

## 論文の内容の要旨

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論文題目 : 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)

Due to open access conditions, the open oceans are a common property of humanity, continuously providing goods (food, biochemical matter) and other benefits (climate regulation, disease control, nutrient cycling) that support human well-being, although some of these ecosystem services are still under limited use (genetic resources) or are largely intangible (spiritual, aesthetic). Human activities that impact the ocean environment are now occurring within the context of increasing rates of climate change on a global scale, including associated global warming and ocean acidification. In 2005, the Millennium Ecosystem Assessment (MA) explained how ecosystem services will change in the face of such perturbations, and cautioned that it will not be easy to return to the original state over the short term after such a downward shift occurs. At the same time, the global population exceeded 7.2 billion in November 2014, and is expected to continue growing until the end of the 21st century, adding enormous pressure on both terrestrial and marine ecosystems. A common concern and shared challenge facing all of humanity is therefore the simultaneous achievement of the dual aims of developing human economic society and maintaining open ocean ecosystem services (OPES) in a sustainable state. Within this context, an effective pathway to achieving such win-win conditions is through cost-benefit analysis (CBA). Nevertheless, in the case of ecosystem services without an obvious market and the open oceans, which remain largely unstudied, a range of different valuation data are needed in order to assess the tradeoffs of different management regimes for accurately conducting CBA.

This thesis contains three main parts, in addition to a general introduction and discussion section.

The first of these parts contains a review of past research on OPES, identifying shortcomings in these methods. The second part employs case studies that aim to avoid these shortcomings by using methods developed in environmental economics to evaluate the open ocean. Specifically, conjoint analysis is used to evaluate OPES and the possibility of applying this method to policy making/implementation is considered. It is important to note that the conjoint analysis method generates higher estimated values compared with alternative methods. The third part seeks to assess the discount rate between present and future OPES (100 years later) with a discussion of the relation between the discount rate and incentives for environmental protection.

#### Classification & definitions of OPES, method choice based on previous studies

The first part introduces and compares different classifications and definitions of ecosystem services. Before focusing on methods and the assessing past OPES research, several representative OPES studies and research projects that contributed to OPES were assessed and the relation between these are systematically described. As reflected in the research of *Costanza et al.* in 1997, the MA completed in 2005, the TEEB project of the late 2000s and the open-ended United Nations World Ocean Assessment, OPES have drawn increasing attention from various research associations as concerns continue to grow about their sustainable use and health. In the next step, a list of methodologies was generated with specific reference to the database of The Economics of Ecosystems and Biodiversity (TEEB). When choosing the valuation method, this list can be referenced, and based on this list, the weaknesses of valuation methodologies for OPES in prior research were highlighted. In particular, we focused on controversial data choices for evaluating the four main OPES, leading to the decision to use the conjoint analysis method in this research to avoid the weaknesses of alternative methods employed in previous studies. Two case studies were then separately conducted and the results are introduced in the subsequent two chapters.

#### Willingness to pay for OPES by conjoint analysis: a case study of Japan

The first case study survey estimated the monetary value of OPES using conjoint analysis. A choice experiment was conducted using a self-explanatory web-based questionnaire with 814 Japanese respondents chosen from five areas representing Japan's range of coastal and landlocked areas (Tokyo and Osaka representing metropolitan areas facing bays, Shizuoka and Ishikawa prefectures representing rural areas facing seas, and Nagano representing the country's landlocked prefectures) to elicit the marginal willingness to pay (WTP) of respondents for three main OPES: fish production, carbon dioxide absorption, and water purification. "The case study in Japan found a 1% marginal WTP for fish production, carbon dioxide absorption, and water purification of open oceans with respective average per capita values of USD 0.06, 0.19 and 0.16 per year. Variation was also found across different prefectures in WTP trends for the three OPES, implying the influence of traditional food culture, mass media and natural hazards. Differences in WTP trends were also found to depend on income level and gender. The case study included respondents across five income

levels. Positive correlations can be observed between marginal WTP and income levels for each of the three OPES. In addition, female respondents were found to have a higher WTP than male respondents for improving each of the three OPES.” (Double quoted part has been published in Shen et al., 2015)

Therefore, when formulating ecosystem-based management policies related to the open oceans, it is necessary to consider differences in WTP based on region, income, gender and other relative specific factors. This will aide in consensus-building and maximizing cost-benefit outcomes.

#### Social discount rate of Japanese for public goods: approach of marginal WTP for OPES

The second case study survey provided estimates of the value of several representative OPES, and suggested attribute factors that may affect the results. A similar method but different process was used in comparison with the first case study. The data for the second case study was collected from 964 responses by individuals in Japan across 47 prefectures. The questionnaire was distributed and results were collected using an online survey. Respondents were asked to choose between two different questionnaires (Type A or Type B), and respondents were not informed of differences between the two types before choosing. Registrants who chose Type A were then defined as Group A, while the 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 assess respondents' marginal WTP for future (100 years later) OPES. After collecting all the questionnaire results, choice-based conjoint analysis was conducted based on a conditional logit model. The conjoint analysis results showed that the total marginal WTP for three present-day OPES (marginal WTP for future OPES shown in parentheses) per capita per year was estimated as USD ~0.43 (USD ~0.62), with USD ~0.05 (USD ~0.13) for fish production, USD ~0.21 (USD ~0.29) for carbon dioxide absorption and USD ~0.18 (USD ~0.20) for water purification. The general results for the three main services showed that the marginal WTP for future OPES (100 years later) was higher than for present OPES, particularly for fish supply capacity carbon dioxide absorption. Based on the results of described above, the discount rate of fish production, carbon dioxide absorption and water purification capacity for the next 100 years were calculated as -1.01%, -0.33% and -0.11%. The general discount rate was calculated as -0.35. The obviously positive relation results in general for current marginal WTP based on income levels verifies the conclusion of the first survey. However, the marginal WTP for 100 years in the future showed a non-fixed trend. The middle income group, in particular, demonstrated an especially high value. This trend may also be considered when the government makes environmental protection plans for the future. In slight variance to expectations, obvious marginal WTP trends were not observed for different educational levels for present or future OPES. On the other hand, negative discount rates implied that people consider OPES to be different from “normal market goods”, which should always demonstrate a positive discount rate. We can also speculate that people are looking forward to a

better protection of OPES in the distant future. In other words, people are more worried about OPES 100 years in the future than in the present. People alive in 100 years may be the grandchildren of the respondents, but not the respondents themselves. Separate discount rates for each ecosystem service and their general results identified in this research could be effective tools to help decision-makers realize the difficulties they can expect when engaging in environmental protection activities.

### Conclusion

Human activities have directly (fishing and shipping) or indirectly (climate change and ocean acidification) led to a series of changes in OPES. In some cases, growth in one OPES has resulted in decreases in other OPES. There are strong expectations that higher-level joint management will prevent the decrease in OPES. Results of WTP and social discount rates derived from this research 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. On the other hand, when predicting global economic trends using a global economic growth model, which is an important diagnostic tool used by decision-makers for CBA, 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. Evaluation results in this research regarding OPES should be considered in the future global economic growth models.

Further work is needed, including additional studies of this kind in other developed and developing countries. These results would help people gain greater awareness of the importance and value of OPES, and will help policy-makers engage in acceptable and sustainable management. At the same time, 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, towards improving the accuracy of OPES evaluation results.