Evaluation of ecosystem services of the open ocean based on people's willingness to pay

支払い意思による外洋生態系サービスの価値評価に関する研究

Doctoral dissertation

submitted to the University of Tokyo

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Table of Contents

List of abbreviations

CBD – Convention on Biological Diversity

CAM – Conjoint analysis method

CBA – Cost-benefit analysis

CBE – Choice based experiment

CVM – Contingent valuation method

EBM – Ecosystem-based management

ESD – Education for sustainable development

ESP – Ecosystem services partnership

FAO – Food and Agriculture Organization

GDP – Gross domestic product

GEF – Global Environment Facility

IMO – International Maritime Organization

IPCC – Intergovernmental Panel on Climate Change

ISA – International Seabed Authority

MA –Millennium ecosystem assessment

MPA – Marine protected area

MWTP – Marginal willingness to pay

NEOPS – New Ocean Paradigm on its Biogeochemistry, Ecosystem, and Sustainable Use

NPV – Net present value

OPES – Open ocean ecosystem services

PES – Payments for ecosystem services

TCM – Travel cost method

TEEB – The Economics of Ecosystems and Biodiversity

TEV – Total economic value

TWAP – Transboundary waters assessment programme

UNEP – United Nations Environment Programme

WTP – Willingness to pay

1. General introduction

1.1 The new limits to growth - ecosystem services and natural capital

1.1.1 The limits to growth

In 1968, the Club of Rome was established as the world's first think tank dealing with global issues, and was composed of one hundred influential thinkers from around the world with expertise in various fields. One outcome of their work was a research report titled "The Limit of Growth", which was published in 1972 and triggered global concern surrounding problems of an expanding population and the rapid reduction in natural resources (Meadows *et al.*, 1972). The report was based on a study that used computer simulations based on the theory of system dynamics, with the original model examining five variables: world population, industrialization, pollution, food production and resource depletion. The aim was to analyze the causal relationship between population growth and material world economic growth. In this report, a number of questions were posed, including: whether current policies would result in sustainable development in the future, or collapse, and how to create an economic system that meets the needs of all mankind. The report explained that the Earth's ecological limits would have a significant impact on global development, and a large number of non-renewable resources would suddenly be depleted in twenty to fifty years if no reliable alternatives are developed by then. As a result, there would be an inevitable decline in the living standard/well-being back to levels of several centuries ago. This bold prediction sparked intense debate at the time, but in the three decades since its publication, the crisis of resource depletion has threatened the sustainable development of human society. Researchers have divided the decades into three periods for discussion in order to show how the book's great influence continues today

(Pezzey & Toman, 2002). “The Limit of Growth” has been translated into more than thirty languages and sold worldwide.

The Japanese version had been reprinted 65 times by the time the author of this thesis obtained a copy in 2010 after reading about it in the first chapter of “Environmental Carrying Capacity in Mariculture Grounds” in Furuya *et al.* (2006). While this book is not the sole reason this research started, it was a trigger that made the author think more seriously about the sustainability of human society and importance of the marine environment.

1.1.2 What is the new limit to growth?

Over 40 years have passed since “The Limit of Growth” was published. In the current, for instance, we are currently faced with an unprecedented rate of rising food prices. Food was cheaper than at any time in modern world history in 2001. Prices began to change after 2002, with food prices increasing to a peak in 2008. According to the Food and Agricultural Organization (FAO) of the United Nations, food commodity prices in April 2014 were nearly 1.5 times higher than in 2002. Some foods, such as the vegetable oils, on which many low income people depend for cooking, increased much more (Moore, 2014).

However, it is now known that it is not just visible elements like mineral resources, fresh water, or crops noted above that could limit the development of human society.

On the other hand, some less visible elements like the reduced decomposition capacity for anthropogenic pollutants, the loss of biodiversity which could provide medical resources, the disappearance of coastal mangrove ecosystems capable of resisting or mitigating natural disasters, etc. could also become limiting factors for human well-being.

Here, the former set of limiting elements can be defined as "external restrictions", while the latter, which are more difficult to observe, feel, or measure using market monetary methods could be called "internal restrictions". The "internal restrictions" mentioned here are the new limit on growth for the development of human society and sustained human well-being.

1.1.3 Background of current ecosystem services research

Due to high speed of anthropogenic exploitation since the Industrial Revolution, a lots of natural resources have disappeared at an unprecedented speed and ecosystem services have been depleted at dramatic rates in global scale, raising concerns about unsustainable management. (IPCC, 2007, Maler *et al.*, 2008, Meadows *et al*., 1972). Natural ecosystems were considered as a type of social capital since the end of 1970s (Westman, 1977). Since the end of the 1990s, significance of natural capital and ecosystem services have attracted worldwide researchers to make efforts and remarkable achievements had been promoted (Daily, 1997, Costanza *et al.*, 1997, Alexander *et al.*, 1998). On the processes of addressing issues of unsustainable management towards supporting social development, ecosystem services studies have been a critical topic of the interdisciplinary fields of ecology, economics, policy management and environmental sciences. On this context, coastal and terrestrial ecosystems have been the main focus to make efforts, with particularly fruitful results on integrated management of terrestrial ecosystems (Deal *et al.*, 2012, Radford & James, 2013, Manes *et al.*, 2012, Bateman *et al.*, 2013), coastal ecosystems (Barbier *et al*., 2011, Costanza, 1999, Remoundou *et al*., 2009, Samhouri, 2012, Liu *et al*., 2010) and their composite elements (Mendoza-Gonzalez *et al*., 2012, Rodriguez *et al*., 2006).

For decades, people have recognized that their actions were dismantling the Earth's ecosystems at an alarming rate, leading to high rates of extinction, which have in turn led to questions about the value of biodiversity and how losses of biodiversity will alter the functioning of ecosystems and their ability to provide society with goods and services. This became a hot research topic, particularly after the United Nations Conference on Environment and Development (also known as Earth Summit) held in Rio de Janeiro from 3 to 14 June 1992.

Since then, there has been growing realization of the significance of biodiversity and increasing interest in ecosystem services (Braat & de Groot, 2012). Even though ecosystems services are not directly supplied by biodiversity, few data exist on the evaluation of biodiversity, while the value of biodiversity is usually related to the value of ecosystem services (Tilman *et al.*, 2005). The Convention on Biological Diversity (CBD) named this replacement evaluation method the "ecosystem approach" in 1992, and the Millennium Ecosystem Assessment (project from 2001 to 2005) conceptual framework is entirely consistent with this approach. It would be impossible to list all of the application efforts here, but emerging initiatives at the regional, national, and global level, like the Ecosystem Services Partnership (ESP) and The Blue Growth project in the European Union are doing just that and are gradually expanding their influence (http://ec.europa.eu/maritimeaffairs/policy/blue_growth/).

According to Boyd (2011), "we live in an economic age. The success and failure of policy implementations are judged by economic measures like GDP, profits, and income."

Economic incentives encourage people to over-emphasize short-term economic effects, which would easily lead to a variety of short-sighted policies, while ignoring natural costs. However, natural costs will eventually be reflected in human society through different dimensions of trade-offs. For example, greenhouse gases play a part in accelerating global warming, which is expected to cause broad impacts on global economics in the future (Stern *et al.*, 2006). Within the context of climate change, many ecosystem functions demonstrate obvious declining trends. This also causes changes in ecosystem services like disease control, pollution decomposition and nutrient cycling. These ultimately lead to a range of different types of damage or crises for human well-being and society as a whole (MA, 2005). Accordingly, if people undertake responsible actions for future generations, this could help to avoid irreversible ecosystem changes and provide sustainable ecosystem services (Figure 1.1).

Overall, as pointed out by Costanza *et al*. (2014), widespread recognition of the role of ecosystem services not only contributes to helping people rediscover the relationship between people and the rest of nature, but also creates a better understanding of ecosystem services with an emphasis on natural capital as an important component of sustainability, social wealth and human well-being.

1.2 Open ocean ecosystem services (OPES[1])

1.2.1 Defining the "open ocean"

A common impression of the open oceans has been formed in our minds through media or books: unlike coastal areas, the open oceans are far from the land, deep and mysterious. However, this description is just an ambiguous image. Different occasions or backgrounds have formed different definitions. For example, The Economics of Ecosystems and Biodiversity (TEEB) gives the following definition of open oceans: "the open ocean is the largest area of the marine ecosystem, including deep sea (water and sea floor below 200m). Excluded from this biome are shelf sea, ocean islands and atolls which are included in other marine sections" (TEEB, 2010). Costanza *et al*. (1997) estimated the total area of global open oceans as 33,200 $\times 10^6$ ha based on the area of primary production ability.

In the natural sciences, open oceans are often confused with the pelagic zone. According to Robison (Robison, 2004), the pelagic zone encompasses the entirety of the water column, beginning at the sea surface and ending above the seabed. The pelagic marine ecosystem is the largest on Earth and comprises over 99.5 percent of areas suitable for habitation. In fact, the open ocean is included within the pelagic zone, which can be broken down into the neritic and oceanic (open ocean) zones. The neritic zone lies adjacent to the shore, over continental shelves, and covers about 8% of the total sea area. Because the neritic zone is not the main focus of this thesis, more details regarding the natural attributes of the pelagic zone and the differences within the different neritic zones are not presented here, but can be found in Chapter 7 of Marine Ecology (Kaiser, 2011). Beyond

[1] In this thesis, we use "OPES" for short of "OPen ocean Ecosystem Services".

the continental shelves, therefore, is the vast open oceanic zone (occupying 92% of the total sea area and covering near 2/3 of the planet's surface), with its boundaries normally delimited based on the 200m depth contour (Kaiser, 2011).

Figure 1.2 depicts the various ocean areas. It's worth noting that the "high seas" can easily be confused with the "open oceans", which is a scientific concept. The "high seas", however, are a legal concept used to delimit the scope of rights in each country's waters, including law enforcement and management rights, while no country has jurisdiction rights over the high seas.

1.2.2 Significance of assessing the open ocean ecosystem services

There is no doubt that ecosystem services have become a source of concern for the mainstream media and business today. While containing extremely rich levels of biodiversity, ocean ecosystems are still less understood and valued compared with other ecosystems. From the pelagic zone to coastal mangroves, and from coral reefs to estuarine areas, all marine systems face a lack of recognition regarding the monetary value of the ecosystem services they provide, including vital services such as greenhouse gas absorption for climate mitigation, and providing food and livelihoods to millions of people in the developing world. Studies on the valuation of ecosystem services not only provide a rationale for decision-making, but can also help policymakers achieve comprehensive ocean management, and invest in marine conservation for its economic benefits and risk management value (Costanza *et al.*, 2014, Muradian & Rival, 2012).

As described by TEEB, the vast oceans and seas provide the largest space for life on the Earth. Marine ecosystems support nearly half of the world's primary production, based on which benefits that humans depend on for survival, food, livelihoods and well-being can be provided.

As mentioned in Chapter 1.1.3, through a series of efforts, large-scale collection of case study findings have been promoted by several international projects. “Two of the most comprehensive efforts being the Millennium Ecosystem Assessment (MA, 2005) and The Economics of Ecosystems and Biodiversity (TEEB, 2010). It was referred to nature providing indispensable “ecosystem services” to humanity as a “life-support system” by the MA, and almost all the ecosystems’ state of the Earth were analyzed. Twenty-four ecosystem services were considered in the MA and the results of the MA reveals that only four of these have been improved over the last fifty years, when five are in a stable condition but under threat in several areas of the world, and the rest fifteen are in largely decline condition (MA, 2005). An insightful vision for the future had been provided by the MA and its results have shown a roadmap for future studies on ecosystem services (Daily *et al.*, 2009, Carpenter *et al.*, 2009). The major concerns of TEEB are ecosystem degradation and the growing costs of biodiversity loss. The publication of summaries and guidelines that can help decision-makers recognize the importance of ecosystems services and biodiversity and reveal the values of them, and which include suggestions on how to reflect these values into decision-making has become a prominent contribution of TEEB (TEEB, 2010). These projects share a common shortcoming, in spite of their contributions on a global scale, as both have considerable limitations in their evaluation of OPES. Therefore, Global Environment Facility had promoted a “Trans-boundary Waters Assessment Program” for resolving the lack of assessments focused on the open oceans (GEF, 2011). Likewise, data availability gaps are also exist in the “Ecosystem Services

Valuation Database" (ESVD) (Van der Ploeg & de Groot, 2010). Only eleven data refer to the open oceans in the over 1,300 data estimates included in the ESVD[2], while the all rest focus on terrestrial areas and coastal areas (including wetlands, coral reefs and other coastal biomes). Through a review of the supplemental information based on ESVD, we found that all the data for the open oceans was estimated using alternative methods (Figure 1.3).

Why has the evaluation of OPES showed such slow progress? The following two reasons provide some explanation. One is due to the huge area of the open ocean: approximate 70% of the planet is covered by the ocean, of which more than 60% is accounted by open oceans. However, even nearly 40% of the world's population lives close to the coastline, but no people live on the open ocean. Difficulties of access to open ocean areas resulted that coastal areas are heavily exploited for mineral and biological resources even through much of the open ocean remains unexplored (Kaiser, 2011). Although a large area is defined as the open ocean, through a more detailed focus, it can be broken down into different areas according to their characteristics and various aspects, including greenhouse gas absorption capacity, primary production capacity, etc. It is not a simple work, however, to collect all these natural science data accurately: this requires not only analysis of satellite data, but also the need to send ships for *in situ* research, which carries huge costs. Therefore, expanding scales of time and space make it more difficult to achieve management goals (Figure 1.4). In addition, OPES are still under a non-joint management state. For example, seabed mineral resources in open ocean areas are under the management of the UN International Seabed Authority (ISA); global fisheries data were

[2] Database can be accessed through this page: http://www.fsd.nl/esp/80763/5/0/50.

gathered and problems of fishery resources analysis and management were addressed by the Food and Agriculture Organization (FAO); the security and safety, as well as the prevention of pollution arising from shipping are under the management of the International Maritime Organization (IMO).

Despite the difficulties mentioned above, the international community is undertaking a number of different assessment efforts. Such as the United Nations World Ocean Assessment has taken a leadership and provided an outline for the "Integrated Marine Assessment", which draw a clear roadmap for future assessment research (www.worldoceanassessment.org). Practically, many of the global coastal areas have not been protected until the over-exploitation happened to mineral and biological resources. In recent years, human influence on open ocean ecosystems has kept increasing and has even accelerated for certain services that have been under management – like pelagic fisheries. (Doney, 2010, Worm *et al.*, 2006)." At the same time, human activities impacting on the ocean environment are being carried out within the context of increasing rates of climate change on a global scale, like global warming and ocean acidification. "Some studies have argued that degradation has occurred on the ocean's provisioning services, which the most widely studied OPES and represented by food service, over the past several decades due to direct catch (including by catch) activities (Pauly *et al.*, 1998, Myers & Worm, 2003) and indirect climate change impacts (Cheung *et al.*, 2013, Perry *et al.*, 2005). Marine environments were also impacted by increasing human activities in terrestrial areas, these changes finally contributing to a series of global climate change (IPCC, 2013, Wu *et al.*, 2014, Kroeker *et al.*, 2012). Through biogeochemical cycles, such changes can be transferred to open oceans and accumulated over decades or even centuries (Doney *et al.*, 2009, Doney, 2010). Ultimately, all changes manifested in ecosystem services can therefore feed back into human economic activities (Stern, 2007, Tol, 2009, NCE, 2014).

While ecosystem goods are a relatively simple concept to grasp (e.g. the acquisition of food or minerals), the cultural value of biodiversity is considered a more abstract concept to understand. Research has suggested that when compared with tangible ecosystem goods, intangible cultural values should be paid greater attention because of the large value of the culture itself may be no less than the material value (Wakita *et al.*, 2014).

At the same time, broader application of economic valuation of ecosystem services have been indicated by EBM (ecosystem-based management) that to balance the multiple benefits provided by ecosystems (Katsanevakis *et al.*, 2011, Bermas-Atrigenio & Chua, 2013). For achieving both the aims of development and protection, the monetary value of open oceans ecosystem services and the trade-off relationships among them are necessary to be reveal (Bateman *et al*., 2013, Murillas-Maza *et al.*, 2011).

Research on ecosystem service valuation is helpful for intuitively understanding the quantitative effects of climate change on open ocean services. Aside from TEEB (2010), few studies on the monetary value of ecosystem services of global open oceans have been published over the past 15 years since Costanza's pioneering study. While analyzing the database of TEEB and (Costanza *et al*., 1997) supplementary information, the author found that both studies provided an average value calculated from local cases of every biome/ecosystem, which then used the average value to extrapolate the total value of every biome/ecosystem. When these averaged values are used for different local areas, however, the results rarely provide an accurate reflection of the value of the target biome/ecosystem, since the situation in local areas differ from one another even if they are classified as the same biome/ecosystem (Farley & Costanza, 2010). The differences are particularly noticeable for the open ocean ecosystem, which contains the largest marine biome and includes the deep sea (water and seafloor below 200 m). For example, the high-nutrient, low-chlorophyll (HNLC) regions of the open ocean contain less phytoplankton biomass than other open ocean regions, which suggests that they likely provide distinct services (fishery production, carbon sequestration, etc.) through food webs (Longhurst *et al.*, 1995, Cavender-Bares *et al.*, 1999). Therefore, it is necessary to divide open ocean ecosystems into additional categories based on the quantitative evaluation of different ecosystem services (fishery production, nutrient cycling, carbon sequestration, gas regulation, biological control, raw material, etc.). Nevertheless, how to link the phytoplankton biomass (an ecosystem function, which is not treated as an ecosystem service) of the open ocean to ecosystem services remains a critical problem. In contrast, special efforts have already been made for coastal ecosystems, for example through the Large Marine Ecosystems (LMEs) program conducted since 2005 to combat the degradation of coastal ocean waters caused by unsustainable use. Ocean ecology has begun to break traditional scientific boundaries and to interface with economics and the social sciences to understand the wider social importance of ocean ecosystem services and biodiversity (Kaiser, 2011). Therefore, further efforts to study OPES are needed in the future.

1.3 Purpose of this study & Content of dissertation

1.3.1 Purpose of this study

As described above, insufficient research has been conducted on OPES. Considering the necessity and urgency of OPES research, the author has focused on methods for valuation of the three main ecosystem services of open oceans: provisioning services like the production of sea food, regulation services like gas absorption, and supporting services like nutrient cycling and waste treatment.

The purpose of this study is summarized as follows:

1) Review previous research and identify gaps in past research methodologies;

2) Bridge these gaps using subsequent case studies and environmental economics methods to evaluate the open ocean; evaluate OPES using conjoint analysis and discuss the possibility of its application to aide policy making/ implementation;

3) Evaluating the OPES in present and 100 years later, with which results to calculate the social discount rate of OPES in the future 100 years.

1.3.2 Structure of dissertation

This thesis is composed of four chapters. Chapter 1 provides a general introduction. In Chapter 2, a discussion is provided about which methods are most suitable for evaluating OPES. First, past methodologies are summarized and their respective shortcomings or disadvantages are considered. Subsequently, a discussion is provided of other methods used for terrestrial and fresh water ecosystems in terms of their suitability for OPES evaluation. Finally, the conjoint analysis method is proposed as an appropriate method for this stage of OPES evaluation based on an introduction of its research history and applicability. A description is also provided of how the evaluation processes based on conjoint analysis were applied.

In Chapter 3, a case study that elicited the marginal willingness to pay (MWTP) for OPES is introduced, the result of which can be interpreted as the value of OPES. In Chapter 4, the importance of researching discount rates and time preferences are introduced; then the discount rate is calculated using the same method introduced in Chapter 3. In this case, however, the method is conducted twice in order to elicit separate results for present-day OPES and also for OPES 100 years in the future. In this chapter, the relationship among discount rates, time preferences and environmental protection incentives are also investigated.

The results obtained in the present study and future perspectives are discussed in detail in Chapter 5. A short summary is finally provided in Chapter 6.

Some parts introduced in Chapter 3 of this thesis have been already published in Shen *et al.*, (2015), and the text has been reproduced in accordance with the express permission granted by the author and co-authors:

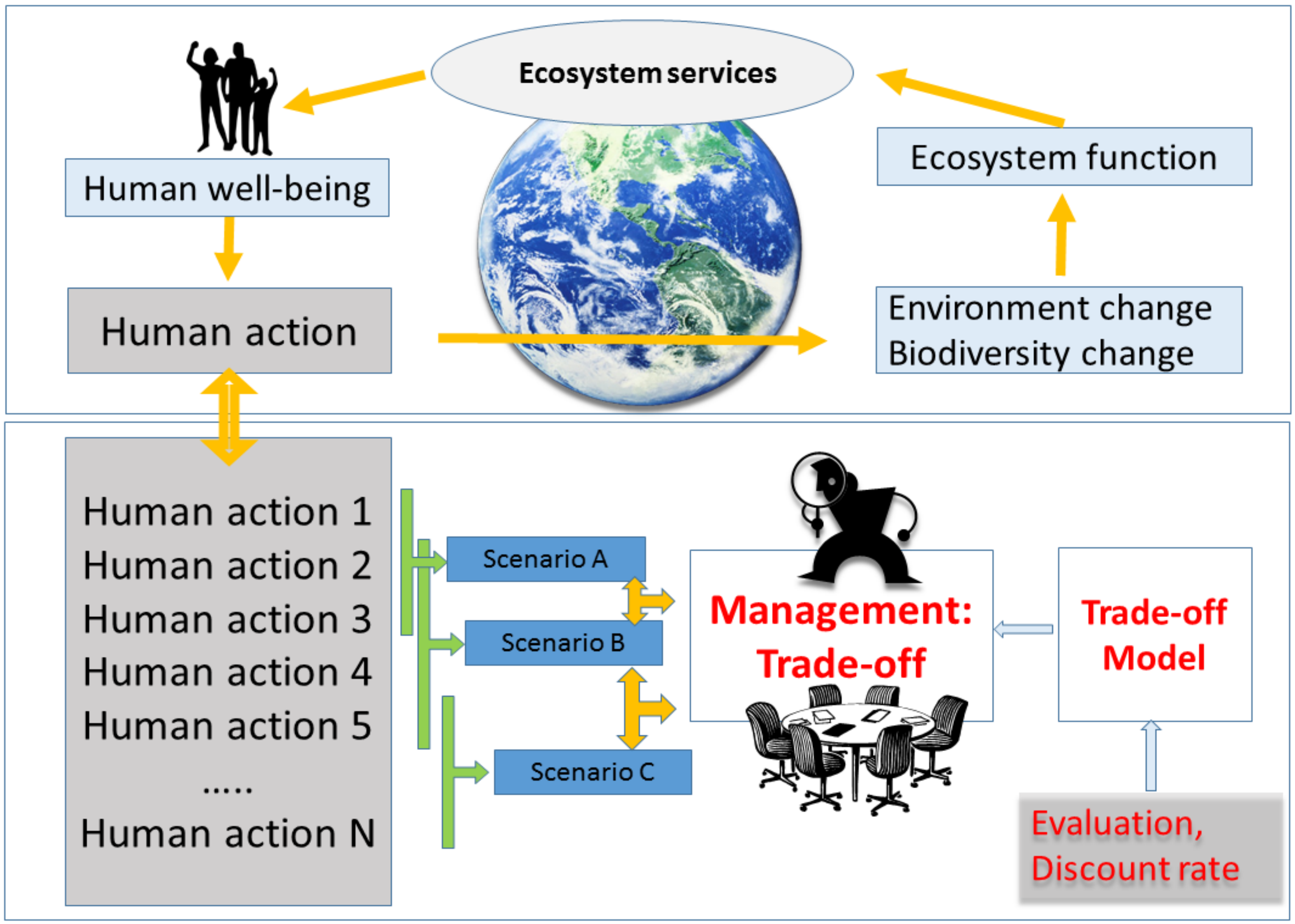

Figure 1.1. Relationship between human society, human action, ecosystem functions, ecosystem services and feedback.

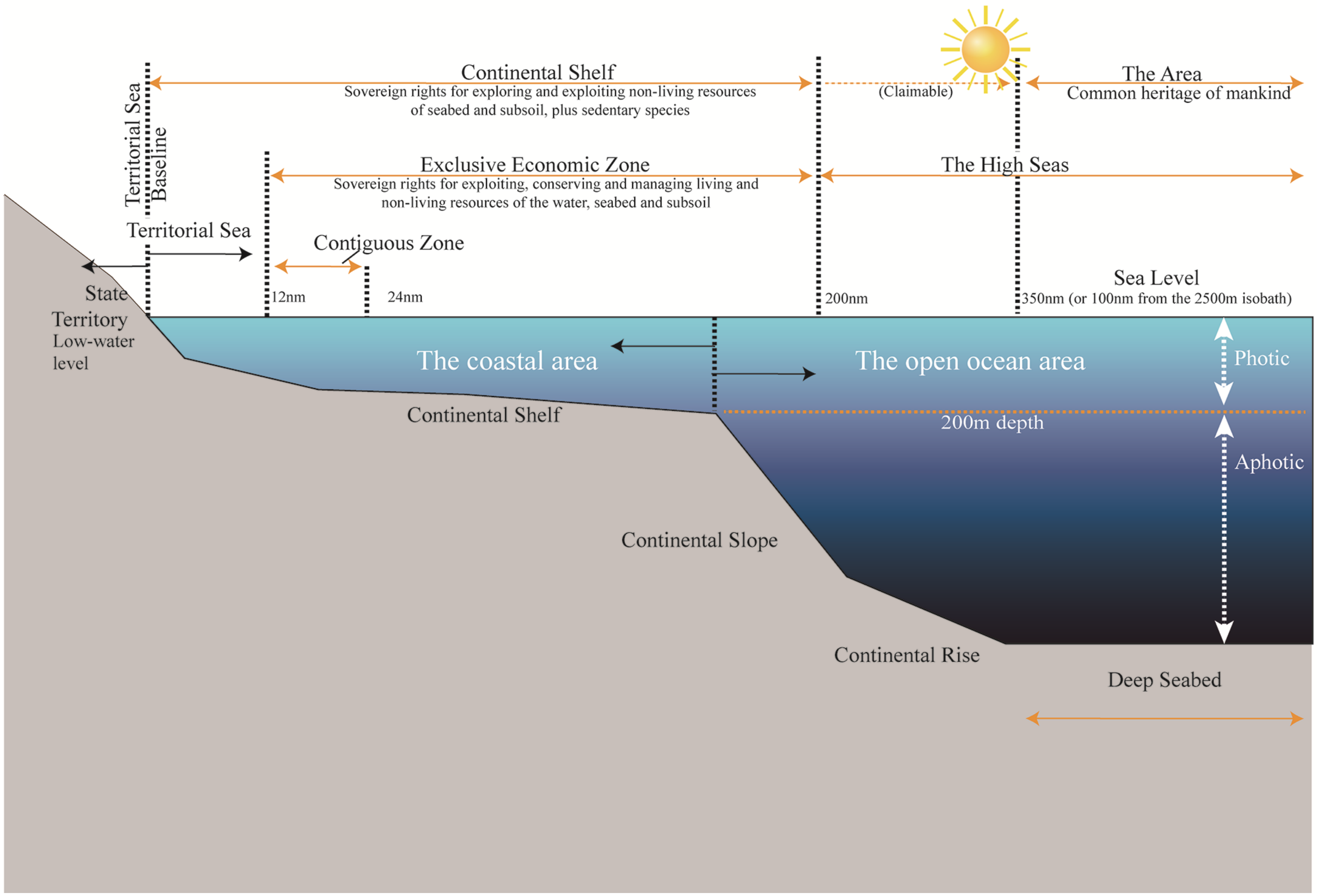

Figure 1.2. Diagram of maritime zones
Source: Authors' elaboration adapted from Maine Ecology (Kaiser, 2011) & Global Ocean Assessment (Rogers *et al.*, 2014)

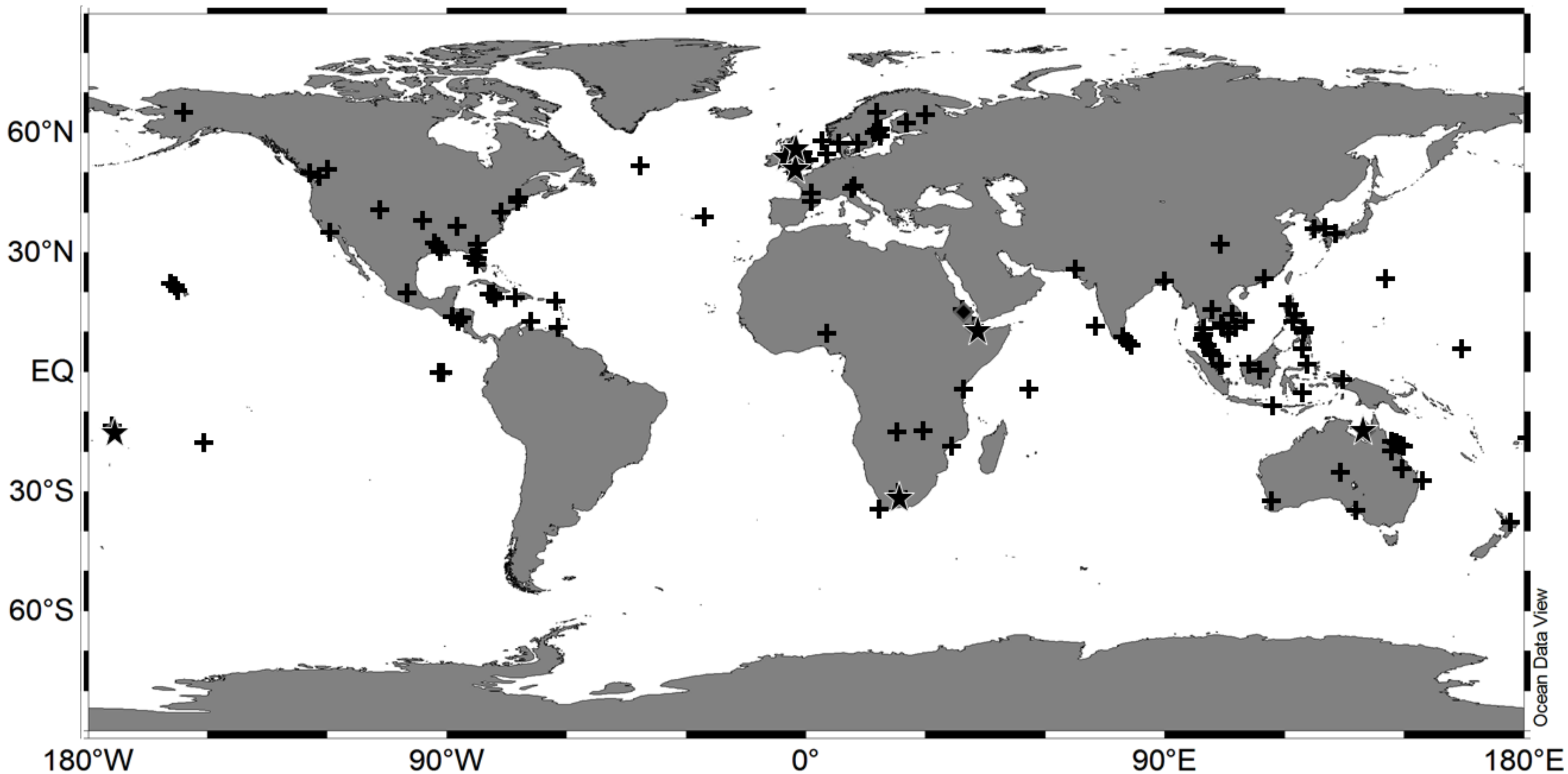

Figure 1.3. Locations of case studies on open ocean and coastal areas according to open access database of TEEB (Van der Ploeg & de Groot, 2010). Stars indicate the 11 data points on open oceans, while crosses indicate the 401 -data points on all marine areas except the open ocean.

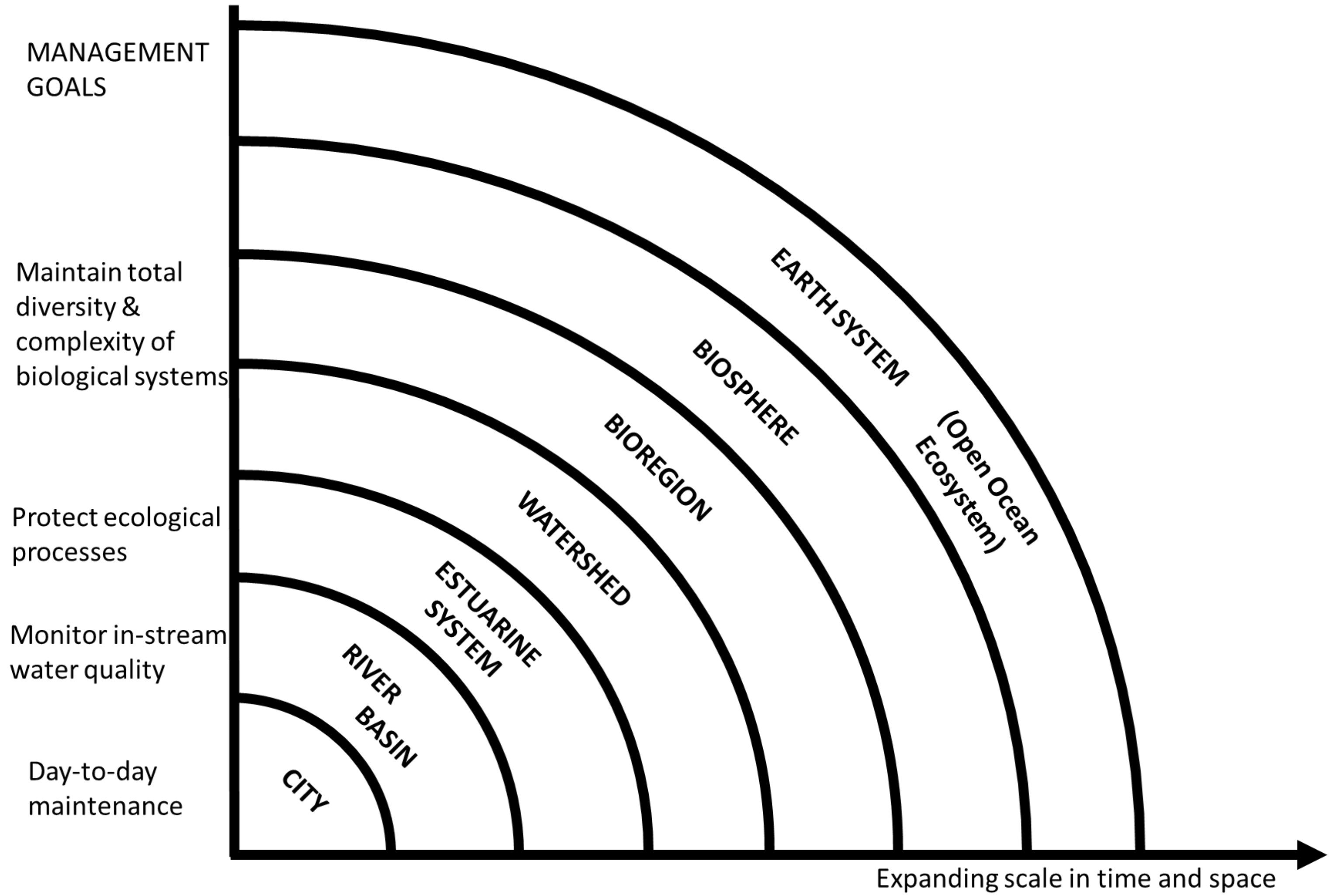

Figure 1.4. The scale of whole ecosystem management.
(Source: Adapted from “Ecological economics: the science and management of sustainability” (Costanza, 1992))

2. Methodology

2.1 Classification and definition of ecosystem services

The concept and terminology of "ecosystem services" was first proposed by Costanza in the 1990s (Costanza *et al*., 1992), although similar ways of considering the benefits provided by nature appeared as early as the late 1970s (Westman, 1977). According to one widely accepted definition of ecosystem services:

> *"Ecosystem services are the conditions and processes through which natural ecosystems, and the species that make them up, sustain and fulfill human life. They maintain biodiversity and the production of ecosystem goods, such as seafood, forage, timber, biomass fuels, natural fiber, and many pharmaceuticals, industrial products, and their precursors. In addition to the production of goods, ecosystem services are the actual life-support functions, such as cleansing, recycling, and renewal, and they confer many intangible aesthetic and cultural benefits as well." (Daily, 1997)*

For a long time, however, ecologists and economists have espoused different views of the definition of ecosystem services and have failed to standardize their measurement methods (Boyd & Banzhaf, 2007).

In this chapter, the definition and classification regarding the ecosystem services were introduced through several representative studies during the last two decade.

2.1.1 Milestone of ecosystem services studies: Costanza *et al*, 1997

In 1997, Costanza and his group systematically summarized past research, combined natural science and economic data, and published their global results covering 17 kinds of ecosystem services in 20 different biomes / ecosystems. In this section, heavy reference is made to work done by Costanza's research group; this is not the first study on ecosystem services, but rather one of the most comprehensive and influential within the field of ecosystem assessment. According to "Web of Science", this paper had already been sited more than 12,300 times by Nov. 2014.

According to Costanza *et al*. (1997), the entire valuation of ecosystem services to human welfare is estimated to be an average of USD 33 trillion per year, a figure significantly larger than gross domestic product (GDP) of the world in 1997 (30.4 trillion[3]). The open ocean contributes only a quarter of the total value. Supposing that the value has been underestimated, as was mentioned by one of the article's contributing authors, it is necessary to conduct additional study.

In 2011, 17 years after this controversial study was published, the same methods were applied using updated data, leading to an estimate of total global ecosystem services being estimated to total USD 125 trillion per year (assuming updated unit values and changes to biome areas) and USD 145 trillion per year (assuming only changes to unit values) using 2007 currency levels (Costanza *et al*., 2014).

The open ocean ecosystem was considered to offer six services with a combined value of USD 252 per hectare per year: gas regulation, nutrient cycling, biological control, food production, raw materials, and cultural values. In landscape scale research, results always provide a mean and underestimated value when making loose estimations (Costanza *et al*., 1997). When conducting research to evaluate a regional area of the open ocean (e.g. the EEZ of Japan; Japanese MPAs; the western Pacific), however, landscape

[3] http://www.economywatch.com/economic-statistics/year/1997/

scale data is less meaningful. A large number of local experiments and mathematical theory are needed to describe how biodiversity controls basic “ecosystem functions” (Cardinale *et al.*, 2012). Although a number of gaps in the research methodology led to the later controversy, the study’s impact on later ecosystem services research is profound and positive.

2.1.2 Millennium Ecosystem Assessment (MA)

Within the context of international cooperation, the MA was conducted from 2001 to 2005 with support from the United Nations. The assessment aimed to meet demands from decision-makers and the public for information about how changes in the environment and ecosystems impact human well-being, while also providing scientists with the information needed for assessment processes. This project is the first global project on ecosystem services and is based on collaboration by more than 1300 experts from over 70 countries. In 2005, an assessment report was published, and one of the strongest contributions of the MA has been its popularization of the term ecosystem services, which refers to the benefits gained by humans from ecosystems. Ecosystem services were proposed along four different categories: provisioning services, regulating services, cultural services and supporting services (Table 2.1).

One of the failings of the MA project is that while its four categories of ecosystem services was created by and was easily understandable to scientists with professional knowledge, it did not reflect the views of the general public. Therefore, misunderstandings may be generated during the application process for environmental protection projects (Wakita *et al.*, 2014). Although four years is not a long time for such an comprehensive international project, the MA’s influence and fame were unprecedented, and successfully attracted people's attention to the relationship between sustainability of ecosystem services and their well-being.

2.1.3 The Economic of Ecosystems and Biodiversity (TEEB)

Supported by DEFRA (Department for Environment, Food and Rural Affairs, UK), a report named “Marine Biodiversity: An Economic Valuation” was finished (Beaumont, 2006), in which the authors argue that the provision of all the goods and services presented are linked to marine biodiversity. This provides a method for estimating the biodiversity values through evaluating ecosystem services. Based on this report, two papers were published: “Identification, definition and quantification of goods and services provided by marine biodiversity (Beaumont *et al.*, 2007)” and “Economic valuation for the conservation of marine biodiversity (Beaumont *et al.*, 2008)”. The former gives a category-based definition, and the latter a case study to determine the economic value of marine biodiversity in the UK. It should be noted that Beaumont *et al*. (2007, 2008) deal with shelves and coastal waters in the UK and don’t consider the open ocean, due to a lack of information about biodiversity in the open ocean. Subsequently, to compare the benefits under the two different management regimes (normal conservation status and highly restricted status), between 2007 and 2010, a second international initiative was undertaken by the United Nations Environment Programme (UNEP), called The Economics of Ecosystems and Biodiversity (TEEB, 2010). The TEEB report was picked up extensively by the mass media, bringing ecosystem services to a broader audience. Hussain *et al.* (2010) calculated the value of marine conservation zones (MCZs) using the same categories and definition as Beaumont *et al*. (2008) and the Millennium Ecosystem Assessment (MA, 2005a). Furthermore, the TEEB report (sponsored by UNEP) recommended the calculation methods published by Hussain *et al.* (2010), who was also the leading author of the open ocean biomes section of the TEEB report. However, since Hussain *et al*. (2010) adopted the evaluation methods of Beaumont *et al*. (2008), which lack open ocean data, the TEEB's results in regards to the open ocean can be considered incomplete.

The services provided by ecological systems are critical to the functioning of the Earth's life-support system. Without exception, all types of human welfare in the world are fundamentally and directly dependent on ecosystem services. Over the past decades, however, ecosystem management based on GDP-focused develop theory have led to the loss of biodiversity. If there are no more effective efforts are taken to improve the present situation, it will threaten the functioning of our economy and human welfare.

TEEB supplied one type of classification that is more comprehensive than that of any other study (Costanza *et al*., 1997, Murillas-Maza *et al*., 2011) as shown in Table 2.2. A review of studies on open ocean ecosystem services is provided in Table 2.3 with a comparison of their classification methods to understand the evaluation situation. Each circle in the table indicates that the services have monetary data, while those without circles indicate that no data is available. A horizontal comparison show that aside from the "food service", there is no available monetary data as a common service across the three studies shown in Table 2.3.

The list shown in the tables at the end of this chapter (see also Section 2.2) not only helps to judge by which methods one ecosystem service can be evaluated, but also shows which services can be evaluated by one method. In this way, this chapter provides a pathway to expanding the methods to include different services in different ecosystems.

2.1.4 World Ocean Assessment (WOA)

Marine biodiversity underpins a wide range of ecosystem services on which life depends, which is why its importance for human well-being can never be overemphasized. In recent years, sustainable use and health of the rich biodiversity in pelagic and benthic, most of which located in the area beyond any national jurisdiction, has tracked more and more attention and tracked more and more concerns.

Another representative of recent efforts by the international community is the United Nations WOA, which has taken a leading role and provided an "Outline for the First Global Integrated Marine Assessment". WOA is an outcome of "a regular process under the United Nations for global reporting and assessment of the state of the marine environment, including socio-economic aspects, both current and foreseeable, building on existing regional assessments" (the "Regular Process") under the UN Division for Ocean Affairs and the Law of the Sea started in 2004 (www.un.org/depts/los/global_reporting/global_reporting.htm).

Unlike the TEEB and MA, WOA is not a project with a specific timeframe (open-ended). It was started with a preparatory phase from 2002 to 2005 followed by a start-up phase aimed at carrying out an "Assessment of Assessments" that continued until 2012. The second phase of the first assessment cycle has been ongoing since 2013. To Dec. 2014, working group meetings have already been conducted five times, and the latest results are available on the internet (www.worldoceanassessment.org).

According to a work report from WOA, part of the assessment work has been finished and will be introduced in the near future. It was divided into five sections: 1) The context of the assessment; 2) Assessment of major ecosystem services from the marine environment (other than provisioning services); 3) Assessment of the cross-cutting issues; 4) Assessment of other human activities and the marine environment; and 5) Assessment of marine biological diversity and habitats. This research focus on assessing ecosystem services and therefore will contribute to section 2), which including the detailed statement: Scientific understanding of ecosystem services; the oceans' role in the hydrological cycle; sea/air interaction; Primary production, cycling of nutrients, surface layer and plankton; ocean-sourced carbonate production.

As previously noted in Chapter 1.2.1, there is a distinction between "open oceans" and "high seas". Since there is substantial overlap in the areas defined by both, however, we consider the concept "ecosystem services in high seas" as being approximately equal to the concept of "ecosystem services of open oceans" in this research. Therefore, the classification and definition of ecosystem services used in the WOA are not precisely equal to those mentioned as OPES. The outcomes of the WOA are strongly supported by the UN and set a clear direction for future ocean assessment research.

2.1.5 Transboundary Waters Assessment Program (GEF TWAP)

Considering that "many transboundary water areas continue to be degraded and managed in fragmented ways (from GEF homepage: http://www.thegef.org/gef/whatisgef)", TWAP was developed to identify and assess the influence of human activities. At the same time, one feature of TWAP is that data, reports and other products from this project can be explored and downloaded not just by policy-makers and scientists, but by the general public as well.

Unlike the other projects and processes introduced above, TWAP is a project that receives administrative and financial support from the Global Environment Facility, which was established in 1991 as a pilot program of the World Bank to "assist in the protection of the global environment and to promote environmental sustainable development". Before moving out of the World Bank system to become a permanent, separate institution in 1994, GEF supported projects that were implemented by three partners: the United Nations Development Program, the United Nations Environment Program, and the World Bank. GEF is also responsible for the financial mechanism for both the UN Convention on Biological Diversity (CBD) and the UN Framework Convention on Climate Change (UNFCCC). Therefore, in relation to the OPES study, there is a connection to TWAP not only in terms of the value of ecosystem services, but also in terms of the health and the value change of the biodiversity of the open ocean.

TWAP aims to supplement the targets mentioned above across five types of water systems using independent indicator-based assessment: groundwater, lake/reservoir basins, river basins, large marine ecosystems and the open ocean. It is noteworthy that the thematic assessments of the previous four water systems are conducted independently, while the thematic assessment of the open ocean is led by the Intergovernmental Oceanographic Commission (IOC) of UNESCO, which also supports the World Ocean Assessment mentioned in Chapter 2.1.4.

Ultimately, it is impossible to introduce all the research on open ocean ecosystem services and related organizations here, but this section provides an overview of representative studies and organizations.

2.2 Methods for valuation of ecosystem services

Since ecosystem services just refer to specific aspects of an environment, many methods used in environmental economics can also be effectively applied to the valuation of OPES. Methods used in TEEB are listed in Table 2.6, and up to 13 kinds of methods can be chosen from to evaluate the various ecosystem services. Circles in the grids of Table 2.6 indicate methods that have been used in at least one previous study on ecosystem services. Blank spaces indicate the opposite – these methods have not been used to evaluate the ecosystem services. At the same time, the scope of application for each method is shown in Figure 2.4. Researchers can choose the method according to their needs by using Table 2.6 and Figure 2.4.

On the other hand, Table 2.7 shows valuation methods used for ocean ecosystems. Table 2.7 was created based on the TEEB case study database. Tables 2.8a and 2.8b show whether a method has been used in at least one previous study on ocean ecosystem services. Similarly, if Tables 2.7, 2.8a, and 2.8b were used together, researchers could choose which method to employ for evaluating a specific ocean ecosystem service.

This thesis specially focuses on four main services provided by ocean ecosystems and their sub-ecosystems: marine ecosystem, coastal ecosystem, coastal wetlands ecosystem and coral reefs ecosystem (Table 2.4). These four ecosystem services were chosen because they largely match up with previous case studies (bars standing on red line in Figure 2.1). In order to simplify the selection of methods, the valuation methods for each of the four ecosystem services are also listed in Table 2.5. In Figure 2.3, the blue bar shows the amount of all kinds of ocean ecosystem services, while the red bar shows the amount for the four main ocean ecosystem services. A geographical representation of where the case studies were conducted (based on the total of 433 data) for each of the four ocean ecosystem services is also plotted on the map in Figure 2.2. It is expected that this sorting of data will highlight the biomes for which insufficient data is available for applying the "benefits transfer method" (an economic method for non-market valuation at the local level) to evaluate local ecosystem services. Finally, Table 2.3 shows a comparison of which OPES have been evaluated in three representative previous research projects.

2.3 Methodological challenges for OPES valuation --- limitations of alternative methods in past research

Costanza *et al*. (1997) wrote one of the most frequently cited studies on ecosystem services, but used "Replacement Cost Methods (CM)" for evaluating the ecosystem services of open oceans. However, with the CM method, non-use (including legacy, existence & altruism) value cannot be revealed, and hence this produces underestimated values (Figure 2.4).

At the same time, all of the marine biome data included in the TEEB database was examined. According to TEEB, "ocean" is a general concept that includes the open oceans biome, coastal biome, coral reefs biome and a part of the wetlands biome (excluding inland wetlands). These biomes are considered to provide 22 types of ecosystem services that directly or indirectly contribute to human well-being. Based on the open TEEB database[4], 4 of the 22 ecosystem services provided by ocean were selected due to their comparatively larger datasets. These are food services (86 data entries), raw materials services (51 data entries), gene pool services (62 data entries) and recreation services (74 data entries), with each of the other 18 ecosystem services having a dataset with 30 or fewer entries.

2.3.1 Evaluation of Food Service

TEEB data points from the Pacific Ocean were used to compare the evaluation methods with Costanza's method (Costanza *et al.*, 1997) using food services as an example.

Fish prices were used based on calculated imports and exports of total marine fish catches from the FAOSTAT database: USD 2.28 kg^{-1} (± USD 1 s.d.). Potential catch for

[4] Downloaded row data from website: www.research.pdx.edu/dev/esvd/, accessed in 1st Aug. 2012

both upwelling and open ocean areas (Houde & Rutherford, 1993): 0.0497 MT / ha/ year ~ 0.0059 MT / ha/ year; Area: Upwelling: 5×10^8 ha (Cushing, 1971); Oceanic: 332×10^8 (Whittaker & Likens, 1973). Based on the data shown above, the total food services for the open ocean can be estimated as Fish Price $\times$MSY $\times$Area = USD 8~22 ha^{-1} y^{-1} (2007 price). Costanza *et al* (1997) use the average price of USD 15 ha^{-1} y^{-1}. And TEEB derives its values from Costanza.

2.3.2 Evaluation of Gas Regulation Service

Three significant studies have been conducted on the services provided by the world's ecosystems (Costanza *et al*., 1997), the marine protected areas (MPA) ecosystems of the UK (Beaumont, 2006) and the ecosystems within the Spanish exclusive economic zone (EEZ) (Murillas-Maza *et al*., 2011). In Costanza's research, two estimates of CO_2 absorption by the world's oceans were used: (1) Schlesinger (1991) estimated net storage of organic carbon (C) in marine sediments as 0.1 Gt C y^{-1}; (2) Butcher *et al.* (1992) discussed a simple model of the global carbon cycle, in which the net input of C to the oceans from the atmosphere is 1×10^{16}mol y^{-1}, which equals 120 Gt C y^{-1}. With the price of USD 20.4/t carbon given by (Fankhauser & Pearce, 1994), the average price is estimated as USD 38.3 ha^{-1} y^{-1}.

In Beaumont *et al*. (2007), using the satellite model of ocean primary production improved by Smyth *et al.* (2005), the CO_2 absorption ability of MPAs in the UK is estimated as 0.07 +/- 0.004 Gt C y^{-1}. Referring to the price GBP 6-121/t CO_2 (GBP, 2004) (Clarkson & Deyes, 2002), total price is estimated to be GBP 0.4-8.47 billion. This estimate was revised by Hussain *et al*. (2010), and the total price was fixed as GBP 8.2 billion. This result was directly cited by TEEB as part of the estimation of OPES.

In the Spanish EEZ case study, Murillas-Maza *et al*. (2011) used the average price of EUR 21.5/ t CO_2 (2005). The average primary production (1997-2002) was used to estimate the annual primary production for 2005, based on a remote sensing model from Platt and Sathyendranath (1988). The total value was estimated as EUR 3.8 million (4.2 million in USD2005), giving an average value for Spain's EEZ of EUR 36.6 ha^{-1} y^{-1}.

Two points should be highlighted in regards to these methods. The first is in the data calculating process of Costanza *et al*, (1997), CO_2 absorption ability data of global ocean were used an arithmetic mean value from data of two case studies (0.366×10^{15}g CO_2 y^{-1} from Schlesinger (1991) and 10×10^{15}g CO_2 y^{-1} from Butcher *et al*. (1992), even this arithmetic mean value is near the data revealed in nowadays (Sabine & Tanhua, 2010). This method was incautious and therefore should be carefully used. The second is that the other two studies regard MPAs and the EEZ as the open ocean, although both include coastal areas. These issues need to be resolved in future studies aimed at estimating OPES. At the same time, previous research such as that conducted by Costanza *et al*. (1997) and TEEB scientists didn't provide an answer to an important question about how to consider oceans' future CO_2 absorption capacity in terms of OPES. In summary, there hasn't been a reasonable study that estimates the value of CO_2 gas regulation service provided by open ocean ecosystems.

2.3.3 Evaluation of Nutrient Cycling Service

The definition of "Nutrient Cycling Service" in Costanza *et al*. (1997) includes storage, internal cycling, processing and acquisition of nutrients that encompasses nitrogen fixation, nitrogen, phosphorus and other elemental or nutrient cycles that should be considered when evaluating this ecosystem service. The definition of "Nutrient Cycling Service" employed by TEEB (2010) does not go into detail, but in addition to "waste treatment" and "maintenance of soil fertility", consideration should also be paid to water purification and soil/fertility formation when evaluating this ecosystem service.

From the data that "The total annual water inflow from the rivers to the World Ocean was 39,530 km^3/ year on average for the period 1921 to 1985." Costanza *et al*. (1997) used total annual water inflow from rivers is $40 \times 10^{12}\ m^3\ y^{-1}$. Then use the replacement cost based on US sewage treatment plant is USD 0.15 – 0.42 m^{-3}. At the same time, assume that open oceans' contribution proportion was assumed to the 1/3 of Total Ocean. Therefore, value of nutrient cycling service can be shown as:

$$\text{Total rivers flow} \times \text{treatment cost} \times 1/3$$

$$= 40 \times 10^{12}\ m^3\ y^{-1} \times \$0.15 - 0.42\ m^{-3} \times 1/3$$

$$= \text{USD } 2\sim 5.6 \times 10^{12} \text{ (in 1995 USD)}.$$

However, the assumptions given by Costanza *et al*. (1997) is unrealistic. Because if the water treated by under water treatment plant, one necessary requirement for example, is phosphorus concentration of input sewage is demanded between 0.5 to 5 g Ł$^{-1}$. However, due to Costanza's consumption, concentration of input sewage was 0.0001 g Ł$^{-1}$, in which concentration the water cannot be treated by underwater treatment plant for removing the phosphorus and nitrogen from the water. Therefore, we can conclude Costanza's assumption is overestimated and the results is unfeasible.

2.3.4 Evaluation of Cultural Service

One case study regarding Lyme Bay was introduced in TEEB database that GBP 4.13 ha^{-1} yr^{-1} for recreation service, which one kind of the cultural service (also shown at MESP homepage: http://www.marineecosystemservices.org/node/8264).

On the other hand, monetary value of services provided by open oceans by Costanza *et al*. (1997) (open ocean "Attractive landscapes"). The price was estimated as USD 76 in 1995. This method assumed that the whole coastal area around the world are covered villas, and then multiplied the coastal area with the villa price based on developed and undeveloped areas, respectively. Therefore, it can be get a total price of USD 5.52~105.2 $\times 10^{12}$. Then divided the results by the total area open oceans. At last Costanza *et al*. (1997) assumed that total price of open oceans' cultural service in the world could be alternated by the calculated average price. It is easy so concluded that above assumptions given by Costanza *et al*. (1997) is so unrealistic. Therefore, this results is controversial.

2.4 Conjoint analysis as applied to environmental economics[5]

Traditionally, environmental valuation methods can be divided into two categories: stated preference and revealed preference. Revealed preference methods, represented by the travel cost method and hedonic price method, mainly estimates the value of environment reflected in the data of existing market. Stated preference, as represented by the contingent valuation method (CVM)[6] and conjoint analysis (CA), are methods to reveal environmental value without a market but based on the valuations stated by beneficiaries in a survey questionnaire (Hanley *et al.*, 2013, Kolstad, 2011). Therefore, the latter is more suitable for evaluating OPES, most of which are unmarketable except the food service and CO_2 (even CO_2 is still only tradable among some countries) (Costanza *et al*., 1997, Daily, 1997). Moreover, based on this research's aim of estimating the marginal WTP for three representative OPES, the CA method is considered most appropriate since it not only allows for direct comparison of various policy alternatives using a single questionnaire, but can also reveal the valuation of each service, in contrast to the other stated preference method, CVM (see also Figure 2.4).

The CA method is usually implemented by conducting discrete choice experimentation, also known as choice-based conjoint analysis (CBC), and this technique

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[5] Section 2.4 has been extracted from Shen *et al*. 2015 based on express permission granted in writing by the leading author and all co-authors.

[6] CVM is used in four variations: 1. Willingness to pay to implement the policy. 2. Willingness to accept compensation, if the project stops; 3. Willingness to pay to stop the project; 4. Willingness to accept compensation, to implement the project.

has been under development since the 1960s. Recently, CBC has been applied to cases that elicit residents' WTP for each environmental attribute, which are indispensable for policy makers to implement comprehensive and effective management (Pathak & Dikshit, 2006, Cheung & Chung, 2008, Chan-Halbrendt *et al.*, 2010). On the other hand, few applications were found in the cases of coastal or open ocean environments.

Finally, after collecting all the respondents' answers, we conducted CBC based on a conditional logit model with TSP 4.5 (TSP international) statistical software.

Following the notation ofManagi (2012), if we consume respondent i chooses j from options J, utility U can be expressed as:

$$U_{ij} = V_{ij} + \epsilon_{ij} \quad (1)$$

In formula (1), V represents the deterministic component and ε represents the stochastic component of utility. Due to people prefer utility maximization, therefore, if respondent i choose j option, the utility should higher than choosing other options. It can be shown in formulas as.

$$\text{Prob}\ (j) = Prob\ (U_{ij} > U_{ik}; \forall\ \text{k}\ \neq\ \text{j}) \quad (2)$$

$$= \text{Prob}\ (V_{ij} + \varepsilon_{ij} > V_{ik} + \varepsilon_{ik};\ \forall k \neq j)$$

$$= \text{Prob}\ (V_{ij} - V_{ik} > +\varepsilon_{ik} - \varepsilon_{ij};\ \forall k \neq j);$$

Then, due to McFadden (McFadden, 1973), choosing j probability can be expressed in the logit model as:

$$\text{Prob}(j) = \frac{e^{V_{ij}}}{\sum e^{V_{ik}}}; \quad (3)$$

Representative utility (V) is usually specified to be linear in parameters: $V = \beta' x_{ik}$, in which x represent different attributes (different ecosystem services), β' is the coefficient of each attribute and x_{ik} is the vector of observed variables relating to random alternative k. With this specification, (3) transforms into:

$$\text{Prob}(j) = \frac{e^{\beta' x_{ij}}}{\sum e^{\beta' x_{ik}}}; \tag{4}$$

On the other hand, we know the utility that the respondent gets is:

$$V_{ij} = \beta_0 ASC + \beta_1 * V_{fishery} + \beta_2 * V_{\mathrm{CO_2}} + \beta_3 * V_{nutrient} + \beta_p * V_{price}; \tag{5}$$

In formula (5), fishery, CO_2, price represent fish production, carbon dioxide absorption and water purification, respectively. ASC refers to the alternative specific constant of the discrete choice. The values of β $(\beta_1, \beta_2, \beta_3, \beta_P)$ that maximize this quantity of V_{ij} are calculated using the maximum likelihood estimation provided by formula (4). Ultimately, the marginal WTP of every ecosystem service is calculated using formula (6).

$$MWTP_{x_1} = -\beta_x / \beta_p \,. \tag{6}$$

In the next two chapters, two case studies are separately introduced. Both are based on the same questionnaire that was conducted in Japan. The first case deals with Japanese WTP for OPES using the conjoint analysis method introduced above. The second case is based on the findings of the first case and was conducted by dividing respondents into two groups in order to assess the WTP for present and future OPES (100 years later). This process made it possible to calculate the social discount rate.

Table 2.1. Four categories of ecosystem services.

Provisioning	Regulating	Cultural
products obtained from:	benefits obtains from:	non-material benefits obtained from:
ecosystems	regulation of ecosystem processes	ecosystems
food	climate regulation	spiritual
freshwater	disease control	recreational
fuel	flood control	aesthetic
Biochemical matters	detoxification	inspirational
genetic resources	pollination	educational
		communal
		symbolic

Supporting

Services necessary for the production of all other ecosystem services

Soil formation

Nutrient cycling

Ecological processes/functioning

Source: Author's elaboration based on Millennium Ecosystem Assessment (2005)

Table 2.2. Total monetary value for each biome 1ha/yr.

Biome	Minimum value	Maximum value
Marine / Open Ocean	13	84
Coral Reefs	14	1,195,478
Coastal	248	79,580
Coastal Wetland	1,995	215,349
Inland Wetland	981	44,597
River & Lake	1,779	13,488
Tropical Forest	91	23,222
Temperate Forest	30	4,863
Woodlands	16	1,950
Grasslands	297	3,091
Tundra	—	—

(Unit: USD/ha/yr.)

Source: Author's elaboration based on TEEB (2010).

Table 2.3. Twenty-two ecosystem services shown in TEEB, and OPES mentioned in other studies

Services \ Study	*Costanza et al*, 1997 (world)	TEEB, 2010 (edited by Kumar) (UK)	*Murillas-Maza et al*, 2011 (Spain)
Production Services			
1 Food	○	○	○
2 (Fresh) water supply			○
3 Raw materials			○
4 Genetic resources			
5 Medicinal resources			
6 Ornamental resources			
Regulatory Services			
7 Influence on air quality	○		○
8 Climate regulation		○	
9 Moderation of extreme events			
10 Regulation of water flows			
11 Waste treatment / water purification			○
12 Erosion prevention			
13 Nutrient cycling / maintenance of soil fertility	○		
14 Pollination			
15 Biological control	○	○	
Supporting (Habitat) Services			
16 Lifecycle maintenance			○
17 Gene pool protection		○	○
Cultural Services			
18 Aesthetic information	○		
19 Recreation and tourism		○	
20 Inspiration for culture, art and design			
21 Spiritual experience			
22 Cognitive information (education and science)			

Table 2.4. Account and percentage of case studies on ecosystem services of total ocean areas (marine, coastal, wetlands, coral reefs).

Biome	Marine (deeper than 50m)		Coastal (shallower than 50m)					Coastal wetlands				Coral reefs
Ecosystem	Open ocean	Unspecified	Seagrass/ algae beds	Continental shelf sea	Estuaries	Shores	Unspecified	Mangroves	Salt water wetlands	Tidal marsh	Tropical forest general	Coral reefs
Account	11	19	7	14	15	15	8	131	43	40	1	129
Percentage	3%	4%	2%	3%	3%	3%	2%	30%	10%	9%	0%	30%

Data source: TEEB database.

Table 2.5. Methods for evaluating the four main ecosystem services of open oceans

Services	Valuation Method
Food service	Benefit Transfer Direct market pricing Factor Income / Production Function Group Valuation Hedonic Pricing Replacement Cost
Raw materials	Avoided Cost Benefit Transfer Direct market pricing Factor Income / Production Function Group Valuation
Genepool	Benefit Transfer Contingent Valuation Direct market pricing Factor Income / Production Function Group Valuation Mitigation and Restoration Cost PES (Payments for environmental services)
Recreation	Benefit Transfer Contingent Valuation Direct market pricing Factor Income / Production Function Travel Cost

Source: TEEB database.

Table 2.6. List for checking the relation between the evaluation methods and the biome/ecosystems in TEEB.

Method \ Biome	Coastal	Coastal wetlands	Coral reefs	Marine	Cultivated	Desert	Forests	Fresh water	Grasslands	Inland wetlands	Multiple ecosystems	Tropical forest	Urban	Woodlands
Avoided cost		●	●	●	●		●		●	●	●	●		●
Benefit transfer	●	●	●	●	●		●	●	●	●	●	●	●	●
Choice modeling		●												
Contingent valuation	●	●	●	●		●	●		●	●	●	●		●
Direct market pricing	●	●	●	●	●		●	●	●	●	●	●		●
Factor income/ Production function	●	●	●	●				●		●		●		●
Group valuation			●							●		●		
Hedonic pricing	●			●					●	●		●		
Mitigation and restoration cost	●	●			●		●			●				
PES			●		●							●		
Replacement cost	●	●	●	●	●		●	●		●	●	●		●
Total economic value	●	●	●	●	●		●	●	●	●	●	●		●
Travel cost	●	●	●				●			●		●		

Table 2.7. Comparison of valuation methods across four main ecosystem services and all ecosystems services of oceans

Valuation methods used on 4 main ecosystem services of ocean	**Valuation methods used on all ecosystem services of ocean**
Avoided Cost	Avoided Cost
Benefit Transfer	Benefit Transfer
Contingent Valuation	Contingent Valuation
Direct market pricing	Direct market pricing
Factor Income / Production Function	Factor Income / Production Function
Group Valuation	Group Valuation
Hedonic Pricing	Hedonic Pricing
Mitigation and Restoration Cost	Mitigation and Restoration Cost
PES	PES
Replacement Cost	Replacement Cost
Travel Cost	Travel Cost
	Unknown
	Choice Modeling
	Other
	Total Economic Value

Source: TEEB database.

Table 2.8a. Examples of original case studies in TEEB database

Valuation Method about Ocean's 4 main services	Example of Original Research			
	Food service	Raw materials	Genepool	Recreation
Avoided Cost		Economic valuation of mangroves and the roles of local communities in the conservation of natural resources: case study of Surat Thani, South Thailand. Unpublished report, EEPSEA research report series, Singapore.		
Benefit Transfer	The value of the world's ecosystem service and natural capital. Nature 387: 253-260.	The value of the world's ecosystem service and natural capital. Nature 387: 253-260.	The value of the world's ecosystem service and natural capital. Nature 387: 253-260.	The value of the world's ecosystem service and natural capital. Nature 387: 253-260.
Contingent Valuation			An ecosystem services approach to assess managed realignment coastal policy in England. CSERGE Working Paper ECM 08-04, CSERGE, University of East Anglia, Norwich, UK.	Welfare loss of wetlands disintegration: a Louisiana study. Contemporary Economic Policy 14: 92-106
Direct market pricing	The value of the world's ecosystem service and natural capital. Nature 387: 253-260.	Functions and socio-economic importance of coral reefs and lagoons and implications for sustainable management. MSC Thesis, Wageningen University, the Netherlands.	Functions of nature: evaluation of nature in environmental planning, management, and decision making. Wolters-Noordhoff, Groningen, the Netherlands, 315pp.	The economic contribution of GBRMP - Report 2006-2007. Access Economics PTY Ltd. For Great Barrier Reef Marine Park Authority, Australia.
Factor Income / Production Function	Economic valuation for the conservation of marine biodiversity. Marine Pollution Bulletin 56(3): 386-396.	Some aspects of economic resources of Sundarban mangrove forest of Bangladesh.	Marine protected areas: the case of Kisite Marine National Park and Mpunguti Marine National Reserve, Kenya. IUCN Eastern Africa Regional Office, Nairobi, Kenya.	Economic valuation for the conservation of marine biodiversity. Marine Pollution Bulletin 56(3): 386-396.

Table 2.8b. Examples of original case studies in TEEB database

Valuation Method about Ocean's 4 main services	Example of Original Research			
	Food service	Raw materials	Genepool	Recreation
Group Valuation	Poverty and reefs. Volume 2: Case studies. DFID-IMM-IOC/UNESCO, 260pp.	Poverty and reefs. Volume 2: Case studies. DFID-IMM-IOC/UNESCO, 260pp.	Valuing the role of aquatic resources in Livelihoods: economic aspects of community wetland management in Stoeng Treng Ramsar Site, Cambodia. IUCN Water, Nature and Economics Technical Paper No. 3.	
Hedonic Pricing	The value of the world's ecosystem service and natural capital. Nature 387: 253-260.			
Mitigation and Restoration Cost			Valuation of the mangrove ecosystem in Can Gio mangrove biosphere reserve, Vietnam. The Vietnam MAB National Committee, UNESCO / MAB.	
PES			Paying for biodiversity conservation services in agricultural landscapes. Final draft. Forthcoming as Environment Department Paper No.96.	
Replacement Cost	Replacement costs as economic values of environmental change: A review and an application to Swedish sea trout habitats. Beijer International Institute of Ecological Economics, The Royal Swedish Academy of Sciences.			
Travel Cost				Valuing recreational and conservation benefits of coral reefs: the case of Bolinao, Philippines. Ocean & Coastal Management 50(2): 103-118.

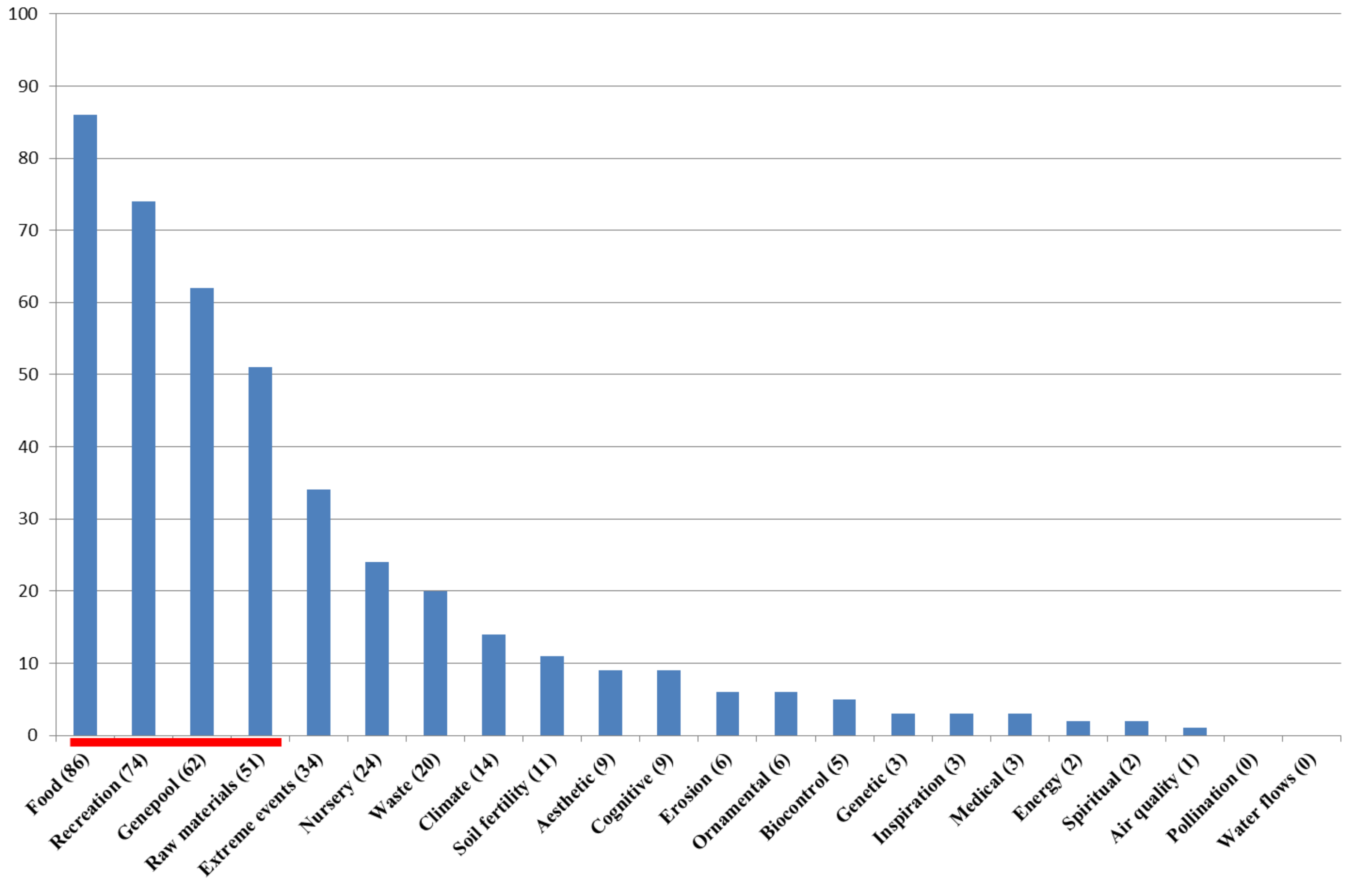

Figure 2.1. Number of each type of ocean ecosystem service; red line indicates the four main ocean ecosystem services.

Source: TEEB database.

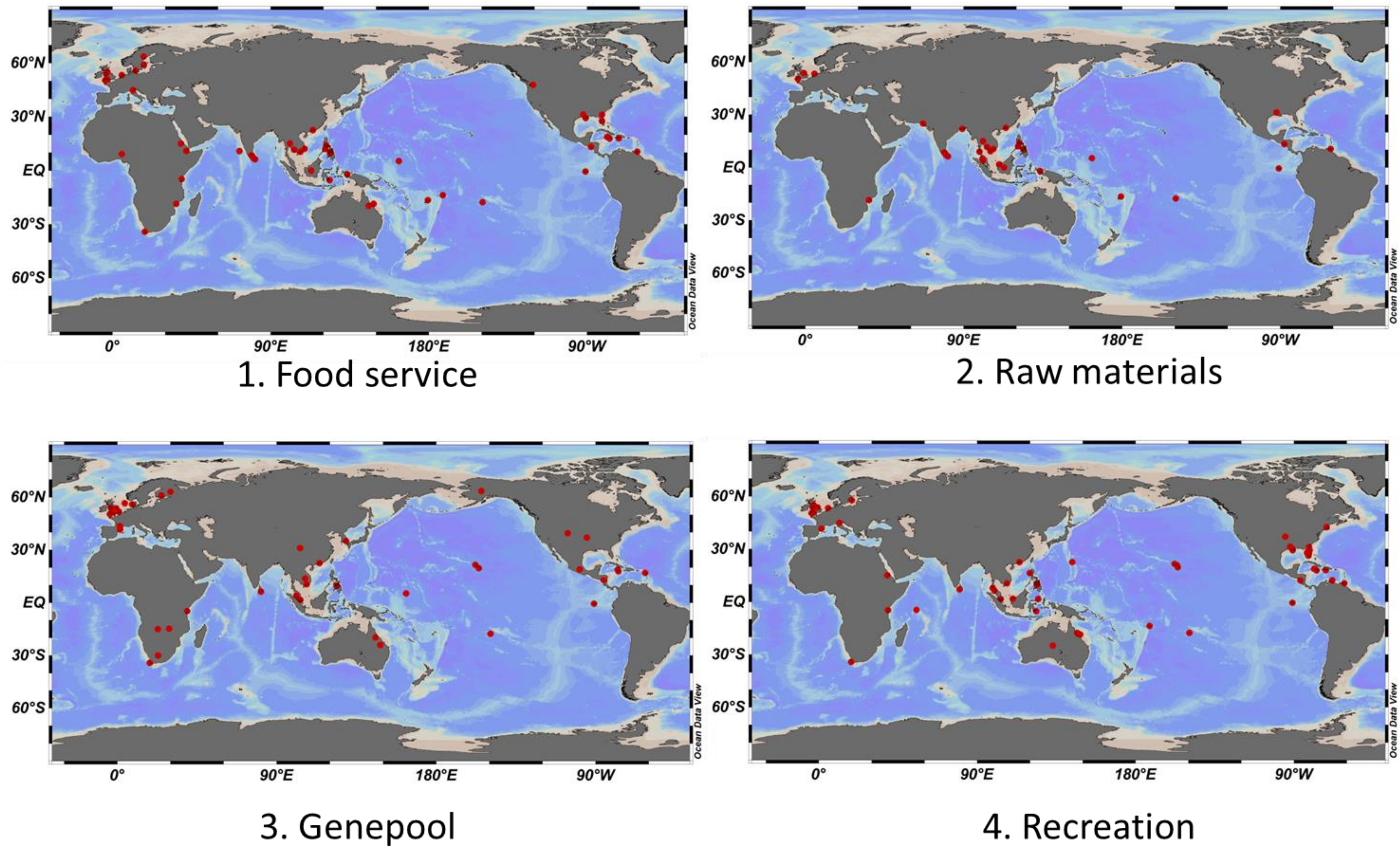

Figure 2.2. Plotting case studies of four main ocean ecosystem services

Source: TEEB database.

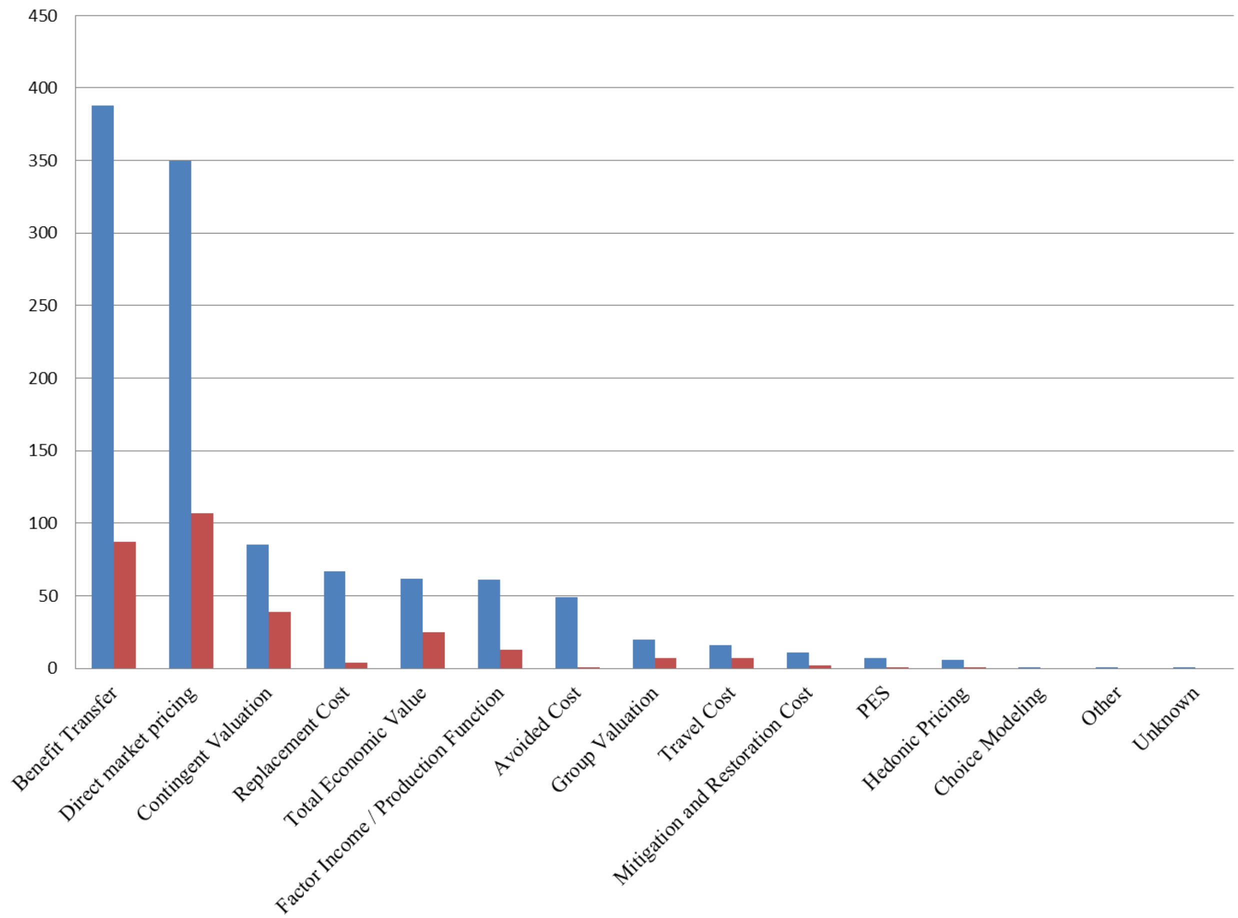

Figure 2.3. Number of each type of valuation method. Blue bars indicate the number of all kinds of ocean ecosystem services; red bars indicate the number of the four main ocean ecosystem services.

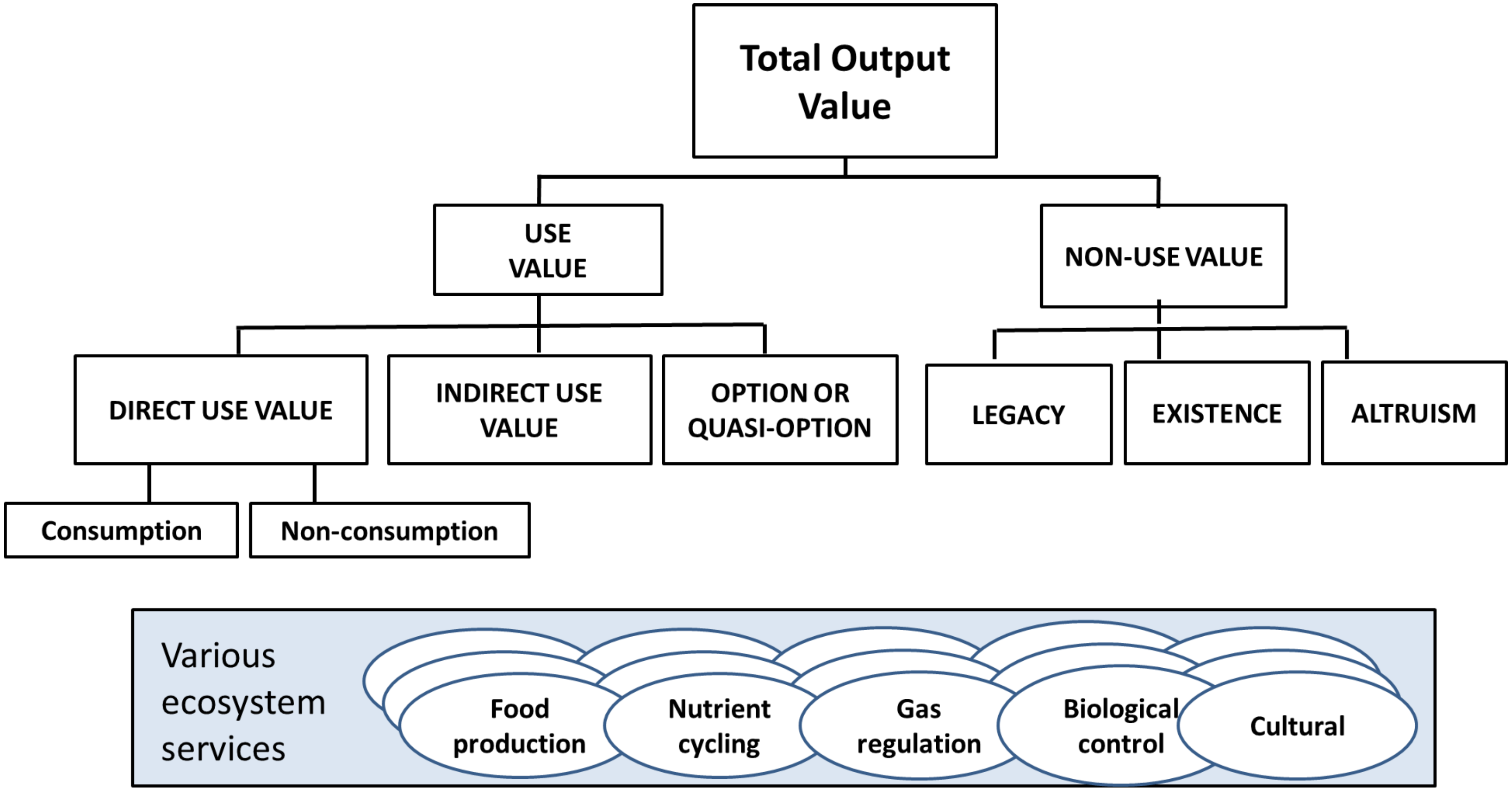

Figure 2.4. Approaches for estimating nature's values.

Source: adapted from Turner *et al*, 1994; Costanza *et al*, 1997; TEEB 2010

3. Willingness to pay for OPES by conjoint analysis: a case study of Japan[7]

3.1 Introduction of questionnaire design

Data for this study was obtained from 814 responses from individuals in Japan to a self-explanatory web-based questionnaire distributed by “MACROMILL, INC.” The distribution of the questionnaire as well as the collection of responses took place over the period from 15-17 February 2013. The respondents received 60-90 online points, equivalent to approximate 60-90 Japanese yen, which can be used for online shopping. The procedure for conducting the questionnaire was as follows.

First, representative areas were selected taking into account geographical balance in regards to the seas: Tokyo and Osaka representing metropolitan areas facing bays, Shizuoka and Ishikawa prefectures representing rural areas facing seas, and Nagano representing landlocked prefectures, reflecting representative areas of coastal to landlocked prefectures in Japan (Figure 3.1). The targeted respondents were twenty years of age or above, and the questionnaire was sent to all people registered with the research company who met the above conditions. The research company sent the questionnaire to 6,416 registrants, and received 220 responses from each respective area, constituting a total sample of 1,100 respondents.

Next, the representativeness of the respondents in terms of age-based hierarchy was examined. Although 42 respondents over 70 years of age answered the questionnaire, the

[7] This chapter has been extracted from Shen *et al*. 2015 based on express permission granted in writing by the lead author and all co-authors.

data was excluded from the sample in consideration for the fact that internet usage by people over this age was below 50% at the end of 2012 (MIAC, 2013), and the respondents were judged as not being a representative sample of the population over the age of 70. The remaining 1,058 collected questionnaires were then randomly selected through a stratification process in accordance with the specific age demographics of each respective prefecture, based on data from the Statistics Bureau, Ministry of Internal Affairs and Communications (MIAC, 2010). Thus, the number of questionnaires ultimately used in the analysis fell to 814: 173 from Tokyo, 141 from Osaka, 168 from Shizuoka, 157 from Ishikawa, and 175 from Nagano.

The questionnaire was designed to measure marginal WTP of Japanese residents. Firstly, the respondents were provided information that an assumed geoengineering project (Fe fertilization[8]) would be conducted in the open ocean of the North Pacific with the aim of improving OPES such as CO_2 absorption, food production, and water purification to a certain level (Figure 3.2). It is also assumed that this project will only be supported by an independent foundation fed by donations from Japanese residents. Therefore, an improvement in the three ecosystem services would be achieved at different levels depending on the different donation levels.

[8] It is worth noting that story of Fe fertilization is provided as a technical hypothesis in order to elicit realistic values of WTP from respondents in this study. The Fe fertilization effects for improving ecosystem services (5%, 30% or 50%) in the description of the questionnaire are not based on scientific facts backed up by experimental data. In addition, large-scale ocean fertilization actions on the high seas are strictly regulated by the London Convention and Protocol.

Secondly, respondents were shown one question followed by four options, which represent a choice set of WTP. Every WTP option corresponds to a different combination of improvement levels regards to the three main ecosystem services, respectively (Figure 3.2). To conduct conjoint analysis, a set of six similar questions for each respondent was designed and incorporated into this questionnaire based on the experimental design.

3.2 Results

The marginal WTP for OPES was calculated based on the attributes of location (prefecture in this research), annual income, age and gender, provided by the respondents (Table 3.1). The conjoint analysis results based on location (Table. 3.2 and formula 2) reveal marginal WTP for OPES in descending order of JPY 19.0 (USD 0.19)[9] for CO_2 absorption capacity, JPY 15.8 (USD ~0.16) for water purification capacity and JPY 5.7 (USD ~0.06) for fish supply capacity. The total marginal WTP for these three OPES is JPY 40.4 (USD 0.40~). Large regional differences were observed both in terms of the total WTP for ecosystem services as well as the WTP for each individual ecosystem service. Obvious trends may not be evident from comparing the total value for the highly urbanized port cities (Tokyo, Osaka) and more rural areas (Nagano, Shizuoka, Ishikawa), or comparing Eastern (Tokyo, Shizuoka, Nagano) and Western Japan (Osaka, Ishikawa) (Table 3.3). Looking at each of the three ecosystem services individually reveals statistical differences in marginal WTP for each ecosystem services among these five areas. In terms of the provisioning service (food), WTP expressed by respondents from landlocked Nagano was much lower than for the Pacific Ocean coast or the Sea of Japan coast (Ishikawa). On the other hand, marginal WTP of residents in Tokyo and Nagano for CO_2 absorption and water purification capacity was 20% higher than for the other three areas significantly (Table 3.3).

The marginal WTP for OPES at each of the five income levels indicated by respondents was also assessed and a positive correlation was found between them for each of the three OPES. More specifically, a higher income corresponded to higher WTP for

[9] Estimates in US dollars are based on values from Feb. 1 2014: USD 1 ≈ JPY 100. The same exchange were used throughout this thesis.

each ecosystem service. This trend was particularly evident for the WTP for the provisioning service (fish production). Although the WTP was much lower than for CO_2 absorption when the annual income was under JPY 9 million (USD 90,000), it became two times higher than CO_2 absorption when the annual income was JPY 9-14 million (USD 90,000-140,000) (Table. 3.4a). Differences could also be observed, however, across different ages, and a correlation between age and marginal WTP was not observed (Table 3.4b), eliminating the possibility that age influences income and in turn influences WTP.

Gender differences for marginal WTP for OPES were also observed. Based on the collected data, female respondents had a generally higher WTP for each of the three OPES than male respondents. The results, however, varied across the five prefectures (Table 3.5). Implications and potential reasons for these findings are described in the following section.

3.3 Discussion

Past research on valuation of OPES has largely used alternative methods to reveal respondent preferences. One weakness of such alternative methods is that when there is an absence of corresponding market goods, the valuation results for environmental goods will be very different depending on which market goods the researcher selects as a proxy. For instance, past research has equated the value of the open ocean's water purification capacity with the cost of sewage plants (Costanza *et al*., 1997). If the cost of water purification plants for generating drinking water were used as a proxy, however, this would result in a much higher valuation result. The conjoint analysis method used in this research allows market participants (questionnaire respondents) to value OPES, while avoiding the shortcomings associated with a researcher's subjective choice of a proxy for assessment purposes.

One of the most prominent pioneering studies on OPES was conducted by Costanza *et al*. (1997), who calculated a total OPES value of USD 8.4×10^{12} per year, including food services (fish production) valued at USD 15 ha^{-1} yr^{-1}, CO_2 absorption (gas regulation) of USD 38 ha^{-1} yr^{-1} and a water purification (nutrient cycling) service of USD 118 ha^{-1} yr^{-1}. Using Costanza *et al*. (1997) estimates for an open ocean spanning 3.32×10^{10} ha, annual global totals for these three services can be calculated as USD 4.98×10^{11}, 12.6×10^{11}, and 39.2×10^{11} respectively. Considering the current global population of around 7 billion in 2013, the marginal (1% of total) annual per capita values can be approximately calculated as USD 0.71, 1.80 and 5.60, respectively.

On the other hand, our results estimated a marginal annual WTP for food, CO_2 absorption and water purification services of JPY 5.65 (USD ~0.06), JPY 18.99 (USD

~0.19) and JPY 15.78 (USD ~0.16) per capita, respectively. Costanza *et al*.'s (1997) results can therefore be estimated to be roughly 12 times, 10 times and 35 times higher than our results, respectively.

It is a remarkable departure from our results, for Japan seems particularly well-suited for strong recognition of the value of marine services and willingness to pay for them. It is a "maritime nation" consisting of more than 3,000 islands and surrounded by the ocean, and is a member of the OECD, with above-average income and education levels. While these factors would suggest a positive impact on our results that would exceed global averages, the results seem to show just the opposite. A number of factors could explain this gap, not least the possibility of different methodologies resulting in underestimation or overestimation.

Perhaps one of the greatest contributions of Costanza *et al*. (1997) research was to emphasize the enormous value provided by the open oceans and remind people not to discount their contribution to human society. By contrast, our study provided a reference valuation data for managing the open ocean ecosystems from the perspective of tradeoff, including the challenges of "ecosystem-based management approach", "marine protected area (MPA)" settings, deep-sea resources exploration and other practical applications.

3.3.1 Low WTP for provisioning service (food)

On average, Japanese are consuming about 57kg of seafood per year. They are ranked sixth in the world, and are consuming more than twice the seafood per capita as people in the United States or Canada (MAFF, 2014). Seafood captured through deep-sea and offshore fishing activities is common part of Japanese cuisine. Compared with both the

CO_2 absorption and water purification services, however, the results indicate a relatively low marginal WTP for the provisioning service (fish production) (Table 3.3). One possible explanation is that increased fish production does not translate into direct benefits for normal residents, and only brings increased income to fishers or others involved in the fishing industry. Unlike the fish production service, there is no intermediary for transferring the benefits of increased CO_2 absorption and water purification to normal residents. Another explanation is that CO_2 absorption or water purification play vital roles as regulating services in maintaining human well-being. However, as just one of various types of food, seafood can be replaced by alternatives such as livestock, aquaculture products, or kinds of terrestrial agricultural products. In recent decades, a dietary shift has become evident in Japan, as meat consumption steadily grows in converse to fish consumption. In fact, meat consumption outpaced fish consumption for the first time in 2006 (FA, 2011). As a result, this may explain why low marginal WTP was observed for the provisioning service *vis-à-vis* the two vital regulating services.

3.3.2 Regional differences in marginal WTP for OPES

Concerns about global warming have drawn lots of public attention to the large capacity of oceans to mitigate rising temperatures and sea levels (Stocker *et al.*, 2013). The comparatively high marginal WTP for the ocean's CO_2 absorption capacity shown in this study suggests that the general public places high importance on the role of the open oceans in mitigating global warming.

As in other parts of the world, residents living in different regions across Japan have different traditional food cultures (Ashkenazi & Jacob, 2003). It is demonstrated in Table

3.3 that the value people place on food services (marginal WTP) changes depending on where they live. People living along Japan's Pacific coast (Tokyo, Shizuoka and Osaka) had higher marginal WTP than those living on the Sea of Japan side (Ishikawa) or in a landlocked area (Nagano). This result matches the suggestion by Wakita *et al*. (Wakita *et al*., 2014) that utility of marine ecosystem services may fluctuate in accordance with the scarcity of the services in their places of residence.

On the other hand, marginal WTP for water purification and CO_2 absorption capacity are both higher than for the provisioning service, with this trend being especially strong in Tokyo and Nagano compared with the other study areas (Table 3.3). One possible interpretation aside from scarcity (Wakita *et al*., 2014), is that air and water pollution have been a frequently topic in terms of the impacts of the Fukushima nuclear power plant accident following the Great East Japan Earthquake of 2011. Likewise, the absolute distance between Fukushima and Tokyo/Nagano is shorter than for the other three regions, perhaps leading to higher expectations for the open ocean's role in purifying the environment. One survey conducted by the Ministry of the Environment of Japan, for example, showed that 45.2% of Japanese wanted further emphasis to be placed on the importance of the natural environment and living environment (MEJ, 2013).

Above all, the regional variation in the results shows the importance of considering regional differences when attempting to reach consensus on future marine policy-making.

3.3.3 Higher income leading to higher marginal WTP

A positive correlation was observed between household income levels and marginal WTP (Table 3.4a), with marginal WTP for OPES following an increasing, concave function against mean household income. This result is consistent with the past literature, which found a positive relation between WTP for public ecosystem services and mean household income level (Baumgärtner *et al.*, 2012). Similar phenomenon were also observed between income levels and WTP on biodiversity conservation (Jacobsen & Hanley, 2009). In the case of Canada, WTP surveys found that higher income levels led to higher donations for wildlife conservation (Yen *et al.*, 1997). Meanwhile, no correlation was found between marginal WTP and the age of the respondents regarding each OPES (Table 3.4b). Although the relationship between income level and age has been assessed by the government (SBJ, 2014), we noted that few studies have demonstrated the relationship between donor action and age. The results of our case study help to bridge this gap in the literature.

3.3.4 Gender differences for marginal WTP for OPES

The influences of gender on volunteering activities vary according to country (Musick & Wilson, 2007). In Japan, women are more likely to join in volunteer activities than men. Based on a breakdown of categories, in Japan, women were more likely to volunteer for health-related activities, e.g. helping the elderly, the handicapped and children; joining environmental conservation activities, and engaging in disaster relief. Men, on the other hand, were more likely to volunteer for activities related to sports, culture and the arts, and public safety (MIAC, 2002). Our questionnaire stated that donations would be used to set up a foundation to improve OPES, which can be considered to be a form of environmental conservation.

Interestingly, although some general statements can be made about the overall values of men and women in Japan, when the data is broken down into each prefecture, clear trends disappear, which shown a possibility of small sample size. This result suggests underlying trends and the need for more extensive research into the gender dimensions of values on a regional basis (Table 3.5).

Table 3.1. Attributes of respondents

		Number	Percentage
Total		814	100.00%
Prefecture	Ishikawa	157	19.3%
	Nagano	175	21.5%
	Osaka	141	17.3%
	Shizuoka	168	20.6%
	Tokyo	173	21.3%
Gender	Male	420	51.6%
	Female	394	48.4%
Age	20~29	133	16.3%
	30~39	180	22.1%
	40~49	166	20.4%
	50~59	155	19.0%
	60~69	180	22.1%
Educational background	Less than high school	21	2.6%
	High school graduate	271	33.3%
	College under 4 years	174	21.4%
	Bachelor's or higher degree	338	41.5%
	Others	2	0.2%
	No answer	8	1.0%
Annual income (JPY)	0~3 million	30	15.3%
	3~6 million	276	33.9%
	6~9 million	149	18.3%
	9~14 million	74	9.1%
	14~ million	33	4.1%
	No answer	158	19.4%

Table 3.2. Conjoint analysis results based on survey answers using a conditional logit model.

	Total	Conjoint analysis results by region (t-statistic)				
		Tokyo	Ishikawa	Nagano	Shizuoka	Osaka
Fish (β_1)	.0026	.0057	.0011	.0001	.0035	.0039
	(1.73) *	(1.71) *	(.32)	(.02)	(1.02)	(1.07)
CO_2 (β_2)	.0089	.0109	.0086	.0091	.0069	.0083
	(7.18) ***	(4.26) ***	(2.92) ***	(3.50) ***	(2.44) **	(2.80) ***
Water (β_3)	.0074	.0104	.0051	.0095	.0045	.0067
	(6.39) ***	(4.27) ***	(1.91) **	(3.85) ***	(1.74) *	(2.41) **
Price (β_p)	-.0005	-.0005	-.0005	-.0004	-.0005	-.0005
	(-38.09) ***	(-17.77) ***	(-17.74) ***	(-16.24) ***	(-17.60) ***	(-15.75) ***
ASC (β_0)	.1246	.1856	.3127	-.0469	.1287	.0753
	(2.11) **	(1.44)	(2.36) **	(-.36)	(1.0)	(.53)
No. of obs.	4884	1038	942	1050	1008	846
Log likelihood	-5777.47	-1237.96	-1083.98	-1265.65	-1168.35	-1000.23
Schwarz B.I.C.	5798.71	1255.32	1101.1	1283.04	1185.64	1017.08

Note 1: Figures in parentheses are test statistics in the t-test. Single asterisk (*), double asterisks (**), three asterisks (***) denote that the t-statistic for comparing with 0 Yen were significant at the 10%, 5%, and 1% levels, respectively.

Note 2: BIC is short for "Bayesian Information Criterion".

Table 3.3. Marginal willingness to pay (2013 Japanese yen/year for 1% improvement)

		Estimates by region				
	All regions	Tokyo	Ishikawa	Nagano	Shizuoka	Osaka
Fish	5.7	12.5	(2.2)	(0.1)	(7.1)	(8.4)
CO_2	19.0	24.1	16.6	21.7	13.9	17.9
Water	15.8	22.9	9.8	22.7	9.2	14.4
Total	40.4	59.5	28.6	44.5	30.2	40.8

Note: Figures in parentheses are not significant at 10% in Table.

Table 3.4a. Marginal willingness to pay of respondents at each income level (2013 Japanese yen/year for 1% improvement)

Stratified Income	0~3 million	3~6 million	6~9 million	9~14 million	14~ million
Fish	(7.5)	(5.1)	(3.3)	40.8	(40.3)
CO_2	12.7	21.6	26.6	22.9	45.1
Water	14.0	19.8	21.7	29.3	33.1

Note: Figures in parentheses are not significant at 10% in Table.

Table 3.4b. Marginal willingness to pay of respondents at each age group (2013 Japanese yen/year for 1% improvement)

Stratified age	20~29	30~39	40~49	50~59	60~69
Fish	16.9	(0.3)	16.3	(-3.0)	(9.5)
CO_2	29.4	18.5	14.5	27.5	19.3
Water	13.9	19.3	11.4	19.2	28.2

Note: Figures in parentheses are not significant at 10% in Table.

Table 3.5. General marginal willingness to pay by male and female respondents (2013 Japanese yen/year for 1% improvement)

		MWTP (Japanese yen/year)	
Areas	Parameters	Male	Female
General	Fish	(6.3)	9.9
	CO_2	20.6	21.4
	Water	15.6	20.7
Tokyo	Fish	23.2	16.5
	CO_2	30.2	27
	Water	26.3	26.6
Osaka	Fish	(-7.4)	28.3
	CO_2	(7.4)	27.1
	Water	(12.6)	21.9
Nagano	Fish	(3.9)	(-5.9)
	CO_2	24.3	17.2
	Water	18.3	25.3
Shizuoka	Fish	(7.1)	(11.2)
	CO_2	(10.8)	20.4
	Water	(3.1)	18.5
Ishikawa	Fish	(6.5)	(9.4)
	CO_2	24	19.1
	Water	18	12.9

Note: Figures in parentheses are not significant at 10% in Table.

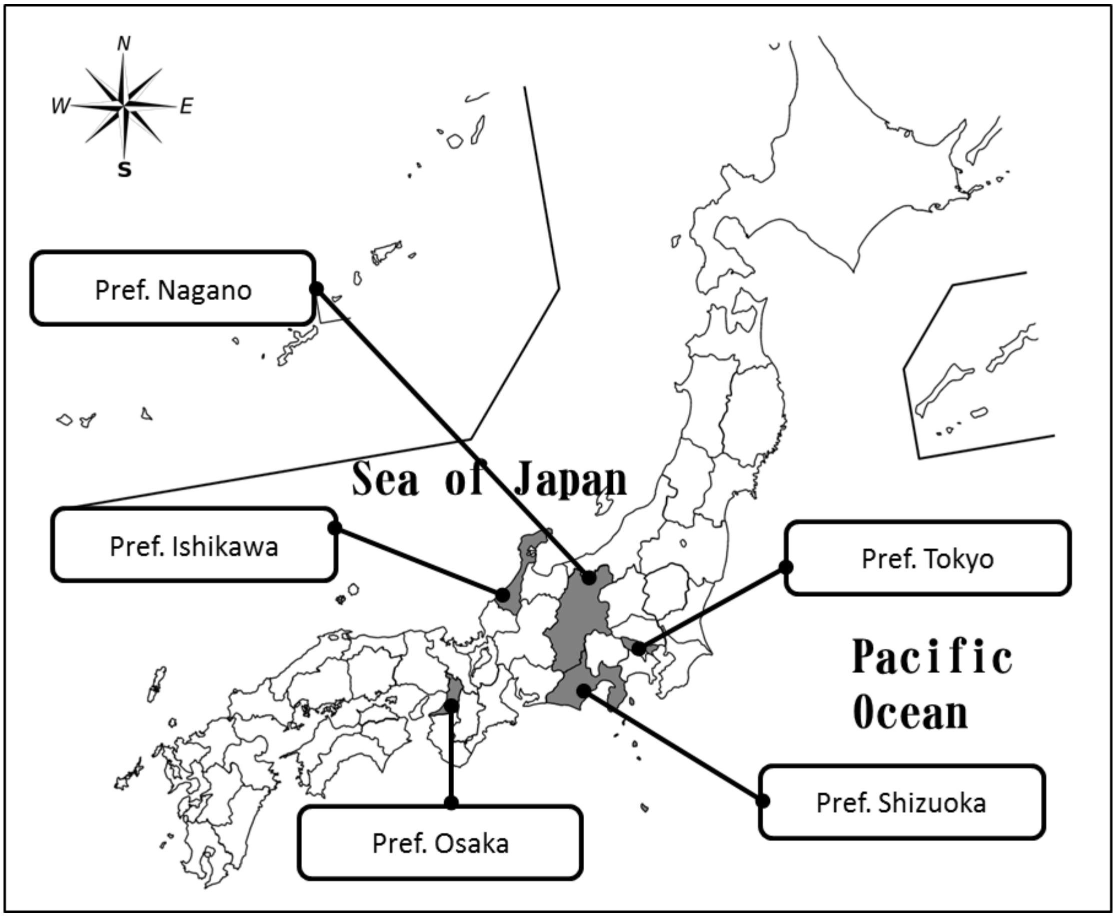

Figure 3.1. Location of each prefecture surveyed in this study.

Purpose of this question set: elicit the general American willingness to pay for ecosystem services of open oceans by the method of "choice-based conjoint analysis".

Please read the following introduction before answering the questions.

The world's oceans are comprised of coastal areas, where the water depth is less than 200 meters (approximately 650 feet) and open ocean areas, where the water depth is 200 meters or more.

Open ocean areas account for 91.5% of the surface area of the world's oceans, most of which is outside the boundaries of any country's territory. These areas, however, provide a broad range of different ecosystem services to human societies around the world.

For example, by absorbing large amounts of carbon dioxide, the ocean plays a role in maintaining stable atmospheric conditions; fish caught for human consumption rely on the food and habitat provided by the ocean; similar to sewage treatment plants, open oceans can also decompose harmful substances and help to purify water.

This study, being conducted by the University of Tokyo, aims to get a deeper understanding of variation across different countries in the willingness to pay for the ecosystem services provided by the open oceans.

For the purpose of this questionnaire, let us assume that a geoengineering technology (Fe fertilization) exists with which the open ocean's ecosystem services can be improved. In order to continuously utilize this technology, operating costs must be paid through volunteer donations.

Based on the information provided above, please answer the following six questions. You will be asked to select from among three different donation levels, each of which is associated with a set of percentage improvements to different ecosystem services. Please select which of these sets you consider most desirable. If none of the options appears appropriate, please select the final option "no satisfactory combination".

Note: Although the options may seem very similar, the percentage increases (5%, 30 or 50%) are different for each option in every question.

Variable	Attribute	Level to increase
fish	Fishery	5% up; 30% up; 50% up
gas	CO_2 absorption	5% up; 30% up; 50% up
nutri	Nutrient cycling	5% up; 30% up; 50% up
price	Willingness to pay	500; 3,000; 5,000

Question 1) which of the four options do you consider most appropriate?

	Option 1	Option 2	Option 3	Option 4
Willingness to pay (US$/year)	$5.00	$30.00	$50.00	No satisfactory combination
Increase in fisheries catch	5%	5%	5%	
Increase in CO2 absorption capacity	5%	30%	50%	
Increase in water purification capacity	5%	30%	50%	

Answer: Option (   )

Question 2) which of the four options do you consider most appropriate?

	Option 1	Option 2	Option 3	Option 4
Willingness to pay (US$/year)	$50.00	$5.00	$30.00	No satisfactory combination
Increase in fisheries catch	30%	30%	30%	
Increase in CO2 absorption capacity	5%	30%	50%	
Increase in water purification capacity	30%	50%	5%	

Answer: Option (   )

Question 3) which of the four options do you consider most appropriate?

	Option 1	Option 2	Option 3	Option 4
Willingness to pay (US$/year)	$30.00	$50.00	$5.00	No satisfactory combination
Increase in fisheries catch	50%	50%	50%	
Increase in CO2 absorption capacity	5%	30%	50%	
Increase in water purification capacity	50%	5%	30%	

Answer: Option (   )

Question 4) which of the four options do you consider most appropriate?

	Option 1	Option 2	Option 3	Option 4
Willingness to pay (US$/year)	$5.00	$50.00	$50.00	No satisfactory combination
Increase in fisheries catch	5%	30%	50%	
Increase in CO2 absorption capacity	5%	5%	30%	
Increase in water purification capacity	5%	30%	5%	

Answer: Option (   )

Question 5) which of the four options do you consider most appropriate?

	Option 1	Option 2	Option 3	Option 4
Willingness to pay (US$/year)	$5.00	$5.00	$30.00	No satisfactory combination
Increase in fisheries catch	50%	30%	50%	
Increase in CO2 absorption capacity	50%	30%	5%	
Increase in water purification capacity	30%	50%	50%	

Answer: Option (   )

Question 6) which of the four options do you consider most appropriate?

	Option 1	Option 2	Option 3	Option 4
Willingness to pay (US$/year)	$50.00	$30.00	$30.00	No satisfactory combination
Increase in fisheries catch	5%	30%	5%	
Increase in CO2 absorption capacity	50%	50%	30%	
Increase in water purification capacity	50%	5%	30%	

Answer: Option (   )

Figure 3.2. Details of the survey questionnaire including six survey questions.

4. Social discount rate of Japanese for public goods: assessing marginal WTP for OPES

4.1 Introduction of questionnaire design

4.1.1 Discount rate: an incentive to invest in environmental protection

Policies such as the decision to invest in a public project or explore/conserve a natural wetland usually generate both costs and benefits. In some cases, benefits do not necessarily return to the "investor" who bear the short-term costs. Cost-benefit analysis (CBA) uses a methodology that aims to reveal the net benefits by comparing the costs and benefits of public investment projects. Another important tool is needed, however, to transform the costs and benefits into the same temporal and spatial dimensions. Discount rates are used in CBA to reveal the net benefits in terms of their present and future values. Furthermore, discount rates not only help decision-makers judge whether a management measure or investment is feasible, but also to evaluate its subsequent performance. In democratic societies, it is necessary to show the expected net benefit when engaging in decision making to explore or conserve public or local environments, ecosystems and projects (Zhuang *et al.*, 2007, Boardman, 2011). Discounting is not only required for decision-making in regards to public investment, but also for the private sector, where companies or individuals invest with consideration for the present value of benefits of an action compared with the costs. Depending on what is being considered, in the public cases, "social discount rates" are usually used (Kolstad, 2011). Despite being such an important concept and effective tool, the estimation of appropriate social discount rates for CBA in public investment projects remains challenging and a source of controversy.

According to basic cost-benefit theory, it is only within a context void of market distortions (also referred to as "perfect competition" in economics) that an appropriate social discount rate can be easily measured (Dasgupta & Pearce, 1973, Zhuang *et al*., 2007). However, in the case of some public and open access goods, perfectly competitive markets rarely exist, making it challenging for decision-makers and academics to identify social discount rates (Howarth & Norgaard, 1993, Howarth & Farber, 2002). As a global commons and open access area, the open oceans continuously provide both tangible and intangible OPES forms that support human well-being, although most OPES are not marketed.

Previous studies have shown several methods to the choice of the social discount rate in the absence of perfect competition, but does not a consensus exist on judging which is the best one (Pearce *et al.*, 2003, Gollier, 2002, Newell & Pizer, 2003). These different cases reflect different thinks on how public investment affects private investment and consumption. Sometimes, long-term projects with impacts lasting for several generations, in this case, the choice of social discount rate became more important since more factors need to be decided, such as global warming problem and other environment issues (Boardman, 2011). People's incentive to invest in marine environments can include factors spanning ocean acidification, ocean warming, hypoxia, sea level rise, pollution and the overuse of marine resources.

Outstanding previous research has focused on coastal and marine areas. Regulatory services provided by marine ecosystems were, for instance, evaluated by Mangi *et al.* (2011), based on their aggregations of discount rates. Concerns associated with the global commons (Nordhaus, 1982) and sustainable development (Harris, 2003, Quiggin, 1997) have also been discussed in terms of discount rates. Sumaila (2004) and (Daw & Gray, 2005) conducted CBA on future fishery resources and international policy, and recently there has been an increase in the number of case studies about MPAs using CBA (e.g. Pascal (2011); Brown *et al.* (2001).

At the same time, as with the definition of social discount rate, there is a concept of time preference rates, which under normal conditions describe the inclination of consumer activities towards present consumption over future consumption. Under normal circumstances, when consumer's future income is expected to be higher than his/her current income, the consumer will have a high time preference rate. Similarly, if the present income is expected to be more than the future income, the consumer will be tend to save even if the interest rate is not so high. Demonstrating the relation between social discount rates and time preference rates is a necessary process before conducting environmental management. To decide on the worth of a project involving public expenditure, CBA must be employed under the assumption that social objectives can be defined in terms of individual preferences and that individuals can weigh up the pros and cons rationally (so that CBA helps to identify societal preferences), even though some difficulties exist in obtaining overall social preferences by aggregating individual preferences (Bouyssou *et al.*, 2009).

Lastly, it is worth mentioning that the CBA approach is not perfect, but should play a role in showing decision-makers which options are most socially preferred (Dasgupta & Pearce, 1973). If CBA cannot be correctly used or appropriately employed by decision-makers, it could have an opposite effect on overall interest, as critically indicated by previous studies. In one example related to fishing activity, it has been found that high discount rates favor myopic fisheries policies, which result in short-term economic efficiency but ultimately global overfishing (Pauly *et al.*, 2002, Clark, 1973). Some basic criticisms of the CBA approach were introduced in Sagoff (1944) and Kelman (1981). Still, the choice of the social discount rate should not only take economic efficiency under consideration, but also intergenerational equity.

In this chapter, a case study is introduced analyzing social discount rates in regards to OPES. The social discount rates of Japanese respondents' marginal willingness to pay for OPES were estimated and the possible application of these results is discussed.

4.1.2 Questionnaire design

As mentioned in Chapters 2 and 3, conjoint analysis (CA) is one of the most widely-used quantitative methods in marketing research. It was originally used to measure preferences for various features of a product and to elicit how changes in prices affect consumer demand for these features. It could therefore be used to forecast the likely acceptance of a product when it was brought to market. In automobiles, for example, CA can be used to reveal which features consumers wish to be improved while maintaining the same price increase: increased speed, comfort or cool design. CA usually involves discrete choice experiments, which are also known as choice-based conjoint analysis. In choice experiments, respondents are not asked to give their WTP for a single scenario, but instead, as stated by Snowball (2008), "are asked to choose between bundles of attributes at different levels that make up the good. Price is usually one of the attributes, which enables the calculation of marginal WTP for each attribute". "This method was firstly developed around half century ago and has been used to elicit residents' WTP for different environmental attributes recently, which can help policymakers to implement management comprehensively and effectively (Pathak & Dikshit, 2006, Cheung & Chung, 2008, Chan-Halbrendt *et al*., 2010)". In recent years, CA was found to not only be efficient at evaluating use values, but also non-use values. It has therefore been extended into applications within the area of environmental economics.

As with the first case study, the questionnaire used for the second study was also prepared in compliance with the guidelines of the ethics committee of The University of Tokyo and consists of two parts: questions used for conjoint analysis and questions aimed at collecting background information about the respondents (gender, age, income, job, educational background). A statement with details about the research was provided at the head of the questionnaire to help respondents answer the subsequent questions accurately. The following questions aims to elicit respondents' marginal WTP for 4 types OPES. Based on discussions of several times with survey experts, the questionnaire was made and developed through a pre-testing conducted on two individuals. Ultimately, a revised version was then retested by setting up a "focus group", consisting of several university students, who were asked to discuss questionnaire's comprehensibility, any problems and concerns. Based on the process and suggestions collected above, a final version of the questionnaire was fixed and then distributed for this study. The distribution of the questionnaire and collection of responses took place from 10-12 August 2013. Through a professional web survey company, the respondents received online points, which can be used for internet shopping equivalent to around Japanese yen (JPY) 60-90. The procedure for conducting the questionnaire was as follows.

First, 1042 (521+521) respondents were randomly selected from Japan's 47 prefectures: The questionnaire was sent to 10,000 adults registered with MACROMILL, who were then randomly selected based on the above conditions from the company's database of over one million registered members. Registrants were asked to choose between answering the Type A or Type B questionnaire, and the differences between the two versions was not explained to the respondent in advance. Registrants who chose Type A were then defined as Group A, while registrants who chose Type B were defined as Group B. The Type A questionnaire was designed to assess respondents' marginal WTP for present OPES. The Type B questionnaire was designed to investigate respondents' marginal WTP for the future OPES (in this case, we set it 100 years later). As a result, 521 responses were selected from each group, creating a total sample of 1,042 respondents.

Next, the representativeness of the respondents was considered in terms of age group. Although 41 of the respondents from Group A and 37 of the respondents from Group B were over 70 years of age, this data was excluded from the sample due to internet usage by people over 70 being below 50% in Japan by the end of 2012 (MIAC, 2013), leading to the assumption that these respondents were not a representative sample of Japan's over-70 population.

Both questionnaires were designed to measure marginal WTP per year of Japanese residents for each OPES. "The Group A respondents were first provided with information that an assumed geoengineering project (iron fertilization) would be conducted "at present" in the open ocean with the aim of improving OPES, including food production, CO_2 absorption, and water purification to a specific level. It is also told that this project would only be supported by an independent and donation-based foundation from the general public. Different levels of improvement to each of the three ecosystem services would be generated by different donation levels. After that, the respondents were asked to answer six questions representing a total of 18 different profiles (6 questions; 3 profiles per question), which produced balanced design based on orthogonal to estimate the each levels of the three attributes. Each question included four options (3 profiles and 1 null choice) and each option represents a different answer of WTP which corresponds to a different combination of improvement levels regarding the 3 main OPES." The Group B respondents followed the same process as Group A except that the assumed geoengineering project would be conducted not "at present" but "100 years later" to improve the OPES at that time.

Ultimately, with the collected questionnaire results, choice-based conjoint analysis was conducted based on a conditional logit model using the statistical software TSP 4.5 (TSP international).

4.2 Results

Distribution of properties of two respondent groups including gender, age, educational background levels, and annual income levels were displayed in Table 4.1.

With the conjoint analysis results in Table 4.2, employing the same methodology described in Chapter 2 and applied in the previous case study in Chapter 3, the marginal WTP (MWTP) was calculated for present and future OPES individually using formulas 1 and 2.

$$V_{ij} = \beta_0 ASC + \beta_1 * V_{fishery} + \beta_2 * V_{CO_2} + \beta_3 \times V_{water} + \beta_p \times V_{price}; \quad (1)$$

$$MWTP_{x_1} = -\beta_x / \beta_p . \quad (2)$$

It can be calculated that the total MWTP for the three present OPES is JPY 43.4 (USD ~0.43), including JPY 4.6 (USD ~0.05) for fish supply capacity, JPY 20.9 (USD ~0.21) for CO_2 absorption capacity and JPY 17.9 (USD ~0.18) for water purification capacity. Likewise, the total marginal WTP for the three future OPES is JPY 61.7 (USD ~0.62) including JPY 12.5 (USD ~0.13) for fish supply capacity, JPY 29.1 (USD ~0.29) for CO_2 absorption capacity and JPY 20.0 (USD ~0.20) for water purification capacity. These general results (Table 4.3) show that, for the three main OPES, the MWTP for the future is higher than for the present, particularly for the services of fish supply capacity and CO_2 absorption capacity.

If we use the results of present and future MWTP got above and based on the discounted utility model (Samuelson, 1937) to calculate people's time preference rate, a negative value will be got. The calculating process can be shown for short as below:

If we set U_t as person's cardinal instantaneous utility (in this case, utility of 100 years later improvement on OPES, "intertemporal utility function" U_p' therefore can be shown as

$$\mathrm{U}_p' = \sum_{\mathrm{t}=0}^{100} \beta_t \mathrm{U}_t \tag{3}$$

In formula 3, β_t is one's discount function, showing relative weight one attaches in period *t*:

$$\beta_t = \left(\frac{1}{1+\delta}\right)^t \tag{4}$$

In formula 4, δ represents the individual's pure rate of time preference. Likewise, U_p (utility of present improvement on OPES) can also be shown as formula 4.

$$\mathrm{U}_p = \sum_{t=0}^{0} \beta_0 \mathrm{U}_0 = \frac{1}{(1+\delta)^0} \times \mathrm{U}_p \tag{5}$$

During the questionnaire design process, we assumed that the marginal utility of OPES's improvement equal to people's WTP for them, they can be shown in formula 6 and 7, separately.

$$\mathrm{U}_p' = \mathrm{V}_p' = 61.7 \tag{6}$$

$$\mathrm{U}_p = \mathrm{V}_p = 43.4 \tag{7}$$

From formula 3 and 6, we can get formula 8

$$\frac{\mathrm{U}_{100}}{(1+\delta)^{100}} = 61.7 \tag{8}$$

Likewise, by combining formula 5 and 7, we can get formula 9

$$\mathrm{U}_p = 43.4 \tag{9}$$

During the questionnaire design process, we assumed that OPES will not change during next 100 years, which can be expressed as formula 10

$$\mathrm{U}_p = \mathrm{U}_{100} = 1\% \text{ improvement of OPES} \tag{10}$$

Above all, we can get formula 11 by combining formula 4, 8, 9, 10

$$\frac{1}{(1+\delta)^{100}} = \frac{61.7}{43.4} \tag{11}$$

Therefore, people's time preference rate for general OEPS $\delta_{General}$ can be calculated as

$$\delta_{General} = \left(\frac{\mathrm{U}_p}{\mathrm{U}_p'}\right)^{\frac{1}{100}} - 1 = \left(\frac{43.4}{61.7}\right)^{\frac{1}{100}} - 1 = -0.35\% \tag{12}$$

By modifying formula 12 for individual OPES, we can likewise calculate values for δ_{Fish}, δ_{CO_2}, and δ_{Purif}. Based on the estimated present and future MWTP and formula 12, the discount rates for fish supply capacity δ_{Fish}, CO_2 absorption capacity δ_{CO_2} and water purification capacity δ_{Purif} for the next 100 years are -1.01, -0.33 and -0.11 respectively.

Here, if we don't consider the time preference rate δ should be negative or positive, following the notion of Kolstad's (2010), δ can be defined as the individual's pure rate of time preference in formula 13. The value of property will grow through investment at an annual rate of g, which should be taken into account when comparing one generation to another. Let η be the value of the elasticity of the marginal utility of consumption, representing the curvature of the utility function. In other words, η shows how much marginal utility should go down if consumption increases by 1% (Dasgupta, 2007).

$$r = \eta g + \delta \quad (13)$$

In the case of Japan, annual consumption growth rate (g) was published by the Bank of Japan every year and in 2013 the data is 2%[10]. Following formula 13 described above, if we follow previous research assuming the value of the elasticity of the marginal utility of consumption η to be 1, and use the δ value can be calculated.

Against anticipation, there were no obvious MWTP trends observed at different educational levels for present or future OPES (Table 4.4). On the other hand, the MWTP for present OPES at each of the five stratified income levels indicated by respondents was also assessed and found to be positively correlated.

The same comparison with income levels was conducted for future OPES and once again neither positive nor negative correlations were found. The middle level income group, however, indicated a particularly high value compared with the low or high level income groups. This trend may be taken into consideration when governments develop environmental protection plans in the future (Table 4.5).

[10] Annual consumption growth rate in 2013: www.stat.go.jp/english/data/handbook/c0117.htm, accessed on Dec. 15th 2014.

4.3 Discussion

Few studies have focused on time preference rates of common "ecosystem services" aside from previous research by Dasgupta (2007) and Mangi *et al*. (2011), although some papers exist on similar studies regarding "environment" and "climate change" discount rates. These rates are used to transform the future benefit or cost into "net present value" (NPV) to compare with the present benefit or cost, so that time preference rates δ is a key variable for the CBM during decision-making process. People use it as a tool to judge whether a project (good) is worth investing in. For a long period, negative time preference rates were considered to indicate poor investment opportunities. Quiggin (1997) pointed out that controversies over discounting for time and risk had become an issue in sustainable environmental management. Weitzman (1998) pointed out that the discount rate of investing r in the environment should be considered as "catastrophe insurance", hence a negative time preference rate should also be applied in environmental policy-making processes. At the same time, social discount rates continued to attract more attention until Stern *et al*. (2006) discussed the importance of social discount rates on climate change from an economics viewpoint. At the same time, as a prerequisite, discount rates have been applied in climate impact assessment models (Fleurbaey & Zuber, 2012, Weitzman, 2012).

The higher MWTP for the future OPES improvement implies that people consider the OPES to be different from "normal market goods", which always have a positive value. The higher MWTP for the future OPES improvement, we can speculate that people are looking forward to a better protection from OPES in the distant future. In other words, people are more worried about OPES 100 years later than in the present. As shown by the results noted above, if we assigned both the present and future MWTP results into discounted utility model, negative discount rates are found for each of the three OPES (-1.01, -0.33 and -0.11 for fish production, carbon dioxide absorption, and water purification, respectively), with a general time preference rate of -0.35.

Furthermore, as mentioned in Chapter 4.1, positive or negative value of social time preference rate reflect whether a public project is expected to be invested or not. From the relation shown in formula 14, social interest/discount rate (r) is decided by the individual consumption growth rate (g) and the social time preference rate (δ) calculated in Chapter 4, simultaneously. At the same time, it had been proved that social interest/discount rate (r) related to individual consumption economic growth (g) (Arrow *et al.*, 2013). Moreover, climate impacts play a critical role on economic growth (g) had also been a widely accepted fact (Weitzman, 2012). Thus, with the higher MWTP on future OPES revealed in this study, more efforts in future study should be made for clarifying the relationship between economic growth, time preference rate and social discount rate, which helpful to conduct a low-cost high-payback investment on environmental projects.

On the other hand, as an extended interpretation of the Ramsey's (1928) theory, the future generation can inherit utility from improvements made to ecosystem services by the present generation. When social discount rate $r < 0$, utility of present improvement on OPES (U_p) should shows a higher value than utility of present improvement on OPES (U_p'), namely, $\mathrm{U}_p > \mathrm{U}_p'$ should be observed. From results shown in this chapter, negative time preference rate data (δ) has shown a possibility that leading to a negative social discount rate (r). Thus, utility of present improvement on OPES (U_p) and utility of present improvement on OPES (U_p') should have a relation as $\mathrm{U}_p' > \mathrm{U}_p$, which contradictory with Ramsey's theory and discounted utility model.

It is worth mentioning that there are some inadequacies needed to notice when one applying discounted utility model to calculate the discount rate. The first is that discount rates are not constant over time, which pattern are described as hyperbolic discounting. The second is discount rates shows large difference between gains and losses, small amounts and large amounts, or multiple outcomes and outcomes considered singly. Another feature of the discounted utility model is positive time preference. Some previous researches have shown that time preference should be positive on logical grounds (Hirshleifer & Hall, 1970, Olson & Bailey, 1981, Parfit, 1982). Negative preference rate leading to a positive rate of return on saving, which would cause the infinite delay of all consumer action. In response to the anomalies of applying of discounted utility model, a variety of alternative models have been developed and can be considered as candidates to alternate discounted utility model in the future study (Frederick *et al.*, 2002). We list a few models here: models of hyperbolic discounting can help to deal with the problem of inconsistent anomaly in discounted utility model, in which case, the level of information people grasping will strongly influence their time preference rate; habit-formation models, the utility from present consumption can be influenced by past consumption, as the people's taste changing over time, details about this model can following (Pollak, 1970, Ryder & Heal, 1973); reference-point models, incorporate ideas from prospect theory, time preference rate might depend on past consumption, expectations and such. Using this model one can response to the problem as the time preference differences between gain and loss; mental-accounting models can contribute on deal with the problem of time preference differences between small and large money amount, see Thaler (1985) and Thaler (1999) for more details.

The reason of higher future MWTP for OPES may be explained as that people consider ecosystem services to be separately beneficial to the present and future generation; present-day improvements to ecosystem services are only beneficial to the present generation, while improved ecosystem services in the future are only beneficial to the future generation. Meanwhile, the higher future MWTP improvement of OPES probably results from two reasons, one is altruistic feelings in the present generation; another possibility is related to the notation in the questionnaire that people live in today may worried about the risk of conducting the clean technology nowadays, but less worried to be conducted in the future, which leading to a higher MWTP to conducted this uninsured clean technology in the future so that avoid happened in the near. The obviously positive correlation for present MWTP and income levels verifies the conclusion of the first survey. However, the future MWTP shows a non-fixed trend. The middle level income group, in particular, demonstrated an especially high value. This trend may also be considered when the government develops environmental protection plans in the future.

Table 4.1. Distribution of respondent characteristics

Total		480	100.0%	484	100.0%
Gender	Male	229	47.7%	230	47.5%
	Female	251	52.3%	254	52.5%
Age	20~29	66	13.8%	66	13.6%
	30~39	90	18.8%	91	18.8%
	40~49	85	17.7%	84	17.4%
	50~59	83	17.3%	82	16.9%
	60~69	156	32.5%	161	33.3%
Educational background	Less than high school	13	2.7%	12	2.5%
	High school graduate	144	30.0%	145	30.0%
	College under 4 years	112	23.3%	113	23.3%
	Bachelor's or higher	209	43.5%	213	44.0%
	No answer	2	0.4%	1	0.2%
Annual income (JPY)	0~3 million	80	16.7%	93	19.2%
	3~6 million	187	39.0%	139	28.7%
	6~8 million	68	14.2%	63	13.0%
	8~10 million	35	7.3%	37	7.6%
	10~ million	27	5.6%	35	7.2%
	No answer	83	17.3%	117	24.2%

Table 4.2. Conjoint analysis results based on survey answers using the conditional logit model.

	Conjoint analysis results by different periods (t-statistic)	
	A) Present (480 respondents)	B) Future (484 respondents)
Fish (β_1)	.0024	.0056
	(1.17)	(2.83) ***
CO_2 (β_2)	.0108	.0130
	(6.63) ***	(8.39) ***
Water (β_3)	.0093	.0089
	(6.18) ***	(6.19) ***
Price (β_p)	-.0005	-.0004
	(-31.78) ***	(-29.32) ***
ASC (β_0)	.3272	.1511
	(4.29) ***	(1.95) *
No. of obs.	2880	2904
Log likelihood	-3979.64	-4021.01
Schwarz B.I.C.	3983.63	4025

Note: Figures in parentheses are test statistics in the t-test. Single asterisk (*), double asterisks (**) and triple asterisks (***) denote that the t-statistic for comparing with JPY 0 were significant at the 10%, 5%, and 1% levels, respectively.

Table 4.3. Marginal willingness to pay (2013 JPY per year for 1% improvement) for present and future OPES.

	Estimates by periods	
	WTP for 1% present improvement (U_p)	WTP for 1% 100 years later improvement (U'_p)
Fish	(4.6)	12.5
CO_2	20.9	29.1
Water	17.9	20.0
Total	43.4	61.7

Note: Figures in parentheses are not significant at 10%.

Table 4.4. Marginal willingness to pay of respondents with different educational backgrounds (2013 JPY per year for 1% improvement)

	Stratified Income	Less than high school	High school graduate	College under 4 years	Bachelor's or higher
Present	Fish	(4.7)	11.8	(-3.3)	(5.4)
	CO_2	(14.0)	9.8	27.2	25.1
	Water	(24.6)	(7.5)	18.9	24.2
	Total	43.3	29.1	42.8	54.7
Future	Fish	(-20.5)	(11.0)	(4.6)	19.5
	CO_2	(38.7)	17.5	23.9	42.3
	Water	(6.9)	31.9	14.5	15.7
	Total	25.0	60.4	42.9	77.5

Note: Figures in parentheses are not significant at 10%.

Table 4.5. Marginal willingness to pay of respondents at each income level (2013 JPY per year for 1% improvement)

	Stratified Income	0~3 million	3~6 million	6~8 million	8~10 million	10~ million
Present	Fish	(-11.6)	(9.6)	(6.4)	31.2	(22.4)
	CO_2	21.2	16.4	27.7	(17.3)	33.9
	Water	(7.3)	18.2	29.8	23.5	40.6
	Total	16.8	44.2	63.9	72.0	96.8
Future	Fish	(6.5)	13.4	43.2	(16.3)	(9.1)
	CO_2	27.1	20.5	47.5	39.1	46.1
	Water	(9.7)	22.2	31.0	(10.3)	(9.3)
	Total	43.4	56.1	121.8	65.8	64.5

Note: Figures in parentheses are not significant at 10%.

5. General discussion

The purpose of this study is to provide a reference framework that aids policy-makers and managers to establish guidelines for sustainable OPES management. There is currently almost no interface between the general public and the governance regimes for the open ocean. This should not, however, be an obstacle for attempting to achieve sustainable management of the world's largest commons. Reasonable methods should be supplied for decision-makers to consider the current context of the global environment during the development and implementation of policies.

Various valuable and successful experiences in coastal area management have already been accumulated; these should be consulted when conducting open ocean management activities. However, the limited availability of data and evaluation methods for the open ocean has already delayed the development of sustainable management mechanisms. That's why this research has aimed to supply a new method and source of data for specific applications, e.g. in relation to ecosystem-based management, high seas marine protected areas, etc.

Given the urgency and necessity of OPES research (Chapter 1) and the inadequate evaluation methods for OPES used in previous research (Chapter 2), the value of this study is in its supplemental evaluation of OPES. Specifically, two case studies are used to reveal WTP (Chapter 3) and the social discount rate of Japanese for OPES using a conjoint analysis method (Chapter 4).

5.1 From theories to practice: the specific contribution of this research

Human activities have directly (fishing and shipping) or indirectly (greenhouse gas and ocean acidification) led to a series of changes in OPES. In some cases, growth in one OPES has resulted in decreases in another. In other cases, increases in well-being in terrestrial and coastal areas has led to decreases in the open oceans: Karl's research group (Kim *et al.*, 2014) shows the latest findings related to anthropogenic nitrogen emissions from northeastern Asia, potentially leading to changes in the North Pacific from primary production being nitrogen-limited to becoming phosphorus-limited in the future, possibly causing changes to most OPES. An inverse correlation exists between the natural capital of ecosystem services and their marginal value; therefore, a continuing state of decline will inevitably lead to a high marginal value of OPES (Figure 5.1). The rising value of OPES, which has been considered commonplace until recently, will probably become an unstable social and economic factor. Therefore, in order to prevent these changes, higher-level joint management on OPES is urgently needed.

Common challenges are not just facing OPES, but also the establishment of "joint management" of common resources and environments on a large scale (like the link between carbon emission permits and global warming). Namely, consideration is needed on how to distribute costs and share benefits. To deal with this commons problem, several issues must be addressed. First, a better understanding is needed of how these common resources and environments are treated and recognized by people, not just as defined by policy-makers or researchers. This will help policy-makers identify people's motivations for protecting the environment, and then help them to develop more feasible policies. Substantial progress had been made towards addressing this issue by Wakita *et al*. (2014), who found significant differences in the recognition and classification of marine ecosystem services by researchers and the general public.

In addition, better understanding is needed of the value of shared resources and environments, which will help people to judge the returns that can be expected by specific actions. Poorly informed actions may result in inefficiencies at other sites while trying to protect another. Shen *et al.* (2015) (introduced in Chapter 3 of this thesis) have conducted a case study on Japanese residents regarding OPES, which helps to clarify trade-offs among different OPES or different stakeholder groups and to maximize cost-benefit outcomes.

Another problem needing to be resolved is that the beneficiaries of actions aimed at protecting “common resources and environments” are often not the present generation, which would generate questions about how to distribute the obligations and rights across different generations. Both the concepts of “altruism” and of “a gift to future generations” may influence the behavioral motivations of the present generation to protect the environment and commons. Clarifying people’s time preference rate and social discount rate could not only contribute to balancing issues of obligations and rights when taking specific actions, but could also provide effective tools to help decision-makers realize the difficulties they can expect when engaging in environmental protection activities. Therefore, an effort was made to address this issue in Chapter 4 of this thesis, which introduces the social discount rate results on three main OPES using the conjoint analysis method.

It is worth mentioning that higher MWTP for future OPES improvement than present in Chapter 4, which will leading negative time preference rate, indicating that social discount rate of OPES is not suitable to be calculated by discounted utility model.

5.2 Application of the present research results

This section discusses the possible applicability of this study to processes of developing and implementing policies.

5.2.1 Considering the environmental costs in GDP

Gross national product (GNP) and Gross domestic product (GDP) are still being employed as critical indicators of the economic condition of a region or country, as well as for assessing the governance ability of administrators. However, actions like depletion of wildlife species, which narrow the options of future generations, and environmental pollution, which is degrading the quality of people's lives, cannot be totally reflected in simple GDP or GNP figures. Similarly, "Agenda 21", a conference report published by UNCED in 1992, also pointed to the problem that "Commonly used indicators such as the gross national product (GNP) and measurements of individual resource or pollution flows do not provide adequate indications of sustainability (Chapter 40 "Information for decision-making" of Agenda21 (1992))". Therefore, new indicators need to be developed to ensure sustainable development. In order to achieve this goal, the United Nations recommended to import the System of integrated Environmental Economic Accounting (SEEA[12]) into the traditional System of National Accounts (SNA) as one of the satellite accountings for SNA (SEEA, 1993). Within this context, new approaches for assessing environmental pollution and natural costs into social economic figures have been

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[12] See more details from Integrated Environmental and Economic Accounting 2003 from: http://unstats.un.org/unsd/envaccounting/seea2003.pdf (accessed on 2014/12/10)

challenged, including the natural capital accounting (NCA) by Wealth Accounting and the Valuation of Ecosystem Services (WAVES) in Spain and the Eco Domestic Product (EDP: One kind of the "green" GDP[13]) proposed in Japan.

However, aside from fishery production (food service), OPES provided by areas beyond national jurisdiction do not have a direct market value, meaning that the environmental costs of OPES will not be reflected into any country's GDP or "green" GDP. These conditions are unique within the global ecological system. Therefore, in order to achieve sustainable management of the open oceans, research is urgently needed that can provide the basic monetary data for helping conduct assessment approaches.

Similar to the concept of GDP, it is time to propose a concept that can be called Gross Oceanic Product (GOP) or Gross Global Product (GGP). These concepts differ from the GWP (gross world product) and GGDP (global gross domestic product), because they not only add up the GDP of all countries in the world, but would also take the environmental costs and outputs of the open oceans into consideration. Results introduced in this thesis (WTP for OPES) could contribute to assessing the monetary value of the environmental costs of open oceans within the context of global warming and ocean acidification related to climate change, providing further data to support "green" GDP accounting for the world.

[13] Two representative green GDP systems are the Genuine Progress Indicator (GPI) and the Index of Sustainable Economic Welfare (ISEW) Talberth, J. and A. K. Bohara, 2006: Economic openness and green GDP. *Ecol Econ,* **58,** 743-758..

5.2.2 Providing data for a global economic growth model and integrated assessment models

Natural capital and ecosystem services also contribute to local and global economic growth. When predicting global economic trends using a global economic growth model, which is an important diagnostic tool used by decision-makers as part of an integrated assessment model for CBA (Figure 5.2), monetary assessments of terrestrial and coastal ecosystem services are often used as key data for improving the model's predictive capacity. Based on a literature review, however, OPES have not yet been incorporated into any local or global economic growth models. Since open oceans are open access areas and constitute the Earth's largest ecosystem, despite the slow rate of change in the functions supporting each OPES, any such change may carry enormous impacts for global economic development that are unlikely to be reversible over the short term. This is why OPES should be considered in global economic models. Results derived from this research (including WTP and social discount rates) constitute an important complement to the body of OPES evaluation research and contribute to the growing body of data for conducting CBA and improving the accuracy of economic models.

5.3 Limits of this research

5.3.1 Results of the case study are not representative on a global scale

Although this study provides important data for evaluating OPES, some limitations should be mentioned here.

As the case study was carried out within a single country, data in this research cannot be directly applied to evaluations of the global oceans. For example, as described in

Chapter 3.3.1, Japan is a maritime nation surrounded by oceans, while at the same time, is an OECD member with high income and educational levels. Therefore, all these factors may lead to relatively higher literacy about the oceans and lead to the results having limited representativeness for global OPES. If the same survey were conducted for inland or developing countries, it is not difficult to imagine that totally different results would be collected. Therefore, if the results of this study are applied directly to worldwide OPES assessments, the outcomes would be highly questionable.

As a complementary measure, one can choose among a number of samples from other developed and developing countries to perform more extensive case studies to gain relatively more representative data. Based on this viewpoint, the greatest significance of this study is in providing a useful template for conducting these broader case studies.

5.3.2 The possibility of bias when applying the conjoint analysis method

This study introduces exploratory research in area of OPES assessment. In this study, online questionnaires were chosen because following the enactment of the "Act on the Protection of Personal Information" in Japan, relevant authorities have been careful about providing personal information, such as addresses. Hence, surveying using random sampling has become difficult in Japan. In addition, citizens have also become more sensitive about providing personal information, and the problem of recovery rate bias also emerges if postal questionnaires are used. At the same time, the number of internet users in Japan has been increasing every year. All of these reasons contributed to the decision to use an online survey. The varying internet penetration rates, levels of participation and educational levels across different countries, however, may amplify bias and hinder the implementation of a multi-country survey, thus affecting the credibility of the results. When implementing this kind of survey in developing countries, data acquisition methods need to be improved to include other options such as telephone, direct interviews with respondents, or sending letters.

Another point worth noting is that it is possible for people answering online questionnaires (respondents) and receiving incentives to demonstrate certain tendencies, leading to "bias". But if the survey is conducted without any incentive factors, some respondents may refuse to answer the questionnaire because of the lack of incentives, generating a different type of bias. At the same time, since the level of incentives is constant, less bias will be generated by the expectation, for example, of receiving a larger incentive for a special answer.

5.3.3 Limited applicability to ecosystem-based marine spatial management

One important application of the CBA in the case of oceans is ecosystem-based spatial management, which has been widely accepted in relation to coastal areas management in recent years (Crowder & Norse, 2008, Halpern *et al.*, 2008, Katsanevakis *et al.*, 2011). At the same time, however, some researchers have also noticed that it is not always beneficial for biodiversity conservation to value the environment in economic terms. Even though ecosystem-based management involves trade-offs between one service and another, it is difficult to reflect biodiversity itself in this process, because calculation of ecosystem services will not always favor conservation. New efforts are needed to express the correct value of biodiversity itself instead of only considering the ecosystem services during policy-making. It is important to avoid letting ecosystem service valuation become "just one argument for the conservation of nature" (Adams, 2014).

5.4 Conclusions and Future Work

5.4.1 General conclusion

In summary, within the current global environment, deeper understanding of the WTP and intergenerational social discount rate for OPES by stakeholders is of immediate significance. Within this context, this study first introduced and compared different classifications and definitions of ecosystem services and generated a list of methodologies with specific reference to the database of The Economics of Ecosystems and Biodiversity (TEEB). Second, this study estimated the monetary value of open ocean ecosystem services (OPES) using conjoint analysis: the value of OPES was defined as equal to people's WTP for OPES. Next, the marginal WTP of Japanese residents for three key OPES was estimated: JPY 5.65 (USD ~0.06) for fish supply capacity (food service), JPY 18.99 (USD ~0.19) for CO_2 absorption capacity (gas regulation service) and JPY 15.78 (USD ~0.16) for water purification capacity (nutrient regulation service), per capita per year. Discrepancies were also found between evaluation results using the conjoint analysis method in this research and alternative methods in previous research: Costanza's (1997) results were estimated to be roughly 10 times higher than our results. Despite Japan's social homogeneity, considerable regional variation exists in WTP, which should be considered in future policy-making processes. Third, we identified factors (gender, income, educational background) that influence the marginal WTP for OPES in the case of Japan: female respondents were found to have a higher WTP than male respondents for improving each of the three OPES;

positive correlations can be observed between marginal WTP and income levels for each of the three OPES; obvious marginal WTP trends were not observed for different educational levels for present or future OPES. At last, compared with MWTP for current, higher MWTP for future OPES improvement is observed. These results indirectly reveals that it is not suitable to calculate the time preference rate with discounted utility model, due to discounted utility model do not supporting a negative discount rate.

5.4.2 Future work

Even though this study has taken a significant step, due to time and funding limitations, the research in this thesis only focuses on the Japanese case. Other attributes such as occupation, education level, religious beliefs, etc. should also be examined in future research. Re-assessing the value (WTP) change when different knowledge is provided to the same respondents can help decision-makers to fix the details of their policies to ensure efficient management in the context of a limited budget. At the same time, previous research has already shown that social discount rates are quite different in different countries (e.g. for UK: Evans and Sezer (2002); for France: Evans (2004); for Italy: Percoco (2007)). When conducting actions aimed at exploiting or protecting resources against the backdrop of multi-national cooperation for OPES, there is a need to carry out separate assessments in each of these countries. Likewise, there is a need for this type of research to evaluate other countries with different cultural backgrounds, contributing to the formation in the future of a socio-economic database. However, considering varying internet penetration rates, levels of participation and educational levels across different countries, this survey methodology may have limited applicability in other locations.

As another important future work which also had be shown in the conclusion in Chapter 4 of this thesis: when considering the social discount rate of intergeneration in the case of OPES, suitable models need to be discussed and chosen out to deal with the problem of negative discount rate that discount utility model do not supporting. To achieve this goal, data eliciting methods need to be improved. Take Chapter 4 as an example, for obtaining people's time preference rate using hyperbolic discounting models, more subdivision interval is demanded, as 5 years, 20 years and 50 years, not only detected the 100 years.

At the same time, additional studies of this kind are needed in other developed and developing countries. These results would help people to gain greater awareness of the importance and value of OPES, and will help policy-makers engage in acceptable and sustainable management. Additionally, efforts are needed to identify which factors are affecting the assessment of WTP (not only the factors we revealed in the first case study, but also natural science factors). This will not only help decision-makers to specifically consider such issues when taking action, but can also prompt natural science researchers to focus on gaps in the body of data to improve the accuracy of OPES evaluation results.

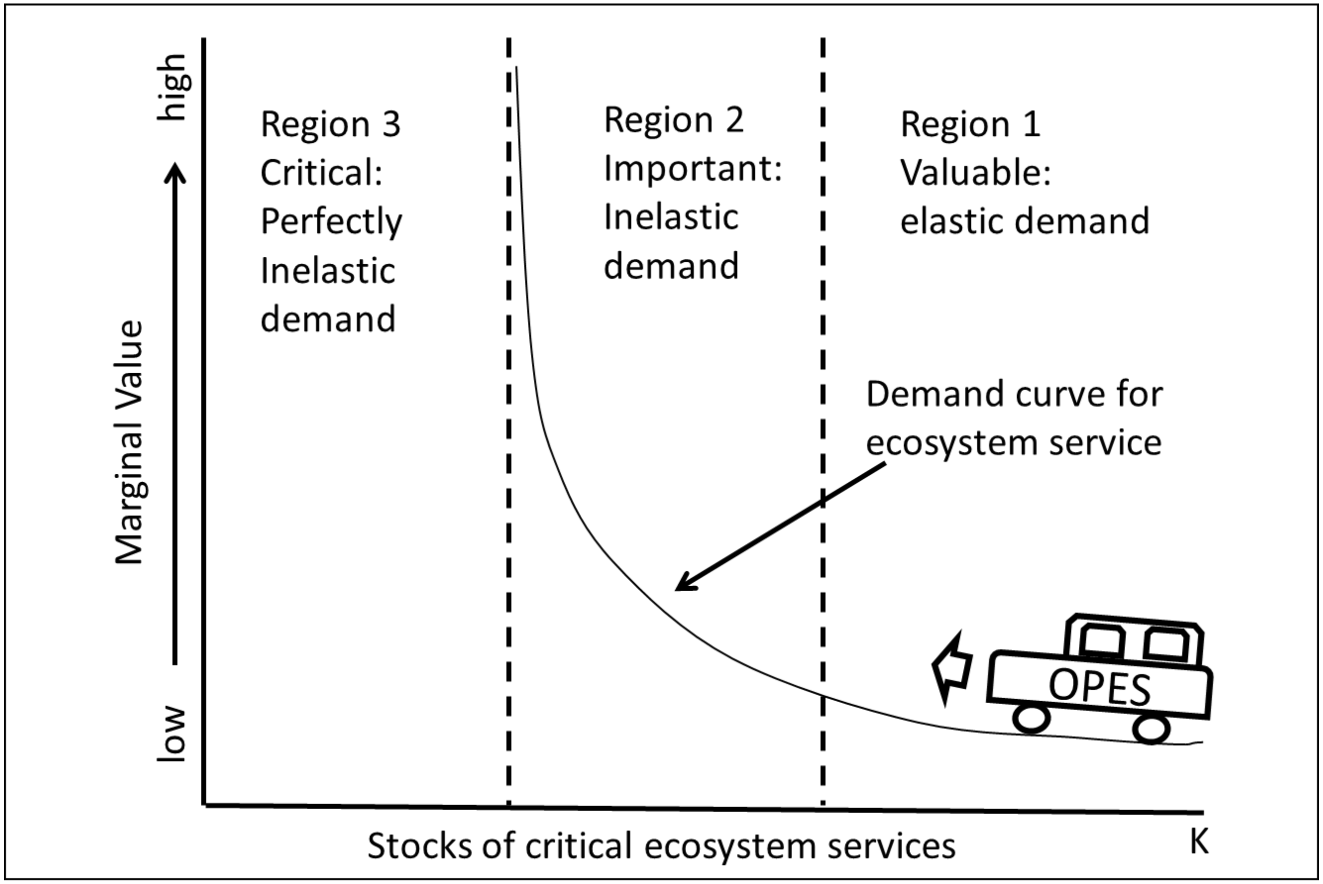

Figure 5.1. Relation between stocks of ecosystem services and their marginal value. OPES is in region 1 but in a declining state.
Source: Adapted from Farley, 2008 (The role of prices in conserving critical natural capital)

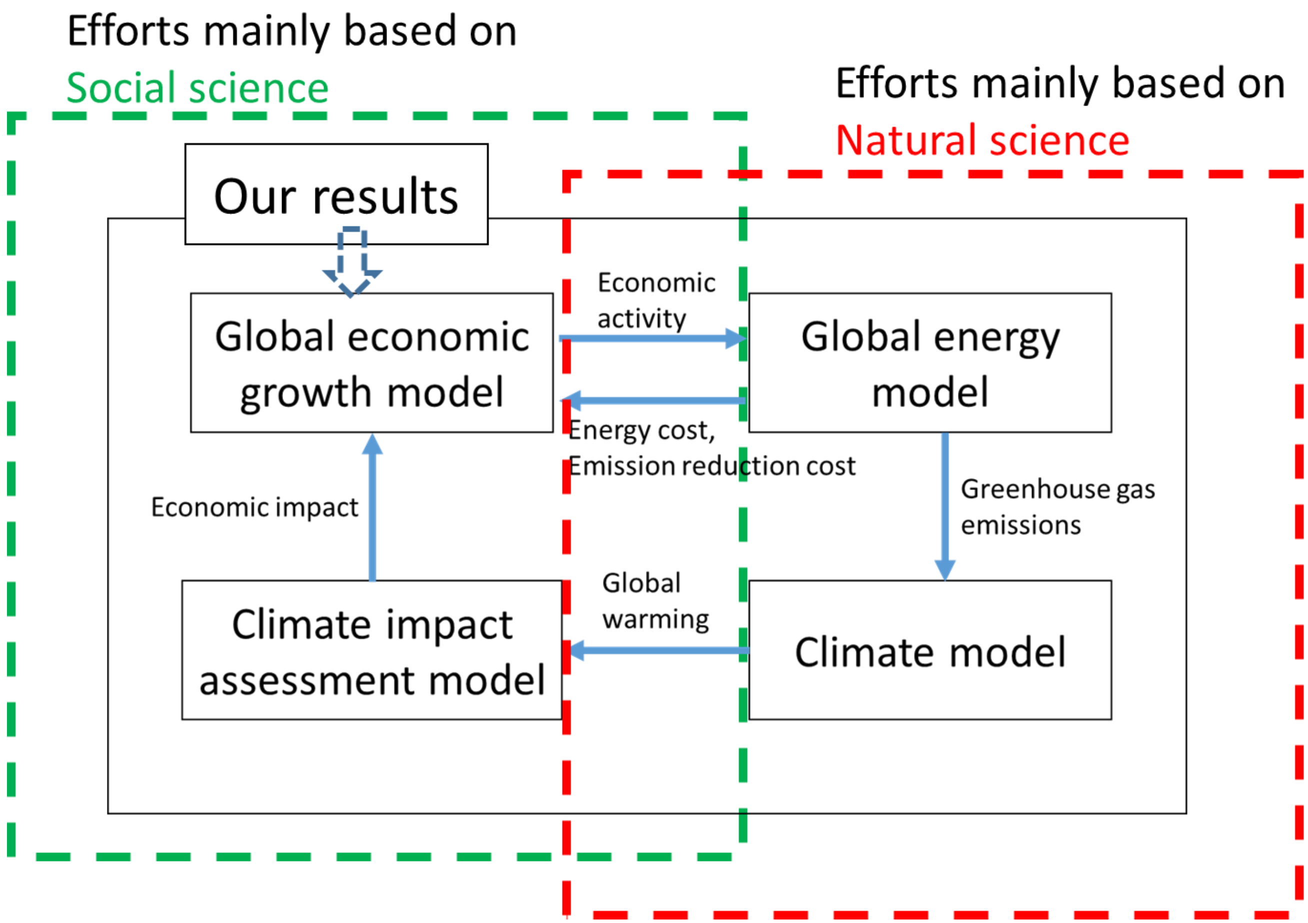

Figure 5.2. Position of our research results in the framework of Integrated Assessment Models (IAM), which combines the four models shown in the black box
Source: IAM image is adapted from (Maeda (2010))

6. Summary

1. This study introduced and compared different classifications and definitions of ecosystem services.
2. A list of methodologies was generated with specific reference to the database of The Economics of Ecosystems and Biodiversity (TEEB).
3. This study estimated the monetary value of open ocean ecosystem service (OPES) using conjoint analysis: the value of OPES was defined as equal to people's WTP for OPES.
4. This study explored Japanese residents' marginal WTP for three key OPES: JPY 5.65 (USD ~0.06) for fish supply capacity (food service), JPY 18.99 (USD ~0.19) for CO_2 absorption capacity (gas regulation service) and JPY 15.78 (USD ~0.16) for water purification capacity (nutrient regulation service), per capita per year.
5. It is found that discrepancies existing between evaluation results of conjoint analysis method in this research and alternative methods in previous research: Costanza's (1997) results were estimated to be roughly over 10 times higher than our results.
6. Despite Japan's social homogeneity, considerable regional variation exists in WTP: which should be considered into the future policy-making process.
7. Identified factors (gender, income, educational background) that influence the marginal WTP for OPES in the case of Japan: female respondents were found to have a higher WTP than male respondents for improving each of the three OPES; positive correlations can be observed between marginal WTP and income levels for each of the three OPES; obvious marginal WTP trends were not observed for different educational levels for present or future OPES.

8. Social discount rates (SDR) between present days and 100 years later regarding OPES were explored and discussed based on the time preference rates we calculated: SDR data can be used to conduct a cost-benefit analysis in the future open oceans management.
9. There are some limits in this research which should be noticed in the future: appropriate survey methods should be chosen based on the conditions of a country, especially in developing countries. Broader case studies are demanded to obtain comprehensive data for practical applications on OPES.
10. This study provides a good template for conducting OPES assessment studies in other countries or areas.

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9. Appendix: questionnaire used in Chapter 4

Questionnaire Items of Group A

Please read the following introduction before answering the questions:

The world's oceans are comprised of coastal areas, where the water depth is less than 200 meters and open ocean areas, where the water depth is 200 meters or more.

Open ocean areas account for 91.5% of the surface area of the world's oceans, most of which is outside the boundaries of any country's territory. These areas, however, provide a broad range of different ecosystem services to human societies around the world.

For example, by absorbing large amounts of carbon dioxide, the ocean plays a role in maintaining stable atmospheric conditions; fish caught for human consumption rely on the food and habitat provided by the ocean; similar to sewage treatment plants, open oceans can also decompose harmful substances and help to purify water.

This study, being conducted by the University of Tokyo, aims to get a deeper understanding in the willingness to pay for the ecosystem services provided by the open oceans.

For the purpose of this questionnaire, let us assume that a clean technology exists with which the open ocean's ecosystem services can be improved. In order to continuously utilize this technology, operating costs must be paid through volunteer donations.

Based on the information provided above, please answer the following six questions. You will be asked to select from among three different donation levels, each of which is associated with a set of percentage improvements to different ecosystem services. Please select which of these sets you consider most desirable. If none of the options appears appropriate, please select the final option "no satisfactory combination".

Note: Although the options may seem very similar, the percentage increases (5%, 30 or 50%) are different for each option in every question.

Question 1) which of the four options do you consider most appropriate?

	Option 1	Option 2	Option 3	Option 4
Willingness to pay (US$/year)	$5.00	$30.00	$50.00	No satisfactory combination
Increase in fisheries catch	5%	5%	5%	
Increase in CO2 absorption capacity	5%	30%	50%	
Increase in water purification capacity	5%	30%	50%	

Answer: (   )

Question 2) which of the four options do you consider most appropriate?

	Option 1	Option 2	Option 3	Option 4
Willingness to pay (US$/year)	$50.00	$5.00	$30.00	No satisfactory combination
Increase in fisheries catch	30%	30%	30%	
Increase in CO2 absorption capacity	5%	30%	50%	
Increase in water purification capacity	30%	50%	5%	

Answer: (   )

Question 3) which of the four options do you consider most appropriate?

	Option 1	Option 2	Option 3	Option 4
Willingness to pay (US$/year)	$30.00	$50.00	$5.00	No satisfactory combination
Increase in fisheries catch	50%	50%	50%	
Increase in CO2 absorption capacity	5%	30%	50%	
Increase in water purification capacity	50%	5%	30%	

Answer: (   )

Question 4) which of the four options do you consider most appropriate?

	Option 1	Option 2	Option 3	Option 4
Willingness to pay (US$/year)	$5.00	$50.00	$50.00	No satisfactory combination
Increase in fisheries catch	5%	30%	50%	
Increase in CO2 absorption capacity	5%	5%	30%	
Increase in water purification capacity	5%	30%	5%	

Answer: (   )

Question 5) which of the four options do you consider most appropriate?

	Option 1	Option 2	Option 3	Option 4
Willingness to pay (US$/year)	$5.00	$5.00	$30.00	No satisfactory combination
Increase in fisheries catch	50%	30%	50%	
Increase in CO2 absorption capacity	50%	30%	5%	
Increase in water purification capacity	30%	50%	50%	

Answer: (   )

Question 6) which of the four options do you consider most appropriate?

	Option 1	Option 2	Option 3	Option 4
Willingness to pay (US$/year)	$50.00	$30.00	$30.00	No satisfactory combination
Increase in fisheries catch	5%	30%	5%	
Increase in CO2 absorption capacity	50%	50%	30%	
Increase in water purification capacity	50%	5%	30%	

Answer: (   )

Questionnaire Items of Group B

Please read the following introduction before answering the questions:

The world's oceans are comprised of coastal areas, where the water depth is less than 200 meters and open ocean areas, where the water depth is 200 meters or more.

Open ocean areas account for 91.5% of the surface area of the world's oceans, most of which is outside the boundaries of any country's territory. These areas, however, provide a broad range of different ecosystem services to human societies around the world.

For example, by absorbing large amounts of carbon dioxide, the ocean plays a role in maintaining stable atmospheric conditions; fish caught for human consumption rely on the food and habitat provided by the ocean; similar to sewage treatment plants, open oceans can also decompose harmful substances and help to purify water.

This study, being conducted by the University of Tokyo, aims to get a deeper understanding in the willingness to pay for the ecosystem services provided by the open oceans.

For the purpose of this questionnaire, let us assume that a clean technology will be developed in the future (100 years later), with which the open ocean's ecosystem services can be improved (Although it is an unrealistic assumptions, please assume that the marine environments and conditions will not change during the next 100 years). In addition, if <u>the cost of developing this technology costs must be paid through volunteer donations for realizing the improvements of open ocean ecosystem services 100 years later (improvement percentages were set in the questions below), how much would you like to donate every year.</u>

Based on the information provided above, please answer the following six questions. You will be asked to select from among three different donation levels, each of which is associated with a set of percentage improvements to different ecosystem services. Please select which of these sets you consider most desirable. If none of the options appears appropriate, please select the final option "no satisfactory combination".

Note: Although the options may seem very similar, the percentage increases (5%, 30 or 50%) are different for each option in every question.

Question 1) which of the four options do you consider most appropriate?

	Option 1	Option 2	Option 3	Option 4
Willingness to pay (US$/year)	$5.00	$30.00	$50.00	No satisfactory combination
Increase in fisheries catch	5%	5%	5%	
Increase in CO_2 absorption capacity	5%	30%	50%	
Increase in water purification capacity	5%	30%	50%	

Answer: (   )

Question 2) which of the four options do you consider most appropriate?

	Option 1	Option 2	Option 3	Option 4
Willingness to pay (US$/year)	$50.00	$5.00	$30.00	No satisfactory combination
Increase in fisheries catch	30%	30%	30%	
Increase in CO2 absorption capacity	5%	30%	50%	
Increase in water purification capacity	30%	50%	5%	

Answer: (   )

Question 3) which of the four options do you consider most appropriate?

	Option 1	Option 2	Option 3	Option 4
Willingness to pay (US$/year)	$30.00	$50.00	$5.00	No satisfactory combination
Increase in fisheries catch	50%	50%	50%	
Increase in CO2 absorption capacity	5%	30%	50%	
Increase in water purification capacity	50%	5%	30%	

Answer: (   )

Question 4) which of the four options do you consider most appropriate?

	Option 1	Option 2	Option 3	Option 4
Willingness to pay (US$/year)	$5.00	$50.00	$50.00	No satisfactory combination
Increase in fisheries catch	5%	30%	50%	
Increase in CO2 absorption capacity	5%	5%	30%	
Increase in water purification capacity	5%	30%	5%	

Answer: (   )

Question 5) which of the four options do you consider most appropriate?

	Option 1	Option 2	Option 3	Option 4
Willingness to pay (US$/year)	$5.00	$5.00	$30.00	No satisfactory combination
Increase in fisheries catch	50%	30%	50%	
Increase in CO2 absorption capacity	50%	30%	5%	
Increase in water purification capacity	30%	50%	50%	

Answer: (   )

Question 6) which of the four options do you consider most appropriate?

	Option 1	Option 2	Option 3	Option 4
Willingness to pay (US$/year)	$50.00	$30.00	$30.00	No satisfactory combination
Increase in fisheries catch	5%	30%	5%	
Increase in CO2 absorption capacity	50%	50%	30%	
Increase in water purification capacity	50%	5%	30%	

Answer: (   )