusks, 884 species of crustaceans, and 278 species of echinoderms. The number of species of reef and shore fishes, 557, is low compared to other Indo-West Pacific reefs. However, Hawaii has the highest percentage of endemic fish species (24.3%) in the world.

The Hawaiian Island archipelago consists of 8 large islands and 124 small islands, atolls, reefs, and shoals. The Hawaiian reefs consist of two regions with distinct differences: the MHI are made up of large, populated islands with platform, fringing, and barrier reefs and the Northwestern Hawaiian Islands (NWHI) are comprised primarily of uninhabited atolls and banks.

1. All estimates reported in Rohmann et al. (2005) are calculated using the 10-fathom depth curve.

2. The exclusive economic zone is the area over which a state or country has the right to exploit or use marine resources. It generally extends about 200 nautical miles seaward from the edge of the state or country's seaward edge.

The MHI reefs exist in close proximity to high levels of human activities. They provide important shoreline protection functions, generate sandy beaches, and provide food products and recreational opportunities (Gulko et al., 2000b). These reefs cover approximately 1,231 square kilometers (Rohmann et al., 2005).

The NWHI are older and more isolated than the MHI. They begin approximately 200 kilometers west of the MHI and stretch northwest for more than 2,000 kilometers (NOAA, 2009). Habitats extend from the shorelines of small islands and atolls to submerged banks and reefs at depths of up to 183 meters (NOAA, 2009). The NWHI coral reefs account for 4.3% of all coral reefs in the United States and cover approximately 1,595 square kilometers (Rohmann et al., 2005). The NWHI reefs contain 51 species of stony coral and 8 species of soft coral and coral-like anemones (NOAA, 2002). The diversity of coral species in the NWHI is low compared to other coral reefs around the world, most likely because of their geographic isolation.

Up to half of the 7,000 marine species documented in the Hawaiian Islands are found only in the NWHI (NOAA, 2002). The reefs there support a complex association of species, including vertebrates (e.g., monk seals, reef and bottom fish, turtles, birds, sharks), invertebrates (e.g., corals, anemones, jellyfish, mollusks, shrimp, crabs, lobsters, sea urchins, sea stars, sea cucumbers), sea grasses, and algae (NOAA, 2002). Average fish biomass in the NWHI is nearly three times greater than that in the MHI, largely due to high proportions of large predators and larger average body sizes of fish (Maragos and Gulko, 2002).

Species of particular importance found in both the MHI and the NWHI include the endangered Hawaiian monk seal (*Monachus shauinslandi*) and the threatened green sea turtle (*Chelonia mydas*). Nearly the entire population of the Hawaiian monk seal is found in the NWHI, and many areas of the islands have been designated as critical habitat for this endangered species (NOAA, 2002). Additionally, the reefs provide important nesting habitat for the threatened green sea turtle. Ninety percent of green sea turtle nesting in the NWHI occurs at one site, the French Frigate Shoals.

1.1.4 Risks and threats to coral reefs

Coral reefs appear to be resilient in response to periodic natural disturbances, such as destructive storms, outbreaks of predators, and shifts in oceanographic conditions. However, they are less able to adapt to chronic, persistent disturbance (Moberg and Folke, 1999). Additionally, chronic anthropogenic impacts can reduce a coral reef’s ability to respond to natural disturbances.

Anthropogenic threats to coral reefs occur at the global and local levels. The primary global threat to reefs is increased sea temperature, which results in coral “bleaching” (Cesar, 2000b). Increases in ocean temperature have been linked to the loss of zooxanthellae, the corals’ symbiotic microalgae that assist in the production of calcium carbonate and provide the corals with their color (Moberg and Folke, 1999). Corals are much more susceptible to pollution and eventually die without the assistance of zooxanthellae (NOAA, 2008).

Local threats can be summarized under the following four main categories: destructive fishery practices; mining and dredging; sedimentation, pollution, and waste; and nonsustainable tourism (Cesar, 2000b). Jennings and Kaiser (1998) and Jackson et al. (2001) found that although pollution, coastal development, invasive species, and global climate change all impact coral reefs, overfishing[3] is the most pervasive and direct threat to coral reefs and other coastal ecosystems.

Other activities with similar impacts include dredging for the maintenance of navigational channels (Cesar, 2000b; NOAA, 2001), ship groundings (Gulko et al., 2000b), and the extraction of oil and gas from below coral reefs (Moberg and Folke, 1999).

Although tourism can be a sustainable use of reef ecosystems, nonsustainable tourism can cause adverse impacts (Cesar, 2000b). Particular problems include the collection of reef organisms for souvenirs (Miller and Crosby, 1998; Moberg and Folke, 1999), boat groundings, and damage by anchors (Miller and Crosby, 1998; Gulko et al., 2000b).

The highest priority threats to reefs in the MHI include coastal development and runoff, coastal pollution, tourism and recreation, fishing, trade in coral and live reef species, ship and boat groundings, and nonnative species. The highest priority threats for the NWHI include ship and boat groundings, marine debris, and alien species (NOAA, 2002). In 2006, nearly all of the NWHI, including coral reefs, came under full protection when the area was designated as the Papahanaumokuakea Marine National Monument.

1.1.5 U.S. coral reef policy

In June 1998, President Clinton established the U.S. Coral Reef Task Force (CRTF) [Executive Order (EO) 13089], which is a partnership of federal, state, territorial, and commonwealth governments; the scientific community; the private sector; and other organizations. The goal of the CRTF is to strengthen and fill the gaps in existing efforts to conserve and sustainably manage coral reefs and related ecosystems (e.g., sea grass beds and mangrove forests) in U.S. waters and "to inventory, monitor, and identify the major causes and consequences of degradation of coral reef ecosystems" (EO 13089). Duties of the task force include mapping and monitoring of U.S. coral reefs, researching causes of reef degradation, developing measures to restore reefs and

3. Throughout this report, we use the term "overfishing" in the way it is used in fishery economics, and not in the strict legal sense of the term used in implementation of the Magnuson-Stevens Fishery Conservation and Management Act as amended.

prevent further degradation, and promoting conservation and sustainable use of coral reefs internationally (U.S. Coral Reef Task Force, 2009; U.S. EPA, 2009).

The CRTF developed the National Action Plan to Conserve Coral Reefs, which lays out 13 strategies to address challenges to coral reefs (U.S. Coral Reef Task Force, 2000). These initiatives focus on increasing the understanding of and reducing adverse impacts to coral reefs.

The National Oceanic and Atmospheric Administration (NOAA) is co-chair of the CRTF and has significant responsibilities for managing U.S. coral reef habitats and for undertaking scientific research studies to better understand the nation's coral reef resources.

NOAA also manages three National Marine Sanctuaries (NMS) with coral reef resources under the National Marine Sanctuaries Act (NMSA, 16 U.S.C. 1431, et seq.): the Florida Keys National Marine Sanctuary (FKNMS), the Flower Gardens Bank National Marine Sanctuary, and the Fagatele Bay National Marine Sanctuary. Additionally, NOAA has the authority to conduct research to understand the use of Marine Protected Areas (MPAs) under EO 13158.

1.2 Motivation for this Study

Given the economic and environmental importance of coral reef ecosystems to the United States and around the world, NOAA convened a research team to develop better methods to evaluate public preference for and economic values of coral reef ecosystems. The Research Team (hereinafter referred to as "the Team") has expertise in economics, coral reef ecology, survey methodology, and statistical analysis.

The Team chose Hawaii as a case study. The study was conducted within a total valuation framework to account for a wide range of possible values, including passive use values (see Chapter 2 for more details). As shown in the literature review that follows (Section 1.2.2), this is the first major total value study of coral reef ecosystems conducted using a state-of-the-art survey of the population of a developed nation.

The Team also addressed several methodological issues, including:

- **Using internet surveys in nonmarket valuation studies.** The rapid growth of the internet over the past two decades has made internet administration of surveys increasingly feasible. However, the application of internet surveys in nonmarket valuation studies is still in its infancy, as shown in the literature review below. This issue was addressed by administering the survey to two independent internet panels.

- **Designing a stated-preference (SP) and stated-choice hybrid survey.** Internet administration allowed the Team to develop a new approach to SP surveys. In recent years, researchers who have chosen to go beyond traditional contingent valuation (CV) have gravitated toward the stated-choice approach. That is, survey respondents are asked to choose their most preferred alternative from a choice set composed of two or at most three alternatives, each of which is described in terms of its attributes. This mimics the types of choices consumers face in the marketplace; people compare alternative products and choose one. This is in contrast to the SP approach, which involves ranking. In ranking questions, respondents are presented with several alternatives and asked to rank them from most preferred to least preferred. In the marketplace, consumers are not required to determine a full ranking. On the other hand, ranking provides more information about preferences. Using an internet survey (see Appendix A), we were able to use a hybrid approach that combines CV with the stated choice format, yet obtain a full ranking of four alternatives (see Chapter 2).

- **Dealing with multiple SP questions.** Data from surveys involving more than one SP question create what has turned out to be a persistent econometric problem. When any given respondent answers more than one such question, successive choices are not an independent observation. Rather, successive choices are correlated. We offer here a rank-ordered probit model, which has some desirable properties to deal with this issue, instead of other econometric approaches that have been applied in the past (see Chapter 8).

- **Testing representativeness of internet panels.** Furthermore, as discussed in the literature review, questions remain regarding whether internet surveys can produce results that are representative of a general population like that of the United States. We attempt to help inform this issue by procuring and comparing survey results from two internet samples that were recruited in different ways (see Chapter 5).

1.2.1 Review of coral reef valuation literature

As part of the research process, the Team assessed whether the existing literature on coral reef valuation provides useful insights. For Hawaii, the most notable study is by Cesar et al. (2002). They estimate the total economic values[4] of the coral reefs of the MHI to be $364 million per year.

4. "Total economic values include all the several kinds of economic values that have been identified by economists. Total economic value is the [willingness to pay] (WTP) for a change in the state of the world" (NRC, 1999, p. 90).

Although their goal may have been comparable to ours, the approach of Cesar et al. (2002) is very different from the present effort. Both studies begin with the concept of total value, but they involve very different empirical approaches. Our study conducted a survey of probability samples of U.S. residents, and the survey sought to capture the fullest possible array of values through SP questions. Cesar et al. (2002) attempted a “bottom-up” approach where they tried at the outset, on an a priori basis, to select “the most important goods and services for coral reef valuation” (Cesar et al., 2002, p. 11). They divided potential values into recreational value, amenity value, fisheries value, and biodiversity value and attempted to estimate these values separately and then total them. Cesar et al. (2002) did not account for values of U.S. residents outside Hawaii, and many assumptions were made to complete their study.

In Cesar et al. (2002), recreational value includes an allowance for consumer surplus based on (1) a small CV survey conducted with a convenience sample, (2) estimated recreational expenditures associated directly with diving and snorkeling (assuming value added was 25%), (3) estimated indirect expenditures on hotels and travel (assuming value added was 25%), and (4) a multiplier effect of 1.25.

Amenity value was based on property prices. Project resources were inadequate for a hedonic property value study, so amenity value is based on a simplified approach that involves expert opinions of real estate agents and information obtained from real estate listings, tax records, and other sources of data plus many assumptions.

Fishery value is based on the potential productivity of coral reef ecosystems from the literature multiplied by an assumed price of $5 per kilogram, an allowance for value added, and an assumed multiplier effect.

The estimate of biodiversity value from Cesar et al. (2002) includes an explicit estimate of passive use values of $7,390,000. This value is not based on an original survey, but on benefits transfer from the study by Leeworthy and Wiley (2000), who conducted a socioeconomic impact analysis of the proposed Tortugas 2000 Ecological Reserve. Five alternative plans for the reserve were under consideration by NOAA and the State of Florida. Although they judged that some sort of recognition of passive use values was desirable in the context of their impact assessment, they point out that, “To date there are no known studies that have estimated nonuse or passive use economic values for coral reefs or marine ecological reserves” (Leeworthy and Wiley, 2000, p. 57). Hence, they decided to gain a very rough idea of the potential magnitude of passive use values for the reserve by referring to 19 passive use value studies that did not actually involve coral reefs, 18 from Desvousges et al. (1992) and 1 from Carson et al. (1992). From this review, Leeworthy and Wiley (2000) judged that values from $3 per household per year to $10 per household per year were plausible for their case. To be very conservative, they used the low figure and assumed that it would apply to only 1% of U.S. households.

Cesar et al. (2002) assume that Hawaii's households have a passive use value for reef biological diversity of $10 per household per year (the upper end of the range from Leeworthy and Wiley, 2000) and that 1% of mainland households hold values of $3 per year (Leeworthy and Wiley's lower bound value). Whatever this approach's merits are, Cesar et al. (2002) provide few insights for our Coral Reef Valuation Study.

We were able to identify only one other published economic study of the Hawaiian reefs. Mak and Moncur (1998) present results from a political economic analysis of efforts to protect Hanauma Bay, a popular recreational destination that includes a large reef complex managed by the City of Honolulu. Unfortunately for our efforts to estimate total values, the only dollar values in Mak and Moncur (1998) are revenues from user fees.

Looking beyond Hawaii, it became clear that the international literature is dominated by recreational studies. Brander et al. (2007) find 166 coral reef recreation studies worldwide. A search of the Environmental Valuation Reference Inventory (EVRI)[5] added more recreation studies. Although some of the studies involved surveys that could have included some passive use values, nearly all the studies involved samples of locals and tourists and focused heavily on recreational direct use values rather than total values. Most of these studies are found only in the grey literature. Exceptions published in professional journals include White et al. (1997) on various benefits and costs of reef restoration at a tourist destination in Sri Lanka; Berg et al. (1998) on the environmental economics of reef destruction in Sri Lanka; Bowker and Leeworthy (1998), Park et al. (2002), and Bhat (2003) on recreational direct use values of reef visits in the Florida Keys; Arin and Kramer (2002) on the value to divers of preserving marine biodiversity associated with coral reefs in the Philippines; Carr and Mendelsohn (2003) on recreational direct use values of the Great Barrier Reef in Australia; Wielgus et al. (2003) on the value to divers of damage to the Eilat Coral Beach Nature Reserve in Israel; and Parsons and Thur (2007) on the value to scuba divers of changes in the quality of a coral reef ecosystem in Bonaire.

Studies by Seenprachawong (2001, 2002) devoted more attention to passive use values. Seenprachawong (2001) included passive use values in a study of domestic visitors to Thailand's Phi Phi Island reefs. Resulting value estimates per visitor are expanded to estimate the passive use values of the Thai working population. The value per hectare was used in a benefits transfer to estimate the value of Thailand's other marine national parks.

Seenprachawong (2002) is worthy of special note because it involved stated choice questions to obtain total values. The topic is improvements in coral reefs and associated mangrove forests of Phang Nga Bay, Thailand. The stated choice experiment was conducted using four choice sets.

5. EVRI is a database of environmental valuation studies for use in benefits transfer maintained by Environment Canada.

Each choice set included the status quo and two alternatives or “plans” involving reef ecosystem improvements. Quoting from the study’s report (pp. 16–17):

> Each plan is defined using four ecosystem attributes: living coral cover (a proxy for recreational use), income from fishery (a proxy for consumptive use), flood occurrence (a proxy for indirect use), and area protected (a proxy for nonuse [passive use] value). The increase in income tax in 2002 is included as a [willingness to pay] WTP measure attribute, which will provide the link between the parameter weights of the ecosystem attributes (recreational use, consumptive use, indirect use, and existence value) and money.

Seenprachawong (2002) differed from our study in several respects. Most importantly, data were gathered by intercepting visitors to Phang Nga Bay and interviewing them personally.

Cesar (2000a) provides a collection of essays on the economics of coral reefs, with frequent references to economic values. Several economically important issues are addressed including the external effects of forestry, damaging fishing practices, coral mining, and bleaching. One of the essays, Rodwell and Roberts (2000), surveys the positive impacts of MPAs on fisheries, arguing that the impacts are probably substantial and so far underappreciated. The potential importance of total values is emphasized throughout this volume. However, the only empirical research on reef values is reported by Spash (2000) who conducted a CV study of maintaining and improving coral reefs in Jamaica and Curaçao. Like so many other studies in this literature, the samples were drawn from locals and tourists and only estimated recreation direct use values.

This review shows that the research presented in this report is unique in several respects. Specifically, we:

- Set out to estimate total values, not merely direct use values
- Surveyed the national population of a major developed country, not smaller subpopulations of users
- Employed SP methods using an uncommonly large sample of respondents
- Developed econometric methods that have rarely been applied in nonmarket valuation and have never been applied, to our knowledge, in a coral reef valuation study
- Gathered data using state-of-the-art internet administration, which led us to consider the literature on survey research, in addition to the economics literature.

1.2.2 Review of internet survey literature

The rapid expansion of the internet through the 1990s provided opportunities to develop a new survey mode, internet administration. The popularity of internet surveys for both marketing and social science research has grown rapidly. According to sources cited by Deutskens et al. (2006), by 2004 online surveys accounted for 35% of the U.S. survey research market. As use of internet surveys expanded, several potential advantages and disadvantages of internet administration were soon identified (Evans and Mathur, 2005).

Best et al. (2001, p. 131) summarize why many researchers have embraced internet surveys:

> The internet offers unprecedented opportunities for data collection. It provides access to millions of potential research participants …. It permits complex instruments capable of experimentally manipulating stimuli, accommodates audio and video transmissions, and facilitates live interaction between participants …. And it can be employed quickly, conveniently, and inexpensively by eliminating the need for interviewers or synchronous interaction ….

Not surprisingly, researchers performing nonmarket valuation surveys are trying to capitalize on the opportunities provided by this relatively new medium. Examples of SP studies in the peer-reviewed literature that rely on internet-based data collection include studies on the value of a statistical life by Alberini et al. (2004); climate change by Berrens et al. (2003, 2004) and Li et al. (2005); dead zones in the Gulf of Mexico by Hudson et al. (2004); recreational fishing in Germany by Arlinghous and Mehner (2004); water pollution at a site in Japan by Tsuge and Washida (2003); preservation of agricultural landscape as bird habitat in Portugal by Marta-Pedroso et al. (2007); and landscape effects of new highway construction in Denmark by Ladenburg and Olsen (2008) and Olsen (2009). A recent study focuses on the value of morbidity reductions (Cameron and DeShazo, 2009). Additional SP studies, including Vossler and Kerkvliet (2003) and Rollins et al. (2008), have allowed respondents the option of responding via the internet if they wished. In addition to SP surveys, at least one travel cost survey used the internet, that is, Fleming and Bowden's (2009) study of recreation at Frazier Island in Australia.

Internet surveys also have some disadvantages that could affect the validity of this study's results. The most serious issues from the perspective of the present study have to do with whether parameter estimates (most notably WTP) based on state-of-the-art internet surveys are representative of the parameter values for the underlying population. In this review, we limit ourselves to surveys of the general public. In our case, the issue is whether values of Hawaiian coral reef ecosystems derived by internet-based surveys are sufficiently representative of the values of the U.S. population to be reliable.

Two closely related issues require consideration: the coverage error and potentially low overall response rates. Schonlau et al. (2002, p. 29) describe the first issue this way:

> Coverage error is the most widely recognized shortcoming of internet surveys. Although the fraction of the population with internet access and the skills and hardware necessary to use the web is continually increasing, the general population coverage for internet-based surveys still lags considerably behind the coverage achievable using conventional survey modes.

The second issue is one of response rates and the extent to which sample results can be generalized to the population of interest. With relatively high response rates, say 80% or higher, a good prima facie argument can be made that for most variables, distortions due to nonresponse bias, if any, are not likely very large. But when response rates are low, those who did respond may not be representative of the sample, or population, as a whole. If generalizing survey results to the population is the goal, the question of potential nonresponse bias needs to be evaluated.

So far, most internet surveys of general populations have had low overall response rates. Even for the best internet surveys, potential response rate problems have arisen because of attrition of respondents through various stages of recruiting. To understand how this happens, consider a simplified example.[6] Suppose that the goal is to conduct an internet survey and generalize the results to all U.S. households. Suppose that the first contact with potential respondents is through a random digit dialing (RDD) survey. Suppose 10,000 numbers are drawn and 6,000 calls are completed. We will assume that the original sample of telephone numbers is representative of U.S. households. Suppose further that 3,000 individuals agree to participate and that 70% or 2,100 actually complete the survey. That would yield an overall response rate of 21% (2,100 out of the original 10,000). Since the 21% who decided to complete the survey may not be representative of the full sample, results may contain nonresponse bias.[7]

It is important to recognize that a low response rate does *not* necessarily mean that nonresponse bias is a significant problem in a dataset. It only signals that one should investigate the potential for nonresponse bias. Nevertheless, there is evidence that, even for state-of-the-art internet sampling, issues of coverage and low response rates persist.

Lee (2006) provided a particularly thorough empirical investigation of the issues. She examined coverage and nonresponse error in an internet survey of a sample drawn from a pool of

6. For a full discussion of response rate calculation for internet surveys, see DiSogra and Callegaro (2008).

7. Such an outcome is consistent with even the better general population internet surveys found in the literature. For example, Berrens et al. (2004) used a sample from the general population of the United States that was drawn from a larger, RDD pre-recruited pool of respondents; the “multistage response rate” was 24.1%. Care should be exercised in interpreting reported response rates. For example, Olsen (2009) reported a response rate of 63.6%. On its face, such a figure would dampen concerns about nonresponse bias. However, this is a response rate for only the last stage of the research process, where the numerator is the total number of returned surveys and the denominator is the size of the sample drawn from a pre-recruited pool. Attrition at stages before selection of the final sample is not accounted for in the 63.6% figure.

respondents recruited in advance by Knowledge Networks (KN). KN recruited its pool of potential respondents using state-of-the-art RDD procedures. Potential coverage problems were addressed by making WebTV available to respondents. Respondents could then use their television sets to complete their internet surveys. New recruits were surveyed to establish sociodemographic and other characteristics. At the time, KN had about 100,000 U.S. residents in its pool of potential survey respondents. KN drew samples from this pool to match the U.S. population in terms of sociodemographic and other characteristics. After the survey was completed, KN provided weights to make statistical analyses more representative.

Lee (2006) reports an overall response rate of 5.5%. She focused on four variables: computer ownership, prior web experience, employment, and household size. Each variable was evaluated for the overall sample and subsamples broken down by age, education, ethnicity, region of the country, and gender. Lee (2006) based her conclusions on comparisons with U.S. Census Bureau (Census) statistics. Errors relating to nonresponse on part of the final sample disappeared when controls for demographic differences between the respondents and the full sample were introduced. "However, coverage properties of the full survey sample show some problems, and traditional post-survey adjustments were limited in alleviating the unequal coverage of the survey sample. The coverage problem was more evident for the subpopulation-level estimates" (Lee, 2006, p. 460).

Of course, there are no perfect surveys. From our perspective, what matters is whether the sorts of issues identified by Lee (2006) are sufficient to seriously bias SP estimates of WTP. Hence, nonmarket studies that have addressed the issue are of particular interest. Berrens et al. (2003) compared telephone and internet survey results.[8] Two internet sampling approaches used by two leading internet survey firms were considered. Harris Interactive recruits pools of potential respondents using invitations extended through advertisements, telephone surveys conducted for other purposes, product registrations, and other means. At the time of the Berrens et al. (2003) study, Harris Interactive had a pool of about 7 million American adults who had volunteered. Volunteers in the pool had to have an internet connection; at the time, only about half the U.S. population fulfilled this criterion. Berrens et al. (2003) estimated their overall response rate from their sample at roughly 5%. Hence, both coverage and potential nonresponse bias are possibilities. Harris International addressed these potential issues by providing "propensity weights" for use in statistical analyses. Berrens et al. (2003) pointed out that Harris International has had excellent success in predicting election results using this approach.

8. Berrens et al. (2004) use data from the same surveys, but focus more on the role of information in SP studies. They do not explicitly consider whether coverage and non-representativeness are problems in that paper.

The other internet sample is from KN. The overall response rate for Berrens et al. (2003) is 24.1%. The standard for comparison is a survey administered entirely by telephone to an RDD sample with an overall response rate of 45.6%.

Berrens et al. (2003) did not find reasons to be concerned about the representativeness of either the Harris International or KN samples. They conclude (p. 2), “with appropriate weighting, samples from these [internet] panels are sufficiently representative of the U.S. population to be reasonable alternatives in many applications to samples gathered through RDD telephone surveys.”

Marta-Pedroso et al. (2007) compared performance of in-person and internet surveys in Portugal. Their in-person interviews were conducted on beaches at a time when many Portuguese vacation there. They achieved a response rate of 84%. For their internet sample, they sent out email invitations to a nonrandom sample of subscribers to Portugal’s leading internet service provider. The overall response rate was 5.1%. The internet sample tended to be younger and better educated than the in-person sample and to have higher incomes. Nevertheless, WTP to protect an agricultural landscape to benefit birds was lower for the internet respondents. Matra-Pedroso et al. (2007) take this to be a virtue, since it is more conservative. They conclude that the internet approach is promising for CV studies and deserves further research.

Fleming and Bowden (2009) compared the performance of travel cost surveys administered by mail and the internet. Mail surveys with mail-back envelopes were distributed to visitors to the recreation site. The mail response rate was 31.6%. Internet respondents were recruited through invitations posted on several websites. Their internet response rate was estimated to be 33%, which is based on the number of completed surveys divided by the number of times the invitations were opened.[9] Fleming and Bowden (2009) conclude (p. 88), “We find that the web-based survey yields a sample not significantly different than the mail survey in terms of gender, age, income, education and country of residence of respondents, and at a substantially lower cost.” Estimates of consumer surplus per visit based on the two datasets were quite close.

Olsen (2009) used stated-choice questions to evaluate landscape effects of highway location. Mail and internet administration are compared. In Denmark, where this study was done, internet coverage is not so large an issue as in other countries. Fully 90% of the Danish population has access to the internet, either at home or at work, and 74% report using the internet at least once a week. Olsen’s internet sample came from a pre-recruited pool assembled by a Danish survey firm. Olsen reported an internet response rate of 63.6%. This is the number of completed surveys

9. Fleming and Bowden (2009) argue that this underestimates the response rate since some people may have opened the website more than once before completing the survey. On the other hand, they also admit that it is impossible to estimate how many people viewed the invitation and had visited the recreation site, but decided not to open the invitation.

divided by the sample size, so the response rate would have been lower had attrition through the entire recruitment process been accounted for.

In the Olsen study, the mailed survey was targeted to a sample drawn at random from names and addresses in the Danish Civil Registration System. The mail response rate was 60.3%. The results from the two samples were compared based on response rates, protest responses, demographics, WTP, estimation precision, and certainty of choice. Some differences were observed, but they did not translate into a difference in estimated WTP. Olsen (2009, p. 607) concluded that while some mode effects[10] may persist, "Considering the advantages as well as the continuing increase in internet access in the general population, internet sampling appears to be a valid replacement of the traditional mail sampling approach in SP surveys considering valuation of nonmarket goods."

In a groundbreaking study, Cameron and DeShazo (2009) addressed this issue for a stated choice study that focused on the value of health outcomes. Their survey was administered to a U.S. sample by KN. As noted above, KN addresses the coverage issue by offering free internet access and WebTV to potential respondents who do not have internet access. As was also noted, KN samples are drawn to match the U.S. population in terms of demographics from the Census and other characteristics. Also, weights are provided to facilitate statistical analyses, which hopefully lead to final results that are representative of the U.S. population. In an appendix to their paper, Cameron and DeShazo (2009) ask whether these procedures succeeded in overcoming the coverage and response rate problems.

Studying nonrespondents is difficult because, by definition, there are no survey responses from them. To overcome this hurdle, Cameron and DeShazo (2009) assembled a dataset from the Census tracts where nonrespondents lived. They compared Census tract characteristics of the more than half a million people in the original RDD sample with characteristics of the 1,801 people who completed their survey and met certain criteria for inclusion in the final dataset. Though it was not a perfect match, the authors concluded that it was strong enough to generalize their results to the population.

We find results from the nonmarket valuation literature encouraging. Possible issues stemming from coverage and nonresponse errors do not appear to be as serious as some have feared, at least for high-quality internet surveys. Still, this literature is in its infancy and more research is obviously warranted. The present study is in this tradition. We compare results from two internet panels (described in Chapter 6 and Appendix H), recruited in different ways, to see whether coverage and response rate effects were present.

10. Olsen (2009) is not referring to coverage or nonresponse effects here, but to other ways in which mail and internet responses may differ.

1.3 Report Structure

This report presents the Team's efforts to use an SP survey to estimate the public's value for protecting or repairing Hawaiian coral reefs and to address some methodological issues discussed in Section 1.2. Chapter 2 defines the environmental "goods" to be valued in this study and explains the theoretical and methodological foundations of the Team's approach. Chapter 3 outlines the steps involved in the survey development process, which included focus groups, one-on-one interviews, design of the survey information, external review, Office of Management and Budget (OMB) clearance, pretesting, and finalizing the survey instrument. Chapter 4 presents the section-by-section wording of the coral reef valuation survey instrument, providing insights as to why the Team chose to present illustrations, questions, and other materials to respondents. Chapter 5 describes the survey implementation process, including sample design and selection and the data collection process. Chapter 6 compares the two internet panel samples to the 2008 General Social Survey (GSS) and the 2006–2008 American Community Survey (ACS) in order to identify any systematic differences in the two datasets. Chapter 7 presents the responses to the choice questions and describes the responses to other key questions in the survey, including scenario acceptance and validity questions. Chapter 8 identifies the WTP estimate for the value of protecting or repairing coral reefs in the MHI.

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