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A COST-BENEFIT ANALYSIS OF PRESERVING THE GREAT BARRIER REEF

By
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A thesis submitted to the faculty of The University of Mississippi in partial fulfillment of the requirements of the Sally McDonnell Barksdale Honors College.

Oxford, MS

May 2023

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Abstract:

This paper investigates both the economic benefits and costs of protecting Australia's Great Barrier Reef (GBR). The benefits associated with the Reef come from a 2016 Deloitte Touche Tohmatsu Limited report and quantifies direct economic contributions, nonuse values, and a social, economic, and icon value. The costs of protecting the Reef come from a collection of sources, including the Reef 2050 Long-Term Sustainability Plan, "The Cost and Feasibility of Marine Coastal Restoration", and a number of annual reports from governmental and non-governmental organizations. By analyzing these documents, the net benefits were calculated. The Great Barrier Reef contributes \$6.4 billion to the Australian economy annually, supports 64,000 jobs, and has a total social, economic, and icon value of \$56 billion. While there are large monetary benefits associated with the Reef, average costs associated with ensuring the Reef's survival add up to \$264 million annually, and restoration costs of \$45,621 for each hectare of reef restored. Of the direct contribution benefits and direct costs, there are net benefits of approximately \$6.1 billion each year. However, when looking at the net benefits of restoring the Reef, only 7% of the Reef could be restored while remaining economically efficient. Although the true benefits provided by the Reef are underestimated, and the costs are likely overestimated, the finding of this paper is that the Great Barrier Reef can and should be protected from further damage.

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1. Introduction:

The Great Barrier Reef (GBR), located off the coast of Queensland, Australia, is one of the world's most treasured natural landscapes. Holding a place among the likes of the Grand Canyon and Mt. Everest, the Great Barrier Reef is one of the Seven Natural Wonders and is a prized UNESCO World Heritage Site. In addition to supporting a breathtaking array of life, it provides economic support and cultural significance to the country and continent of Australia. The Reef supplies thousands of jobs and provides billions of dollars to economies connected to the Reef. However, despite the Reef's ecological, economic, and cultural importance, it is threatened with extinction.

In spite of billions of dollars invested by the Queensland government since 2015, the Reef and its aquatic life are dying. Several mass bleaching events have resulted from overheated waters caused by climate change, weakening the corals and their survival ability. In addition to bleaching events, the impacts of land-based run-off, coastal development, and illegal fishing have led to poor water quality and a decline in marine life and habitat. All of these factors have contributed to a nearly 50% decline in all corals in the Great Barrier Reef (Cameron). While a fundamental scientific question is whether the Great Barrier Reef is capable of being salvaged, an equally important economic question is whether it should be; that is, whether the ecological, economic, and other critical benefits associated with protecting the Reef are greater than the costs of doing so. Some studies have attempted to value the benefits of coral reefs generally, and a few have studied the Great Barrier Reef in particular, but no study exists that compares the benefits of the Reef to the costs of slowing its decline and possibly improving the quality of its health and the marine life it sustains. This paper draws on published information and valid,

mainstream economic methodologies to estimate the net benefits of saving the Great Barrier Reef.

The organization of this paper begins with a short methodology and literature review followed by a detailed explanation of the types of benefits provided by the Great Barrier Reef. There is then a section detailing the costs of preserving the Great Barrier Reef. The role of the Commonwealth and the Queensland Government, and their associated costs (qualitative or quantitative), is provided. There are other promising efforts on the part of concerned nonprofits, independent scientific agencies, and others to postpone the Reef's premature demise. These are also described and quantified. To the extent possible, the benefits are then compared to the costs. Even if the net benefits assessment suggests that the Reef should be saved, it is highly uncertain whether it can be. The sources of these uncertainties are then discussed, along with suggestions for future research. The paper closes with a conclusion and an appendix providing more detail on market theory.

2. Methodology

The Great Barrier Reef's existence is currently threatened, and many scientists project its disappearance by 2050 due to the impacts of climate change. The Great Barrier Reef is an integral part of Australia's national identity, ecosystems, and economy, and government and nongovernment entities alike have spent billions of dollars trying to ensure its survival.

While many studies seek to answer the question of whether the Great Barrier Reef can be saved, the primary aim of this paper is to determine if it is worthwhile to try and do so. By conducting a cost-benefit analysis, the current and future actions aimed at protecting the Reef will be analyzed to determine whether they are economically justified, or simply whether the benefits outweigh the costs. Employing quantitative and qualitative methods will allow for the calculation of both annual and total values associated with the benefits and costs of protecting the Great Barrier Reef. Through this analysis, this paper finds that protecting the Great Barrier Reef is both economically justified and has the potential for more to be done.

3. Literature Review

There are a number of ways to calculate values associated with natural environments. The methodology of this paper comes from data collected from a variety of published reports and papers.

The primary report used in this paper to establish the benefits provided by the Great Barrier Reef was published by Deloitte Touche Tohmatsu Limited, an international professional services network, which primarily deals with accounting services, headquartered in London, England. At the request of the Australian government, the report identifies market contribution values, social and icon values, and brand values associated with the Great Barrier Reef. It also analyzes economic contributions from tourism and recreation, fishing and aquaculture, and research. For each category, Deloitte divided the economic contribution into direct or indirect amounts, which they then totaled. Additionally, full-time employment (FTE) was also noted within each subsection and finally totaled at the end.

In addition to the Deloitte report, various other sources were used to support the paper's findings and provide further estimates of the benefits associated with the Great Barrier Reef. Two papers by Rolfe and Windle from 2012 add to the understanding of nonuse evaluations of the Reef.

While all of these estimates create a number of different valuations of benefits provided by the Reef, it is important to note that these are underestimates. In total, it is not feasible to analyze every benefit provided by the Reef, nor is it possible to include every tourist in surveys to calculate consumer surplus and willingness to pay.

On the other side of the cost-benefit equation, the paper breaks down the costs of protecting the Great Barrier Reef into four categories: costs incurred by the Australian Government, costs incurred by the Queensland Government, expenditures on the Reef by nongovernment organizations (NGOs), and restoration costs. These costs are derived from numerous sources and documents. However, the source referenced most often is the Reef 2050 Long-Term Sustainability Plan, which was most recently updated in 2021. The Reef 2050 Long-Term Sustainability Plan includes a breakdown of expenditures made by both the Australian and Queensland governments from 2014-2024.

Additionally, organizational and governmental finance reports are heavily utilized to develop the cost estimates of protecting and restoring the Great Barrier Reef. Governmental reports, such as the Great Barrier Reef Marine Park Authority Annual Reports, were used to verify spending on the Reef 2050 Plan. Annual reports also provided fundraising and expenditures on the Reef by nongovernmental organizations.

Estimates from the above sources were compiled to conduct a comprehensive cost-benefit analysis of continuing protection of the Great Barrier Reef. While some estimates figure more prominently in to the paper than others, each was beneficial in the creation of this paper and is in the final analysis.

4. Benefits

a. Direct Economic Contribution Values

There are several methodologies for evaluating reefs and other ecosystems. Some studies may only assign value to the direct use of an ecosystem, such as evaluating the impacts of tourism. Other studies calculate values from surveys asking how much a respondent would be willing to pay to visit or protect a specific ecosystem. As stated in the introduction, this paper will look at a number of different valuation methods for estimating the contributions of the Great Barrier Reef to the economy and human well-being.

The ecosystem services that will be analyzed are direct and indirect market use values. These use-values are a direct contribution to the economy. For this study, the analysis of use values is taken primarily from the Deloitte report.

Overall, the Great Barrier Reef contributes \$6.4 billion to the Australian economy annually and provides over 64,000 jobs to community members (Simes et al.). These figures come from looking at the value added to the economy in the industries of tourism and recreation industries, fishing and aquaculture, and research in relation to the Great Barrier Reef. In the following sections, the benefits of each industry stemming from the Reef will be broken down and explained.

i. Tourism and Recreation:

The Great Barrier Reef plays a significant role in Australia's economy. As the largest reef in the world, its vastness extends along the northeastern side of the continent, becoming part of many local economies. As a UNESCO World Heritage Site and one of the Seven Wonders of the World, the Great Barrier Reef draws in tourists from across the globe. Over two million people

travel yearly to see the Reef itself (“Facts About the Great Barrier Reef”), a number additional to those who travel to Australia for other purposes but end up seeing the Reef as a supplementary part of their trip. Because of the general nature of travelers, the values associated with tourism and recreation can be combined easily. In this paper, they will be summed together to create one comprehensive value, which is the Great Barrier Reef’s largest market contribution to the Australian Economy.

Due to the COVID-19 pandemic, the nature of the global economy and travel policies have varied greatly over the last two and a half years. Because of this, the annual contributions have varied as lockdowns have limited international and domestic travel. The first paper drawn upon to articulate values for tourism and recreation comes from Deloitte, which analyzes the market transactions associated with the Reef for the 2015-16 fiscal year. This data was obtained from the Australia Trade and Investment Commission in their National Visitor Survey and International Visitor Survey (Simes et al.).

From this data, Deloitte was able to compute an annual contribution of \$5.7 billion in the tourism industry for the 2015-16 fiscal year. They looked specifically at travelers' origins, the trip's length, and average spending per day. Because there are several different locations from which to see the Reef, each attracting different types of visitors, the focus of the retrieved data were the areas within the Great Barrier Marine Park (GBRMP), which covers approximately 99% of the entire reef. The GBRMP consists of the Wet Tropics, Burnett Mary, Burdekin, Fitzroy, Mackay Whitsunday, and Cape York. The Wet Tropics include the most popular town for tourists to see the Reef, Cairns. The Wet tropics had the greatest value-added, at \$2.42 billion. Additionally, this area and the Burnett Mary (Bundaberg, Fraser Island, and surrounding areas), which

contributed \$1.05 billion, hosted more than half of the total nights spent when looking at all of the regions combined (Simes et al.).

When looking at the breakdown of the \$5.7 billion figure, the report highlights the different classifications of visitors that came to the Reef in terms of spending. The distance traveled to see the Reef can impact expenditure, so it was important to analyze how this affected GBR's overall contribution to the economy. International travelers in the previously listed regions spent an average of \$98.5 per day, while domestic day and overnight travelers spent averages of \$127.16 and \$185.67 daily. These figures come from averaging the given expenditures from the report.

In addition to tourism values, recreation also contributes to the total worth of the Great Barrier Reef to the Australian economy. Recreation values related to the GBR are understood as the expenditure on recreational activities, such as snorkeling, diving, sailing, boating, fishing, and others. The total expenditure can be broken down into categories of spending on equipment or personal expenses, with equipment expenses amounting to more than half of total recreation expenditure.

Considering the broad range of activities that contribute to recreational values, it may be beneficial to look at the actual costs of different activities. Due to the zoning ordinances and park rules, visitors are required to pay an entrance fee of \$3.50 for part-day visitors and \$7.00 for full-day visitors ("What are the Charges"). Prices can then increase dramatically depending on whether visitors pay for boat tours, dive expeditions, or other reef-related activities. These expenses can range anywhere from around \$115 to a couple of hundred dollars, depending on the type of excursion (Cameron). For example, what is considered a "low budget" basic Great Barrier Reef Tour is \$115, with upgrades that range from \$5-\$65 per person (Cameron). Some of

these excursions include equipment, but others require additional costs of purchasing or renting the necessary supplies.

In the Deloitte study, it was found that Burnett Mary had the highest recreational value with \$107 million (Simes et al.). Burdekin closely followed this at \$106 million (Simes et al.). In total, recreational expenditures were around \$415 million and contributed \$346 million to the AU economy (Simes et al.). Combining this with the precalculated values of tourism equals over \$6 billion in spending annually. Nearly 90% of the direct value added to the Australian economy by the GBR comes from tourism. In 2015-16, tourism for the entire continent of Australia had a direct contribution of \$53 billion, meaning the Great Barrier Reef was responsible for over 11% of the contributions made to the tourism industry (State of the Industry 2017).

While the market value is calculated based on what tourists and recreational users actually paid, a comprehensive benefits assessment must also consider what users of the GBR would have been willing to pay. The difference between users' willingness to pay and what they actually paid is called consumer surplus (CS) or the additional benefit accruing to consumers above the price paid (see Appendix for more detail). The Deloitte report calculated CS for domestic tourists at around \$662 per person per trip to the GBR and a CS of \$43 for recreational activities (Simes et al.). This was derived by surveying 268 travelers and analyzing their travel costs to see the Reef, which includes flights, accommodations, and equipment. The drawback of this method is that it is based on survey results, which can sometimes be unreliable, and it also excludes international travelers (who pay the most to see the Reef). However, in total, there is a consumer surplus of around \$1.5 billion in direct benefits associated with domestic tourists to the GBR and \$170 million for recreational direct benefits annually.

ii. *Fishing and Aquaculture*

Although tourism makes up the majority of direct value added to the economy by the Great Barrier Reef, commercial fishing and aquaculture also help contribute to the overall direct market value as well. The GBR is one of the most biodiverse ecosystems in the world, making it a unique place for these industries to thrive.

Similar to the tourism and recreation analysis, this paper will look at studies done by Deloitte to evaluate the total market value added by the fishing and aquaculture industries. The Deloitte study utilizes the same six regions as before, but instead of looking at visitor nights and expenditure to calculate value-added, it uses a gross value of production to arrive at its final figures. Additionally, just like tourism and recreation, this section adds together direct and indirect values to come up with a combined total.

In total, these two industries add an estimated value of \$162 million to the Australian economy (Simes et al.). The Wet Tropics contribute the most overall at \$52 million, and Burdekin contributes the next highest amount at \$38 million (Simes et al.). One important thing to note is that the total economic contribution here is vastly understated due to the fact that aquaculture data in Cape York, Fitzroy, and Mackay Whitsunday were unavailable due to undisclosed confidentiality reasons.

Commercial fishing and aquaculture can be broken down and analyzed as sub-groups. The first sub-group is the most popular form of commercial fishing in the Great Barrier Reef region, and is denoted as "line, net, pot, and trawl" in the study. This particular type of fishing contributes around \$95 million (Simes et al.). The next type, harvest, was only utilized in Cape York and Fitzroy and accounted for \$9 million. Lastly, aquaculture accounted for \$95 million as well

(Simes et al.). Due to confidentiality issues in obtaining information from the other areas, these values are only from the Burdekin, Burnett Mary, and Wet Tropics regions and are therefore underestimated.

More than 120 different fish species are captured in commercial fishing practices in the GBR, but the most targeted species are coral trout, red throat emperor, red emperor, tropical snapper, and Spanish mackerel (“Line Fishing in the Great Barrier Reef”). Coral trout are the most commonly caught fish in the commercial industry, with just over 40% of total catches per year (“Line Fishing in the Great Barrier Reef”). Much of the fish harvested becomes part of the Australian seafood industry and is eaten by consumers. Other fish harvested are used in aquariums.

Overall, the fishing and aquaculture industry is important to the Australian economy and it is also an indicator of reef health. In total, these industries added about \$162 million to the Australian economy annually. This industry supplies nearly 1,000 full-time jobs to the Queensland area and helps feed the country. Concerns over reef degradation have led to concerns over the stability of fish populations throughout the Reef. One study analyzed the impact of coral bleaching on fish populations, finding that coral is important for structuring these ecosystems, and its disappearance can lead to fish population declines (Richardson et al.). Other studies, such as one done in Papua New Guinea, have found that fish populations in their marine reserves have had a 75% decline in reef species abundance and around half of all fish species declined 50%, even in marine reserve areas (Jones et al.).

A continued decline in reef health may undercut the monetary contributions of the fishing and aquaculture industries. These two activities provide jobs and services for communities that rely

on them. They also directly support the local and nationwide economies, meaning a decrease in the output of these services will have a negative economic impact.

iii. Research

Coral reefs are some of the most beautiful and biodiverse ecosystems on the planet. Beyond the beauty of these reefs is the ability to study them to learn more about aquatic life. Coral reefs have also contributed to medical breakthroughs in our own societies. Research on coral reefs has led to several medical advances, including the creation of life-saving medicines that deal with HIV, Alzheimer's, and cancer (Clarke). Because the Great Barrier Reef is the largest and most well-established reef in the world, it brings in more researchers than any other reef, contributing to local and national economies.

While the GBR is considered one of the "best-studied tropical marine ecosystems in the world," information about the research is often unavailable. The Deloitte report looked at five organizations that have conducted extensive research on the Reef and analyzed the revenue generated from their research. These organizations include the Great Barrier Reef Foundation, Australian Institute of Marine Science (AIMS), Great Barrier Reef Marine Park Authority, JCU ARC Centre of Excellence, and Lizard Island Reef Research Foundation. These five organizations' scientific research and reef management contributed \$182 million to the Australian economy in the 2015-16 year. This figure can be divided between direct and indirect contributions, at \$62 million and \$120 million, respectively. This data comes directly from the organizations and their websites. Additionally, research relating to the Great Barrier Reef supplies researchers with over 900 full-time employment opportunities.

b. Nonuse Values

In addition to the use values obtained from the Great Barrier Reef, there are also ways in which the Reef can provide benefits without direct or indirect usage. Examples include bequest, option, and existence values.

Nonuse values are much harder to estimate and are generally undervalued due to their subjective nature. This paper will use the Deloitte study and another paper written by John Rolfe and Jill Windle (2012) to create a comprehensive view of how the Great Barrier Reef's nonuse values can be calculated. Even though these values are not added to the annual contribution of \$6.4 billion, they are considered valid economic benefits in environmental economic theory and should be considered.

i. *Existence, Option, and Bequest Value*

Existence values differ from the previous values discussed. Unlike the earlier values, existence values are not derived from actual interaction with or use of the Great Barrier Reef. Instead, an existence value is simply the value people place on something by knowing it is there and it exists. In addition, an option value is a value a person places on preserving something, even if the person is unlikely to ever use what they are preserving themselves. Lastly, bequest values are the values placed on a future generation's ability to use something.

This paper will utilize the Deloitte study results to estimate existence values. In this study, a contingent value survey was administered to a sample of both Australians and international persons, where they were each asked about their willingness to pay (WTP) for preserving the Great Barrier Reef. When looking at the answers to the questions asked in the study, the results create a combined existence, option, and bequest value. The respondents' WTP was derived by

asking whether they supported a weekly charge denoted as the "Great Barrier Reef Future Health Charge" to pay over the following ten years.

The study's results concluded that 58% of Australians were willing to pay for the preservation of the GBR (Simes et al.). Of the respondents who indicated a WTP, the average amount was \$1.30/week or \$67.60/annually (Simes et al.). If this value was extrapolated across the entire Australian population, it would total \$1.2 billion annually. The Northern Territory region had the largest WTP at \$1.90, while the Western Australia region had the lowest amount at \$0.80.

In comparison, international respondents from ten countries were also surveyed regarding their WTP. Of all the responses collected, 73% indicated that they were willing to pay for the preservation of the GBR, and the average WTP was \$1.98/week (Simes et al.). Due to the small sample size of only 555 international respondents, extrapolating this data across all populations globally was deemed too unreliable to be representative (Simes et al.). However, the study does indicate that if a WTP was calculated for the United States, United Kingdom, France, Germany, and Canada, the total would be \$5 billion in purchasing power parities (PPP) (Simes et al.). PPP is the currency conversion rate that equalizes the purchasing power of different currencies. This figure is derived from the proportion of each country's employed population over the age of 15 in middle-income percentiles.

The study also asked respondents to choose why they were willing to pay for the preservation of the Great Barrier Reef. When combining the responses for domestic and international surveys, 61% said they were willing to pay to protect because the GBR is important to the planet (Simes et al.). This was the most commonly given reason for protection, while the importance of the GBR for the region's economy was the least chosen reason.

In addition to this first study, John Rolfe and Jill Windle published a study that calculated an aggregated WTP for a 1% improvement in the Great Barrier Reef's condition. This study gathered data from individuals across Townsville, Brisbane, Sydney, Melbourne, Adelaide, and Perth through a survey to understand values for environmental protection. Their research found that the average WTP for Australian households was \$21.68 per annum for 5 years (Rolfe and Windle).

In the Rolfe and Windle study, results for WTP varied by location and demographics. For example, Townsville had the highest WTP at \$37.93. Perth had the lowest at \$18.10. The study found that the WTP was influenced by a number of factors, among them were those who planned to visit the Reef in the future, those who lived closer to the Reef, and those with higher incomes and educations all were willing to pay more for the Reef.

In both of these studies, the value that people placed on the Great Barrier Reef was analyzed and quantified. Even though these studies were looking at values based on different premises (weekly willingness to pay for future reef preservation vs. what individuals were willing to pay for a 1% increase in the quality of the Great Barrier Reef), they were able to establish a non-use value that has the potential to be extrapolated across larger populations. It is likely that these values are actually understated, and it is important to note that there is no accepted calculated value for non-Australians.

c. Economic, Social, and Icon Value

After considering the use and nonuse values, as well as other factors such as brand value and traditional owner value, the Great Barrier Reef was valued at a total of \$56 billion. Although this value comes directly from the Deloitte report and does not include other studies' evaluations of

the Reef, and the conditions of the Reef have changed greatly since the publishing of this report, it is the most comprehensive valuation of the Reef available.

The \$56 billion figure comes from applying a 33-year net present value (NPV) and applying a social discount rate of 3.7% across nonuse values, direct-use values, and indirect-use values. The actual breakdown consists of \$29 billion in value from Australians who have visited the Reef, \$24 billion for Australians who have not yet visited the Reef but value its existence, and \$3 billion from Australia's recreational users (Simes et al.). It's important to note that international persons and travelers are not included when deriving the Great Barrier Reef's asset value, and while it would be difficult to extrapolate this data across different countries, it does demonstrate that even though this \$56 billion figure is large, it is an underestimate of its true value.

There are also other aspects of the Reef that are non-quantifiable. Ideas of traditional owner value and brand value emphasize the importance of the Great Barrier Reef to the identity and culture of individuals and the country itself. Traditional owner value emphasizes the value from indigenous perspectives and utilization, and while no studies have been able to come up with an actual figure, there have been numerous articles written about indigenous culture's commercial benefits, nonuse values, and even replacement value of subsistence production. These studies include ones such as: "Indigenous Management of Land and Sea and Traditional Activities in Cape York Peninsula" and "Hunter-gatherers Today: An Aboriginal Economy in North Australia."

In addition, the Great Barrier Reef is considered to be a part of the "brand" identity of Australia. Through domestic and international surveys by Deloitte, individuals expressed that the Great Barrier Reef is an iconic landmark that contributes to national identity and international standing

(Simes et al.). Just like traditional owner value, measuring brand value is difficult. However, one important thing to note from the administered surveys is that more respondents indicated they wouldn't visit a damaged Great Barrier Reef, indicating that the value individuals place on the Reef is closely associated with the health of the Reef. This demonstrates that in order to maintain the overarching value of the Reef, it needs to be protected and preserved.

5. Costs

While the Great Barrier Reef provides ample benefits, they are maximized when the Reef is in a healthy state. Unfortunately, at this point in time, that is not the case. As of 2022, the Great Barrier Reef had its sixth mass bleaching event (“Coral Bleaching Events”). Four of the six bleaching events have happened in the last six years. Since the 1990s, around 50% of corals within the Reef have been lost (“Great Barrier Reef has lost half of its corals since 1995”).

However, there is some good news. In 2022, researchers found hard coral cover had increased from 27% in the northern third and 26% in the central third to 33% and 36%, respectively (Jones and Pearce). Countries around the globe are committing more time, money, and research to reefs, leading to new developments and strategies, such as genetic engineering and selective breeding. These factors may help to make further strides in assisting reefs to recover.

As important as these small victories are, unless the main threats to the Great Barrier Reef are mitigated, the Reef may not survive. Issues such as agricultural runoff and sedimentation are major threats to the Reef, but the most pressing issue is climate change (“Threats”). The effects of climate change alter a reef’s ability to survive by increasing ocean temperatures, sea levels, and acidification. Rising ocean temperatures increase biological stress for the corals, leading to increased bleaching events and infectious diseases. Increased sea levels would further alter water temperatures and sunlight access for the Reef, while acidification slows coral growth rates.

The Australian government and other organizations have passed legislation and developed more strategies to help reverse the damage done to reefs and prevent further destruction. The Great Barrier Reef Marine Park Act 1975 and the Reef 2050 Long-Term Sustainability Plan are among two plans that have created comprehensive guidelines for necessary action to try and ensure the

Reef's survival. The local and national governments have pledged over \$4 billion since 2014 in the forms of water quality projects, reef management and conservation, and research and adaptation (Davis and Bathgate).

In the following section of the paper, the costs of different projects and plans will be analyzed and compared against the benefits provided to help determine the net benefits of reef preservation.

a. Costs to the Australian Government

The Australian government has taken on an active role in reef preservation and protection in the form of partnerships, legislation, research, and investments. One of the national government's most important bodies of work is the Reef 2050 Long-Term Sustainability Plan. The plan, which was created in 2015, builds off of prior legislation, such as the Great Barrier Reef Marine Park Act of 1975, and has been updated twice to keep current with spending, research, and reef conditions. This plan involves governments, traditional owners, industries, researchers, and community stakeholders working together to manage the Reef until 2050. The program is governed by the Queensland Government, the Commonwealth, and other groups such as the GBR Ministerial Forum, Standing Committee of Officials, Reef 2050 Executive Steering Committee, Reef 2050 Advisory Committee, and Independent Expert Panel (Department of Agriculture).

Because this plan's scope is far-reaching with a multitude of different goals and partners, a large amount of money has been spent since it started in the 2014-15 fiscal year. In the most recent Reef 2050 Long-Term Sustainability Plan published in 2021, the national government's current and future funding was broken up into categories of money supplied to reef programs, reef

science, the Great Barrier Reef Marine Park Authority, and the Maritime Safety Authority from 2014-2024. While not every program within these categories received funding every year, and some of the amounts have yet to be determined, the current estimated total spending is almost \$2.1 billion over a ten-year period (Department of Agriculture).

The first and largest source of spending is on reef programs, which include the Reef 2050, the Reef Trust, the Reef Program, and other reef funding. Within this category, the Reef Trust has been given the largest financing with around \$700 million (Department of Agriculture). More than half of this funding is from a 2017 investment of over \$485 million towards a Reef Trust Partnership with the Great Barrier Reef Foundation. Aspects of this funding focused on improving water quality, controlling the crown-of-thorns starfish population, and creating opportunities for traditional owners (Department of Agriculture). In total, the Australian government will have spent \$877 million on reef programs over the period of 2014-2024 (Department of Agriculture).

The next area of funding includes investments in reef science. The budget included actions such as giving money to the National Science Program, the Australian Institute of Marine Science, the Center of Excellence for Coral Reef Studies, and the Commonwealth Scientific and Industrial Research Organization (CSIRO). These investments aimed to identify new strategies in reef protection, such as coral IVF and genetic engineering, and inform future decision-making processes (Department of Agriculture). The Australian Institute of Marine Science received the greatest amount of funding at \$322.6 million, and the overall amount spent towards reef science research was \$465 (Department of Agriculture).

Another big source of spending was dedicated to the Marine Park Authority. One of the most important pieces of legislation implemented to protect the Reef was the Great Barrier Reef Marine Park Act of 1975. The legislation's goal was to provide a long-term plan for conserving the Reef and a framework for planning and managing it. The Act established a governing body to oversee the Reef's protection as well as the ability to enforce its rules through civil, criminal, and administrative actions. As a result of this initial legislation, the Great Barrier Reef Marine Park (GBRMP) was established. The GBRMP is an Australian National Park and a Marine Protected Area which span over 132,806 square miles. The park contains over 1,500 fish species, 5,000 mollusks species, and 10% of the world's total coral reefs (UNESCO World Heritage Center).

Due to the vastness of the park, the work necessary to monitor and maintain the Reef within the park involves significant costs. These costs vary year to year, depending on factors such as the total number of employees and grants awarded, but the most recent 2050 plan details the exact amount of funds given to the Authority from the Australian government at \$469 million (Department of Agriculture). In addition to the report's details on funds, annual financial statements of the GBRMP are publicly available from the 2018-19 year to the present. Over time the costs of the GBRMP have increased, with the most recently available annual report noting \$78,268 in expenses in 2019.

The final area of spending for the Australian government is the Maritime Safety Authority, which will have cost them around \$267 million by 2023-24 (Department of Agriculture). The Authority regulates all shipping activity in the region. Because the Great Barrier Reef is located in highly trafficked areas, the Authority helps minimize the damage done by ships. This

institution works closely with Maritime Safety Queensland, whose costs will also be discussed in the following section.

New governmental spending bills and plans also have altered the current and future spending on the Great Barrier Reef. In January 2022, the Reef 2050 Long-Term Sustainability Plan was allotted an additional investment of \$1 billion by the Australian government over the next nine years until 2029-30 (Davis and Bathgate). Of this \$1 billion, \$579.9 million is dedicated to water quality initiatives, and \$253 million is dedicated to the GBRPMA (Davis and Bathgate). Additionally, \$92.7 million was allocated to the Reef Trust for engineering more resilient reefs and an unspecified amount towards reef restoration and adaptation research (Davis and Bathgate). The final aspect of funding is for the traditional owner and community-led projects to strengthen partnerships and stewardship. Around \$74.4 million will be spent on this over the nine-year period (Davis and Bathgate).

Leading up to 2030, around \$3.1 billion will be spent on the Great Barrier Reef to support the Reef 2050 Long-Term Sustainability Plan. While the Reef is nowhere near a pristine state, the investment has helped better its overall condition. The steps taken by the government demonstrate its commitment to protecting one of the country's most important ecosystems and is a hopeful sign that the Reef will survive for generations to come.

All figures in AUD \$m	2014–15	2015–16	2016–17	2017–18	2018–19	2019–20	2020–21	2021–22	2022–23	2023–24	Total
Australian Government Reef Programs											
Reef 2050	-	-	2.090	9.432	8.671	8.729	7.876	7.984	9.700	TBD	54.482
Reef Trust	7.702	15.865	37.554	485.722	31.212	25.401	36.249	29.853	34.494	TBD	704.052
Reef Program	29.650	32.850	10.100	10.150	-	-	-	-	-	-	82.750
Other Reef funding	15.507	10.426	5.986	1.996				0.226	0.887	0.887	35.915
Subtotal	52.859	59.141	55.730	507.300	39.883	34.130	44.125	38.063	45.081	0.887	877.199
Australian Government Reef Science											
National Environment Science Program (Tropical Water Quality Hub)	2.200	5.630	5.400	5.400	5.400	5.400	2.550	-	-	-	31.980
National Environment Science Program - Phase 2 (Marine and Coastal Hub)	-	-	-	-	-	-	-	TBD	TBD	TBD	TBD
Australian Institute of Marine Science	15.100	15.100	15.100	29.100	39.200	38.500	42.500	45.600	46.100	46.300	332.600
Australian Research Council (Centre of Excellence for Coral Reef Studies)	6.437	6.409	6.304	6.778	6.956	8.210	5.910	3.684	2.557	0.926	54.171
CSIRO	3.922	5.627	5.621	9.709	8.886	7.149	5.736	-	-	-	46.65
Subtotal	27.659	32.766	32.425	50.987	60.442	59.259	56.696	49.284	48.657	47.226	465.401
Great Barrier Reef Marine Park Authority											
Joint Field Management Program (Australian Government funding)	8.372	8.372	9.961	14.859	11.965	12.740	16.576	19.428	18.990	19.059	140.322
Great Barrier Reef Marine Park Authority	18.773	19.845	22.411	24.830	41.256	42.833	56.683	36.066	33.751	33.047	329.495
Subtotal	27.145	28.217	32.372	39.689	53.221	55.573	73.259	55.494	52.741	52.106	469.817
Australian Maritime Safety Authority											
Subtotal	23.459	24.185	21.088	24.888	27.448	28.620	28.832	29.191	29.588	30.006	267.305
Australian Government total	131.122	144.309	141.615	622.864	180.994	177.582	202.912	172.032	176.067	130.225	2,079.722

Figure 1: Spending Breakdown of the Australian Government from Reef 2050 Plan (Department of Agriculture)

b. Costs to the Queensland Government

The Queensland government has passed its own legislation and dedicated funding to reef protection and preservation. Although the amount is much less than the investment from the Australian Government, only making up 23% of the total costs, it is still significant.

According to the Reef 2050 Long Term Sustainability Plan, funds can be broken down into three major categories: Queensland Government Reef Programs, Queensland Sustainable Fisheries programs, and Maritime Safety Queensland. The first mentioned category is the largest source of funding. It consists of the Reef Water Quality Program and the Joint Field Management Program. The Water Quality Program has cost a total of \$486 million from 2014-

2024, while the Field Management Program has cost around \$134 million (Department of Agriculture).

In addition to the Reef Programs, the Queensland Sustainable Fisheries Programs is a \$76 million expense. This program has set out to reform current management strategies into new sustainable management to ensure fishing is a low risk to Queensland's aquatic resources, optimizes benefits to the community, and contributes to the Reef's survival (Department of Agriculture) over a ten-year period from 2017-2027. The fisheries addressed in this plan sit adjacent to the Great Barrier Reef and have the ability to impact the Reef and its economic contribution through the seafood industry and recreational charter fishing. This plan sets out to protect the fisheries through sustainable maintenance, which helps produce healthy and resilient reefs.

Finally, Maritime Safety Queensland has contributed significantly to protecting the Great Barrier Reef. In the ten years of past and future spending, they will have spent \$275 million on the Reef through projects such as ship routes, port procedures, and oil spill risk assessments (Department of Agriculture). Maritime Safety works closely with other institutions, such as the Department of Transport and Main Roads, to ensure that the Reef is not threatened by boats' shipping routes and mining activities.

Together, each of these programs makes up the majority of the Queensland Government's funding for the protection and restoration of the Great Barrier Reef. The 2050 plan states that the Queensland Government contributed over \$972 million, bringing the combined total up to a little over \$3 billion before the new spending plan (Department of Agriculture). With the additional \$1 billion spending bill, the governments with have spent a little over \$4 billion combined by 2030.

While this \$4 billion figure may seem like a significant amount of spending, when considering that this is over a 15-year period, it doesn't come close to equaling the annual monetary benefits provided by the Reef.

All figures in AUD \$m	2014–15	2015–16	2016–17	2017–18	2018–19	2019–20	2020–21	2021–22	2022–23	2023–24	Total
Queensland Government Reef programs											
Queensland Government Reef Water Quality Program	35.000	33.425	47.145	43.374	68.916	58.214	63.456	36.776	50.000	50.000	486.306
Joint Field Management Program (Queensland Government funding)	8.372	8.372	8.766	8.779	13.279	12.709	16.468	19.227	19.227	19.227	134.426
Subtotal	43.372	41.797	55.911	52.153	82.195	70.923	79.924	56.003	19.227	19.227	620.732
Queensland Sustainable Fisheries programs											
Subtotal	-	7.001	2.674	6.439	7.697	9.541	8.500	14.311	13.175	7.500	76.838
Maritime Safety Queensland											
Subtotal	28.000	28.000	28.000	28.000	28.000	28.000	23.000	28.000	28.000	28.000	275.000
Queensland total	71.372	76.798	86.585	86.592	117.892	108.464	111.424	84.003	47.227	47.227	972.570
TOTAL	202.494	221.107	228.200	709.456	298.886	286.046	314.336	256.035	223.294	177.452	3,052.292
Cumulative total	202.494	423.601	651.801	1,361.257	1,660.143	1,946.189	2,260.525	2,516.560	2,739.854	3,052.292	

Figure 2: Spending Breakdown of Queensland Government from Reef 2050 Plan (Department of Agriculture)

c. Non-Government Organizations Expenditures

The Great Barrier Reef Marine Park Act of 1975 and the contributions made through the Reef 2050 Long-Term Sustainability Plan are not the only sources of protection plans and spending towards the Great Barrier Reef. Nonprofits, known as NGOs, are also spenders in terms of reef protection. There are dozens of local and internationally based nonprofits that work to protect and preserve the Reef. While a majority of these organizations receive funding from the government, they also raise funds on their own through merchandise sales and donations. Although there are many NGOs focused specifically on the Great Barrier Reef, a few will be discussed in particular. The NGOs analyzed for this paper were chosen due to their well-recognized status and the ability to collect accurate and up-to-date information, which is not possible for all organizations.

The first and one of the most well-known nonprofits is the Great Barrier Reef Foundation. This foundation has over 500 partners and raises funds for collaborative projects with these partners, which include things like the Raine Island Recovery Project, coral IVF, and live habitat mapping (“Projects”). One of the biggest aspects to note about this specific organization is its role in the Reef Trust Partnership, a \$443 million collaboration between the Australian Government's Reef Trust and the Great Barrier Reef Foundation. This is the largest global effort to help restore an ecosystem made by a government to date (“Reef Trust Partnership”). Even though a majority of the funding the Great Barrier Reef Foundation has received has been from the Australian government, it has raised over \$53.6 million, or 12% of its funding, since 2018 (Cox). In 2021 specifically, the foundation was able to raise \$3.84 million from donations, membership fees, and project funds (Thodey and Marsden).

In addition to the foundation, other nonprofits are working to protect the Reef. For example, Fight for Our Reef is a partnership between World Wildlife Fund (WWF) Australia and the Australian Marine Conservation Society focused directly on preserving the Great Barrier Reef. Their work includes helping to ban dumping in the Reef, stopping a \$1 billion loan for Adani (a coal mining company whose operations would have had a direct negative impacted the Reef), and improving water quality regulation (Hincks and Baglow). Although this organization has access to far less funding than the GBR Foundation, they have still played a major part. The organization's most recent annual report for 2021 states that it had a reported income of \$6.7 million (Hincks and Baglow). In that year, \$6.51 million was spent by the foundation on projects that would influence the Reef's survival.

The Lizard Island Reef Research Foundation is the smallest of the foundations that will be discussed regarding funding. While this nonprofit was used in the Deloitte Study to analyze the

economic contribution of research provided by the Great Barrier Reef, the organization has expenditures towards the Reef as well. The Lizard Island Research Foundation is a world leader in supplying on-reef facilities for coral reef research and education. In 2021, the foundation spent \$429,836.44, all of which was directed toward projects related to the Great Barrier Reef (McKay and Hayward).

Although many more NGOs focus on reef preservation, finding financial statements for each is unobtainable. While the overall financial contributions made by these three organizations may seem insignificant compared to the figures from the Australian and Queensland governments, the work accomplished by these organizations is important. Each has contributed in a way that has made significant steps in improving the Reef's quality and ensuring its survival. If given the opportunity and additional funding, NGOs would be able to create and implement projects meant to save the Reef.

d. [Restoration Costs](#)

In addition to analyzing the past and future costs of programs and strategies implemented to help preserve the Great Barrier Reef by governments and nonprofits, it is possible to calculate the costs associated with restoring damaged areas of the Great Barrier Reef. “The Cost and Feasibility of Marine Coastal Restoration” by Bayraktarov, et al. (2016) conducted an analysis of the cost of restoring five marine ecosystems, including coral reefs. That study reported a cost of \$41,854 per year to restore one hectare of coral reef in 2010 dollars (Bayraktarov et al.). In this study, restoration is “the process of assisting the recovery of an ecosystem that has been degraded, damaged or destroyed” (Bayraktarov et al.). Of the 71 studies of coral reef restoration

that were analyzed, only one was found that had been conducted in Australia's Great Barrier Reef.

Original research in cost-benefit analyses is quite expensive in terms of time and money. An alternative is the practice of value transfer – the use of an empirical value estimate from a previous study for application in a similar context (Boutwell and Vesta). In the following section reporting on the net benefits, the restoration cost estimate specific to the GBR is used along with the median cost calculated for all 71 studies, which was \$165,607 per hectare in 2010 US, or \$180,512 in 2010 AUD. It is not known why the case study for the GBR reports costs so much lower than the overall median value for reef restoration generally; possible reasons could include location, restoration technology, economics of the region (developed versus developing country, etc.), but the authors decided to include them for comparison. This estimate of \$41,854 restoration cost per hectare is most probably an overestimate due to the connectivity of reef marine life. For example, reef populations are linked by the exchange of eggs, juveniles, adults, and larval dispersal; also by the ecological linkages associated with adjacent and distant habitats. This connectivity helps maintain coastal resilience and lowers the costs of restoration.

6. Net Benefits

So far, this paper has looked at both the quantitative and qualitative benefits provided by the Great Barrier Reef, as well as the costs associated with protecting it. From this analysis, the following questions can be answered:

- (1) Can the Great Barrier Reef be saved?
- (2) If yes, should it be? In other words, do the benefits to those who value the GBR outweigh the costs of protection? The previous analysis suggests another question that is important to address:
- (3) If the net benefits are positive to preserve the GBR as a global treasure, are the investments being planned between now and 2030 by the Australian Government, the Government of Queensland, and NGOs sufficient to maintain and improve its health?

a. [Can the Great Barrier Reef be saved?](#)

In November 2019, UNESCO published a report on the state of the Great Barrier Reef, stating that: “the long-term outlook for the ecosystem...has deteriorated from poor to very poor and that climate change remains the most serious threat...” Further, “other key threats are land-based runoff, coastal development and some direct human uses (and) accelerated action to mitigate climate change and improve water quality was essential to turn this outlook around” (“Great Barrier Reef”). As a result of its findings, UNESCO recommended that the Great Barrier Reef be placed on its “In Danger” list. However, the Australian government was able to delay this designation by agreeing to submit a report to the World Heritage Committee on its plan of action.

New strategies have appeared with the money and research granted by governments and organizations for the preservation of the Reef. Interventions and innovations such as assisted natural adaptation and enhanced coral breeding help ensure that the coral with selective traits,

such as increased temperature and stress level tolerances, reproduce to give new corals the best chance of surviving. Biocontrol of top coral predators, such as the Crown-of-thorns starfish, improves recovery environments after climate change-induced bleaching events. Other forms of intervention, such as stabilization, cooling, and shading, reduce the impacts of ocean acidification and warming waters on sections of the Reef.

In some areas, the Reef is seeing vital improvements. In an article released in September of 2022, it was noted that some sections of the Reef are seeing the "most extensive coral cover in 36 years" (Jones and Peirce). However, only two months later, ocean temperatures broke a record set in 1985, raising concern over another potential mass bleaching event. These events demonstrate that while some of the actions and strategies undertaken have proved to have positive results, the biggest threat remains global climate change, a threat to the GBR that Australia has little control over. As long as climate change remains a problem, the Reef will be at risk of further mass bleaching events. Understanding that Australia cannot solve this issue alone, the state of the Reef depends on the action of other nations all across the globe, making the Reef's survival that much more uncertain.

b. [Do the Benefits of Restoration Outweigh the Costs?](#)

This paper uses two different approaches to calculating the net benefits of protection/restoring the GBR (i.e., the benefits minus the costs). The first method compares the annual direct market contributions to the average annual spending on reef preservation. The average annual spending does not reflect the true cost of protecting or restoring the GBR directly (for example, the cost of transplanting corals); however, it can be assumed that government and NGO expenditures are protective in nature. The second method utilizes the social, economic, and icon value and the restoration cost values transferred from the "The Cost and Feasibility of Marine Coastal

Restoration” study. In this method, the restoration costs will be subtracted from the social, economic, and icon value to define the total amount of hectares that can be efficiently restored.

As previously mentioned, the annual economic contribution to the Australian economy is \$6.4 billion from tourism, recreation, fishing, aquaculture, and research expenditures. When considering the total money spent from 2014 – 2030 by the Australian and Queensland governments was \$4.1 billion, and adding to that the total average expenditures of the nongovernmental organizations from 2018 – 2021, the average costs of protection through 2030 are approximately \$264 million a year. This leaves a net benefit of approximately \$6.1 billion annually. One thing to note, however, is that this calculation assumes a constant NGO budget through 2030 and adds to the \$4.1 billion averaged over the years 2014 – 2030.

The second approach is more problematic, as the value for the cost of restoration is taken from one study specific to the Great Barrier Reef. There are many reasons why a value transfer might not be appropriate; however, it is the only estimate of restoration costs for the Reef found in the literature. As a result, it was found necessary to use this value in order to calculate the costs necessary to perform a cost-benefit analysis.

The social, economic, and icon benefits of the Great Barrier Reef, as estimated by the Deloitte study, is \$56 billion. As long as the costs are less than \$56 billion, the net benefits of restoration are positive, and the Reef should be rebuilt. At a per hectare cost of \$45,621 AUD (\$41,854 2010 US converted into 2010 AUD), around 1,227,000 hectares of coral reef can be restored for \$56 billion. The GBR is measured at 34,706,000 total hectares, and 50% of this area, or 17,353,000 hectares, is thought to be degraded. If this is the case, approximately 7% of the

degraded area (17.35 million hectares divided by 1.227 million hectares) can be restored before the net benefits are zero.

Both methodologies of calculating net benefits lead to the conclusion that there are net benefits associated with protecting and restoring the Great Barrier Reef.

c. [Is the Investment in Restoration planned by the Australian and Queensland Governments enough?](#)

Experts fear that by 2050, the Reef may no longer exist. As one of the natural treasures of Australia and the rest of the world, many organizations and individuals have a stake in its survival. On average, the Reef contributes around \$6.4 billion to the Australian economy each year. It also provides around 64,000 full-time jobs for individuals annually. While the dollar value of the Reef's contributions to the economy has been estimated, its actual value is much larger. Non-use values such as existence, option, and bequest values remain largely uncalculated or underestimated, and other benefits such as coastline protection, biodiversity, and aesthetics have not been quantified. Even with the billions of dollars committed to reef protection and preservation by the Australian and Queensland governments, its survival is uncertain. While much of the money has been spent on projects that deal with major threats to the Reef, such as water quality and the crown-of-thorns starfish, the primary source of degradation, climate change, remains unaddressed. Due to the global nature of climate change, new policies and actions undertaken by Australia alone will not be enough. Instead, it will take countries all across the globe to mitigate the threat of climate change on the Great Barrier Reef. Until this issue is dealt with, the survival of the Reef will remain uncertain.

7. Conclusion

The Great Barrier Reef remains one of the world's most important ecosystems. This paper has demonstrated that the Great Barrier Reef's importance extends beyond the size of the Reef and the millions of organisms it provides for. Instead, by creating a cost-benefit analysis, this paper has shown that the Great Barrier Reef is vital to economies, both locally and globally, that individuals find value in its mere existence, and that its social and cultural significance has made it a part of Australia's national identity.

As it currently stands, the quantifiable benefits provided by the Great Barrier Reef far outweigh the costs associated with preserving it. More can and should be done to ensure its survival. The country of Australia, as well as countries around the world, have an obligation to pay forward the benefits they receive from the Reef by taking actions to mitigate climate change or fund projects that will sustain the Reef until climate change is dealt with. Until more is done, the total benefits will remain unmaximized, and the Great Barrier Reef and its ecosystems will remain threatened with extinction.

While the Reef's outlook may seem dreary, it is important to address the advancements made in recent years that may make vital contributions in the future. Recently, selective breeding programs among the more heat-resistant corals in the Caribbean have shown promise (Howells et al.), showcasing that some corals can be made better equipped to deal with rising sea temperature. Other areas have dedicated time and resources to replanting and restoring reefs after intense storms or bleaching events. For example, Fragments of Hope, a non-profit organization based in Belize, helped initiate a restoration project that helped save the second-biggest coral reef in the world through coral nurseries and replanting projects.

Past successes indicate possible avenues of further funding and dedication to preserving the Great Barrier Reef until climate change can be adequately addressed. While there is much uncertainty about the future of the Reef, there is hope. With more research, data, and spending, the Great Barrier Reef has the potential to survive the coming effects of climate change and persist as one of the most important ecosystems in the world.

8. Appendix¹

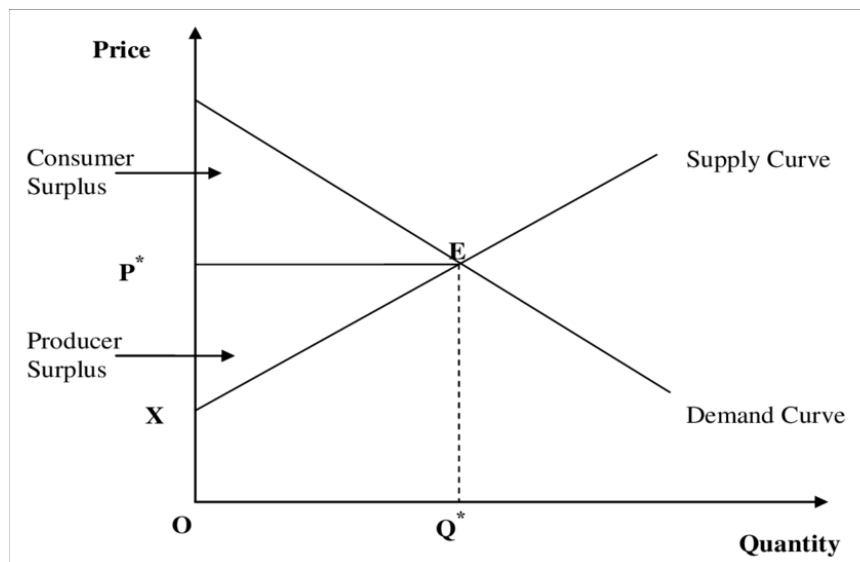
This appendix provides a brief overview of cost-benefit analysis (CB) as it applies this paper's analysis of the Great Barrier Reef and incorporates some of the important but more cumbersome details of the study.

Market Theory

In a market economy, the demand curve equals the marginal benefit or marginal willingness to pay (WTP), which is defined as the amount of money an individual would be willing to pay for one more unit of a good. Further, the total WTP is the aggregate amount the individual is willing to pay for the total quantity demanded. While the demand curve is the marginal WTP curve, a consumer's total willingness to pay is illustrated as the area below the demand curve. The difference between what a consumer is willing to pay and the price actually paid in the market is called consumer surplus, or the amount of extra benefit the consumer gets after paying the market price. On the production side, a firm's supply curve shows the various quantities of a good or service that an individual producer is willing to sell at a given set of prices. The firm will be willing to sell another unit of the good only if the price is greater than or equal to the cost of producing that unit. This cost of producing an additional unit is called the marginal cost of production, implying that the supply curve is also the marginal cost (MC) curve. Economists generally assume that supply curves (MC curves) slope upward. Since resources are scarce, producing an additional unit of a good is greater than the cost of producing the previous unit. While the MC is shown by the height of the supply curve, the total cost of producing a given quantity of a good is the total area below the supply curve from the origin to that quantity.

Producer surplus is the difference between the price that a producer would be willing to sell a good for and the price that the product actually sells for at any given quantity.

In a competitive economy, the intersection of market demand and market supply curves determines the equilibrium price and quantity of a good, with the demand curve reflecting the marginal benefit to the consumer of purchasing an additional unit and the supply or MC curve indicating the marginal cost to the producer of selling an additional unit. This outcome is economically efficient if at this price and quantity society derives the largest possible net benefit; or another way of expressing it is that, the marginal benefits are equal to the marginal cost. In the graph below, Q^* is the equilibrium quantity, which sells for the equilibrium price of P^* .



If markets are competitive and the demand and supply curves reflect society's true marginal cost and WTP, the intersection of the two curves will produce a socially efficient result – equilibrium price (P^*) and equilibrium quantity (Q^*). In a laissez-faire economy, firms take into account full

information about their private costs and make a decision about what and how much to produce and what price to charge. With this information on private costs and the equilibrium quantity determined by the intersection of $MR = MC$, firms will maximize profits.

The total benefit of a given quantity (Q) is the area under the demand curve to the left of Q .

Total cost is calculated as the area under the supply/marginal cost curve to the left of Q . If less than the equilibrium quantity is being produced, total benefits are greater than total costs and net benefits are positive. As Q moves closer to Q^* , net benefits fall but remain positive until demand equals supply or MB equals MC .

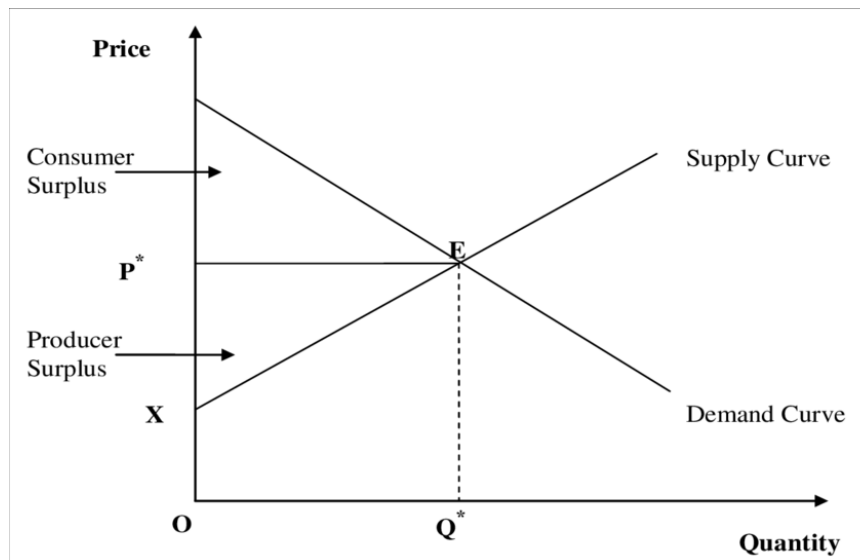
[Applying Market Theory to Environmental Goods and Services](#)

Environmental attributes (clean air, clean water, etc.) are not traded in markets, so a precise estimate of costs and benefits (willingness to pay) is quite difficult (Field and Field, 14).

Nevertheless, this paper attempts to calculate and compare the costs and benefits of protecting/restoring the GBR using a combination of techniques discussed below. In graphical terms, the market this study estimates are illustrated below, where Q is the quantity of GBR acres of coral reef restored, and P is the price measured in dollars. The demand curve for acres restored slopes downward to the right illustrating declining marginal benefit or diminishing marginal utility. In other words, the first acres of coral reef restored are worth quite a lot to people who value them, but as more are restored, the marginal benefit of another acre declines. In the face of limited resources to devote to other social issues apart from protection/restoration of the GBR, the opportunity cost of an additional acre restored is too high (or beyond equilibrium quantity, Q^* , where the marginal cost of restoration is greater than the marginal benefit). The supply curve

slopes upward to the right indicating that the more acres of coral reef restored, the higher the cost of restoring an additional acre (assuming the easiest restoration projects are the first undertaken).

If total benefits exceed total costs, a less-than-equilibrium quantity of acres of coral reef are being restored, and the economic case can be made that more restoration needs to occur. The equilibrium or efficient number of acres of reef restored is where $MC = MB$ or Q^* .



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Footnote 1: This Appendix draws in large part from the EPA’s Guidelines for Preparing Economic Analyses: Economic Theory (Appendix A),