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# The Potential Impact of Macro/Mesoplastic Pollution on Beach Recreation: Determining Economic Value Losses with Comparative Models

# Makro/Mezoplastik Kirliliğinin Plaj Rekreasyonuna Olası Etkisi: Karşılaştırmalı Modellerle Ekonomik Değer Kayıplarının Tespiti

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## ABSTRACT

Macro/mesoplastic (M/MP) pollution has become a critical stressor degrading beach quality, particularly in densely urbanized coastal settings. This study quantitatively assesses the impact of M/MP pollution on beach recreation demand and related local income. In metropolitan coastal areas such as Istanbul, increasing M/MP loads diminish perceived hygiene and aesthetic quality, alter visitor behavior, and generate measurable losses in cultural ecosystem services, including recreation and scenic value. Based on this hypothesis, (*i*) a multi-beach travel cost site-selection model (random utility, mixed logit) to incorporate M/MP density as an environmental quality attribute; and (*ii*) a discrete choice experiment (DCE) to estimate conditional willingness-to-pay (WTP) for enhanced beach cleanliness and hygiene, were applied. Changes in visitor welfare and reductions in regional expenditures were translated into local income effects using input–output multipliers.
Results indicate that higher M/MP concentrations significantly reduce visit probability and per-capita spending. Due to the higher M/MP density at Büyükçekmece Beach (271.6 items/m²), the utility decreases (–134.4), whereas at Florya Beach, which has a lower density (202.2 items/m²), the utility assumes a relatively higher value (–101.3). Visitors expressed a mean WTP of approximately 40 TL for improved cleanliness. To our knowledge, this is the first study in Turkey to evaluate M/MP-driven recreational losses using advanced econometric modeling. Overall, findings demonstrate that rising M/MP densities erode recreational demand and regional spending, while positive WTP signals that targeted policy interventions—such as increased cleaning frequency and upstream pollution reduction—may yield net welfare gains.

**Keywords:** Travel cost method, Discrete choice experiment, Macro/Mesoplastic

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## ÖZET

Makro/mezoplastik (M/MP) kirliliği, özellikle yoğun kentleşmiş kıyı bölgelerinde plaj kalitesini düşüren kritik bir stres faktörü haline gelmiştir. Bu çalışma, makro/mesoplastik (M/MP) kirliliğinin plaj rekreasyon talebi ve yerel gelir üzerindeki etkisini nicel olarak tahmin etmeyi amaçlamaktadır. İstanbul gibi yoğun şehirleşme baskısı altındaki kıyılarda, artan M/MP yükünün hijyen/estetik algısını düşürerek, ziyaretçi davranışını değiştirdiği; dolayısıyla kültürel ekosistem hizmetlerinde (rekreasyon, manzara değeri) ölçülebilir kayıplara yol açtığı bilinmektedir. Bu hipotezden hareketle, (*i*) çoklu-plaj seyahat maliyeti site-seçim modeli (rasgele fayda, mixed logit) ile M/MP yoğunluğunu kalite özniteliği olarak değerlendirmek, (*ii*) DCE ile "temizlik/hijyen" için koşullu ödeme isteğini WTP tanımlamak üzerine yöntemler kullanılmıştır. Bu kapsamda, ziyaretçi refah değişimini ve bölgesel harcamadaki azalışı giriş-çıkış çarpanlarıyla yerel gelire eş değerlemek planlanmıştır. Bulgular, kıyı rekreasyon alanlarında deniz çöpünde ama özellikle M/MPdeki artışın, ziyaret günleri ve harcamaları oldukça azalttığını işaret etmekte hem ziyaretçi günlerini hem de bölgesel harcamayı istatistiksel olarak anlamlı verilerle düşürdüğünü göstermektedir. Büyükçekmece Plajı'nda M/MP yoğunluğu (271.6 adet/m²) nedeniyle fayda azalırken (-134.4), daha düşük yoğunluğa sahip Florya Plajı'nda (202.2 adet/m²) fayda daha yüksek bir değer (-101.3) almıştır. Ayrıca plaja gelen ziyaretçilerin plajın temizliği için ortalama 40 TL ödemeye razı olduğu belirlenmiştir**.** Elde edilen veriler kapsamında, ekonometrik modellerle yorumlanan ilk çalışma olma özelliği taşıyan bu çalışma sonuçları, M/MP yoğunluğundaki artışın ziyaret olasılığını ve kişi-başı harcamayı düşürdüğü; "temizlik" için pozitif WTP'nin ise politika seçenekleri (temizlik sıklığı, kaynakta azaltım) altında net refah kazanımları sağlayabildiğini göstermektedir.

**Anahtar sözcükler**: Seyahat maliyeti yöntemi, Ayrık seçim metodu, Makro/Mesoplastik

## 1. INTRODUCTION

Coastal ecosystems play a critical role in supporting human well-being through cultural ecosystem services, including recreation, aesthetic value, and tourism-driven economic benefits. However, the sustainability of these services has come under increasing pressure, particularly in regions experiencing intense urbanization and coastal development (Smart *et al*., 2021; Drius *et al*., 2025; Zhao *et al*., 2025). Megacities, in particular, impose substantial anthropogenic burdens on marine environments through high population density, wastewater discharges, and intensive tourism activities (Xu and Zhang, 2022; Paskova *et al*., 2024; Ilao *et al*., 2025). Istanbul, located along the Sea of Marmara, represents a prominent example of this dynamic.

Recent studies have documented the region's physical degradation of coastal zones and rising macro/mesoplastic (M/MP) pollution levels. A total of 3787 waste items were collected from waste units across four beaches along the Istanbul coastline. Of these solid wastes, 47.8% consisted of macroplastics, 9.2% of mesoplastics, and the remaining 43.0% comprised other materials such as paper, glass, and metal (Akarsu *et al*., 2022). Domestic wastewater, industrial discharges, and contaminants transported via stormwater runoff are the primary sources contributing to the transport of macro- and microplastics into coastal regions (Okoffo *et al*., 2019). In addition, wind and atmospheric transport processes also play a significant role in the introduction of microplastics into coastal ecosystems (Bergmann *et al*., 2015). Evidence from recent studies underscores the role of plastic pollution as a key factor diminishing the recreational value of beaches. Despite this, no quantitative research has yet evaluated the associated welfare losses through econometric valuation models. In the size classification of plastic debris, the categories are defined as follows: plastics larger than 100 cm are classified as megaplastics; those between 25 mm–100 cm macroplastics; between 5 mm and 25 mm are considered mesoplastics; particles ranging from 1 mm to 5 mm are categorized as large microplastics; those between 1 μm and 1

mm are classified as small microplastics; and particles smaller than 1 µm are defined as nanoplastics (Wagner *et al*., 2014; Bermúdez and Swarzenski, 2021; Aydın *et al*., 2023; Sivri, 2024). Plastic materials, which facilitate daily human activities and are often perceived as non-threatening, can cause severe degradation in ecosystems over time, leading to physical damage across all trophic levels (i.e., each biological entity occupying a specific ecological niche within the food web) and, in many cases, mortality driven by bioaccumulation processes (Sivri and Çullu, 2020). Reports in visual and written media documenting plastic-related wildlife deaths, which appear with increasing frequency, represent only the most visible and least representative fraction of the overall threat—much like the tip of an iceberg (Sivri, 2024). Existing literature demonstrates that increased marine litter reduces visitor numbers and associated tourism revenues (Jang *et al*., 2014; Ballance *et al*., 2000; McIlgorm *et al*., 2011; Schultz *et al*., 2013). However, microplastic-specific studies remain limited due to methodological constraints and challenges related to coastal cleaning practices that primarily target visible waste. Moreover, at the megacity scale, no research has adopted an integrated approach that simultaneously examines visitor behavior and economic value losses associated with M/MP pollution.

In coastal ecosystems, the erosion of recreational value through visibility/hygiene perception due to pressure from M/MPs; and the fact that repeated actions in ancient megacities like Istanbul have a greater impact than the sum of these actions (high cumulative impact) were influential in the development of this study. However, while the increasing impact of marine litter on recreational activities in marine areas is evident, the limited number of studies combining both M/MP and city-focused beach selection and econometric analyses has drawn attention. This study aimed to address this literature gap. While numerous studies and supported ecological indicators exist on the abundance and risks of M/MP along the Marmara/Aegean coasts, one of Turkey's most valuable areas surrounded by the sea on three sides, no study has documented the link between M/MP abundance and recreational value.

This study aims to evaluate the effect of macro/mesoplastic (M/MP) density on coastal recreational value using Istanbul as a case study. The research is guided by the central question: To what extent does beach-level M/MP density reduce recreational demand and associated local income? Within this scope, the study examines (i) the role of M/MPs as an environmental quality attribute influencing beach choice, (ii) visitors' willingness-to-pay (WTP) for cleaner beach conditions, and (iii) the monetary implications of welfare losses for the regional economy.

A key objective of this research is to emphasize the critical contribution of coastal environments to physical and psychological well-being, consistent with the Sustainable Development Goals (SDGs), particularly SDG 3 (Good Health and Well-Being). Additionally, the study supports SDG 14 (Life Below Water) by highlighting the need to protect the ecological integrity of marine systems in the face of rising plastic pollution. Accordingly, the results are expected to provide not only scientific insights but also evidence-based guidance for sustainable coastal management and policy design.

## 2. MATERIAL AND METHODS

The study employed a two-stage methodological framework. In the first stage, the influence of macro/mesoplastic (M/MP) density on visitors' site preferences was analyzed using a travel cost site-choice model, which explains visitors' selection among alternative beaches as a function of travel cost, travel time, and site quality attributes (plastic density, cleaning frequency, and information availability). In the second stage, visitors' conditional WTP for improved beach cleanliness and hygiene quality was estimated through discrete choice experiments (DCEs).

By combining the travel cost method and discrete choice experiments, the analysis captures both revealed and stated preferences regarding the impact of M/MP pollution on coastal recreation. The travel cost model reflects actual behavioral choices (Angelo *et al*., 2025), whereas the DCE approach estimates the conditional WTP for improved beach cleanliness and water quality

(Train, 2009; Hanley *et al*., 2001). These complementary methodologies align with previous evidence indicating that marine litter pollution substantially reduces recreational value. Integrating these two approaches enables the simultaneous estimation of behavioral responses and welfare changes, thereby providing a multidimensional assessment of the economic burden imposed by M/MP pollution on coastal recreation.

### 2.1. Identifying Studies on M/MP

In this study, the Scopus search engine, owned by Elsevier and serving as a comprehensive abstract and citation database covering a wide range of academic disciplines, was used. Scopus is widely recognized for its rigorous indexing process and provides access to peer-reviewed journal articles, conference proceedings, and patents. It is internationally acknowledged as a reputable scientific information source and is extensively used by researchers, institutions, and organizations worldwide for literature reviews, citation analyses, and research evaluation (Akduman *et al*., 2020; Basmacı *et al*., 2022). A literature search was conducted in the Scopus database to identify studies on macro- and mesoplastics carried out in Turkey's coastal regions over the past decade. To increase the specificity of identifying studies related to M/MP, the following keyword combination was used: (("macroplastic" OR "mesoplastic*") AND ("Turkey" OR "Türkiye" OR "Turkish coast*") AND (coastal OR marine OR beach)). The primary objective of this selection was to quantify the preference for studies focusing on M/MP in coastal environments compared to microplastic research conducted during the same period. The search covered the years 2016–2025 (till November 2025). The original articles identified through a structured keyword-based search were systematically screened by reviewing their abstracts, and only studies directly relevant to the objectives and scope of the present research were included in the analysis.

### 2.2. Sampling Area

Sampling of sandy areas was conducted at selected beaches along the Istanbul coastal area to determine M/MP concentrations. Florya and Büyükçekmece (BÇ) beaches, located on the European side of Istanbul, were selected due to their high recreational use, accessibility, and the availability of consistent and comparable M/MP datasets. These beaches represent intensively used urban coastal environments within the metropolitan area. The coordinates and location maps for the selected areas are presented in Figure 1.




**Figure 1.** Coordinates and location maps of beach areas (Directorate General for Mapping, 2025. https://atlas.harita.gov.tr)

### 2.3. Discrete Choice Experiment (DCE) Design

The Discrete Choice Experiment (DCE) was designed based on four key attributes, each with three levels: (i) macro/mesoplastic density (high, medium, low), (ii) beach cleaning frequency (monthly, weekly, daily), (iii) information provision (none, basic, detailed), and (iv) entrance fee (0 TL, 50 TL, 120 TL). Within this design, the assumptions, attribute values, and level thresholds used to determine participants' choices among alternative beach scenarios and to estimate the econometric choice models are summarized in Table 1. All calculations were performed using the values presented in this table.

Macro- and mesoplastic (M/MP) density data for the beach areas were obtained from field surveys conducted between June 2024 and July 2025. The values derived from these surveys were averaged to generate a single representative dataset, which was subsequently used in the calculations. Beach cleaning frequency was determined using official municipal records. To represent the level of information provision regarding water quality, field observations

considered the presence of tables, infographics, information signs, and QR codes. Entrance fees were categorized into three levels based on current municipal or private beach charges, allowing for estimation of visitors' WTP for improved beach quality and cleanliness.

**Table 1**. DCE attributes and level classification *Source: Istanbul Metropolitan Municipality Support Services Directorate* (URL-1, 2025)

| Attribute | Level 1 (low) | Level 2 (medium) | Level 3 (high) |
|---|---|---|---|
| **MP** | >1000 particle/kg sand | 200–500 particle/kg sand | < 100 particle/kg sand |
| **Beach Cleanliness** | 1 time per month | 1 time per week | Daily |
| **Water quality information** | No information | Basic warnings (swimming risk) | Detailed daily M/MP chemical data |
| **Fee** | 0 TL | 50 TL | 120 TL |

## 2.4. Econometric Models

### 2.4.1. DCE – Mixed Logit

The Discrete Choice Experiment (DCE) is an experimental approach designed to examine individual decision-making processes. Participants are presented with alternative options characterized by specific attributes and are asked to select their preferred option, generating data for analysis (Train, 2009). DCEs are widely applied in environmental economics, health economics, transportation, and marketing to quantify the value individuals place on particular attributes such as price, quality, or environmental impact (Louviere *et al*., 2000; McFadden and Train, 2000).

The Mixed Logit model is an advanced econometric technique commonly employed to analyze DCE data. It was developed to address several limitations of the standard logit model, primarily by allowing for random variation in individual preferences (Hole, 2007). Parameters are treated as randomly distributed, enabling the model to capture heterogeneity in price sensitivity and other attribute effects across respondents. Moreover, Mixed Logit accounts for correlated choices and repeated observations, providing a more flexible and realistic representation of decision-making behavior (Hensher *et al*., 2015).

$$U = \beta_{MP}.MP_J + \beta_{clean} + \beta_{info}.INFO_j + \beta_{free}.Fee_J + \varepsilon_{nj} \quad (1)$$

$$WTP_k = -\frac{\beta_k}{\beta_{fee}} \quad (2)$$

$$U = \beta_{MP}.MP + \beta_{clean}.2 + \beta_{info}.1 + \beta_{fee}.120$$

$$U = -0.5 * MP + 0.8 * 2 + 0.6 * Info + 0.02 * Fee$$

$$WTP_{clean} = -(\frac{0.8}{-0.02}) = +40$$

*For Florya* :
M/MP = 202.2, Cleanliness = 2, Info = 1, Fee = 120

$$U = -0.5 * 202.2 + 0.8 * 2 + 0.6 * 1 - 0.02 * 120$$

*For Büyükçekmece* :
M/MP = 271.6, Cleanliness = 1, Info= 1, Fee = 0

$$U = -0.5 * 271.6 + 0.8 * 2 + 0.6 * 1 - 0.02 * 0$$

### 2.4.2. Travel Cost Model

One of the indirect methods widely used to estimate the economic value of recreational areas such as beaches, parks, lakes, coastal zones, and national parks is the Travel Cost Model (TCM). The fundamental principle of this approach is that the travel costs incurred by visitors reflect the benefits obtained from access to the site, expressed as consumer surplus (Artell *et al*., 2025). In this study, the calculation of travel costs in a megacity such as Istanbul accounted for both monetary expenditures and time-related costs. Based on price and expenditure data, the average amount spent per visit by a typical beach visitor was subsequently estimated.

The values presented above reflect direct expenditure. However, the term "impact on the local economy" typically encompasses the indirect and induced effects, which are obtained by applying input–output multipliers. For Turkey, the tourism revenue multiplier was estimated at 1.96 in an earlier study (Fletcher, 1995) and later reported to range between 2.66 and 2.70 in 2015 (Koç, 2015). In practice, this means that each unit increase in tourism revenue

can generate up to 2.7 units of broader economic impact. According to this approach, the daily contribution of beach recreation to the local economy is calculated by multiplying the average individual expenditure by the number of visitors and a coefficient of 2.7. The abbreviations used for the economic models applied in the study are presented in Table 2.

**Table 2**. Table of Abbreviations for Economic Models

| Abbreviation | Description | Source |
|---|---|---|
| **M/MP** | Macro/mesoplastic Density | Land Sampling |
| **Cleanliness** | Cleaning frequency | İstanbul Municipality |
| **Info** | Water Quality Level | Observation |
| **Fee** | Beach Entrance Fee | Beltur (2025) |
| **Cost** | Travel Cost | Metro İstanbul (2025) |
| **TravelTime** | Travel Time | |
| **Xn** | Visitor Socioeconomic Variables | Kaya, (2022) |
| **Visit** | Visitor Preference (1=Choosed, 0=Didn't choose) | Train, (2009) |

## 3. RESULTS

### 3.1. Literature Trends on M/MP Research in Türkiye

The increasing preference for microplastic-focused studies over macroplastic research in coastal areas over the past decade constitutes a key motivation for conducting this study with a specific emphasis on macro- and mesoplastics. In line with the objectives of this study, original research articles addressing macro- and mesoplastics (M/MP) in Türkiye's coastal regions were systematically examined using the Scopus database in order to quantify research output and identify prevailing research trends. The analysis indicates that between 2016 and 2025 (up to November 2025), the number of studies focusing on M/MP (n = 112) remains limited compared to those focusing on microplastics (n = 202). The annual distribution of publications is presented in Figure 2.

**Data show that the highest number of** publications was recorded in 2024, with a total of 28 articles. The lowest publication count occurred in 2016 and 2018, with only one study published in each year. It can be stated that a noticeable increase in the number of studies began after 2020. Research activity has accelerated significantly since 2020.

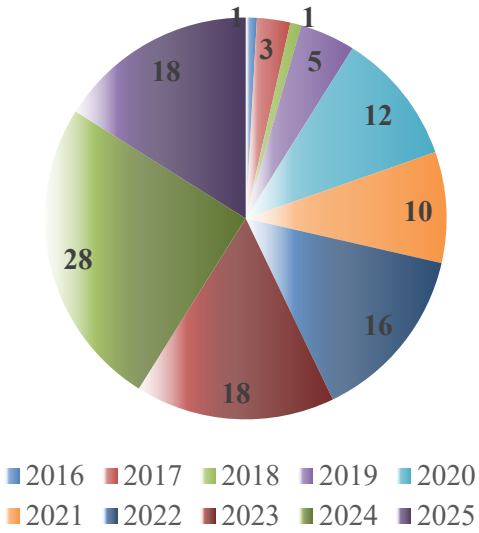



**Figure 2**. Number of articles by year

As the main components of beach litter, macroplastics pose significant risks due to their potential to fragment into smaller particles, including micro- and nanoplastics, over time. The dangers associated with the introduction of these materials into coastal ecosystems have intensified scientific and environmental concern, leading to an increased focus on macro- and mesoplastics in recent studies (Sivri, 2024). In recent years, plastic pollution has increasingly been recognized not merely as a macro-scale waste problem but as a widespread ecotoxicological threat at meso- and micro-scale levels. When the network map generated from the bibliometric analysis is examined, it can be observed that the most frequently studied keywords are "plastic pollution," "marine litter," "macroplastic," "macroplastics," "mesoplastic," and "microplastics." This indicates that the existing literature is predominantly concentrated on these concepts. The results of the bibliometric analysis made using keywords related to the

subject are given in Figure 3. The clusters represented in different colors correspond to themes such as coastal ecosystems, toxicity, and the impacts on marine organisms. This suggests that studies conducted in Türkiye address plastic pollution within a multidisciplinary framework, focusing on environmental impacts/ecosystem health.

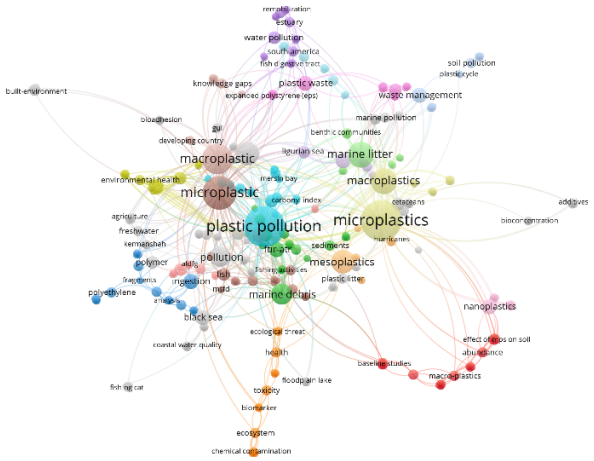



**Figure 3**. Results of the bibliometric analysis

Geographically, the majority of these studies have been conducted in the Marmara Region, particularly in the coastal areas of Istanbul, Balıkesir, and Kocaeli. The authors suggest that the mucilage problem (2021) in the Marmara Sea underscores the importance of investigating interactions between M/MP and ecosystem biota, highlighting a potential driver for the heightened research interest in this region.

### 3.2. Determination of M/MP concentrations

Data on M/MP concentrations were derived from studies conducted at two of the most frequently visited beaches along the Istanbul coastline in the Marmara Sea. The measured M/MP concentration values are presented in Table 3.

**Table 3**. Beaches and M/MP Concentrations

| ***Beach Names*** | ***M/MP (items/m²)*** |
|---|---|
| Florya | 199.1 / 3.1 |
| Büyükçekmece | 271.2 / 0.4 |

### 3.2. Results of Travel Costs

In megacities like Istanbul, travel costs comprise both monetary expenses and significant time costs. Traffic congestion, particularly for private vehicles, leads to prolonged travel times, while public transportation options—such as metro, metrobus, buses, and ferries—are subject to transfer delays, crowding, and limited comfort, which may deter visitation. Additional costs for private transport include fuel, parking, and bridge or highway tolls. Although Istanbulkart fares are subsidized, total costs increase with long-distance and multi-modal trips (URL-1, TÜİK, 2024). Consequently, higher travel times and expenses reduce demand for recreational areas, with low-income groups being particularly sensitive to these barriers.

The TCM enables the estimation of recreational site values by linking travel costs to consumer surplus, as expressed in the standard welfare measurement formulation (Hanemann, 1984; Train, 2009).

$$V_{nj} = \beta_c * Cost_{nj} + \beta_t * TravelTime_{nj} + \gamma * MP_j + \delta * Cleanliness_j + \theta * Xn \quad (3)$$

$$Xn = 30000 - 22104 = 7896\ TL$$

$$Welfare\ change\ per\ visitor: \quad \Delta CS = -\frac{\Delta V}{\beta_C} \quad (4)$$

Based on price and expenditure data, the average beach visitor is estimated to spend approximately 325 TL per visit. Florya Beach is equipped with 1500 sun loungers, 1500 umbrellas, a parking facility accommodating 240 vehicles, covering a total area of 20692 m². In comparison, the total area of Büyükçekmece Beach is 11180 m² (Beltur, 2025).

***For Florya scenario***;
Transportation cost: 27 TL (Metro Istanbul, 2025) + 59.76 TL (TCDD, 2025) = 86.76 TL
Transportation time: 30 min (between Avcılar and Florya)
MP = 202.2 items/m$^2$
Cleaning Frequency = Twice a day

$$V = -0.02*86.76 - 0.01*30 + 0.15*202.2 + 0.10*1 + 0.00005*7896$$

$$V = -32.6$$

***For Büyükçekmece scenario***;
Transportation cost: 27 TL (Metro Istanbul, 2025) Transportation time: 30 minutes (Avcılar

– Büyükçekmece)
MP = 271,6 (271.6) items/$m^2$
Cleaning Frequency = Once a day

$$V = -0.02*27 - 0.01*30 + 0.15*271.6 + 0.10*1 + 0.00005*7896$$
$$V = -41.4$$

### 3.3. Beach Carrying Capacity

Beach carrying capacity is defined as the level of visitor density that allows for comfortable use of recreational areas while ensuring the long-term preservation of natural resources. Relevant variables influencing carrying capacity include site size, visitor density, infrastructure, and ecological sensitivity (Khodkar and Özyurt, 2018). According to Silva et al. (2007), the recommended area per visitor for comfortable use is 15 m².
Using this standard and assuming a daily visitor factor (r) of 2, the carrying capacity
calculations for each beach are presented in Table 4.

**Table 4**. Beach Visitor Expenditures and Carrying Capacity

| Beach | Area | (z/$m^2$) | ® | (A/z) | Capacity |
|---|---|---|---|---|---|
| Florya | 20692 | 1/15 | 2 | 1379 | 2758 |
| BÇ | 11180 | 1/15 | 2 | 745 | 1490 |

Capacity = (A/z)*r  A = Total Area ($m^2$)
z/$m^2$ = Visitors per $m^2$  r = Number of visits per day

When the number of visitors and the average expenditure are multiplied:

$$Florya = 2758*325 = 896350TL$$
$$BÇ = 1490*325 = 484250TL$$

As a result of multiplying the calculated values by 2.7, it is calculated as 2420145 TL/day for Florya and 1307475 TL/day for BÇ.

### 3.4. Model Results

#### 3.4.1. DCE – Mixed Logit Results

The annual macroplastic quantities obtained from the study area ranged between 45 and 652 items at Florya Beach, while the values for Büyükçekmece Beach varied between 45 and 643 items. When mesoplastic quantities were examined, they were found to range from 0 to 18 items at Florya Beach, and from 0 to 5 items at Büyükçekmece Beach.
Florya Beach is frequently visited by the public during the summer months. Based on observations and data from the beach operator, the beach is cleaned twice a day. The entrance fee is reported as 120 TL. Due to frequent visits, the beach faces significant macro/mesoplastic pollution. In the scenario where the M/MP quantity per square meter is determined as 202.2 items/m², the calculated utility (U) value for Florya Beach, based on the assumed coefficients, is -101.3. This result indicates that the beach provides low utility to visitors under current conditions. This outcome is primarily attributed to the high entrance fee and the negative impact of macro/mesoplastic pollution. Although cleaning services and informational activities contribute positively, they are not sufficient to offset the adverse effects. Therefore, under the existing scenario, the attractiveness of the beach is low.
Using the same coefficient assumptions, the utility (U) value calculated for the beach in Büyükçekmece is -134.4. It was determined that, under current conditions, the beach does not provide positive utility to visitors. The presence of macro/mesoplastic pollution and the limited frequency of daily cleaning activities reduce the beach's overall desirability.

#### 3.4.2. Travel Cost Model Results

Within the framework of the Travel Cost Model, transportation cost constitutes the core determinant of recreational demand and represents an essential parameter for both economic assessment and policy formulation. A demand curve was generated by incorporating not only direct transportation expenditures but also travel time incurred by visitors. These combined costs function as the "price" of access to recreational sites and are used to estimate consumer surplus (Lee, 2025).
***Creating a scenario for the coastal area in Florya***: The value of V was calculated as -32.6
In this scenario, beach desirability is low for visitors. The biggest deterrents here are high transportation costs and long travel times. While there is a small positive impact due to high income, this impact is very limited. The benefits could be positive with higher cleaning frequency or lower costs.
***When the scenario is created for the***

***Büyükçekmece coastal area***, The V value was calculated as -41.4.

The negative utility function indicates that visitors do not strongly prefer the beach under these conditions. In particular, high costs and travel time reduce the beach's attractiveness despite the income effect. If the cleaning frequency at the beach is increased, transportation costs are reduced (for example, from 27 TL to 15 TL), or travel time is decreased from 30 minutes to 20 minutes, the utility may become positive. Environmental factors such as enhanced cleanliness and lower macro/mesoplastic levels are additional critical components that support the likelihood of visitor preference. The findings of the study indicate that macro- and mesoplastic pollution on beaches in Istanbul's coastal areas directly influences visitor preferences. The annual average macro/mesoplastic density was determined as 202.2 items/m² at Florya Beach and 271.6 items/m² at Büyükçekmece Beach. This difference suggests that accumulation is more pronounced in Büyükçekmece due to higher recreational pressure and coastal transport activities; however, it can be partially controlled through regular cleaning practices.

On the other hand, the fact that Büyükçekmece Beach is fully open to the public and receives fewer daily cleaning operations compared to Florya Beach has led to increased transport and longer retention of plastics on the shore, particularly during rainy and windy periods.

## 4. DISCUSSION

Based on an extensive review of the existing literature, this study represents the first effort in Türkiye to assess M/MP-related recreational losses using advanced econometric modeling approaches. The findings indicate that increasing M/MP densities generally erode recreational demand and associated regional expenditures, while positive WTP responses suggest that targeted policy interventions—such as increased beach cleaning frequency and the reduction of upstream pollution sources—can generate clear welfare gains. In this context, the results derived from the evaluation presented in the Results section were interpreted through comparison with findings from existing studies.

Accumulations of M/MP in terrestrial and marine ecosystems threaten habitats and increase ecosystem health and ecotoxicological risks. This also impacts economic costs and visitor visits to coastal areas. In this case, it has been determined that visitors to the beach are willing to pay an average of 40 TL for beach cleaning. In studies conducted by Chen and Zhang (2023) and Mutuku *et al*. (2022), β_MP (macroplastic effect) provides solid grounds for assuming a negative MP reduction (macroplastic/litter reduction) coefficient. In this calculation, it was assumed to be (-0.5). Furthermore, WTP measurements expressed as "litter quantity small" are directly related to cleanliness (Chen and Zhang, 2023). Litter reduction strengthens the sense of cleanliness, and this increase has a strong positive effect on WTP (Chernet *et al*., 2024). In this study, β_clean was assumed to be (+0.8). A related study found a WTP of approximately 1.4 USD/visit per visitor for beach ecosystem services and found that "environmental perception" or the level of awareness played a significant role in this WTP (Alarcon *et al*., 2024). Additionally, attitude variables related to environmental awareness, such as "interest in environmental issues," were found to have positive and significant effects on WTP, indicating that knowledge and awareness increase perceived benefits. In light of all this information, the positive β_info coefficient has been supported by scientific studies (Alarcon *et al*., 2024; Danso *et al*., 2017). In this study, the β_info coefficient was set at +0.6.

In a beach study by Alarcon et al., the coefficient for the entrance price was found to be negative, with a decrease in WTP observed as the price increased. A 2016 study by Schuhmann et al. indicated that visitors were willing to pay a fee of approximately 2–8 USD per day to reduce litter (Schuhmann *et al*., 2016). Finally, in a 2024 study by Moreno-Gutiérrez *et al*., visitors were willing to pay ~11 USD per day, demonstrating that sensitivity to the entrance fee (a negative β_fee) is well established in the literature (Moreno-Gutiérrez *et al*., 2024). All of this clearly supports the idea that β_fee should be negative (benefit decreases as the fee increases). In this study, β_fee was assumed to be (-0.02).

Previous studies have highlighted that the negative effect of travel costs is a standard assumption in travel demand models (Wubalem, 2023; Ward and Beal, 2000). Accordingly, the coefficient βc in the travel cost function should be negative; in this study, it was set at -0.02. Similarly, the monetary value of travel time (Value of Time, VoT) is generally estimated at 30–60% of individuals' hourly earnings (Fosgerau, 2016). As leisure time is valued by visitors, increases in travel time reduce utility, and thus the coefficient βt was assumed to be -0.01.

Empirical evidence indicates that the public demonstrates a significant and positive WTP for reductions in plastic pollution (Khedr *et al*., 2023). In other words, lower M/MP densities increase utility, and in this study the γ coefficient was set at +0.15. Regarding cleanliness and environmental quality, Öztürk and Şener (2013) reported that individuals were willing to pay €1.77-2.33 (approximately 60–80 TL) per visit for improved beach cleanliness (Birdir *et al*., 2013). Accordingly, the δ coefficient was assumed to be +0.10, reflecting the positive effect of cleanliness on utility and visitation likelihood.

The term θ·Xn represents the combined effect of individual socio-demographic variables—such as income, age, education, and vehicle ownership—on utility. Xn is typically mean-centered, so deviations from the average value (here, average beach visitor income = 30000 TL, with minimum wage = 22104 TL; Republic of Turkey Ministry of Labor and Social Security, 2025) are incorporated into the model. Based on Koppelman and Bhat (2006), the coefficient θ was set at +0.00005, indicating that higher income increases alternative benefit values. In this study, θ·Xn was calculated as 0.395 under these assumptions.

The local income effect refers to the influence of individuals' income levels on both the frequency of visits to recreational areas and their WTP. Higher income levels reduce sensitivity to travel costs, increase the likelihood of longer-distance trips, and raise demand for recreational services, thereby enhancing overall welfare. Conversely, lower income levels exacerbate the burden of travel costs, decrease visitation rates, and reduce WTP (Kaya, 2022).

DCE model findings showed that an increase in macro/mesoplastic density significantly reduces the perception of beach hygiene and aesthetics. Scenario analyses revealed that an increase in the amount of M/MP could reduce beach preference by 20–40%. This finding is consistent with studies reported in literature (Ballance *et al*., 2000; Browne, 2010; Mendes *et al*., 2024). The travel cost model results also indicated that a "*clean beach*" scenario could significantly increase visitor numbers and, consequently, tourism revenues.

The travel cost model demonstrates that a "clean beach" scenario substantially increases visitor numbers, consistent with similar research on the coast of Tenerife, Spain. Likewise, a 2018 study in Southern California reported that visitors were willing to pay an additional USD 12.91 per person for a 25% reduction in beach litter, corresponding to an estimated welfare gain of USD 29.5 million (Haab, 2018).

Demographic patterns in Istanbul indicate that younger visitors are more sensitive to aesthetic quality and social media perceptions, whereas families with children and middle-aged individuals prioritize hygiene and public health concerns. Generation Z tourists, in particular, exhibit strong responsiveness to digitally shared beach aesthetics (Sumatra, 2025). This aligns with findings from Ontario, Canada, where environmental quality and services—especially cleanliness—were stronger determinants of visitor satisfaction than demographics alone (Dodds and Holmes, 2019).

Overall, the Istanbul findings are consistent with the international literature; however, this study is the first to interpret beach-level plastic pollution through integrated econometric valuation. Mesoplastic and macroplastic (M/MP) density, beach cleanliness, and transportation cost emerged as statistically significant determinants of beach choice behavior. Cleanliness and environmental quality directly influence satisfaction and recreational preferences due to associated health and aesthetic concerns, while transportation costs exert a complementary role by shaping destination accessibility and perceived value.

From an economic perspective, the results

indicate that rising M/MP pollution may reduce per-capita recreational expenditures by approximately 20%, representing a substantial welfare loss amid global economic uncertainty. Beach cleaning therefore constitutes both an environmental and an economic necessity. Evidence from international studies reinforces this view: reducing beach litter by 25% produced welfare gains of USD 12.91 per person (USD 29.5 million total), while a 75% reduction generated USD 42.30 per person (~USD 46.5 million) (URL2). A global review of 63 studies further identified an average WTP of USD 35.29 per year per person for a 50% reduction in litter (Mutuku *et al*., 2022). Large-scale marine debris modeling suggests that doubling beach litter may result in a loss of 4.6 million daily visitors, USD 414 million in tourism revenue, and 4,300 jobs, whereas near-zero litter could yield 2.1 million additional daily visitors, USD 187 million in revenue, and 1,900 new jobs (Marine Debris Program, 2025).

Urban residents exhibit different recreational preferences if they perceive environmental threats to coastal areas (Haab, 2018). The fact that this pollution undermines the health of coastal and marine ecosystems, the biodiversity of marine areas, and cultural ecosystem services (recreation, aesthetic value) deepens the perception of plastic pollution as a global problem. International awareness campaigns are focusing on this phenomenon, conducting awareness-raising campaigns aimed at preventing anthropogenic pollutants. In this study, the WTP of individuals for beach cleaning was estimated to be approximately 40 TL per person per year. This value is consistent with the global meta-analysis conducted by Mutuku *et al*. (2022). The meta-analysis reported an average WTP of 35.29 USD per person per year for a 50% reduction in all types of beach litter; when current exchange rates are considered, this amount closely aligns with the estimate obtained in the present study. Therefore, this similarity indicates that the perceptions of beach users in Türkiye regarding marine litter and the value they attribute to cleaning services are in line with global trends.

The benefit and WTP analyses obtained within the scope of this study quantitatively reveal visitors' behavior regarding beach cleanliness. The calculations indicate that individuals are willing to pay an average of 40 TL for a clean beach. In contrast, beaches with higher M/MP concentrations exhibit negative overall visitor utility, while those with lower pollution levels provide higher utility. For example, the utility is higher at Florya Beach due to its M/MP concentration of 202.2 items/m², whereas the utility is lower at Büyükçekmece Beach, which has a higher concentration of 271.6 items/m².

This suggests that visitors directly shape their preferences based on environmental quality and that M/MP pollution has a significant negative impact on recreational experience. However, regular cleaning practices at Florya contribute to some degree of control over accumulation. At Büyükçekmece Beach, the beach's full public access allows plastics carried away, particularly during rainy and windy periods, to remain on the shore for longer periods. Similarly, studies conducted along the coastal areas of the Sea of Marmara have reported significant spatial differences in macro- and mesoplastic concentrations among beaches. This suggests that local factors such as coastal use intensity, recreational activities, and municipal cleaning frequency play an important role in pollution levels. DCE findings similarly show that visitors are willing to pay additional fees for improved cleanliness and environmental quality, demonstrating that clean beaches generate measurable welfare benefits as cultural ecosystem services. These results are particularly relevant for megacities with coastal recreational systems and directly support Sustainable Development Goals 14 &3 (SDG 14: Life Below Water; SDG 3: Good Health and Well-Being).

## 5. CONCLUSION

Plastic materials, which facilitate daily human activities and are often perceived as non-threatening, can cause substantial ecosystem degradation over time, resulting in physical damage across all trophic levels (i.e., organisms occupying distinct ecological niches within the food web) and, in many cases, mortality driven by bioaccumulation processes. Within this framework, macro- and mesoplastic

concentrations identified in the study area were evaluated in relation to prevailing meteorological conditions and beach-cleaning frequency. Periods of intense precipitation were associated with runoff-driven transport, leading to marked increases in plastic accumulation. In addition, northerly wind regimes intensified coastal current activity, promoting the accumulation of buoyant plastics along specific shoreline segments. Regular daily cleaning practices at Florya Beach contributed to maintaining relatively controlled accumulation levels, whereas the lower cleaning frequency at Büyükçekmece allowed macroplastics to persist for longer periods, particularly following rainy and windy conditions, thereby explaining the observed differences in M/MP densities between the two sites.

Taken together, these findings demonstrate that M/MP pollution in densely populated megacities such as Istanbul exerts critical impacts not only on environmental integrity but also on economic performance and social well-being. From a policy perspective, the results underscore the importance of regular and systematic beach-cleaning programs, plastic reduction strategies, and visitor awareness initiatives as core components of sustainable coastal management. Moreover, effective prevention of plastic pollution requires the coordinated implementation of legislative updates, enhanced sectoral transparency, and improvements in individual consumption and hygiene practices. Such an integrated governance approach is essential to minimizing M/MP accumulation across both terrestrial and marine environments and to supporting long-term environmental sustainability objectives.

Finally, the findings indicate that regular beach cleanup programs can deliver substantial benefits to coastal areas relative to their associated costs. Economic evaluations based on WTP estimates provide valuable evidence for decision-makers by quantifying welfare gains, informing cost-effective management strategies, and ultimately enhancing visitor satisfaction and overall coastal resilience. The results obtained indicate that M/MP pollution in densely populated megacities like Istanbul has critical impacts not only on the environment but also on economic and social well-being. Therefore, regular beach cleaning, plastic reduction policies, and strategies to raise visitor awareness should be considered key elements of sustainable coastal management. Furthermore, preventing plastic pollution necessitates the simultaneous implementation of measures related to legislative updates, sectoral transparency, and individual hygiene practices. This holistic strategy will minimize M/MP accumulation in terrestrial and marine environments, supporting long-term environmental sustainability goals.

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**Yusuf ESMER:** Conceptualization, Methodology, Writing, Data analysis. **Tuğba KAYA:** Sampling, Writing- Review. **Nüket SİVRİ:** Conceptualization, Writing-Review and Editing, Supervision,

## CONFLICT OF INTERESTS

The author(s) declare that for this article they have no actual, potential or perceived conflict of interests

## ETHICS COMMITTEE PERMISSION

Ethical approval was not required for this study, as it did not involve human participants, animals, or identifiable personal data.

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