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Assessment on the Economic Value of Ecosystem Services in Marine Protected Area: Focusing on Yilan Region in Taiwan

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Abstract. Coastal and marine ecosystems deliver critical ecological and economic benefits. This study evaluates ecosystem services from Toucheng and Suao fishery resource conservation zones (FRCZs) within a Marine Protected Area (MPA) in Taiwan's Yilan region, using the contingent valuation method (CVM). Public willingness to pay (WTP) for conservation is influenced by factors such as age (AGE), income (INC), environmental organization participation (EPO), perceived conservation importance (IMP), and number of children (CHI), reflecting sustainability awareness. The estimated total economic value (TEV) of ecosystem services is NT$215.40 million (US$6.51 million) annually within the MPA, and NT$1,489.28 million (US$44.98 million) across the Yilan region. We further calculate the economic value (EV) for different ecosystem services (provisioning, regulating, supporting and cultural) based on respondents' WTP. The results show provisioning services have the highest EV (26.90%) with NT$891.44 yearly, followed by supporting services (25.39%) with NT$841.73. Regulating services are valued at NT$831.79 (25.10%), while cultural services are the least valued, with NT$748.94 (22.61%). These findings inform strategies for optimizing ecosystem service management in the region. Policymakers may prioritize high-value services, such as provisioning (e.g., sustainable harvesting) and supporting functions (e.g., habitat conservation), in line with public preferences. Concurrently, efforts should address lower-valued services, including regulating and cultural functions, through awareness initiatives or balanced investment across different service types.

Keywords: Contingent Valuation Method, Ecosystem Services, Marine Protected Areas, Economic Value, Willing to Pay.

1. INTRODUCTION

The concept of ecosystem services can be incorporated into ecosystem management to enhance the sustainability, efficiency, and equitability of environmental decision-making (Beaumont et al., 2007; Costanza, 2000 and 2020). Since the 1970s, an increasing number of scholars have focused on the study of ecosystem services (Gómez-Baggethun et al., 2009; Jobstvogt et al., 2014; Davis et al., 2019; Pakalniete et al., 2021; Yan et al., 2024; Canonize et al., 2025). The Economics of Ecosystems and Biodiversity (TEEB) is an international initiative supported by the United Nations Environment Programme (UNEP), aimed at raising awareness of the economic benefits of global biodiversity. In terms of the definitions of ecosystem services, Daily (1997) and then Fisher et al. (2009) defined ecosystem service as "the conditions and processes through which natural ecosystems, and the species that make them up, sustain and fulfill Human Life". Costanza (2000, 2014 and 2020) proposed that ecosystem services should be considered as natural capital. These services represent the contribution of natural resources to human well-being. It is crucial to adopt a broad, interdisciplinary approach to effectively address and manage these services. In addition, the Millennium Ecosystem Assessment (MEA, 2005) defined ecosystem services as benefits people obtain from ecosystems and distinguishes four categories of ecosystem services, including provisioning services, cultural services, regulating services, and supporting services. In the early 2000s, government agencies began to integrate ecosystem service concepts into decision making related to environmental management. An international interdisciplinary research project, involving ecology, environmental science, and economics, was established to implement the Millennium Development Goals (MDGs) announced at the 2002 Earth Summit (MEA, 2005). These projects emphasize enhancing the economic value of ecosystem services. Recently, the Taiwanese government has worked to protect marine resources by establishing MPAs, thereby increasing the utilization value of marine ecosystem services. As a result, evaluating the economic value of ecosystem services is an important topic in this study.

Coastal and marine ecosystems, which encompass over 70% of Earth's surface, include the ocean, salt marshes, intertidal zones, estuaries, mangroves, coral reefs, deep-sea environments and the ocean floor. These ecosystems deliver a range of services through both biological and non-biological resources, offering a variety of services or benefits that, in turn, enhance human well-being (Holmlund et al., 1999; Sebastian et al., 2024). They are essential for biodiversity conservation, climate regulation, and supporting fisheries, all of which hold substantial economic value (EV). Kidd et al. (2011) highlight MPAs as key tools in ecosystem management strategies for safeguarding marine resources. MPAs are widely utilized by coastal nations to preserve marine environments. The Convention on Biological Diversity (CBD), established at the 1992 Earth Summit, identified protected areas as essential for biodiversity conservation. Similarly, the World Summit on Sustainable Development (WSSD, 2002) called for advancing marine protection through the establishment of MPA networks, grounded in scientific evidence and international law, with the aim of creating a representative network by 2012. Sinclair et al. (2002) emphasized MPAs' effectiveness in mitigating overexploitation impacts. Additionally, MPAs not only protect and restore marine resources but also support local community development and economic sustainability (Pomeroy et al., 2004). Numerous studies affirm MPAs as effective tools for enhancing fishery resources and biodiversity (Al-Abdulrazzak

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and Trombulak, 2012; Sarker, et al., 2023; Erm et al., 2024).

Currently, Taiwan has five types of MPAs to safeguard marine resources and habitats: national parks, fishery resource conservation zones (FRCZs), wildlife protected areas, nature preservation areas, and national scenic areas. These MPAs are regulated by various authorities through laws such as the Fisheries Act, National Park Law, Wildlife Conservation Act, Cultural Heritage Preservation Act, and the Act for the Development of Tourism (Shao, 2012). According to the International Union for Conservation of Nature (IUCN) classification, FRCZs are categorized as habitat/species management areas (IUCN Category IV). Taiwan has established 28 FRCZs along its coastline, where harvesting specific marine species is prohibited under the Fisheries Act.

This study examines Yilan County, northeastern Taiwan, a key fishing region with eight harbors and the highest catch yields in Taiwan's coastal and offshore waters. The area's nutrient-rich waters attract large numbers of fish, making it highly productive. Yilan's fisheries are economically crucial, with two FRCZs-Toucheng and Suao-serving as case studies. These zones support co-management financing, though further refinement is needed to fully assess marine ecosystem benefits (Chen et al., 2014). By expanding sample size and adjusting the contingent valuation method (CVM), the study aims to improve the economic valuation of ecosystem services and assist in informed decision-making for coastal and marine resource management.

The reminders of this study are organized as follows. Section 2 presents theoretical background and framework for measuring ecosystem services. Section 3 describes the CVM and questionnaire survey. Section 4 depicts the empirical results and implications. Section 5 provides the concluding remarks.

2. THEORETICAL BACKGROUND AND FRAMEWORK FOR MEASURING ECOSSYSTEM SERVICES

2.1. Theoretical Background

The Millennium Ecosystem Assessment (MEA, 2005) identifies four types of ecosystem services: provisioning, cultural, regulating and supporting. Since the 1970s, the concept of ecosystem services has evolved, with scholars increasingly focusing on how ecosystems provide benefits to society. By the 1990s, this understanding gained more clarity, and policymakers started integrating ecosystem services into environmental management in the early 2000s. However, for effective implementation, a detailed cost-benefit analysis (CBA) is needed. This study will apply these principles to evaluate the economic value (EV) of ecosystem services provided by the two FRCZs of MPAs in Yilan region, Taiwan, helping policymakers create more effective management strategies.

The theoretical background, derived from pertinent literature, suggests that cost-benefit analysis (CBA) of ecosystem services should address societal expectations in various contexts (Wegner and Pascual, 2011). Key factors to consider include: (i) intangible dimensions impacting human well-being, (ii) inherent and collective value, (iii) ecological thresholds, complexity and uncertainty, (iv) the differential impacts on socioeconomic groups and (v) context-dependent assessments. Ecosystem service valuation is crucial for implementing ecosystem-based management and conducting CBA. Numerous studies have undertaken economic valuations of ecosystem services (De Groot et al., 2012; Mehvar et al., 2018; Costanza, 2020; Raihan, 2023; Koundouri et al., 2023; Ab Rashid et al., 2024). Researches by Martinez-Harms et al. (2015, 2025) emphasizes that the ecosystem services concept is central to environmental decision-making. Future ecosystem service assessments should clearly define objectives and evaluate the impacts of alternative management actions.

Furthermore, an increasing number of studies have focused on the economic valuation of ocean and coastal ecosystems, using personal willingness to pay (WTP) based on contingent valuation method (CVM) surveys to highlight their importance for human well-being (e.g., Loomis and Larson, 1994; Subade et al., 2007; Barbier et al., 2011; Resende et al., 2017; Matthew et al., 2019; Morando-Figueroa et al., 2023; Wan Ab Rashid et al., 2024). Studies assessing the economic value of ecosystem services (provisioning, regulating, supporting, and cultural) in MPAs have primarily focused on cultural services, such as tourism and recreation (e.g., Alberini and Longo, 2006; Farid, 2015; Jin et al., 2019; Brehe et al., 2021; Koumoutsea et al., 2023). In contrast, other studies have examined multiple services, such as regulating and cultural, or supporting and cultural services (Acharya et al., 2021; Ab Rashid et al., 2024), or extended the assessment to other ecosystems like wetlands and forests, evaluating all four ecosystem services (Ren et al., 2020; Agaton and Guila, 2023; Raihan, 2023; Pappa and Kaliampakos, 2025).

While most studies focus on specific ecosystem services like tourism, recreation, biodiversity or food provision, this study takes a broader approach. It integrates all four dimensions of ecosystem services and provides a comprehensive assessment of their economic value, including the economic weights of each service function.

2.2. Theoretical Framework for Measuring Ecosystem Services

In order to assess the economic value of ecosystem services, a theoretical framework is necessary to assess the economic value of ecosystem services, encompassing all their dimensions: provisioning (like fish production), regulating services (such as climate and water quality regulation), supporting services (like biodiversity maintenance), and cultural services (including recreational and aesthetic value). The framework should integrate these dimensions for a comprehensive economic value (EV) evaluation. The total economic value (TEV) framework is proposed as a method to measure this value.

TEV is a widely accepted method for valuing environmental goods, considering not just market values (like timber or fish) but also non-market and intangible benefits. These include subsistence, ecological functions, cultural

significance, and the preservation of resources for future generations. TEV breaks down into use value (UV) which direct and indirect benefits from nature and non-use value (NUV), which is obtained through non-removable goods and services in nature. This includes existence value (EV), which values assets such as endangered species, bequest value (BV), which preserves resources for future generations and option value (OV) takes into account the potential value of future use. Based on these concepts, TEV can be expressed as Equation (1) (Plottu and Plottu, 2007; Wattage, 2010; Jayathilaka and Serasinghe, 2018; Goswami, 2025):

$$TEV = NUV + UV = DUV + IUV + OV + EV + BV \quad (1)$$

The TEV in this study is related to the public values of a coastal and marine ecosystem services (provisioning, cultural, regulating and supporting services) in the fishery resource conservation zones (FRCZs) of Yilan Region in Taiwan. The TEV of coastal and marine ecosystem services is divided into use value (UV) and non-use value (NUV). Use value (UV) includes direct and indirect benefits obtained from coastal and marine resources. Direct use value (DUV) comes from consumable or experiential resources such as provisioning services that supply essential resources like seafood, offshore wind energy, and tourism (e.g., whale watching, diving). Indirect use value (IUV) covers ecosystem functions that provide indirect benefits, such as coastal protection (mangroves, reefs), carbon sequestration (sea grass, kelp) and water purification (oysters). Supporting services, like nutrient cycling and habitat preservation, are essential for maintaining ecosystem health and enable other services to flourish but do not directly generate economic value.

On the other hand, non-use value (NUV) reflects the benefits of coastal and marine ecosystems people gain without direct use. Existence value (EV), as a cultural service, reflects the value of knowing marine certain species, like turtles, whales or deep-sea corals, continue to exist. Bequest value (BV), also a cultural service, is the desire to protect ecosystems for future generations, such as preserving coral reefs or endangered species. Option value (OV) is the future potential of marine resources, such as new medicines from deep-sea organisms or marine carbon sinks for climate action, categorized into provisioning and regulating services. Detailed information on TEV is shown in Figure 1. The study emphasizes a holistic approach to marine ecosystem services, highlighting both immediate and long-term benefits from conservation for the sustainability of human society.

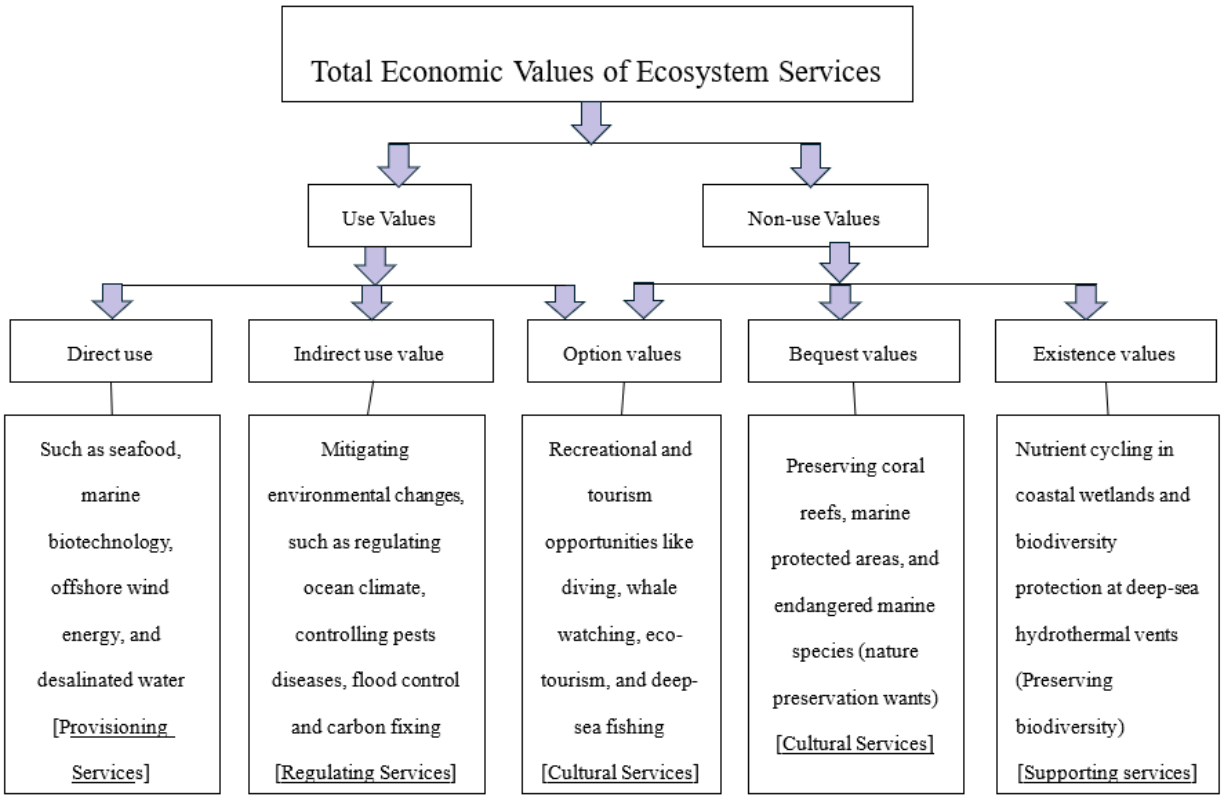

Figure 1: Decomposition of total economic value.

In TEV assessment, the contingent valuation method (CVM) is commonly used to gauge respondents' WTP for maintaining or using ecosystem services, particularly those provided by marine ecosystems. As noted by Mitchell and Carson (2013), many studies, as referenced in Section 2.1, have utilized CVM to assess the economic value of these services. Accordingly, this study applies the CVM method to evaluate the economic value (EV) of MPA ecosystem services in Yilan, Taiwan. It is also one of the few in Taiwan employing CVM to measure the total economic value (TEV) of coastal and marine ecosystem services, incorporating both use value (UV) and non-use value (NUV). CVM surveys estimate WTP and translated that willingness into economic terms as economic value

(EV) both for improving current provisioning and regulating services (use values) and for enhancing or preserving support and cultural services for future generations (non-use values), which collectively constitute TEV.

3. THE CVM AND QUESTIONNARIE SURVEY

This study estimates the economic value of FRCZs through ecosystem services to aid coastal and marine management. As noted, the CVM is applied to estimate this value based on willingness to pay (WTP). This section describes the evaluation method and questionnaire survey process used to develop the empirical model.

3.1. Evaluation Method: Estimating WTP by Applying CVM

The WTP-based approach effectively measures how much individuals are willing to financially sacrifice to preserve environmental resources or support specific programs (Arrow et al., 1993). The CVM is used to assign monetary values to individuals' preferences for goods, particularly in environmental and ecological contexts. This method involves creating a hypothetical market scenario and using surveys to determine the WTP for changes in service levels or environmental quality. The survey data is then analyzed to estimate the benefits or costs associated with changes in service quality. Specific details of this method are outlined below.

The CVM concept states that when a good or service's quality changes from Q^0 to Q^1 (where Q^0 can be either better or worse than Q^1), an individual is willing to pay a certain amount that adjusts their income (Y) while maintaining a specific level of utility (U). This WTP amount is mathematically expressed in equation (2).

$$U(Q^0, Y) = U(Q^1, Y - WTP) \quad (2)$$

Based on this concept, the CVM creates a hypothetical or simulated market and uses surveys to assess respondents' WTP for specific goods or services under assumed conditions. Since respondents are typically unfamiliar with such markets, various scenarios are carefully designed to help them express their WTP. WTP represents the amount consumers are willing to pay to prevent the deterioration or maintain the quality of the environment, often serving as a measure of public value judgments on environmental improvements.

In a CVM survey, the design of a hypothetical market allows respondents to express their true preferences, reflecting how they would act if actual markets for environmental goods and ecosystem services existed. This study focuses on individuals committed to preserving the ecosystem services (provisioning, regulating, supporting, and cultural) of the fishery resource conservation zones (FRCZs) in this marine protected area (MPA) on Yilan Region in Taiwan for future use. Before asking respondents their willingness to pay (WTP) to protect the area, they are given detailed information about the resource, helping them form preferences based on a full range of data. One reason CVM has gained widespread attention is its flexibility and adaptability to different situations, making it a better tool for capturing the public or economic value of natural resources. Its versatility is particularly useful for diverse environmental contexts, as it can be tailored to various ecological settings. CVM's strength lies in its ability to capture both use values (UV, the tangible benefits people derive from nature) and non-use values (NUV, such as the intrinsic value of preserving biodiversity), regardless of direct human use. Ultimately, CVM's ability to measure both public (societal importance) and economic (financial worth) values highlights its crucial role in environmental policy-making, bridging economics and broader societal well-being.

To assess the public or economic value (EV) of marine ecosystem services provided by the FRCZs in this marine protected areas (MPA) of Yilan Region, it is essential to measure the perceived value among local residents and workers. The public value of marine ecosystem services is generally defined as the sum of their use and non-use values (UV and NUV), which together form the total economic value (TEV), as shown in Equation (1). A key principle in assessing the benefits of a proposed policy is consumers' willingness to pay (WTP) for it (Brent, 2006). WTP reflects the amount people are willing to pay for access to specific goods or ecosystem services. Accordingly, we used the CVM to calculate respondents' WTP for conserving the MPA's ecosystems. The goal is to understand how individuals value these services and their willingness to support their protection financially and translated that willingness into economic terms as economic value (EV).

3.2. Questionnaire Survey and Design for Obtaining Contingent Values

The coastal and marine environment in the northeastern waters of Taiwan, particularly around Yilan, is highly favorable, with upwelling currents that attract abundant marine life, creating a valuable traditional fishing ground. The Yilan Region is one of Taiwan's most important fishing areas, with higher output and value compared to other regions. Official statistics show that the region's offshore and coastal fish catch totaled 39,345 tons, valued at NT$2.6 billion (US$86.7 million). To assess the economic value of the FRCZs within Taiwan's Yilan MPA, we selected the FRCZs in Toucheng and Suao for further analysis (Figure 2). Since 1976, the Taiwanese government has established the 395.1 hectare Toucheng FRCZ to protect habitats for lobsters, anchovies, seaweeds, small abalones (Haliotis sp.), and red algae (Gelidium amansii). The 40.8 hectare Suao FRCZ was established to protect similar habitats. The next step is to identify and catalog the ecosystem services provided by these ecological zones in Yilan to construct our survey questionnaire.

In order to collect data for the empirical study, a questionnaire survey was conducted to gather primary data

on respondents' perceptions and willingness to pay (WTP) for various ecosystem services (provisioning, regulating, supporting, and cultural services) of the FRCZs, along with their personal details. To analyze individual WTP and complete the economic valuation of the FRCZs using the CVM, we followed the CVM approach outlined in Section 3.1. In the hypothetical market scenario, respondents were asked: "How much would you be willing to pay or donate annually to improve or maintain the current ecosystem services (provisioning, regulating, supporting, and cultural services) of these FRCZs for the benefit of future generations?"

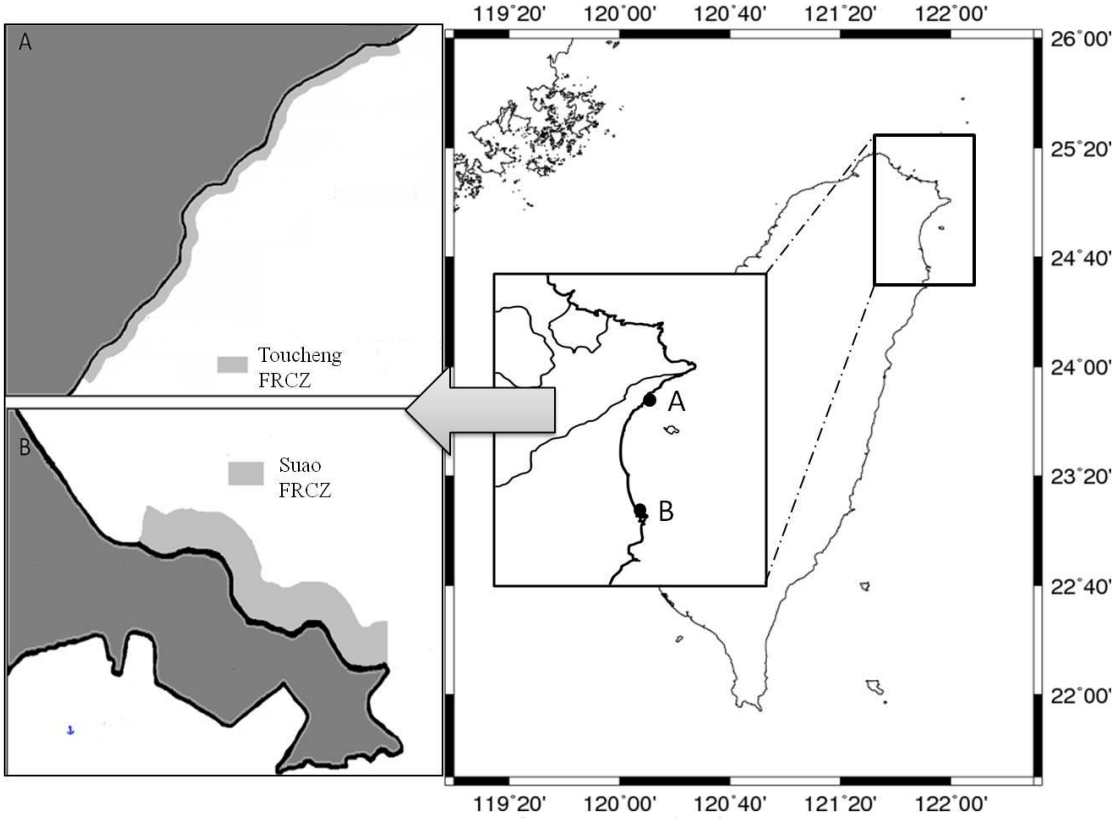

Figure 2: Geographical location of study site.

In addition to ecosystem-related questions, respondents' personal background information was collected, including gender, age, income, education level, marital status, occupation, number of children, and participation in environmental organizations. To improve the reliability and validity of the questionnaire, two pre-surveys were conducted at Daxi Fishing Port, Yilan County. To minimize bias and protest responses, an open-ended willingness to pay (WTP) question was used in the pre-survey to better estimate true WTP and help define the WTP levels for the payment card method used in the official survey. Based on the pre-survey results, a payment card with 10 WTP levels (NT$0, 50, 100, 200, 300, 500, 1,000, 1,500, 2,000, and above 3,000) was established. The official survey targeted fishermen, Fisheries Association employees, and local residents from the Yilan County Fisheries Department, various fishing ports, and the Toucheng and Suao Fishermen's Associations. The field survey involved face-to-face interviews by trained interviewers using the CVM method. A total of 256 individuals participated, with 218 providing valid responses, meeting the required sample size. Based on the feedback, the procedures for determining WTP for various ecosystem services were within the respondents' capabilities.

4. EMPIRICAL RESULTS AND IMPLICATIONS

Using the data collected, we can calculate individuals' willingness to pay (WTP) through the conceptual model of the CVM as outlined in Section 3.1. To estimate the economic value (EV) of the ecosystem services involved in the maintenance and management of the fishery resource conservation zones (FRCZs) at Toucheng and Suao on Yilan Region in Taiwan. Tobit regression analysis is employed for estimation and evaluation. This section will first identify the key determinants of WTP, and ultimately estimate the total economic value (TEV) of various ecosystem services, including provisioning, regulating, supporting, and cultural services. The analysis will also account for the individual economic values (EV) and relative importance (value weights) of each of these four ecosystem service functions.

4.1. The CVM Modeling and the Influencing Factor Variable Characteristics

As mention in section 3.1, CVM approach is useful for developing an equation model to evaluate individual's WTP regarding various ecosystem services, the CVM survey was applied to examine respondents' WTP to maintain the functions of FRCZs of Toucheng and Suao from ecosystem services. The variables (influencing factors) of the CVM model which affecting WTP are shown in Table 1.

In this study, CVM modeling is used to build an equation to evaluate WTP_i for individual i. The influencing factors affecting WTP_i function can be expressed as Equation (3) or (4):

$$WTP_i = \mathrm{f}(AGE_i, SEX_i, INC_i, EDU_i, EPO_i, PRO_i, JOB_i, CHI_i, IMP_i) + \varepsilon_i \quad (3)$$

or

$$WTP_i = \beta_0 + \beta_1 AGE_i + \beta_2 SEX_i + \beta_3 INC_i + \beta_4 EDU_i + \beta_5 EPO_i + \beta_6 PRO_i + \beta_7 JOB_i + \beta_8 CHI_i + \beta_9 IMP_i + \varepsilon_i \quad (4)$$

Where WTP_i denotes the willingness to pay of respondent i for ecosystem services, influenced by factors such as age (AGE_i), gender (SEX_i), monthly income (INC_i), education years (EDU_i), environmental group participation (EPO_i), belief in marine protection (PRO_i), job type (JOB_i), number of children (CHI_i), and perception of FRCZ importance (IMP_i). The residual (error) term (ε_i) satisfies the probability distribution with zero mean and σ^2 variance. Table 1 shows the expected signs of each variable's effect on WTP, offering insights into how personal and attitudinal factors are hypothesized to influence willingness to pay.

Table 1 also summarizes key statistics for the explanatory variables, including their mean, median, and standard deviation (S.D.). Notable gaps between the mean and median indicate that some variables may be skewed, rather than symmetrically distributed. Higher S.D. values for variables like age (AGE), education (EDU), and number of children (CHI) suggest substantial variability among respondents. These statistical insights are essential for accurately interpreting the model, as they reveal how data spread and distribution may influence the estimated relationships.

Table 1: Variable definitions and its descriptive statistics of the variables.

Variables	Description	Type	Mean	S.D.	Median	Expected signs
AGE	The age of the respondent	Numeric variable	43.26	12.71	41	+
SEX	The gender of the respondent (1 represents male; 0 represents female)	Dummy variable	0.70	0.49	1	?
INC	The income (NT$) of the respondent (1 represented 40,000 and above; 0 represented less than 40,000)	Dummy variable	0.29	0.454	0	+
EDU	The educational level of the respondent	Numeric variable	12.96	3.59	12	+
EPO	Dose the respondent participate in an environmental protection organization (1 represents yes; 0 represents no)	Dummy variable	0.17	0.69	1	+
PRO	The respondent agrees that marine resource protection is important or not (1 represents yes; 0 represents no)	Dummy variable	0.95	0.23	1	+
JOB	The occupation of the respondent	Numeric variable	0.48	0.501	0	?
CHI	The number of children of the respondent	Numeric variable	1.49	1.23	2	+
IMP	The respondent agrees that the functions of MPAs are important or not (1 represents yes; 0 represents no)	Dummy variable	0.29	0.454	0	+

4.2. Initial Response for WTP Survey

Before conducting the Tobit regression analysis, analyzing the frequency distribution of WTP offers insight into public awareness and willingness to invest in the management or governance of fishery resource conservation zones (FRCZs) in Toucheng and Suao on Yilan Region in Taiwan. Table 2 displays the results from 13 payment card options across various ecosystem services, including provisioning, regulating, supporting, and cultural services. Results show strong support: about 90% of respondents are willing to pay, with only 10.8% reporting zero WTP. Over half(56.8%) are willing to pay NT$100-2,000 (US$3.3-66.7), and 77.8% fall within the NT$100-4,000 (US$3.3-133.3) range. Notably, more than 25% are willing to pay at least NT$3,000 (US$99.2). These findings demonstrate strong public support for maintaining the functions of FRCZs of Toucheng and Suao from ecosystem services, reflecting high awareness and recognition of the value of coastal and marine conservation.

It is worth noting that 10.8% of respondents who did not express a willingness to pay highlight a potential gap in the understanding of FRCZs or a disconnect with the concept, suggesting the need for better communication or education to enhance public awareness of the importance of coastal and marine ecosystem and fishery resource conservation. The wide range of payment amounts, especially with over half willing to contribute between NT$100 and NT$2,000, demonstrates strong but varied support. This diversity in financial capability indicates that future strategies should be flexible and inclusive, addressing different levels of public interest and economic capacity.

4.3. Regression Results for the Determinants of WTP

4.3.1. Tobit Regression Method

Since the dependent variable (WTP_i) in this study is strictly positive, using Ordinary Least Squares (OLS)

would yield biased and inconsistent estimates (Greene, 2000). To address this, we apply the Tobit model (Tobin, 1958), which is suitable for censored data:

$$y_i = \begin{cases} X_i\beta + \varepsilon_i & WTP_i > 0 \\ 0 & WTP_i \leq 0 \end{cases} \quad (5)$$

In this specification, y_i is the observed dependent variable, $X_i$is a vector of explanatory variables (e.g., age, income, education and preferences), β is a vector of coefficients to be estimated, and the residual (error) terms $\varepsilon_i \sim iidN(0, \sigma^2 I)$.

Considering various individual characteristics, such as age, income, education, and preferences, that influence willingness to pay (WTP_i) for ecosystem services, we employed a Tobit regression model to evaluate the significance of each variable and estimate WTP_i function. Many respondents reported zero or capped WTP values, the Tobit model accounts for this censoring and accurately estimates the relationship between explanatory variables and WTP_i. The responses to the WTP question in the contingent valuation method (CVM) survey were analyzed using a parametric model, with each respondent's observed WTP_i defined as:

$$WTP_i^* = X_i\beta + \varepsilon_i \quad (6)$$

WTP_i^* is the latent willingness to pay, assumed to follow classical linear model assumptions.

Table 2: Frequency distribution, mean, and medium of WTP.

WTP (NT$)	Number	Percentage (%)	Mean (NT$)	Median (NT$),
0	16	10.8		
100~200	23	15.5		
200~400	17	11.5		
400~800	10	6.8		
800~1200	12	8.1		
1,200~1,600	6	4.1	2,142	1,200
1,600~2,000	16	10.8		
2,000~3,000	6	4.1		
3,000~4,000	25	16.9		
4,000~5,000	4	2.7		
5,000~7,500	6	4.1		
7,500~10,000	3	2.0		
10,000~12,000	4	2.7		

Considering the various characteristics of variables (like age, income, education, preferences, etc.) that influence individual willingness to pay (WTP_i) regarding ecosystem service in our analysis, we employed a Tobit regression model to assess the significance of each variable and to estimate the WTP_i function. For example, many respondents might have a WTP_i of zero or a capped value. The Tobit model accounts for this censoring and helps estimate the relationship between the independent variables (such as income, age, etc.) and the WTP_i. The responses to the WTP question in the contingent valuation method (CVM) survey were analyzed using a parametric model, where each respondent's i chosen WTP_i value was observed and defined as:

$$WTP_i^* = X_i\beta + \varepsilon_i \quad (7)$$

$$WTP_i = \begin{cases} WTP_i^* & WTP_i^* > 0 \\ 0 & WTP_i^* \leq 0 \end{cases} \quad (8)$$

Here WTP_i^* is latent variable following the classical linear model assumptions; X_i is the explanatory variables; β is the regression parameters and the residual (error) terms$\varepsilon_i \sim iidN(0, \sigma^2 I)$. This approach allows us to estimate not only the likelihood of a positive WTP but also its magnitude when it occurs. This model captures the idea that individuals may internally value ecosystem services (latent WTP), but external constraints or unwillingness to disclose that value lead to reported zeros. The Tobit model enables this research to estimate these hidden

preferences, offering a deeper insight into true valuation behavior that would otherwise be masked in the data. In terms of estimation, the Generalized Tobit Interval model uses a log likelihood function that accounts for point, left-censored, right-censored (i.e., top WTP_i category with a lower bound) and interval data. The log likelihood function is specified by:

$$In\ L = -\frac{1}{2}\sum_i w_i \left\{\left(\frac{WTP_i - X_i\beta}{\sigma}\right) + In\ 2\pi\sigma^2\right\} + \sum_i w_i\ In\left\{1 - \Phi\left(\frac{-X_i\beta}{\sigma}\right)\right\} \quad (9)$$

Here, Φ denotes the standard cumulative normal, and w_i is the weight assigned to the *i*th individual. The Tobit model is used to identify the factors influencingWTP_i, incorporating censoring in the estimation process. All analyses were conducted using STATA 12, and parameter estimates were derived via Maximum Likelihood Estimation (MLE).

4.3.2. Regression Results for the Influencing Factors Determining WTP_i

As previously mentioned, regression analysis based on Equation (4) is used to estimate individual willingness to pay (WTP_i) for ecosystem services. Due to the censored nature of the data, the Tobit model, estimated via Maximum Likelihood Estimation (MLE) using the log-likelihood function (Equation 9), is the appropriate method. All variance inflation factors (VIFs) are below 10, indicating that multicollinearity is not an issue (Greene, 2000). The model results, presented in Table 3, show an adjusted R^2 of 0.514, an F-statistic of 23.65, a log-likelihood of -1214.384, and a p-value of 0.00, confirming strong overall model significance. The White statistic of 5.215 indicates no heteroscedasticity, ensuring the consistency of the coefficient estimates. These model-fit statistics confirm that the selected explanatory variables are appropriate and well-justified.

Table 3: Estimated results of Tobit regression model for WTP_i.

Variables	Estimated Coefficients		S.D.	z-Stat.	P-value	
Constant	β_0	1415.55	3410.96	0.42	0.68	
AGE	β_1	-102.18	24.54	-4.16	0.00	***
SEX	β_2	33.52	331.90	0.10	0.91	
INC	β_3	1500.17	738.64	2.03	0.04	**
EDU	β_4	17.48	86.95	0.20	0.81	
EPO	β_5	31.89	76.99	1.71	0.09	*
PRO	β_6	961.38	2715.75	0.35	0.68	
JOB	β_7	278.15	513.20	0.54	0.42	
CHI	β_8	2375.59	1077.36	2.21	0.04	**
IMP	β_9	3012.37	1395.91	2.16	0.03	**

Note: 1. ***, **, and * indicate statistical significant at 1%, 5 %, and 10% level
2. Adjusted R^2: 0.514 (F value: 23.65),
3. Log-likelihood value: 1214.384, White statistics: 5.215
3. $\chi^2_{0.01}(9)$ =21.666 and P value: 0.00

The Tobit model results indicate that several key variables AGE, INC, EPO, CHI, and IMP are statistically significant at the 1% to 10% levels (Table 3). These findings highlight the importance of both demographic factors (such as age, income, and number of children) and perceptual or attitudinal factors (such as participation in environmental protection organizations (EPO) and recognition of the importance of conservation (IMP)) in shaping willingness to pay (WTP). The number of children (CHI) may reflect intergenerational awareness and concern for sustainability. Although some estimated coefficients are not statistically significant, the significant variables yield robust and meaningful results that align with the objectives of this study. Overall, the regression model is appropriate for estimating WTP values, as it incorporates the key influencing variables identified. The model effectively captures the relationships between WTP and the various demographic and perceptual factors considered.

In this section, we further explore the statistical implications to emphasize the relationship between WTP (willingness to pay) and key influencing factors. The estimated coefficients (β_1, β_2)for AGE (respondent's age) and INC (respondent's income) show a significant positive impact on WTP at the 1% and 5% levels, respectively. This suggests that older and wealthier respondents are more willing to financially support the operation and management of FRCZs) in Toucheng and Suao. These individuals likely possess more financial resources and a longer-term perspective on the sustainability of ecosystem services in the FRCZs of the MPA in Taiwan's Yilan region. Similarly, the estimated coefficient (β_3) for CHI (number of children) demonstrates a significant positive effect on WTP at the 5% level. Respondents with more children are often willing to pay more, likely due to a stronger concern for future generations' well-being and a sense of responsibility toward sustainability, driving support for long-term environmental and social benefits. The estimated coefficient (β_9) for respondents' agreement

on the importance of MPA functions (IMP) shows a significant positive effect on willingness to pay (WTP) at the 5% level. This indicates that those who value MPA functions are more likely to support FRCZ management financially, emphasizing the role of public perception in motivating contributions to ecosystem services. Similarly, the coefficient (β_5) for involvement in environmental organizations (EPO), significant at the 10% level, suggests that active participants in environmental groups are more willing to pay for ecosystem services. This may reflect their greater awareness of environmental issues and the role of ecosystem services in MPA management, highlighting that engagement in environmental movements fosters support for sustainable initiatives.

It should be noted that the estimated coefficients ($\beta_2, \beta_4, \beta_6,$ and β_7)for variables such as recognition of marine conservation importance (PRO), gender (SEX), education (EDU), and occupation (JOB) are not statistically significant, but they still show positive effects on willingness to pay (WTP). Removing them reduces model accuracy, as indicated by a lower R^2 or higher mean squared error (MSE). This suggests that, while individually weak, these variables enhance the model's overall predictive power, likely through interactions with other factors. Therefore, they are retained to improve the accuracy of WTP estimates for ecosystem services in Toucheng and Suao's FRCZs.

The analysis of variables in Table 3 highlights their critical role in assessing each respondent's willingness to pay (WTP_i) within the estimation model. Including these factors significantly improves the model's ability to simulate and predict WTP_i, capturing key demographic and perceptual drivers of valuation behavior. The results also reveal that most respondents strongly value the functions of FRCZs, leading to a greater willingness to contribute financially to the preservation and management of ecosystem services in the Toucheng and Suao FRCZs within the Yilan MPA of Taiwan. Accordingly, the simulated value of estimated model for $\widehat{WTP_i}$ of each respondent i can be represented by Equation (9)

.

$$\begin{aligned}\widehat{WTP_i} = {} & 1415.55 + 102.18AGE_i + 33.52SEX_i + 1500.17INC_i \\ & + 17.48EDU_i + 31.89EPO_i + 961.38PRO_i + 278.15JOB_i \\ & + 2375.59CHI_i + 3012.137IMP_i \end{aligned} \quad (10)$$

The estimated model indicates that the parameters and influencing factors contribute to a more reliable economic analysis. The total economic value ($\widehat{TEV_i}$) or benefits, represented by the willingness to pay ($\widehat{WTP_i}$) for various marine ecosystem services (including provisioning, regulating, supporting and cultural services) in the Toucheng and Suao FRCZs of the MPA on Yilan Region can also be calculated using Equation (10).

4.4. Estimating and Analyzing the Total Economic Value (TEV) of Ecosystem Services

As outlined in Section 2.2, this study uses the contingent valuation method (CVM) to estimate the TEV of improved coastal and marine ecosystem services, including both use (UV) and non-use values (NUV). CVM surveys assess public willingness to pay (WTP) for maintaining current various ecosystem services and preserving future benefits. Focusing on two FRCZs in Toucheng and Suao, $\widehat{WTP_i}$ for each respondent i is first calculated using mean values of influencing factors used as the explanatory variable, resulting in NT$3,162.69 per person yearly (Table 4). However, due to skewed distributions in variables such as age, education, and number of children, median values of influencing factors are also applied to avoid the impact of outliers, yielding a higher median $\widehat{WTP_i}$ value of NT$3,313.90 per person yearly (Table 4). This suggests that the mean may underestimate $\widehat{TEV_i}$ of total ecosystem services provided through Toucheng and Suao two FRCZs by $\widehat{WTP_i}$, while median-based estimates offer a more accurate reflection of public valuation $\widehat{TEV_i}$ of total ecosystem services.

This makes the median a more realistic representation of what most public would be willing to pay and translated that willingness into economic terms as economic value (EV).

Table 4: The estimated WTP of ecosystem services (value per person yearly)

Service	Provisioning	Regulating	Cultural	Supporting	Total
Percentage (%) of median WTP	26.9	25.1	22.6	25.4	100
WTP(NT$; median)	891.44	831.79	748.94	841.73	3,313.90
WTP (NT$; mean)	850.76	793.84	714.77	803.32	3,162.69

Based on the individual median willingness to pay ($\widehat{WTP_i}$) for each respondent regarding the operation and management of ecosystem services in the Toucheng and Suao FRCZs of the MPA, the average WTP is NT$3,313.90 (US$100.09) per person per year. With a regional population of 65,000 residents in Toucheng and Suao towns as of March 2025, the total ecosystem service value for these two FRCZs is estimated at NT$215.40 million (US$6.51 million) annually. This means that the ecosystem services provided by the Toucheng and Suao FRCZs, including provisioning, regulating, supporting, and cultural services, contribute a total economic value ($\widehat{TEV}$) of NT$215.40 million (US$6.51 million) per year for these towns. Expanding the analysis to the entire Yilan Region, with a population of 44,940, the total economic value generated by the FRCZ ecosystem services would amount to NT$1,489.28 million (US$44.98 million) per year. This highlights the significant economic value of

these ecosystem services and emphasizes the need to integrate their value into governance and investment decisions, ensuring sustainable development and long-term benefits for both local communities and ocean health, whether focused on the FRCZs of the MPA or the broader Yilan region.

In this study, we also estimated the annual economic value ($\widehat{EV}_i$) corresponding to each respondent's WTP for each category of ecosystem services (including provisioning, regulating, cultural, and supporting services) and examined their percentage contribution to the total economic value ($\widehat{\text{TEV}}$) of the integrated ecosystem services (see Table 4). The results show that the estimated economic value $\widehat{EV}_i$ for provisioning services is the highest (26.9%) with a median of NT$891.44, followed by supporting services (25.4%) at NT$841.73. The estimated economic value $\widehat{EV}_i$ for regulating services is NT$831.79 (25.1%), and cultural services have the lowest $\widehat{EV}_i$at NT$748.94 (22.6%). These findings provide key insights for enhancing the operation and management of ecosystem services in the Toucheng and Suao FRCZs of the MPA on Yilan region. Provisioning services, such as food and water, are valued the most, reflecting their immediate relevance to people's well-being and livelihoods. Supporting services, including processes like soil formation and photosynthesis, rank second due to their foundational role in sustaining ecosystems, even if less visible to the public. Regulating services, such as climate regulation and water purification, are also highly valued but rank slightly lower. Cultural services, encompassing recreational, aesthetic, and spiritual benefits, are valued the least, possibly because their importance, while recognized, is less frequently expressed in direct economic terms.

Based on the above $\widehat{EV}_i$ estimates for each type of ecosystem service, these results obviously indicate that if government agencies and wish to align their behaviors or actions with public preferences, they might prioritize services like provisioning services (e.g., sustainable resource extraction) and supporting services (e.g., habitat preservation). The implications also suggest that potential policy focus would be placed on services with lower $\widehat{EV}_i$ (e.g. regulating and cultural services) to enhance their perceived value or to balance investments across different service types.

5. CONCLUDING REMARKS

Coastal and marine ecosystems are vital for both ecological functions and economic benefits. This study aims to evaluate the ecosystem services, including provisioning, regulating, supporting and cultural services, offered by the Toucheng and Suao FRCZs in sustaining Yilan's MPAs. Using a CVM survey, we assess public willingness to pay (WTP) for conservation, revealing how people value these ecosystems and analyze the key factors influencing their willingness to pay (WTP). This approach helps estimate the total economic value (TEV) of FRCZs of MPAs on Yilan Region in Taiwan, reflecting how the public values their ecological benefits.

The findings reveal that WTP for ecosystem protection is significantly influenced by demographic factors such as age (AGE), income (INC), and number of children (CHI) and perceptual factors like involvement in environmental organizations (EPO) and perceived importance of conservation (IMP). Older, wealthier individuals and those with children, tend to show higher WTP, likely due to greater financial capacity and a stronger focus on long-term sustainability. This suggests that these groups are more inclined to support the operation and management of the ecosystem services provided from FRCZs of MPA on Yilan Region in Taiwan.

The results of our empirical analysis is further to obtain simulated or expected WTP values and translate that willingness into the economic value (EV) of ecosystem services. This study estimates the total ecosystem service value (TEV) of the two FRCZs, which sustain coastal and marine ecosystems within the MPA in Yilan, Taiwan, at NT$215.40 million (US$6.51 million) annually, based on individual WTP. In other words, the ecosystem services provided by the Toucheng and Suao FRCZs of the MPA contribute a total annual TEV of NT$215.40 million (US$6.51 million) for these specific services. Expanding the scope to the entire Yilan region, the ecosystem services from these FRCZs would generate a total TEV of NT$1,489.28 million (US$44.98 million), highlighting that managing these services within the MPA provides substantial economic value to the region. This emphasizes the need to integrate the value of marine ecosystem services into governance and investment decisions, ensuring coastal and marine ecosystems continue providing essential ecological and economic benefits, whether for the Toucheng and Suao FRCZs or the entire Yilan region.

We also measure the economic value (EV) of various ecosystem services based on individuals' annual willingness to pay (WTP), including provisioning, regulating, supporting, and cultural services. Provisioning services had the highest value at 26.90% (median WTP: NT$891.44), followed by supporting services at 25.39% (NT$841.73), regulating services at 25.10% (NT$831.79), and cultural services at 22.61% (NT$748.94). These findings offer valuable insights for improving the management of ecosystem services within Taiwan's Yilan region, especially in the Touceng and Suao FRCZs. Provisioning services like food and water hold the highest value, reflecting their direct impact on human well-being. Supporting services, such as soil formation and photosynthesis, rank second for their essential yet subtle role in ecosystems. Regulating services, like climate regulation and water purification, are important but slightly less valuable. Cultural services, including leisure, aesthetics, and spiritual benefits, while recognized, have the lowest economic value, revealing a gap between public awareness and direct economic valuation. The study highlights key management priorities by focusing on services with higher economic value (such as provisioning and supporting services), policymakers can maximize public benefits and concentrate

resources on areas that most effectively provide these services. Economic value (EV) estimates for each ecosystem service suggest that government agencies prioritize high-value services, such as provisioning (e.g., sustainable resource extraction) and supporting services (e.g., habitat protection), in line with public preferences. Policies should also enhance the perceived value of lower-value services, such as regulating and cultural services, or ensure balanced investment across all service types. The findings of this study provide valuable insights into public valuation of various ecosystem services. By prioritizing services with higher WTP or TEV and focusing on median values, policymakers or authorities managing the two FRCZs can design policies that are more realistic, equitable, and effective. Such policies should align with public support for conservation, ensuring both immediate benefits and long-term ecological sustainability.

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