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# The social costs of marine litter along European coasts

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ABSTRACT

This is the first study to assess the social costs of marine debris washed ashore and litter left behind by beach visitors along different European coasts. Three identical surveys, including a discrete choice experiment, are implemented at six beaches along different European coastlines: the Mediterranean Sea in Greece, the Black Sea in Bulgaria and the North Sea in the Netherlands. Beach visitors are asked for their experiences with beach litter and their willingness to volunteer in beach clean-up programs and their willingness to pay an entrance fee or increase in local tax to clean up marine litter. Significant differences are found between countries. This has important implications for the size and transferability of the estimated social costs of marine litter across Europe.



## 1. Introduction

The economic values from coastal recreation are considerable worldwide (Ghermandi and Nunes, 2013). Clean seas and beaches are key to attract local and international tourists and are an integral part of the European Marine Strategy Framework Directive (MSFD), in which marine litter is one of the key indicators to assess good environmental status and the effectiveness of policy measures (Galgani et al., 2013). Marine debris and beach litter have been argued to pose a significant cost on society, in particular in the way they affect coastal tourism and recreation (UNEP, 2009). Marine litter stranded on beaches poses a serious visual and aesthetic stroke for tourists and local beachgoers, limiting overall beach enjoyment and causing a decline in coastal tourism and corresponding revenues (Munari et al., 2016). Since coastal tourism contributes significantly to coastal economies, changes in these revenues will directly affect coastal communities (KIMO, 2010). However, remarkably few studies exist that have investigated the impacts of marine litter on coastal tourism and the social costs of beach litter (Mouat et al., 2010). An exception is the widely cited study by Ofiara and Brown (1999), who reported a reduction in beach visitation along the Jersey shores of between 8 and 33 percent due to large amounts of landfill debris washed ashore in the state of New York during two consecutive summers in 1987 and 1988. The economic loss as a result of reduced local business was estimated at 15–40 percent, equivalent to USD 0.25–1.23 billion.

Although based on an extreme incident, these numbers highlight the extent of the potential social costs involved. Several studies show that litter plays a role in beach selection and the presence of litter may be a reason for tourists not to visit a beach (for a comprehensive overview of these studies, see Tinch et al., 2012). At the same time, a strong correlation exists between beach visitor density and marine litter generation (Santos et al., 2005), and beach recreation and tourism have been found to be among the main responsible for the litter found on beaches (OSPAR, 2009). Those responsible for littering may not necessarily incur the full cost of their actions and may have limited incentives to change their behavior and thus minimize their impact on the coastal environment (Oosterhuis et al., 2014), hence requiring coastal policy and management interventions. In order to inform sustainable coastal management policy, insight is needed in the economic value of the impacts of marine litter.

The non-commercial (non-market) impacts of beach litter on social welfare can be assessed using surveys and asking beach visitors about their perception of marine litter and preferences for clean beaches. As for the assessment of the commercial (market)

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impacts of beach litter, the number of studies applying surveys to assess the social welfare impacts of beach litter based on public perception and valuation is very limited. A number of studies exist, which focus more generally on public willingness to pay (WTP) for beach and water quality improvements. Examples include Blakemore and Williams (2008), Beharry-Borg and Scarpa (2010) and Östberg et al. (2010). These studies refer to beach litter, but in hardly any of these cases is it possible to assess the non-market value for beach litter separately. Beach litter is only one of the aspects influencing beach quality. Smith et al. (1997) were the first to apply contingent valuation (CV) to estimate the non-market values of beach litter management in New Jersey and North Carolina using different baseline scenarios for the valuation. Clean up programs of different baseline situations, depicted on photographs showing varying degrees of beach littering, were valued, as expected, differently. Median WTP values elicited through a mail survey varied between US$ 21 and 72 per person per year in annual income tax (in 1992 price levels). The only other study we are aware of by Loomis and Santiago (2013) compared the results from a CV and discrete choice experiment (DCE) in split samples, interviewing 427 visitors to 5 beaches in Puerto Rico and asking for their WTP to eliminate trash along with improving water clarity. The two methods yielded similar mean WTP values for eliminating trash between US$ 98 and 103 per visitor day (in 2011 price levels).

The main objective of this study is to add to the empirical evidence base and estimate the social costs of marine litter across different European beaches and coastal zones using the same survey design. Six hundred and fifty beach visitors are interviewed in-person at six different beach locations in Greece, Bulgaria and the Netherlands. More specifically, the objectives are to assess (1) public perception of marine litter at these beaches, (2) public willingness to volunteer in beach clean-up actions, and (3) public WTP local entry fees and municipality taxes to reduce marine litter in a DCE. WTP values are derived from the DCE where beach visitors are asked for their preferences for alternative beach clean-up scenarios. The WTP value is directly related to the welfare loss experienced by beach visitors as a result of the presence of marine litter and therefore used as an indicator of their social cost. The novelty of the DCE is that a distinction is made between point and diffuse pollution sources, i.e. litter left by visitors and marine debris washed ashore, given the fact that a large share of the beach litter originates from beach visitors self (OSPAR, 2009). Using the same survey instrument furthermore allows for the fourth and final objective of international comparison and testing of the equality of findings across the different study sites. The application of such identical international DCEs to test the transferability of the non-market costs or benefits of environmental change is very limited (e.g. Brouwer et al., 2015a), but essential to improve our understanding of the context specificity and spatial variation and distribution of the environmental costs and benefits of European policy implementation such as the MSFD across member states (Lopes da Silva et al., 2015).

The remainder of this paper is organized as follows. Section 2 presents the general survey design and the DCE. This is followed in Section 3 by a description of the econometric models estimated in this study, in particular the discrete choice model. Section 4 presents the case study locations and the data collection procedure, while the survey results are presented in Section 5. Finally, Section 6 concludes.

## 2. Survey design

A common survey was developed and pretested over a period of 5 months in the project CleanSea, a large European research project aiming to provide instruments and tools to keep European seas clean. In doing so, it focused on improving the knowledge base of marine litter composition, distribution and impact in order to identify cost-effective policy strategies. As part of the project, a separate working group looked at the socio-economic costs of marine litter.

The questionnaire was first developed and pretested in the Netherlands and subsequently translated and pretested in Greece and Bulgaria. The questionnaire consists of five main parts.

The first part includes relatively easy warm-up questions related to the number of times people visit the beach where they are interviewed, whether they are on holidays, where they live and what recreational activities they generally undertake when visiting the beach. The second part focuses on the specific characteristics of the beach, and visitors' evaluation of these characteristics, including water quality and beach littering. This is followed by a series of questions related to the amount and types of litter found on the beach (or not) over the year and the impact of the presence of beach litter on visitor's beach experience and appreciation.

The third part asks visitors for their willingness to volunteer in beach clean-up schemes for the particular beach where they are interviewed. They are first asked if they are willing to participate in such a voluntary clean-up action, and secondly how many hours per year they would be willing to volunteer. If they are not willing to participate, visitors are asked for the reasons why not.

The fourth part introduces the DCE. Here respondents are asked for their preferences for cleaning up and removing litter from the beach using choice cards depicting alternative littering situations on the beach. Beach visitors as direct beneficiaries of a clean beach and in some cases also as beach polluters are asked to help pay for the clean-up costs of the beach. Against payment of an extra tax or entrance fee, more can be done to clean the beach. The amount of money visitors are being asked to pay will be used exclusively for the removal of beach litter. Beach visitors are told that if no action is taken, the amount of beach litter is expected to increase in the near future. They are explained that currently on average between 10 and 30 litter items are found on 100 square meters beach, ranging from small items such as the cap of a bottle or a cigarette butt to bigger items such as a bottle or plastic bag. Visitors are first shown an example card which is used to explain and clarify the choices respondents are asked to make and this is then followed by 6 new choice cards displaying each time a completely new situation. Respondents are asked to indicate on each card which situation they prefer most. The design of the DCE is presented in Table 1. The litter types are based on global findings reported for example in Ten Brink et al. (2009) and Ocean Conservancy (2014).

Alternative situations are created by combining the attributes presented in Table 1 based on their possible levels. This yields 192 possible combinations. Because visitors cannot be shown all possible choice situations, the number of combinations was reduced to 60 choice tasks, which were blocked in 10 versions of 6 choice tasks each based on a D-efficient fractional factorial design (the design is available from the authors). Each beach visitor was randomly shown one of these 10 versions with 6 choice cards. Interviewers were trained to memorize a standard text introducing the choice experiment to beach visitors. The attributes and their

**Table 1**
Design of the discrete choice experiment.

| Attribute | Levels |
|---|---|
| Type of beach litter | Plastic - Nets - Cigarette butts - Glass |
| Amount of litter | Average - Below average - None |
| Origin of the litter | Washed ashore - From visitors |
| Beach crowdedness | Many visitors - Few visitors |
| Entrance fee/local tax | €0.5 - €1.0 - €2.5 - €5.0 |

levels were conveyed on the choice cards to respondents with as little text as possible to make the task as easy as possible.

Each situation describes what type of litter will be removed from the beach (glass, plastic, cigarette butts or fishnet ropes), where the litter originally comes from (washed ashore by the sea or left behind by beach visitors), and how much will remain after cleaning (average, less than average or nothing at all). In order to reduce overexposure and consequently overestimation of the social costs of beach litter, also an attribute is added related to how many people visit the beach (few or many). Overcrowding is generally also seen as an important factor of disturbance by beach visitors (Marin et al., 2009). Crowding was also included as an attribute in the DCE applied by Loomis and Santiago (2013).

Although the payment levels are the same in the three surveys, different payment vehicles are used based on the pretests and varying institutional conditions related to beach access and use in the three countries. The payment vehicle is a local tax in the Greek and Bulgarian surveys and an entrance fee in the Dutch survey. An entrance fee was also used by Blakemore and Williams (2008) and Birdir et al. (2013), who found it to be the most preferred payment vehicle under beach visitors in Turkey. Smith et al. (1997) used both an entrance fee and a local tax in the US. Loomis and Santiago (2013) did not specify the payment vehicle, but instead referred to an increase in travel costs. Since the beach is visited by both local residents and tourists, an entrance fee was considered a more equitable way of raising money to clean up the beach than a local tax in the Netherlands. A local tax could furthermore lead to strategic behavior by respondents who do not live in the municipality where the beach is found. Visitors from elsewhere could overstate their WTP in order to get a cleaner beach without actually having to pay the local tax. In Greece and Bulgaria a local earmarked tax, dedicated to beach clean-up, is selected as the payment vehicle, because of the fact that in those countries laws exist, which allow free access to beaches for all people, and an entrance fee is therefore not an option.

In order to avoid strategic behavior and free-riding, it is emphasized that both local and non-local beach visitors would pay the tax: local visitors through their municipality taxes and non-local beach visitors through a tourist tax. The levels of the tax and entrance fee were fixed at €0.50, €1.00, €2.50 and €5.00 per visitor per year based on thorough pretesting of visitor WTP and available information in the case studies about the local tourist tax paid by visitors from outside the city and local municipality taxes for waste collection and disposal. An example choice card is shown in Fig. 1.

The example card shows 2 possible situations. In the first situation the amount of plastic washed ashore on the beach like plastic bottles, plastic caps and plastic bags will be reduced to a level below what is found on the beach on average and will not increase despite many beach visitors. In order to reach this situation, the beach visitor is asked to pay 50 eurocents per person per year. In the second situation, all cigarette butts left behind by beach visitors will be cleaned up. In this case there are only a few people on the beach. In order to reach this situation, the beach visitor is asked to pay 2 euro and fifty cents per person per year. Visitors also have the option to choose none of the two. In that case they do not pay anything extra, and no action is undertaken to reduce the amount of beach litter. The amount of litter is in that case expected to increase in the near future.

In order to enhance the DCE's incentive compatibility (Collins and Vossler, 2009), respondents were asked to (i) evaluate every choice card independently of the previous cards they saw, (ii) answer as truthfully as possible and imagine that they will actually pay for their most preferred situation, and (iii) to view their responses as consequential (Carson and Grooves, 2007) as the results of the survey would be used to inform actual decision-making.

Finally, the fifth and final part includes questions about the visitors' socio-demographic characteristics, such as their age, household size, education and income level.

## 3. Econometric models

Three different types of models are estimated in this study. First, a binary probit participation model to assess the driving factors behind beach visitors' willingness to volunteer to clean-up the beach where they are interviewed. Secondly, a multivariate Tobit regression model to explain the variation in the number of days visitors are willing to volunteer to clean up the beach. The Tobit model accounts for the censored nature of the dependent variable, which only has zero or positive values (e.g. Greene, 2007). Thirdly, a discrete choice model is estimated to analyze the choices beach visitors make in the DCE.

The latter choice model has its roots in random utility theory (e.g. Ben-Akiva and Lerman, 1985) and Lancaster's attribute based utility theory (Lancaster, 1991). The random utility approach describes the utility $U_{ij}$ of a respondent $i$'s choice for situation $j$ as consisting of a systematic (observable) component $V_{ij}$ and an (unobservable) error component $\varepsilon_{ij}$ (equation (1)). $V_{ij}$ is usually specified as a linear function, additive in utility, where $x$ is a vector of $k$ attributes associated with alternative situation $j$, in this case the

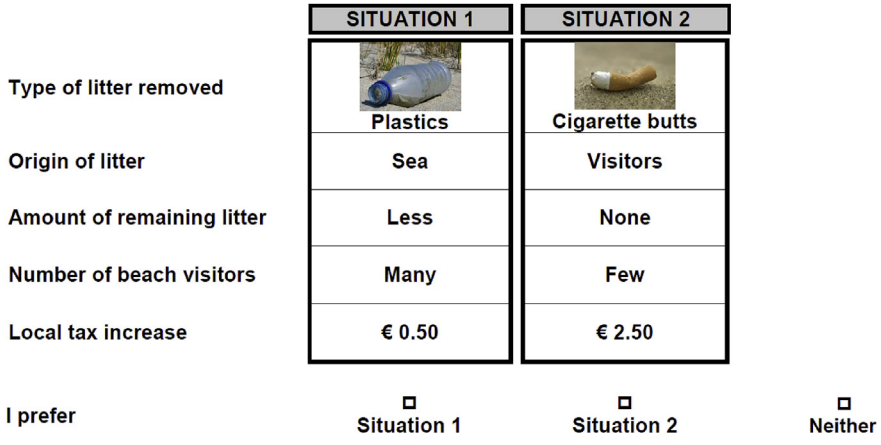



**Fig. 1.** Example choice card.

situation on the beach with clean-up, and $\beta$ is the corresponding coefficient vector.

$$U_{ij} = V_{ij} + \varepsilon_{ij} = \beta' x_{ij} + \varepsilon_{ij} \quad (1)$$

The standard choice model is the multinomial logit (MNL) model (McFadden, 1974), which assumes that the random component of the utility of the alternatives is independently and identically distributed (*i.i.d.*) with a type I extreme value (EV) distribution. Mixed logit modelling approaches have been developed to account for preference heterogeneity (Train, 2003). To this end, a vector of random coefficients of the attributes $x_k$ for individual $i$ can be included in equation (1) representing individual preference variation (equation (2)). The utility coefficients $\beta$ vary according to individual i with density function $f(\beta)$. This density can be a function of any set of parameters and represents in this case the mean and covariance of $\beta$ in the sample population. In this study, alternative situations are defined in terms of the clean-up of litter types from different origins against a payment. The value attached to clean-up of different litter types is measured through the attributes $x_k$ presented in Table 1, accounting for beach visitor characteristics $y_i$ in equation (2).

$$\begin{aligned} U_{ij} &= \beta_i' x_{ij} + \varepsilon_{ij} = \beta' x_{ij} + f(\beta) x_{ij} + \varepsilon_{ij} \\ &= \beta_k' x_{ijk} + f(\beta_k) x_{ijk} + \beta_y' y_i + \varepsilon_{ij} \end{aligned} \quad (2)$$

In order to test to what extent differences exist between the three countries in beach visitors' willingness to contribute to cleaning up beach litter, either in kind (hours) or in money terms, dummy variables will be included for the specific country samples in the estimated models. If these country dummy variables are statistically significant, this means that the results are significantly different between samples and hence not transferable.

## 4. Case study locations and data collection

The same surveys were implemented at different public beaches along the coastline of Greece, Bulgaria and the Netherlands. In each country two different beaches were selected to ensure a wide variety of beach visitor profiles would be included. In all cases, the beaches are located within or in close distance of the boundaries of major cities: Athens along the Mediterranean Sea in Greece, Burgas and Varna along the Black Sea in Bulgaria, and The Hague along the North Sea in the Netherlands (see Fig. 2). In each country the urban beaches somewhat differ from each other in terms of their physical characteristics such as size and visitor profiles to introduce some degree of variation along these two main dimensions and reduce the case studies' context specificity. Unfortunately, no litter monitoring data are available for any of the beaches to facilitate their comparison. Interviewing on all beaches took place on a random 'next to pass' basis, targeting local or national visitors, aiming for an equal amount of men and women and an equal representation of different age groups.

In Greece, two beaches were selected in the larger Attica region with approximately 4 million inhabitants, including the metropolitan city of Athens: Alimos, adjacent to Athens and Mavro Lithari located further south of Athens. Both beaches are located along the Saronikos Gulf. Mavro Lithari is approximately 250 m long and 20 m wide, while Alimos is 370 m long and between 15 and 20 m wide. Beach clean-ups in the region take place on a voluntary basis by NGO's, for example as part of the 'Clean Up the Med' campaign during 2006 and 2007 (Kordella et al., 2013). The two beaches differ in the type of visitors they attract. Mavro Lithari attracts younger people, while older people and families more often visit Alimos. The public has free access to both beaches. Alimos can easily be reached by car and public transport (bus, tram). On the contrary, the beach of Mavro Lithari is less easily accessible. Public transportation is not available, only a private bus service. As a result, visitors of Alimos mainly come from the city of Athens, whereas visitors of Mavro Lithari more often come from the wealthier suburbia. Parking facilities at both beaches are free of charge. Interviews on the two beaches took place in September 2014, mostly during the weekends when more people visited the beaches. Two interviewers randomly interviewed 100 beach visitors on each beach. The overall response rate was 75 percent.

Interviewing in Bulgaria took place in the coastal cities Burgas and Varna. Varna is located north of Burgas and had a population of approximately 335 thousand inhabitants by the end of 2013. Burgas has a population of near 200 thousand people. In 2013, 967 thousand tourists visited the city of Varna and almost 1.3 million Burgas. The beach in Burgas is approximately 1.7 km long with an average width of 38 m, while the city beach in Varna is smaller and about 1 km long with a width of 30 m. Major clean-up activities and removal of construction material, old containers and concrete blocks have been undertaken on the beach in Burgas in 2011. Both city beaches are managed and cleaned on a daily basis during the summer season. Also these two beaches are publicly accessible, with nearby free parking places and surrounding lanes suitable also for cycling. In total, 301 interviews with local and domestic beach visitors were carried out by 4 interviewers in July 2014 on both beaches (149 interviews in Burgas and 152 in Varna). The overall response rate was 54 percent.

In the Netherlands, the city of The Hague with over half a million inhabitants has the highest share of beach area, with around 12 million visitors per year (ECORYS, 2012). The city also has the highest yearly clean-up costs of approximately €1.3 million (Mouat et al., 2010). There are two distinct beach zones in The Hague: the northern beach called Kijkduin and the southern beach called Scheveningen. The latter beach is 3 km long and runs along a promenade and has a higher amount of yearly visitors than the smaller beach of Kijkduin (9.7 and 4.0 million respectively in 2007). The beaches also differ in the type of visitors they attract. Whereas Kijkduin attracts more families, Scheveningen is more attractive to younger visitors. As a result, income levels also differ somewhat between the two beaches as shown in a beach visitors' survey carried out in 2007 (BRO, 2008). According to the beach managers of Kijkduin and Scheveningen, the beach in Scheveningen is generally less clean than the beach in Kijkduin (Cyclus, 2011). One hundred and forty-nine randomly selected visitors, equally divided across the two beaches ($n = 77$ and $n = 72$ in Scheveningen and Kijkdijn respectively), were interviewed by two interviewers in the last two weeks of May 2014. The response rate on both beaches was 50 percent.

## 5. Results

### 5.1. Beach visitor characteristics

The total number of useable interviews for the cross-country comparison is 200 for Greece, 301 for Bulgaria and 149 for the Netherlands. The characteristics of the beach visitors are summarized in Table 2. In view of the fact that no information is available about beach visitors and their characteristics in the three countries, we are unable to assess the representativeness of the samples presented here. Compared to available national statistics (Eurostat, 2015), the three samples include slightly younger, higher income households. Also the share of respondents reporting to be unemployed is lower in the sample than in the three countries as a whole.

We only discuss the main differences here between the three country samples. The Bulgarian sample had the highest share of

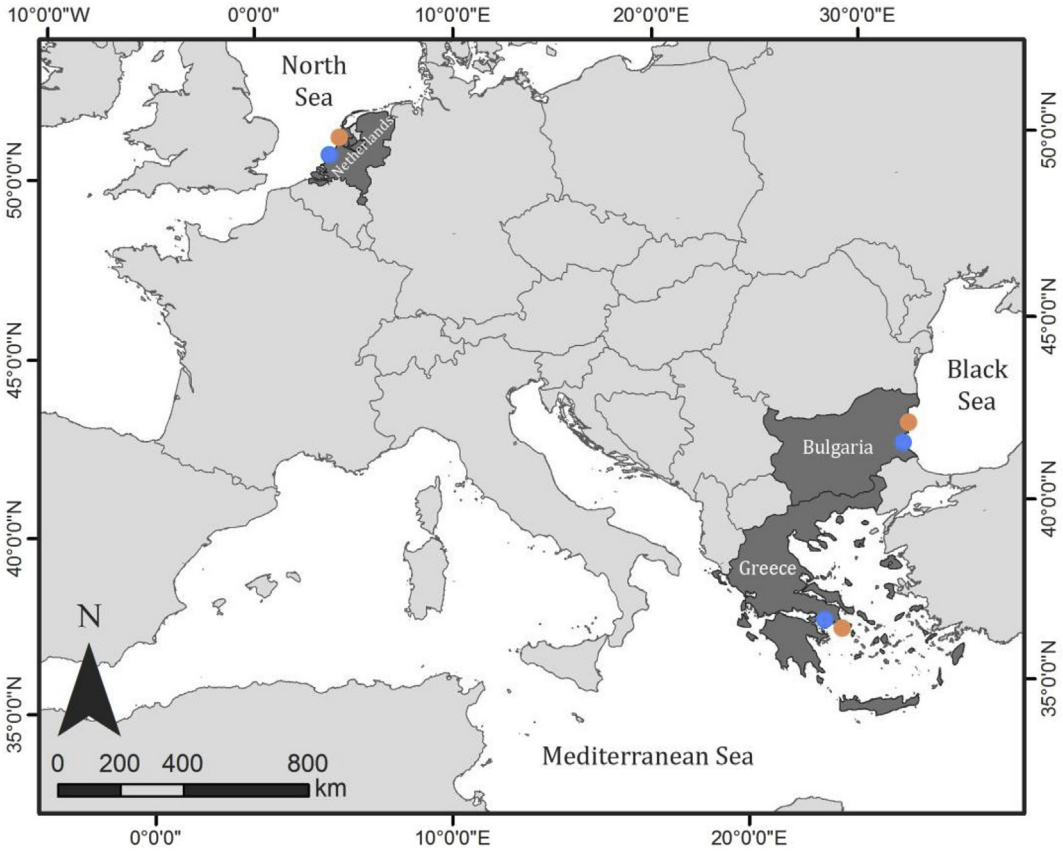



**Fig. 2.** Map displaying the location of the beach surveys.

**Table 2**
Socio-demographic sample characteristics.

| | Greece | Bulgaria | Netherlands |
|---|---|---|---|
| **Beach visiting characteristics** | | | |
| Share holidays (%) | 5.5 | 21.3 | 14.8 |
| Share first beach visit (%) | 18.5 | 11.6 | 9.4 |
| Av. number of years visiting beach | 7.0 (0.5) | 13.5 (0.7) | 23.9 (1.5) |
| Av. number of visits/year (days) | 59.9 (6.3) | 27.3 (1.4) | 32.4 (3.9) |
| **Socio-demographic characteristics** | | | |
| Share female respondents (%) | 51.5 | 50.5 | 44.3 |
| Average age (years) | 41.8 (1.0) | 32.8 (0.7) | 40.6 (1.3) |
| Minimum-Maximum age | 16–80 | 17–72 | 19–74 |
| ***Education level*** | | | |
| Share primary school only (%) | 1.0 | 1.7 | 0.0 |
| Share higher professional education (%) | 23.5 | 10.6 | 25.5 |
| Share university degree (%) | 45.5 | 41.5 | 23.5 |
| ***Household characteristics*** | | | |
| Average household size | 2.5 (0.1) | 2.7 (0.1) | 2.3 (0.1) |
| Average number of children | 0.3 (0.04) | 0.4 (0.04) | 0.4 (0.06) |
| Average household income after tax (€/month) | 1669 (66) | 1034 (28) | 2512 (97) |
| Share member of an environmental organization | 6.5 | 5.0 | 36.2 |
| ***Employment*** | | | |
| Share self-employed (%) | 19.6 | 5.6 | 24.2 |
| Share employed (%) | 28.1 | 57.8 | 43.6 |
| Share unemployed (%) | 17.6 | 3.3 | 4.0 |
| Share housewife (%) | 6.5 | 2.0 | 6.0 |
| Share student (%) | 7.0 | 25.2 | 12.8 |
| Share retired (%) | 20.6 | 5.0 | 8.7 |
| N | 200 | 301 | 149 |

Note: standard errors are presented between brackets.

holidaymakers, the Greek sample the lowest. The share visiting the beach where they were interviewed for the first time was highest in Greece. Nevertheless, most visitors visited the beach before, varying between 81 percent in Greece and 91 percent in the Netherlands. The number of years respondents visited the beach where they were interviewed was significantly higher in the Dutch

sample than in the two other samples. Although some variation also exists between the samples in terms of the number of times they visit the beach every year, in particular between Greece and the two other samples, the difference is not statistically significant.

Turning to the respondents' socio-demographic characteristics, slightly more male than female visitors were interviewed in the Netherlands compared to the Greek and Bulgarian samples (shares are representative for Greece and Bulgaria). Significant differences are furthermore found for respondents' age and household income. Respondents are significantly younger in Bulgaria than in the Greek and Dutch samples (also compared to the national average), while household income after tax is significantly higher in the Dutch sample than in Greece and Bulgaria. A considerable number of Greek visitors is unemployed and retired. Unemployment rates are however lower than the national average. In the Bulgarian sample one in every fourth respondent is a student. The relative share of respondents stating that they have a university degree is substantially higher in Greece and Bulgaria compared to the Netherlands. Finally, a remarkable difference exists between the Dutch sample and the two other samples in terms of membership of an environmental protection organization.

### 5.2. Perception of beach litter

Significant differences in perception exist between samples related to the cleanliness of the beaches (Fig. 3). Sixty-one percent of the Greek sample find the beach where they visit not clean at all, while two thirds of the Bulgarian sample (66%) consider the beach somewhat clean. This share is almost 50 percent in the Dutch sample (49%). Three times as many Dutch than Greek beach visitors consider their beach clean (29% and 10% respectively). Fifteen percent of the Bulgarian sample find their beach very clean. This is only 5 percent in the Dutch sample while none of the Greek visitors think so.

A slightly more equal distribution can be observed when comparing responses between samples related to the frequency with which they encounter beach litter (Fig. 4). The distributions are only significantly different between the Dutch sample and the two other samples, not between the Greek and Bulgarian samples. Dutch beach visitors report to encounter significantly more frequently beach litter than the Greek and Bulgarian beach visitors.

No local monitoring data are available that would allow us to assess to what extent public perception corresponds with actually observed littering rates. The same applies to the types of beach litter. When asking visitors what type of litter they encounter, cigarette butts are mentioned most often in all three samples, followed at a distance by plastic bottles (Fig. 5). Besides cigarette butts, bottles, bags and cans are mentioned by more than half of the sample in the Netherlands. Plastic bottles and bags are also mentioned by a considerable share of the beach visitors in Greece and Bulgaria, but to a lesser extent (24 and 31% of the respondents respectively).

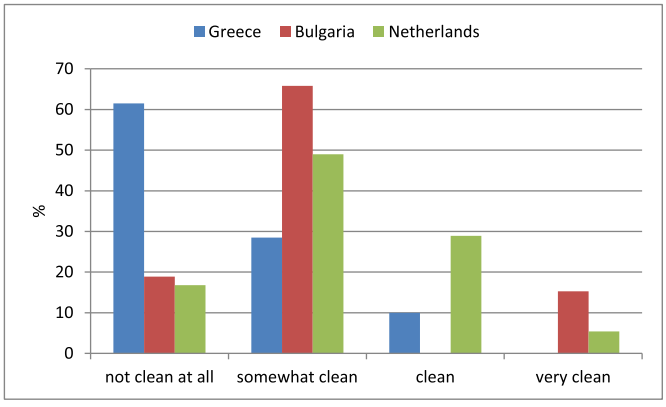



**Fig. 3.** Perceived cleanliness of the beaches in the three samples.

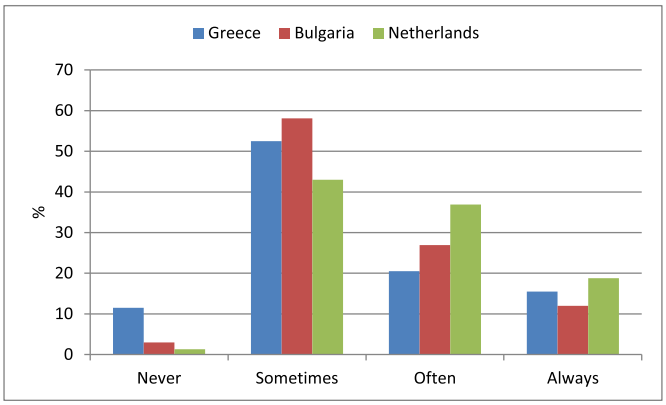



**Fig. 4.** Reported frequency of beach littering in the three samples.

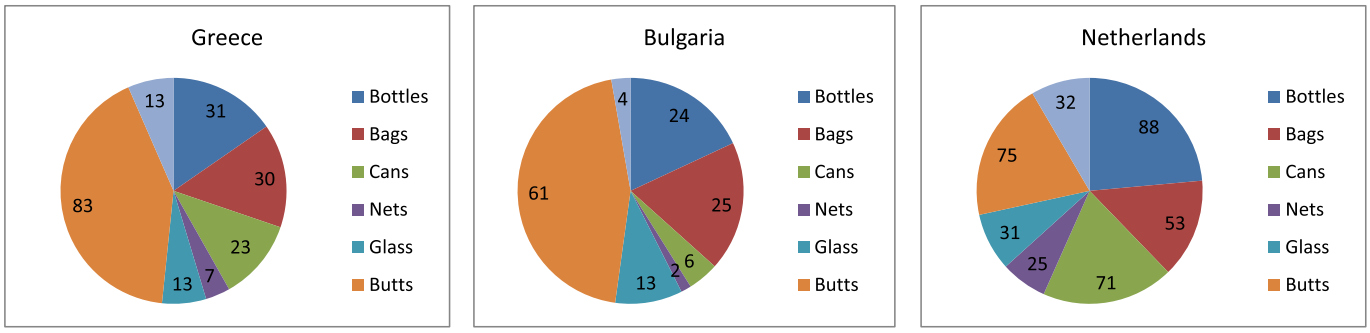
The Greek sample had the highest share of visitors reporting that the beach they visited was not clean at all and also felt most annoyed by it (Fig. 6). Ninety-one percent were very annoyed by the presence of beach litter, and 44 percent of the sample said that this was a reason not to visit a beach again. Bulgarians seem least annoyed, but 95 percent of all respondents claim not to visit a beach if there is littering. This share is 66 percent in the Dutch sample, where 42 percent considers beach littering annoying and 30 percent very annoying. We now turn to the question to what extent beach visitors are willing to contribute to beach clean-up.

### 5.3. Willingness to participate in beach clean-up schemes

Visitors were asked if they are willing to volunteer in cleaning actions for the beach where they were interviewed, and if so, for how many hours per year. Dutch visitors were least willing to volunteer (on average at most 3.4 h per visitor per year with a 72% refusal rate), followed by Greek (on average at most 6.8 h per visitor per year with a 45% refusal rate) and Bulgarian beach visitors (on average at most 14.8 h per visitor per year and a 28% refusal rate). These differences in participation between samples are statistically significant. Based on their responses, two different regression models were estimated: a binary probit model based on their first reply whether respondents are willing to participate in a clean-up scheme and a Tobit regression model based on their second reply how many hours they would be willing to help cleaning the beach. The models were estimated in Stata version 13.0 and the results are presented in Table 3.

A number of consistent results are found across the two models. First of all, the dummy variables for the samples are highly significant in both models. The Dutch sample represents the baseline category and the positive coefficient estimates hence indicate that Greek and Bulgarian beach visitors are more likely to participate and are also willing to contribute more days than Dutch beach visitors whilst controlling, for example, for differences in perception of beach cleanliness and income levels. The differences between the Greek and Bulgarian coefficient estimates are furthermore also statistically significant, implying that the Bulgarian beach visitors are more likely to participate and willing to give up more days to clean up the beach than Greek beach visitors.

As expected, the cleaner a visitor perceives the beach, the less likely he or she agrees to help cleaning it. Similarly, the more beach




Note: shares refer to number of respondents who reported specific beach litter types. Since multiple types could be reported, the shares do not add up to 100%.

**Fig. 5.** Reported shares of beach litter types in the three samples (%). Note: shares refer to number of respondents who reported specific beach litter types. Since multiple types could be reported, the shares do not add up to 100%.

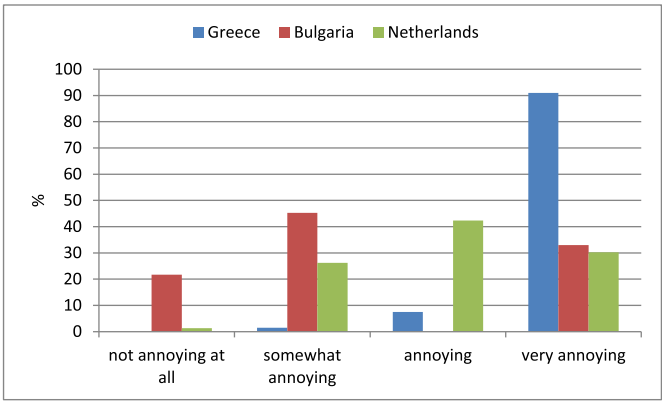



**Fig. 6.** Perceived annoyance of beach littering in the three samples.

littering annoys a visitor, the more he or she is willing to contribute to cleaning it up. Moreover, older female visitors are more likely to participate and give up more days than younger male visitors.

Finally, visitor experience and familiarity with the particular beach, measured through the number of years that someone visits the beach, significantly explains the decision to participate in a beach clean-up action, but not the number of days someone is willing to invest in this. The same applies to a visitor's income level and whether or not someone is a member of an environmental protection organization: members and respondents with a higher income level are more likely to participate than non-members and lower income groups. Whether or not a visitor is on holidays during the visit does not have a significant effect in the two models. Since most respondents live within the cities where the beaches are located, the variation in travel distance to these beaches is very limited and distance-decay was therefore not expected to play a role and not tested in the models presented in this paper.

### 5.4. Estimated choice models

The results from the DCE were analyzed in NLOGIT 5.0. The estimated choice models are presented in Tables 4 and 6. For efficiency purposes, the models are estimated using a Halton sequence of 1000 replications in a quasi-Monte Carlo maximum likelihood simulation (Bhat, 2001). The estimated choice models are highly significant based on the outcome of the chi-square test and the relatively high pseudo $R^2$ for this type of research. The models including the choice attributes only presented in Table 4 provide the basis for the Swait and Louviere (1993) test procedure to see whether the estimated choice models are significantly different, accounting for differences in both scale and preference parameters. The outcome of the test procedure shows that the choice models differ significantly (see Table 5). The null hypothesis of equal preference parameters is convincingly rejected at the 1 percent

**Table 3**
Estimated Probit and Tobit models explaining beach visitors' willingness to participate in beach clean-up programs in the three samples.

| Variable | Probit model (willingness to participate: 1 = yes) | | Tobit model (max. no. of hours willing to clean up) | |
|---|---|---|---|---|
| | Coefficient estimate | St. error | Coefficient estimate | St. error |
| Constant | −2.453*** | 0.848 | −2.151* | 1.323 |
| Greece (1 = yes) | 0.917 *** | 0.212 | 0.948*** | 0.322 |
| Bulgaria (1 = yes) | 1.703*** | 0.193 | 2.496*** | 0.290 |
| Holidaymaker (1 = yes) | −0.018 | 0.168 | −0.309 | 0.257 |
| Number of years visiting the beach | 0.011** | 0.005 | 0.012 | 0.009 |
| Sex (1 = female) | 0.317*** | 0.109 | 0.386** | 0.168 |
| Age (years) | −0.016*** | 0.004 | −0.026*** | 0.007 |
| Household income (Nat log €/month) | 0.245** | 0.110 | 0.205 | 0.169 |
| Member environmental organization (1 = yes) | 0.454** | 0.191 | 0.003 | 0.002 |
| Beach cleanliness perception (0–4) | −0.247*** | 0.072 | −0.347*** | 0.114 |
| Beach litter annoyance (0–4) | 0.149** | 0.067 | 0.449*** | 0.098 |
| LR chi square | 137.97*** | | 150.93*** | |
| $R^2$ | 0.162 | | 0.074 | |
| N | 626 | | 626 | |

***$p < 0.01$; **$p < 0.05$; *$p < 0.10$.

**Table 4**
Estimated mixed logit choice models for the three samples including the choice attributes only.

| Variables | Greece | | Bulgaria | | Netherlands | |
|---|---|---|---|---|---|---|
| | Coeff. est. | St. dev. distr. random coeff. | Coeff. est. | St. dev. distr. random coeff. | Coeff. est. | St. dev. distr. random coeff. |
| Alternative specific constant | −0.103 | 5.838*** | 12.886*** | 11.233*** | −9.414*** | 11.859*** |
| | (0.499) | (0.864) | (2.157) | (1.815) | (2.463) | (2.757) |
| ***Choice attributes*** | | | | | | |
| Litter type: glass bottles | −0.543 | 2.744*** | 2.953*** | 5.371*** | 0.883 | 3.596**(1.600) |
| | (0.334) | (0.802) | (0.402) | (0.797) | (0.590) | |
| Litter type: plastic bags and bottles | 1.443*** | 1.079 | 3.645*** | 3.772*** | −0.576 | 5.308*** |
| | (0.351) | (1.142) | (0.699) | (0.840) | (0.691) | (1.354) |
| Litter type: cigarette butts | 1.334*** | 5.238*** | 2.062*** | 3.389*** | −0.636 | 5.665*** |
| | (0.510) | (0.996) | (0.639) | (0.839) | (0.776) | (1.786) |
| Amount of litter: less than average | 0.126 | 0.567 | 1.637*** | 3.552** | 1.393* | 0.548 |
| | (0.331) | (1.215) | (0.627) | (1.545) | (0.717) | (2.543) |
| Amount of litter: no litter | −0.139 | 2.701*** | 2.768*** | 5.603*** | 2.550*** | 3.974*** |
| | (0.302) | (0.728) | (0.434) | (0.780) | (0.709) | (1.220) |
| Origin of the litter: left by visitors | −0.179 | 2.322*** | 0.521*** | 2.030*** | 1.090** | 2.324* |
| | (0.248) | (0.542) | (0.167) | (0.430) | (0.505) | (1.371) |
| Number of visitors: few | −0.059 | 0.888 | −0.102 | 1.857*** | 1.471*** | 4.387*** |
| | (0.215) | (0.726) | (0.155) | (0.500) | (0.458) | (1.207) |
| Increase local tax | −2.948*** | 2.005*** | −0.785*** | 1.288*** | −2.029*** | 1.795*** |
| | (0.431) | (0.333) | (0.157) | (0.279) | (0.409) | (0.400) |
| ***Model summary statistics*** | | | | | | |
| Log Likelihood | −709.495 | | −1039.498 | | −384.609 | |
| McFadden $R^2$ | 0.462 | | 0.476 | | 0.608 | |
| Number of observations | 1200 | | 1806 | | 894 | |
| Number of respondents | 200 | | 301 | | 149 | |

***$p < 0.01$; **$p < 0.05$; *$p < 0.10$.

**Table 5**
Test results equality of preference and scale parameters between the estimated sample specific choice models.

| | $LL_{s1}$ | $LL_{s2}$ | $LL_{pooled}$ ($\lambda_{s1} \neq \lambda_{s2}$) | LR-test (d.o.f. 9) | $H_0^a$: $\beta_{s1} = \beta_{s2}$ rejected?[1] | $LL_{pooled}$ ($\lambda_{s1} = \lambda_{s2}$) | LR-test (d.o.f. 1) | $H_0^b$: ($\lambda_{s1} = \lambda_{s2}$) rejected?[2] |
|---|---|---|---|---|---|---|---|---|
| Greece - Bulgaria | −709.495 | −1039.498 | −1944.607 | 391.227 | Yes | −1956.073 | 22.933 | Yes |
| Greece - Netherlands | −709.495 | −384.609 | −1144.183 | 100.158 | Yes | −1153.889 | 19.411 | Yes |
| Bulgaria - Netherlands | −1039.498 | −384.609 | −1566.448 | 284.683 | Yes | −1589.114 | 45.331 | Yes |

Explanatory notes: LL: Log Likelihood; LR: Likelihood Ratio; s1: sample 1; s2: sample 2; d.o.f.: degrees of freedom.

**Table 6**
Estimated pooled mixed logit choice model including covariates.

| Variables | Coeff. est. | St. error | St. dev. distr. random coeff. | St. error |
|---|---|---|---|---|
| Alternative specific constant | −22.287*** | 4.964 | 8.459*** | 0.844 |
| ***Choice attributes*** | | | | |
| Litter type: glass bottles | 1.671*** | 0.214 | 4.120*** | 0.471 |
| Litter type: plastic bags and bottles | 2.273*** | 0.285 | 2.276*** | 0.701 |
| Litter type: cigarette butts | 1.360*** | 0.325 | 4.821*** | 0.617 |
| Amount of litter: less than average | 0.667*** | 0.257 | 0.717 | 0.927 |
| Amount of litter: no litter | 1.647*** | 0.235 | 4.484*** | 0.498 |
| Origin of the litter: left by visitors | 0.308** | 0.127 | 2.244*** | 0.373 |
| Number of visitors: few | 0.080 | 0.114 | 1.707*** | 0.355 |
| Increase local tax | −1.376*** | 0.150 | 1.469*** | 0.175 |
| ***Covariates*** | | | | |
| Greece (1 = yes) | 2.859*** | 1.015 | | |
| Bulgaria (1 = yes) | 21.268*** | 2.284 | | |
| Holidaymaker (1 = yes) | −0.021 | 1.158 | | |
| Number of years visiting the beach | −0.132*** | 0.034 | | |
| Sex (1 = female) | 1.929*** | 0.652 | | |
| Age (years) | 0.012 | 0.026 | | |
| Household income (Nat log €/month) | 1.916*** | 0.639 | | |
| Member environmental organization (1 = yes) | 2.217** | 0.950 | | |
| Beach cleanliness perception (0–4) | −0.307 | 0.367 | | |
| Beach litter annoyance (0–4) | 0.968** | 0.395 | | |
| ***Model summary statistics*** | | | | |
| Log Likelihood | −2191.422 | | | |
| McFadden $R^2$ | 0.468 | | | |
| Number of observations | 3900 | | | |
| Number of respondents | 650 | | | |

***$p < 0.01$; **$p < 0.05$; *$p < 0.10$.

level. Due to the confounding of preference and scale parameters in the estimation procedure, it is impossible to attribute this outcome to differences in either preference or scale parameters (Louviere et al., 2003). The outcome of the test procedure implies that the choice models are not transferable across countries.

The test results are as expected when inspecting the results presented in Table 4 for each country separately. Only in the model estimated on the choice data in Bulgaria almost all choice attributes are statistically significant, except the number of visitors. Beach visitors in Bulgaria value the clean-up of glass, plastic, and cigarette butts significantly more than of fishnets (the baseline category). However, the differences between the three coefficient estimates are not significantly different (based on the Wald test). Dutch beach visitors value the removal of all types of litter equally: no significant impact is found for any of the litter types compared to fishnets. The clean-up of plastic and cigarette butts is valued significantly more than fishnets in Greece, but also here no significant difference can be detected between plastic and cigarette butts. The significant negative coefficient for the alternative specific constant (ASC) indicates that all else being equal, Dutch beach visitors prefer the status quo over the presented beach clean-up alternatives. The reverse result is found for the Bulgarian sample, while the ASC is not significant in the Greek model. Note that a majority of the mean coefficient estimates in the three models are characterized by significant preference heterogeneity as can be seen from the standard deviations of the distributions around the randomized coefficient parameters. Except for the price, which is assumed to have a normal distribution, all random dummy variables have a uniform distribution (Hensher et al., 2005).

Contrary to the Greek sample, Bulgarian and Dutch beach visitors significantly value a reduction in the amount of litter from the current situation to less or no litter at all. The differences between the two dummy variables for less litter and no litter are statistically significant too, indicating that having no litter on the beach is valued significantly higher than reducing the amount of litter to less than average (10–30 litter items per 100 $m^2$). Where the litter comes from also matters in the Bulgarian and Dutch samples: willingness to pay is significantly higher for litter left by visitors than washed ashore by the sea (the baseline category). This effect is twice as high in the Dutch model compared to the Bulgarian model. Moreover, Dutch respondents also paid significant attention to the number of beach visitors: less visitors were valued significantly higher than more beach visitors. This attribute did not play a significant role in the Greek and Bulgarian samples. Finally, the price beach visitors were asked to pay, either through a tax increase (Greece and Bulgaria) or entrance fee (Netherlands), has a highly significant negative impact on choice behavior, suggesting that the trade-off worked as expected: the higher the amount of money beach visitors were asked to pay, the lower the likelihood that they would choose one of the two alternative beach situations in the DCE. Greek beach visitors are most sensitive to a tax increase, Bulgarian beach visitors least sensitive.

Based on the above mentioned test results, the dummy variables for the country samples are as expected highly significant in the pooled choice model presented in Table 6. Besides controlling for unobserved preference heterogeneity as in Table 4, also potential sources of observed preference heterogeneity are included in the pooled model. Pooling the data results in a considerably higher number of observations and consequently also a much higher number of highly significant choice attributes. Only the number of visitors does not have a significant effect on choice behavior (less visitors was expected to yield a significant positive value). The litter types are all valued significantly different from fishnets (the baseline category) and from each other. The clean-up of plastic is valued highest, followed by glass and then cigarette butts. The difference between the coefficient estimates for glass and cigarette butts is, however, not statistically significant (based on the Wald test). The difference between less litter and no litter is statistically significant. Respondents are willing to pay significantly more for the clean-up of litter left by visitors than washed ashore by the sea, and the higher the clean-up price, the lower the likelihood respondents are willing to pay.

As for the models estimating willingness to pay in kind (hours) presented in Table 3, whether or not a beach visitor is on holidays does not have a significant effect on choice behavior. Female beach visitors are more likely to pay than male visitors, and the same applies to visitors belonging to a higher income group or members of an environmental protection organization. The more someone is annoyed by beach litter, the more likely he or she will be in favour of cleaning up the beach and paying for it. Contrary to the previously presented models in Table 3, the age of beach visitors and their perception of the current state of the beach do not have a significant impact in the pooled choice model. A slightly unexpected result is that the longer respondents visit a beach, and hence the more familiar they are with the beach, the less likely they are willing to pay for its clean-up. It is not completely clear why this is the case. One possible explanation is that local residents typically visit the beach many more years than non-local visitors and they may feel less responsible for its pollution and clean-up.

### 5.5. Public willingness to pay for beach clean-up

Based on the estimated choice models, beach visitors' willingness to pay can be derived. The results are presented in Table 7. Standard errors and 95 percent confidence intervals (CI's) are calculated based on the Krinsky and Robb (1986) bootstrap procedure. The WTP amounts are adjusted for differences in purchasing power across the three countries. Two different WTP values are estimated: one for the complete removal of plastic litter washed ashore by the sea and one for cigarette butts left behind by beach visitors. The differences between these two WTP values are small and not statistically significant *within* samples. The CI's overlap and also the Poe et al. (2005) test confirms that the differences are not statistically significant.

Differences of the WTP values *between* samples are bigger and more significant. Bulgarian beach visitors are willing to pay

**Table 7**
Public WTP (€/visitor/year) for the removal of plastic litter washed ashore by the sea and cigarette butts left behind by beach visitors in the three countries.

| | | Greece | Bulgaria | Netherlands |
|---|---|---|---|---|
| Plastic litter washed ashore by the sea | Mean WTP | 0.67 | 8.25 | 2.05 |
| | St. error | 0.34 | 1.79 | 0.86 |
| | 95% CI | 0.01–1.33 | 4.74–11.77 | 0.37–3.72 |
| Cigarette butts left by beach visitors | Mean WTP | 0.42 | 7.06 | 2.57 |
| | St. error | 0.39 | 1.58 | 0.94 |
| | 95% CI | −0.34–1.18 | 3.96–10.16 | 0.73–4.41 |

Note: CI: confidence interval.

significantly more than Greek and Dutch visitors for both marine plastics washed ashore and cigarette butts left behind by visitors. Although the 95% CI between the Bulgarian and Dutch sample slightly overlap for cigarette butts, the Poe et al. (2005) test convincingly rejects the null hypothesis of equality at the 1 percent level. No significant differences can be detected between Dutch and Greek beach visitors for either marine plastic or cigarette butts. Note that mean WTP for the removal of cigarette butts is not significantly different from zero for the Greek sample. Compared to the beach visitors' average annual income levels, the estimated WTP values constitute no more than 0.07 percent of a household's disposable income in the Bulgarian sample, 0.01 percent in the Dutch sample and 0.003 percent in the Greek sample.

## 6. Conclusions and discussion

Surveying beach litter, one of the EU MSFD indicators, is the most important tool for assessing the occurrence of marine debris stranded on beaches, informing coastal zone policy and management about their loads and quantities, occurrence and pollution sources (Ryan et al., 2009). The United Nations Environment Program (UNEP, 2009) has highlighted the importance and need for establishing national marine litter monitoring programs and cleanup initiatives through which valuable information on beach marine litter is collected. However, beach cleanup is often based on voluntary actions, such as the International Coastal Cleanup (Ocean Conservancy, 2016). Regular national monitoring programs, necessary to develop and assess cost-effective litter reduction programs, for example in the context of the MSFD, are lacking in many countries. Also, beach clean-up costs as an indicator of the social costs of marine litter are monitored only erratically (Brouwer et al., 2015b). These cleanup costs provide furthermore only a partial indicator of the total costs of marine litter to society.

The impact of marine litter on beach visitors' recreational experience is expected to constitute a much more significant share of the total social costs. This impact is more difficult to measure and quantify, hence the reason why social scientists rely on surveys to measure public perception and valuation of marine litter. Beach visitors themselves are an important source of litter generation too (OSPAR, 2009), and not always aware of this, or willing to help cleanup beaches or change their behavior. In this study, we found that approximately half of all the interviewed beach visitors across the three countries refused to participate in voluntary beach clean-up actions (varying between 30% in Bulgaria and 70% in the Netherlands), while at the same time almost 70 percent of all interviewed beach visitors indicated that they would stop visiting a dirty beach due to littering (varying between 45% in Greece and 95% in Bulgaria). This is substantially more than the reduction in visitors reported in Ofiara and Brown (1999) due to landfill debris washing ashore in the state of New York, and an important indicator to coastal zone policymakers and beach municipalities of the human welfare impacts of beach littering and the potential economic consequences involved.

This is the first study to assess the social costs of both marine debris washed ashore and litter left behind by beach visitors along different European coasts. These social costs were estimated based on public perception of the impact of littering on beach experience and beach visitors' willingness to contribute in kind (volunteering to clean up beach litter a number of hours per year) and in money terms by paying either an entrance fee or an increase in local tax. Previous studies focusing on the valuation of beach recreation neither assessed the impact of marine litter specifically on beach experience in most cases, nor did they make a distinction between pollution sources. This latter distinction is considered important in view of the fact that a large share of the litter originates from beach visitors and requires another type of coastal zone policy intervention than diffuse pollution washed ashore. Assessing how responsible beachgoers feel for the presence of beach litter they partly leave behind themselves and to what extent they are willing to pay for the clean-up of this litter compared to litter washed ashore provides important information for priority setting in coastal policy and management.

Public perception was measured in a qualitative manner in terms of nuisance or annoyance and whether the presence of beach litter is a reason to not visit a beach. Plastic is the main component of marine litter along the coastlines (Rees and Pond, 1996; Kordella et al., 2013; Bouwman et al., 2016). Among plastics, cigarette butts are the most frequently recorded marine litter type (e.g. Laglbauer et al., 2014; Lopes da Silva et al., 2015) and a good indicator of pollution from beach visitors. Cigarette butts were also reported as the main marine litter type in the present study, followed by plastic bottles and plastic bags. The clean-up of the latter was valued highest by beach visitors, followed by glass bottles and cigarette butts. As expected, public annoyance significantly influences willingness to contribute to clean-up programs and paying an entrance fee or increase in local tax.

The estimated WTP welfare measures associated with beach littering are used here as indicators of the social costs involved. Actual or potential clean-up costs can be directly compared to these estimates to assess the economic welfare effects of clean-up actions in a cost-benefit framework. Applying the same study design and carrying out the studies across three different countries provides furthermore important insight into the spatial distribution of the social costs of marine litter across European member states and the extent to which these costs differ across locations depending on public perception of marine litter and socio-economic and demographic profiles of beach visitors. Testing the transferability of these WTP estimates is paramount to assess the validity and reliability of their use in future cost-benefit analysis of litter reduction strategies across EU member states.

The study suffers from a few drawbacks. First of all, the number of observations varies substantially across the three survey locations. Twice as many interviews were carried out in Bulgaria compared to the Netherlands, while the number of interviews in Greece was a third higher than in the Netherlands. Although the goodness of fit of the estimated choice model for the Dutch sample is substantially higher than that for Greece and Bulgaria, this variation in the number of observations may have had an effect on the statistical efficiency of the estimated models. The number of interviews in the Dutch sample is considered a lower limit for applying a DCE, and the results therefore have to be interpreted with the necessary care.

Not much can furthermore be said about the study's representativeness in view of the fact that data on beach visitors' characteristics are missing, as well as on the amount and type of beach litter. The latter means that the analysis had to be based on public perception of beach littering, not on actually observed littering data. For an improved understanding of the context specificity of the results, it is important to be able to link this type of social science research focusing on public perception in the future to the actually observed amounts and types of beach litter.

Secondly, the survey was implemented over a period of 5 months in the three countries, from May until September 2014. This is a relatively long period of time in view of the fact that beach visitation may differ across these months. Whereas the Dutch and Greek surveys were carried out just before and after the summer season, the Bulgarian study was carried out in the middle of the summer. Temperatures, rainfall and the number of sun hours per day, which influence beach visitation behavior, therefore differ somewhat between the three survey locations for which we are

unable to include control. We do not know how the timing of the interviews affected the survey findings. More respondents in the Bulgarian sample were on holidays, but we included control for this in all the estimated models, and could not detect a significant impact between local residents and holidaymakers.

Finally, the payment mode differs between the three samples, based on extensive pre-testing of preferences for different payment mechanisms with local and non-local beach visitors, impairing a direct comparison. Although there were reasons for changing the payment mode across the study locations, payment vehicles have been shown to influence stated preference research, for example income taxation has been shown to reduce WTP (Brouwer et al., 1999) whereas voluntary donations have been shown to increase WTP (Lindhjem, 2007). In their review of economic instruments to control marine litter, Oosterhuis et al. (2014) conclude that there exists not one single instrument that is able to tackle all sources of pollution. The choice for an instrument is case specific, depending among others on existing institutional settings and public preferences.

The private entrance fee is directly based on the beneficiary pays principle, whereas the local tax benefits the public at large. Everybody would in that case pay for a cleaner beach, but whether this was considered credible was questioned in the Dutch case study. The legitimacy of the use of both payment vehicles depends on public perception of what is considered fair and right, but also what is considered feasible and effective. In Bulgaria and Greece, beach access is considered a public right by law, making it impossible to use a private entrance fee. The same applies to the Netherlands, but based on pre-testing an entrance fee was considered a more equitable way of raising money to clean up the beach in the Dutch case study than a local tax given the number of day-trip visitors from outside The Hague and to avoid free riding behavior. Note that similarly in Bulgaria holidaymakers from outside the two cities where the surveys were conducted were asked to pay a tourist tax to avoid free riding behavior. No control was included in the study presented here to test this effect. For example, by allowing the Dutch sample to choose their most preferred payment mode or splitting the sample in two, asking one subsample for their WTP through an entrance fee and the other subsample through a local tax increase. It is therefore impossible to conclude how the use of the entrance fee influenced public WTP in the Netherlands differently compared to the local tax in Bulgaria and Greece, except that when using the in kind contribution as a benchmark similar differences for public preferences for clean beaches are found for Bulgarian respondents compared to Dutch respondents. Previous studies in the US also used both payment vehicles, and it would be interesting to test for possible differences in future research in Europe.

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