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Research article

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ABSTRACT

When assessing strategies for implementing Nature-Based Solutions (NBS), it is paramount to identify and quantify all benefits for securing better, informed decisionmaking. Nevertheless, there appears to be a lack of primary data for linking the valuation of NBS sites with the preferences and attitudes of people interacting with them and their connection to supporting efforts to reduce biodiversity loss. This is a critical gap, as the socio-cultural context of NBS has been proven to play a big role in NBS valuation, especially for their non-tangible benefits (e.g. physical and psychological well-being, habitat enhancements, etc.). Consequently, through co-creation with the local government, we co-designed a contingent valuation (CV) survey to explore how the valuation of NBS sites may be shaped by their relationship with the users and the specific respondent and site characteristics. We applied this method to a case study of two distinct areas located in Aarhus, Denmark, with notable differences related to their attributes (e.g. size, location, time passed since construction). The esults obtained from 607 households in Aarhus Municipality show that the personal preferences of the respondent are the most relevant driver of value, surpassing both the perceptions linked to the physical features of the NBS and the socio-economic characteristics of the respondents. Specifically, the respondents attributing most importance to nature benefits were the ones assigning a higher value to the NBS and being willing to pay more for an improvement of the nature quality in the area. These findings highlight the relevance of applying a method assessing the interconnections between human perceptions and nature benefits to ensure a holistic valuation and purposeful design of NBS.

1. Introduction

It is widely acknowledged that climate change will have a major role in shaping our future, and many predictions are being made regarding the impacts and adaptations that society will face. In the case of Northern Europe, changes in rainfall regimes and an increase in mean sea level, coupled with expanding urbanization, are expected to result in increased direct damages (e.g. lost infrastructure, displacements, damage costs) and negative impacts on human well-being (e.g. mental health impacts) (European Commission, 2021a; IPCC, 2021).

The concept of Nature-Based Solutions (NBS) has emerged to tackle these challenges. NBS are defined as strategies inspired and supported by nature, which not only provide direct solutions to challenges but also enhance the spatial quality of the surrounding area in many direct and indirect ways, from biodiversity integrity to human well-being (physical, psychological and socio-economic) (Cohen-Shacham et al., 2016; European Commission, 2015; IUCN, 2012). Key to implementing and maximizing the value of NBS is quantifying their non-tangible benefits (Díaz et al., 2018; IUCN, 2020). However, the multi-dimensional nature of NBS and the trade-offs between their functions (European Commission, 2021b) make quantification very complex.

Considering the current non-tangible benefits of NBS assessment literature, the majority of studies rarely target the multiple dimensions of the socio-cultural context of NBS (e.g. people's knowledge,

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preferences and relationships to NBS sites) (Demuzere et al., 2014; Derkzen et al., 2017; Han and Kuhlicke, 2019; Madureira et al., 2015). Some studies assess people's characteristics but not their uses of the area (e.g. Ando et al., 2020), while others assess people's preferences and uses but not their knowledge or concerns regarding the risks counteracted by the proposed projects (e.g. Tibesigwa et al., 2020). Still fewer recognize the implicit interconnection between people and nature benefits and the (lost) potential for opportunities when considered separately (Viti et al., 2022). Knowledge, preferences, uses and values are all influential in determining the value attributed to the NBS, which may be an important reason for the substantial uncertainties reported by several meta-studies (Bockarjova et al., 2020; Skrydstrup et al., 2022). Moreover, all of these components are influenced by "external factors", namely the demographic, socio-economic and personal characteristics of the respondents, as well as the physical (e.g. distance from urban areas; size; biodiversity; etc.) and spatial (e.g. distance to the NBS, distance to substitute sites, quality of sites) characteristics of the NBS, as described within the vast urban green area and water body preference literature (Jørgensen et al., 2013; Sutherland and Walsh, 1985; Venkataramanan et al., 2020). Therefore, NBS assessments should consider all these factors to create both a holistic quantification of the NBS benefits and, at the same time, reduce the overall uncertainty associated with the sources and heterogeneity of NBS values.

Specifically, an expansion of the knowledge base on the factors with the greatest impact on non-tangible benefits assessments would be extremely useful to determine the attributes influencing people's evaluation (whether it is e.g. personal preferences or the physical characteristics of the NBS). Moreover, a clear assessment of the underlying reasons for the value attributed to NBS is expected to help with the prioritization and uptake of NBS projects by managing expectations and providing the basis for a more transparent decision-making process (Derkzen et al., 2017; Hérivaux and Le Coent, 2021; Venkataramanan et al., 2020).

Therefore, novel approaches are urgently required to enable a more comprehensive assessment of NBS benefits in a way that integrates the socio-cultural context and is not excessively restricted by local characteristics to enhance (method) transferability and initiate much needed cross-NBS site learnings. The outputs from such assessments are expected to help decision-makers prioritize the implementation of holistic strategies like NBS over "business as usual" (Alves et al., 2019; Sharifi et al., 2021; Viti et al., 2022).

In many cases, Stated Preference (SP) method is the only source to provide a solid base for the assessment of non-tangible NBS benefits in the absence of a market price (Johnston et al., 2017; Mitchell and Carson, 1989). This is particularly the case if the NBS is expected to entail significant non-use values and/or if the valuation of the NBS is ex post their creation. SP approaches usually rely on carefully worded questionnaires to directly seek individual preferences (in the form of monetary amounts, choices, ratings, etc.). Various SP methods exist, but Contingent Valuation (CV) is recommended when trying to quantify the total value attributed to an environmental good or service (Bateman et al., 2002).[1]

This study aims to begin filling the gap related to holistic assessment studies for the non-tangible benefits of NBS through the co-development and application of a quantitative assessment of the non-tangible benefits of NBS, which.

(i) Considers the influences of uses, preferences and values of the respondents on the NBS assessment and how they vary depending on external factors (i.e. socio-economic characteristics, physical environment); and
(ii) Can be easily compared across sites.

The developed approach is applied to a case study comprised of two distinct NBS sites located in Aarhus, Denmark. Both NBS areas have as primary aims to: (i) prevent flooding from cloudbursts or water bodies, (ii) improve the local biodiversity and (iii) benefit the local population, but they differ in various characteristics, such as size and time passed since implementation. The latter dissimilarities are fundamental to highlight the different impacts of diverse NBS features on the value attributed to a NBS site.

2. Materials and methods

2.1. Study areas

Aarhus is the second largest urban area in Denmark with approximately 300,000 inhabitants. Since 2007, Aarhus Municipality has been working with climate change adaptation, focusing primarily on the pressure from the water, i.e. rising sea levels, flooding from cloudbursts and waterbodies, and areas swamped by increasing groundwater levels (Aarhus Kommune, 2014). Recently, a cloudburst storm in 2012 heavily impacted the Aarhus area, causing widespread flooding. Various projects aiming at limiting the chances and damages of flooding have therefore been carried out in the area, and particular attention has been given to NBS, pinpointed as holistic strategies with multidimensional benefits (e.g., the reduction of coastal eutrophication and the enhancement of biodiversity in the area).

This paper focuses on testing the developed approach on two of the NBS project areas; specifically, the Lake Egå and Hovmarksparken sites. Both are found in the river catchment area of River Egå in the northern part of the city (Fig. 1). Lake Egå is placed in a low-lying area especially vulnerable to flooding, while Hovmarksparken is situated on a hillslope.

Lake Egå is an artificial waterbody established in 2006 as a large water reservoir (155 ha). Initially, Lake Egå's main task is to retain nutrients (e.g. nitrogen loss from upstream farmland) before the water flows into the Bay of Aarhus. However, its usefulness in reducing floods to residential areas was demonstrated, specifically concerning the 2012 cloudburst event. Moreover, the area adjacent to the lake has been reconstituted into natural riparian areas, including wetlands and meadows with different humidity levels. The adjacent area is now a protected natural area and provides both habitat to many species (especially birds, mostly waterfowl, both migratory and resident, but also rare birds of prey, have been observed repopulating the grounds) and increased recreational opportunities for visitors. Regarding the latter, 5.2 km of walking and cycling paths have been established around the lake, together with a birdwatching tower and an "activities area", including shelters, playgrounds and information signs. Using the total economic terminology (Pearce, 1993), Lake Egå has both large use-values (e.g. recreation opportunities) and potentially non-use values (e.g. habitat enhancements).

Hovmarksparken, adjacent to Lake Egå, contains one of 11 local rainwater management sites in the suburb of Lystrup, and is part of a larger urban cloudburst adaptation strategy. The 11 local climate adaptation sites have been implemented between 2015 and 2017. They are all interconnected, and all have in common that they either delay or retain the rainwater or direct it to areas where any ensuing damage should be reduced, e.g. fields and ponds. Given its recent establishment, the Lystrup adaptation sites have not yet been exposed to the hazard it was built to combat (i.e. a 100-year event), despite successfully counteracting severe rain episodes. Hovmarksparken is the largest of the adaptation sites, covering 6 ha and including a rainwater pond and rainwater dikes, as well as fields and green areas. The latter are mostly open to recreational activities, and some facilities are present as well (e.g. jetties on the pond, football goals). In order to support biodiversity

[1] If the goal is to estimate the value of the specific NBS attributes, such water body qualities, access levels and types etc. the method Discrete Choice Experiments is recommended (Adamowicz and Louviere, 1998; Louviere and Woodworth, 1983).

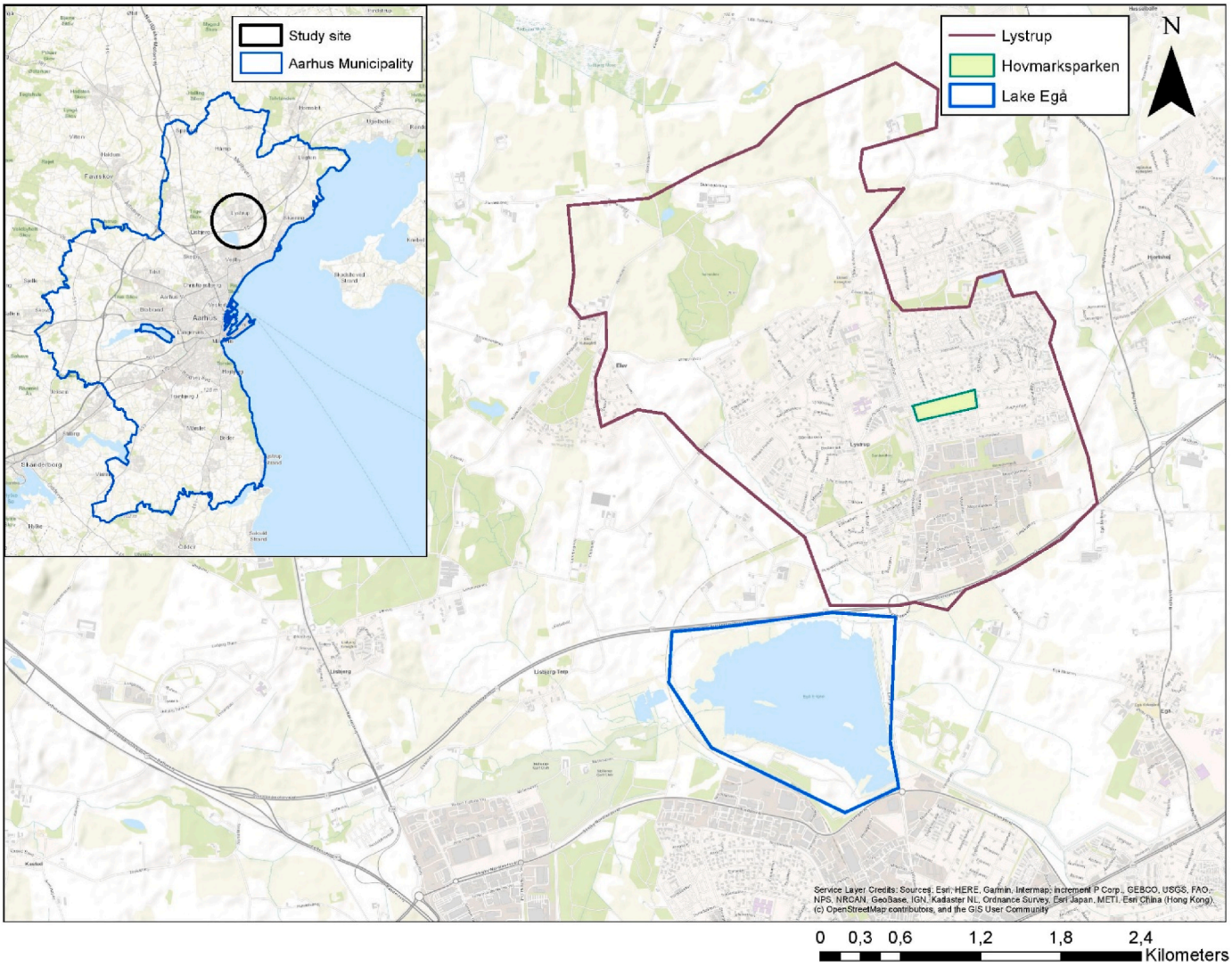

Fig. 1. *Location of the two study sites in Aarhus Municipality, Denmark (DMS Coordinates: 56°09′24.26″ N 10°12′38.74″ E).*

within the park, several biodiversity-enhancing elements were implemented as well, including planting rare native vegetation using nutrient-poor soils, leaving deadwood in situ, creating small habitats, converting a green lawn to grazed meadows, etc. These elements were partly determined and implemented through the local population's participatory processes (Knudsen et al., 2019). Pictures of the two sites can be found in the SI (Figs. S1–S4).

The two NBS sites are geographically quite close, approximately 2.5 km from each other, see Fig. 1. Despite their proximity and common goal, their physical characteristics place them in two different recreational and nature categories. Hovmarksparken is an urban NBS, while Lake Egå can be classified as a peri-urban, large-scale NBS. This makes the two substitute areas very interesting case studies, where two NBS sites can be evaluated by residents who are likely to be familiar with both.

2.2. Survey design

For the design of our survey, we worked to integrate the steps needed for a proper assessment of NBS (e.g. assessing both the social and environmental benefits) with the CV methods' characteristics to create a holistic framework specifically targeting the quantification of non-market benefits of NBS. Once the basic structure was defined, the survey was subjected to a co-design process. Testing surveys with relevant target groups and adjusting them according to feedback is a staple of Stated Preference (SP) methods (Presser et al., 2004). However, in our study, we went a step further, inviting local decision-making stakeholders to be actively involved in the co-creation of the survey. Specifically, we worked with Aarhus Municipality to ensure that the survey was tailored correctly to the study sites and adjusted so that planners and decision-makers could maximize the use of the results for better understanding and communicating the outcomes of the projects. The resulting survey was structured into four sections, listed below, and the collected variables are summarized in Table 1.

1. **Relationship between respondents and the study sites.** Descriptive texts for the NBS areas were developed together with Aarhus Municipality. Here we included a map of the sites and a short description of the NBS projects, summarizing their characteristics and ability to reduce the targeted problem. After reading the descriptions, the respondents could choose if they wanted to complete the questionnaire only with regards to Lake Egå or Hovmarksparken, or both. Once they chose one of the three options, they were asked about their (travel) distance to the area(s), frequency and reasons to visit, travel time and travel method to the site(s).
2. **People's preferences.** This section enquired about the respondents' concern concerning flood risk, the importance of recreation in green areas, and the presence of nature-enhancing elements. Respondents

Table 1
Summary of all the quantitative variables collected through the survey, divided by section.

Section	Variable name	Description	Answer method
Relationship between people and the study sit			
	Site	Choosing for which site to complete the survey (i.e. Lake Egå, Hovmarksparken, or both)	Multiple options
	Distance	Distance from the study site chosen	Multiple options
	Frequency	Frequency of visit to the study site	Multiple options
	Travel time	Length of travel time to the study site	Multiple options
	Visit time	Time spent visiting the study site	Multiple options
	Visit nature	Visiting the area to enjoy nature	Dichotomous
	Visit social	Visiting the area to spend time with family/friends	Dichotomous
	Visit sport	Visiting the area to practice sport	Dichotomous
	Visit pass	Visiting the area just passing by (e.g. on the way to work)	Dichotomous
	Flood worry	Respondent's concern regarding flooding	Likert scale (1–7)*
	Flood direct	Direct experience with flooding	Dichotomous
	Flood indirect	Knowing someone with flooding experience	Dichotomous
People's preference			
	Flood private	How important it is for the respondent to avoid flooding in their private property	Likert scale (1–7)
	Flood public	How important it is for the respondent to avoid flooding on public property	Likert scale (1–7)
	Green areas	How important it is for the respondent to access green areas	Likert scale (1–7)
	Recreation	How important it is for the respondent to have access to recreation facilities	Likert scale (1–7)
	Biodiversity	How important it is for the respondent that biodiversity enhancement features are in place	Likert scale (1–7)
	Nature only	How important it is for the respondent that areas set aside for nature (i.e. without access for people) are present	Likert scale (1–7)
Valuation questions			
	WTP base	Respondent's WTP for the maintenance of the area	Multiple options
	WTP nature	Respondent's WTP for the enhancement of nature benefitting features (additive)	Multiple options
	Protest	Respondent's reason for expressing 0 WTP in both valuations	Multiple options
Socio-demographic information			
	Post	Postal code	Open ended
	Age	Age	Multiple options
	Sex	Sex	Dichotomous
	Residence time	Time living in Aarhus Municipality	Open ended
	People household	Number of people in the household	Open ended
	Children	Presence of people younger than 18 in the household	Dichotomous
	Income	Household income	Multiple options

*1 being the lowest score and 7 being the highest.

were asked to rate how important each of these benefits was for them on a Likert scale from 1 to 7. This was followed up by questions in which the respondents elaborated on the response given through a series of pre-set sentences.

3. **Valuation questions.** This section included the description of a hypothetical scenario leading to the assessment of the Willingness-To-Pay (WTP) for having the NBS area in question (for those chosen by the respondent in section one). The WTP assessment was a two-step process using the payment card approach (Bateman et al., 2002). First we proposed that the maintenance of the NBS area would have to be paid for through a monthly fee per household, and we asked the respondents to state a WTP (referred in this paper as WTP base). Then, a second valuation question was asked, asking how much the respondents would be willing to increase their initial bid if further actions to improve the quality of nature were to be implemented in the NBS area(s) (WTP nature. The sum of WTP base and WTP nature is referred to as WTP total). In both questions, the respondents were supplied with a payment card with the possibility to also state a different amount. If the respondents stated a null WTP for both steps, they were asked a debriefing question to identify protest voters, i.e. those respondents who do not accept the hypothetical valuation scenario and therefore refuse to state a WTP (Bernath and Roschewitz, 2008; Meyerhoff and Liebe, 2008).
4. **Socio-demographic information.** The final section included questions for the collection of the demographic and socio-economic data of the respondents, e.g. residence postal codes, age, gender, income, and so on.

The complete survey can be found in the Supplementary Information (SI).

2.3. Distribution

We used a randomized electronic distribution of the survey, which, aside from being faster and more practical on larger scales, allowed us to avoid sample selection bias, i.e. over-representing frequent visitors of the areas. The final survey was transferred to the online survey platform SurveyXact and set to be completely anonymous (in compliance with EU GDPR requirements).

The respondents were contacted through an email to their digital online mailbox containing a cover letter explaining the scope and aim of the research and a link to the survey. The respondents were randomly selected from the municipal population register based on the numbers present in their birthdates. The program used by the Municipality to distribute the mails was used to operate the random selection. The only limits imposed were that the respondents had to be older than 18 and that half of the sample had to be residents of Lystrup (Fig. 1). The latter would ensure variation in distance to the study sites in the collected data. The collection started at the beginning of June 2021 and closed approximately one month later (at the beginning of July 2021), with reminders to participate sent after two weeks. After discarding the incomplete questionnaires, a total of 607 complete surveys were registered. This corresponds to a response rate of 15%, which is quite low if compared to other Danish survey using the same distribution methods, e.g. a Covid-19 study (Ladenburg and Christensen, 2021) and one on musculoskeletal disease (Boyle et al., 2021) obtained response rates of 34% and 36% respectively.

2.4. Identifying protest votes

Before proceeding to the statistical analyses, we separated the registered responses into protest and non-protest votes. The protest votes were identified by examining the answers to the debriefing question presented only to those respondents who chose a WTP of 0 DKK in both valuation scenarios (see section 2.2). These respondents were asked to justify why they would not spend any money on the study sites by choosing their main reason from five given options. If the respondents chose the options "I do not have the possibility to pay extra money each month", or "I do not think that it is important to maintain this site and its functions", they were classified as genuine zero bids. Those answering "I think that exclusively public funds should be used to finance the maintenance of the areas and their functions", or "I don't have enough information to choose a fee" were classified as protest voters. Finally, the last option let the respondents state other reasons. Depending on the reason, these 20 responses were manually classified as either protest or

Table 2
Summary of the methods used as part of the statistical analyses. The analyses have been carried out in R using the car and ggplot 2 packages.

Aim	Methods
Step 1 – Assess sample properties	
Is the sample biased compared to the general population in Aarhus?	Descriptive statistics of the respondents' socio-demographic characteristics relative to the general population, and of their direct responses to sections 2 and 3 of the survey.
Are protest votes associated with particular groups and would their exclusion thus bias the results in any direction?	Logistic regression model, with the binary protest variable as response variable. The entire dataset was used, and the final model was obtained through backwards selection. $\log\left(\frac{p}{1-p}\right) = a + bX + cY + dZ + \varepsilon$ (1) p = stating a protest vote; X, Y, Z = vectors of explanatory variables regarding preferences, uses and socio-demographic characteristics of the respondents, respectively; a, b, c, d = vectors of parameters to be estimated in the logistic regression model; ε = error term.
Have we correctly identified protest voters?	Definition of two different datasets to be used for the analyses in step 2. Dataset 1: excluding all protest voters identified through the debriefing question (n = 387); Dataset 2: including plausible "false" protest votes (n = 517).
Step 2 – Analyze willingness to pay values	
Do respondents increase their original WTP bid (WTP_{base}) after "pointing out" the biodiversity benefits of the NBS measures (WTP_{total})?	Compare sample means using t-tests and bootstrapping (SI Table S2) $H_0 : WTP_{base} = WTP_{total}$ for Lake Egå (2) $H_0 : WTP_{base} = WTP_{total}$ for Hovmarksparken (3)
Is WTP statistically different across the two sites?	Same as above, but only the bids of respondents who chose to answer for both sites were included. The bootstrapping tests were used to test whether the means of the WTP bids were statistically different across sites $H_0 : WTP_{base}$Egå $= WTP_{base}$ Hovmarksparken (4) $H_0 : WTP_{total}$Egå $= WTP_{total}$ Hovmarksparken (5)
Which explanatory variables influence the WTP bid levels?	Multiple linear regression models, three for Lake Egå and three for Hovmarksparken, each pair separately using the three WTP bids (WTP base, WTP nature and WTP total) expressed for each site as dependent variables. WTP values were log-transformed due to the skewed data distribution. Both datasets 1 and 2 were used, and the final models were obtained through backwards selection Lake Egå $\log(WTP_{base} + y_0) = \alpha + \beta X + \gamma Y + \delta Z + \varepsilon$ (6) $\log(WTP_{nature} + y_0) = \alpha + \beta X + \gamma Y + \delta Z + \varepsilon$ (7) $\log(WTP_{total} + y_0) = \alpha + \beta X + \gamma Y + \delta Z + \varepsilon$ (8) Hovmarksparken $\log(WTP_{base} + y_0) = \alpha + \beta X + \gamma Y + \delta Z + \varepsilon$ (9) $\log(WTP_{nature} + y_0) = \alpha + \beta X + \gamma Y + \delta Z + \varepsilon$ (10) $\log(WTP_{total} + y_0) = \alpha + \beta X + \gamma Y + \delta Z + \varepsilon$ (11) where y0 = 1 is introduced to allow WTP bids of zero value, X, Y, Z = vectors of explanatory variables regarding preferences, uses and socio-demographic characteristics of the respondents; α, β, γ, δ = vectors of parameters to be estimated in the linear regression models; ε = error term.
Is the quality of our models satisfactory?	Sensitivity analyses including model diagnostics (SI Fig. S13-S24) and F-tests (SI Table S6) were conducted for all the models.

non-protest votes during the analysis. This debriefing question was inspired particularly by the studies of Bernath and Roschewitz (2008) and Ramajo-Hernández & del Saz-Salazar (2012).

Despite their seemingly very high number (36% of the total responses in our study), protest bids are an expected outcome when eliciting WTP through a payment scenario, and our rate of protest votes fits the range expected in a CV study, i.e. from 20% to 40% (Carson, 1991). Once the two groups of respondents (protest and non-protest) were defined, we proceeded with the creation of different statistical models to explore the relationship between the registered variables and the valuation of the NBS. In hindsight, we could have used a Protest Reduction Entreaty (i.e. a statement presented in the survey before the WTP questions highlighting that the payment is included to allow the respondent to convey the value of the good in focus, and not to collect money from them) to reduce the number of protest respondents, as done by Bonnichsen and Ladenburg (2009). Using such an entreaty might also have improved the systematic relations between WTP and the perceived qualities of the two NBS (Bonnichsen and Ladenburg, 2015).

2.5. Statistical analyses

We divided our analysis into 2 steps. First, we analyzed the socio-demographic properties of the full sample and those of the protest voters. Second, we assessed the variation of WTP values and which variables explained these variations. These latter assessments were performed on two different datasets: dataset 1 excludes all protest votes, and dataset 2 includes part of the protest votes as zero values. This was done to account for an ambiguity in the interpretation of the protest votes and derive a sensitivity range for the results. Table 2 summarizes all the methods used, inspired by different sources (Bernath and Roschewitz, 2008; Crawley, 2005).

3. Results

3.1. Socio-demographic characteristics of the respondents

Table 3 compares the socio-demographic characteristics of our respondent sample with those of the general population living in Aarhus Municipality. Our sample appears to be representative based on gender, family size and income. However, there is a slight overrepresentation of elderly citizens and an underrepresentation of people under 35 in our sample. Moreover, there appears to be an overrepresentation of households with higher incomes.

In addition to the characteristics, we were able to determine both the respondents' average cost per square meter of property and their distance to the coast (approximated to the postal code area) due to the

Table 3
Comparison of the sample and census demographics of Aarhus (2021 census data from Statistics Denmark).

Demographics	Categories	Percentage of sample	Percentage in Aarhus Municipality
Gender	**Male**	**51%**	**49%**
	Female	**49%**	**51%**
	Other	**0.2%**	**N/A**
	Prefer not to say	**0.3%**	**N/A**
Age	**18–25**	**8%**	**22%**
	26–35	**10%**	**22%**
	36–45	**13%**	**13%**
	46–55	**18%**	**13%**
	56–65	**20%**	**12%**
	66–75	**23%**	**10%**
	Older than 75	**8%**	**7%**
Income (household/ year)	**Under 200.000 DKK**	**13%**	**24%**
	200.000–299.999 DKK	**8%**	**19%**
	300.000–449.999 DKK	**16%**	**19%**
	450.000–699.999 DKK	**25%**	**17%**
	700.000–849.999 DKK	**20%**	**6%**
	850.000–999.999 DKK	**9%**	**5%**
	Over 1 million DKK	**9%**	**10%**
Household	**Single**	**17%**	**24%**
	Without children	**56%**	**44%**
	With children	**27%**	**27%**

available statistical information in Denmark. These variables were used in the analyses to give a more complete picture of the respondents' socio-economic characterization.

3.2. Use of the case studies

The first part of the survey was dedicated to collecting data regarding the respondents' use of Lake Egå and Hovmarksparken. Fig. 2 offers an overview of the most relevant people-place relationship variables.

Most respondents answered the survey for Lake Egå, followed by people who answered for both sites. The most often cited reason to visit Lake Egå is to enjoy the nature in the area (57% of the respondents), while in the case of Hovmarksparken it appears to be "passing through" (40%), an option that included e.g. crossing the park to go to work. On average, the respondents spend a longer time at Lake Egå but visit Hovmarksparken slightly more often. Most of the respondents reside no further than 5 km from both sites, with the vast majority of the people answering for Hovmarksparken living less than 1 km from the park (see Supplementary Information, Figs. S1 and S2). For both sites, the most common travel time is less than 30 min (Figs. S1 and S2), but the respondents tend to travel by car to Lake Egå, and by foot to Hovmarksparken.

Overall, Lake Egå was the preferred choice of the population outside of Lystrup. It is seen as a natural area worth visiting specifically for spending time in it and enjoying the nature there. On the other hand, Hovmarksparken is depicted as an area mostly known to people living in its' immediate proximity and visited quickly, often only passing by.

3.3. Background preferences

In the survey, we registered the respondents' preferences towards three impact spheres targeted explicitly by the examined NBS sites: flood risk reduction, recreation enhancements (incl. the presence of green areas) and improvements to nature (Fig. 3).

The respondents appear to be highly concerned about flooding in private and public settings, with more than 70% expressing the highest concern (Likert value 7) regarding avoiding private flooding and more than 50% for public flooding. The presence of green areas is also deemed very important for more than 70% of the respondents, while the presence of recreation facilities is slightly less. The presence of features enhancing biodiversity is perceived overall as very important by more than 50% of the respondents. However, it received slightly lower scores from the group of respondents who chose to answer only for Hovmarksparken compared to the respondents who chose Lake Egå or both sites (Fig. S7). "Nature for nature" zones with no entry for visitors are the characteristics that got the lowest scores out of all the features, despite still being indicated as overall important.

3.4. Evaluating protest votes

Table 4 shows which variables significantly affected the occurrence of protest votes. A full model with all variables is in the SI (Table S1).

Four variables significantly influenced the probability of stating a protest vote. Regarding socio-demographic characteristics, protest voters appear to be older and living in an area associated with lower property value. Notably, our sample had an overrepresentation of older people, which may have influenced the number of protest votes registered. In addition, protest voters attribute less importance to the presence of characteristics enhancing biodiversity or areas set aside for nature.

We proceeded to visualize the outcomes of the logistic regression, as shown in Fig. 4, by clustering the respondents according to the four relevant variables (Table 4). The first division is driven by the most significant variables, namely the importance attributed to areas set aside for nature and to the presence of biodiversity. We then further divided this group according to the less relevant variables influencing the probability of stating a protest vote, i.e. property cost and age of the respondent. Note that the limits indicated in the graph were subjectively chosen based on the distribution of the responses (e.g. the mean value for "importance of space for nature areas" was 5, therefore a value of 6 or higher corresponds to respondents very interested in nature areas). There is a disproportional representation of protest votes among the respondents valuing the nature benefits of the NBS less (lower left quadrant in the larger graph). In contrast, there is an overrepresentation, although less extreme, of protest votes among the older and less wealthy respondents (lower right quadrant in the smaller graph).

The overrepresentation of protest votes among people who associate less value to nature benefits challenged the idea of proceeding by simply eliminating all protest votes from the dataset. People less interested in nature are also less likely to highly (if at all) value a NBS, regardless of their disagreement on the hypothetical valuation scenario. In other words, they could be representing "false protest votes", and the exclusion of these zero bids would translate into a biased assessment of the WTP, which would be higher than in reality. To avoid this, we created two datasets that we have used for the following analyses. In the first set, all the respondents being classified as protest votes are excluded (dataset 1, $n = 387$). In the second data set, only the protest voters that stated an interest of 6 or higher for "nature for nature" areas were excluded (dataset 2, $n = 517$).

3.5. Distribution of WTP responses

The freedom to choose one or both NBS when answering the survey might have caused the respondents to select only the NBS they gained the highest utility from. In that case, we would expect that the WTP for Egå would be higher among respondents who only stated a WTP for Egå, when compared to the respondents who stated WTPs for both NBS. However, the WTPs of the single-site respondents were observed to be generally lower than the WTPs of both sites' respondents, though not significantly (SI Tables S2a&b). This denotes that potential sorting into stating a WTP for only one of the sites or both sites is not significantly

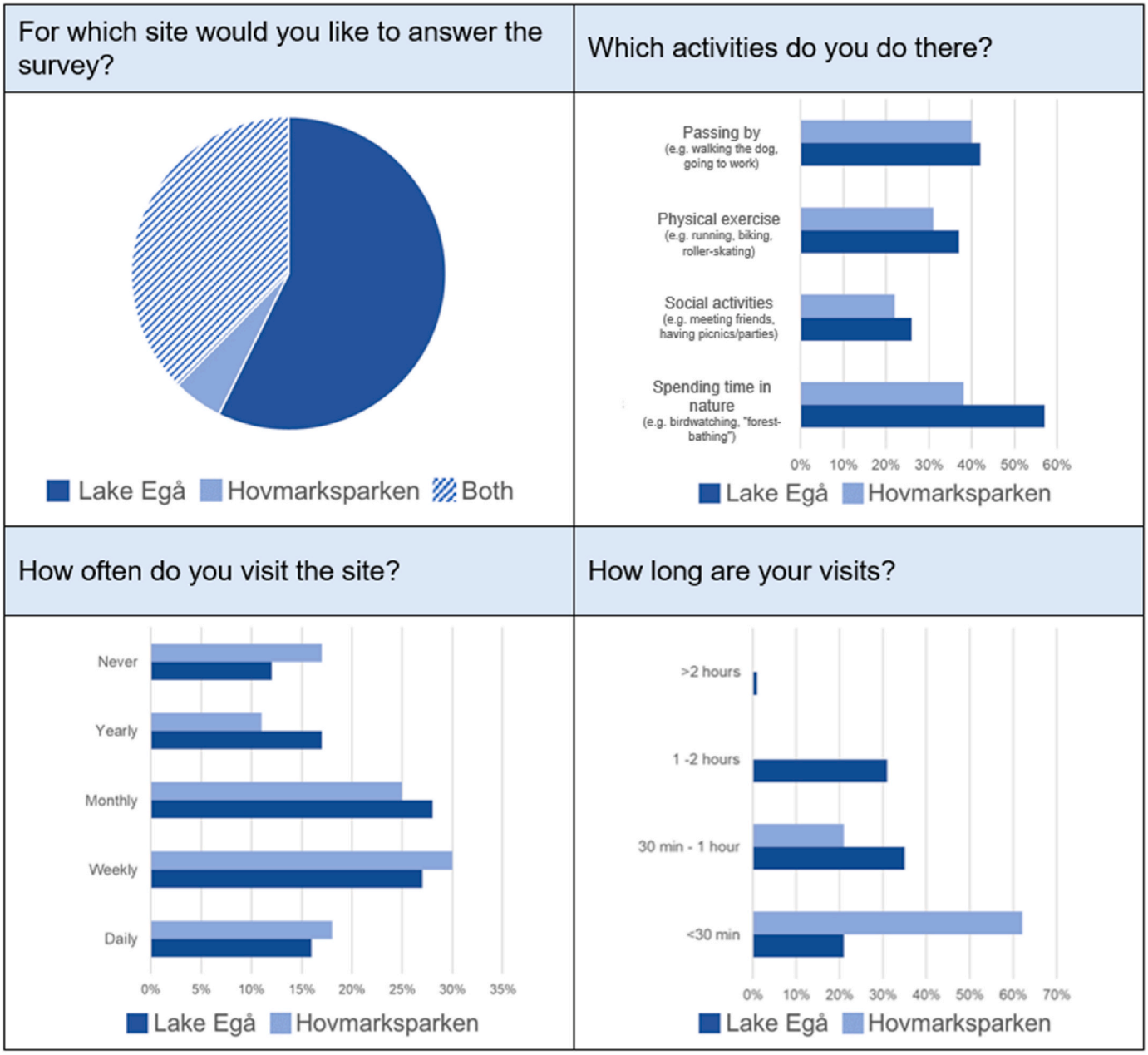

Fig. 2. Percentages showing the respondents' answers to 4 of the survey's questions (indicated above the graphs) on the relationship between people and the NBS area, divided by site.

related to the level of the stated WTPs. Therefore, we joined the three groups in the analysis of WTP for the two NBS sites.

The respondents generally appear to increase their bid when asked about considering the benefits for nature for both sites. This tendency can be observed in the graphical representation of the WTP means in Fig. 5 (compare the distribution of the blue and the green boxes). The "base WTP" bids for the two areas follow the same pattern for both datasets (see the blue and light blue boxes), in the same way, the "total WTP" (i.e. WTP base + WTP nature) values do (see the green and light green boxes). The data also showed a strong correlation between WTP base and WTP nature (Pearson's correlation index higher than 0.85 in both sites and in both datasets), showing that the same people who attribute a high value to the NBS area as it is, are also the ones that would pay more for an improvement of the nature quality.

Overall, the respondents were willing to pay between 30 and 40 DKK/month/household (corresponding to app. 4 and 5.50 EUR) for the maintenance of Lake Egå as it is, while their bids increased to between 50 and 66 DKK/month/household (app. 6.70 and 9 EUR) if further nature enhancements were to be implemented. As for Hovmarksparken, the bids were between 25 and 35 DKK/month/household (app. 3.50 and 4.70 EUR) for the NBS maintenance and between 40 and 58 DKK/month/household (app. 5.50 and 7.80 EUR) with the inclusion of nature benefits enhancements (SI Table S2a&b). Bootstrapping tests (SI Table S3) confirmed a statistically significant difference between the two WTP values for both areas and considering both datasets, substantiating that the respondents are willing to pay on average a greater amount of money for enhancing the nature benefits in addition to maintaining the NBS areas.

Fig. 5 shows slight differences between the expressed WTP for Lake Egå and the one for Hovmarksparken, with the latter being slightly lower (compare the light blue boxes with the blue ones and the light green with the dark green). We investigated if this difference was

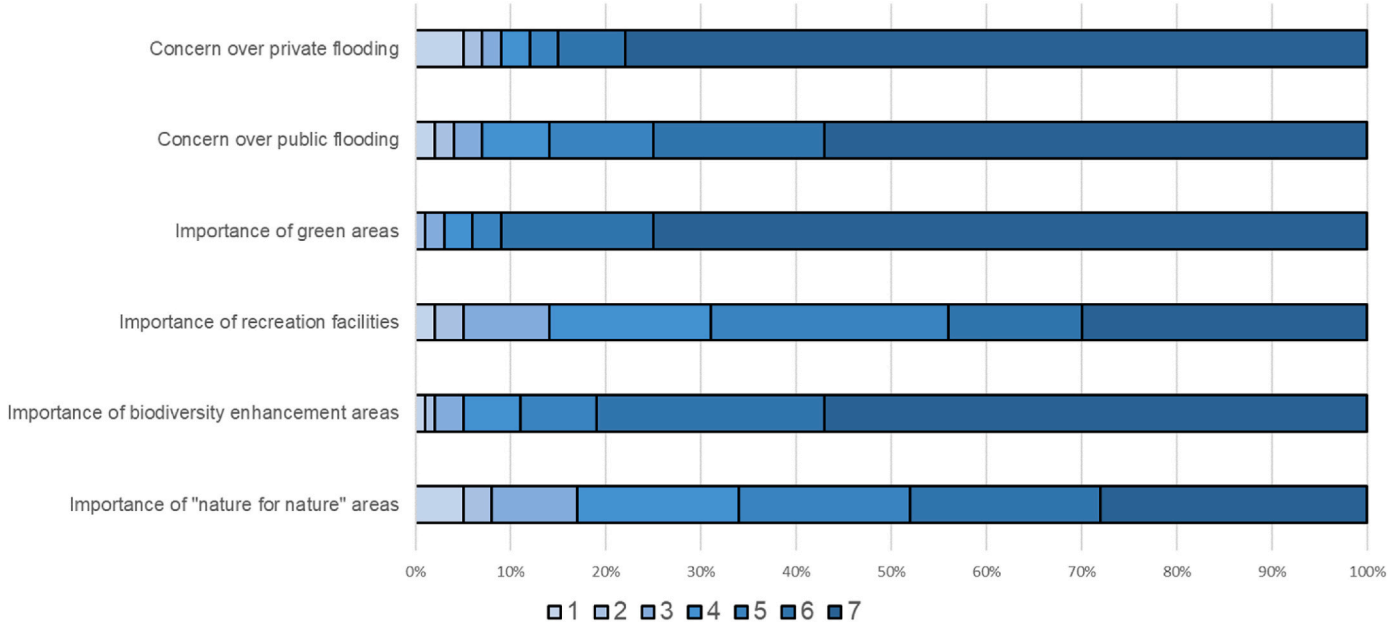

Fig. 3. Importance (1 being not important and 7 being very important) of the different functions of NBS, as expressed by the respondents. The results divided by site can be seen in the SI (Figs. S7–S12).

Table 4
Estimated logistic regression model using the binary variable indicating protest votes as dependent variable (only the significant results are shown). The full sample of respondents was used in this analysis.

Logistic regression model (dependent variable = expressing a protest vote)	Estimates
Importance attributed to the presence of biodiversity	− 0.205**
Importance attributed to areas set aside for nature	−0.155**
Property cost	− 3.048e-05*
Age of the respondent	0.014*

*p < 0.05.
**p < 0.01.
***p < 0.001.

statistically significant and if the respondents were willing to pay the same amount on average for the two sites. Once again, we applied both a *t*-test and a bootstrapping test using a subset of the data. We used only the bids of the respondents that expressed a WTP for both NBS (n = 139 for dataset 1 and n = 196 for dataset 2). The outcome (SI Table S4) shows no statistically significant difference between the bids stated for Lake Egå and those stated for Hovmarksparken.

3.6. Variables affecting WTP

Table 5 shows the significant variables in the different multiple linear regression models. As reported in Table 2, the dependent variable WTP was log-transformed. We have tested that the resulting models are robust towards variations of y_0. The independent variables were used without transforming them. We used the same method for model building for both datasets 1 and 2.

The importance given to "nature for nature" areas non-accessible for visitors appears to be the most relevant variable linked to the WTP expressed by the respondents, as it is the only variable appearing across all 12 models. Also, the importance attributed to biodiversity enhancements remains relevant throughout sites and datasets, specifically for the models concerning Lake Egå. These properties denote substantial none-use values associated with the two NBS.

Variables indicating recreation uses (e.g. reasons for visiting the area) appear to fill a more marginal role but generally seem to confirm that people doing activities in the area tend to attribute a higher WTP to the site. Moreover, passing through Hovmarksparken is associated with higher WTPs. In contrast, increasing distance to Egå is associated with lower WTP. The latter result nicely illustrates the spatial properties of NBS WTP, which are found in the spatial preferences literature.

The socio-economic variables are largely insignificant, and they appear to have some relevancy only in the context of Lake Egå. As expected, higher income levels are associated with higher WTPs. Finally, our models do not seem to distinguish a defined influence of the flooding concerns on the WTP. Despite a clear result, the variables on flooding perception become relevant in both datasets when eliciting the additive bid on nature enhancements. It seems that a greater concern for private flooding corresponds to a higher WTP for nature benefits, while the concern over flooding in public property negatively influences the WTP. It is interesting to observe how the concern over flooding in different areas determines whether the respondent sees the improvement of benefits for nature as a useful addition to the risk reduction capacities of the NBS.

Overall, the models created for the WTP total appear to summarize the ones created for WTP base and WTP nature of the respective site, as expected. Notably, most of the collected variables were irrelevant in any models. Tests excluding the "interest for nature" variables (i.e. importance of no access "nature for nature" areas and importance of biodiversity enhancements) from the models did not lead to the expression of new significant variables.

4. Discussion

4.1. Effect of NBS characteristics and relationship with the area on WTP

We find a quite distinct preference of the respondents for choosing Lake Egå instead of Hovmarksparken, also for those people living close to the park, namely in Lystrup (Fig. 1). Analyzing more in-depth the relationships between the respondents and the two areas (SI Fig. S5 & S6), it appears that Lake Egå is considered more of a "destination" worth visiting for the people of Aarhus (e.g. longer visits, visiting to enjoy the nature). In comparison, Hovmarksparken is seen as a part of the urban context that is, for the most part, passively experienced by close

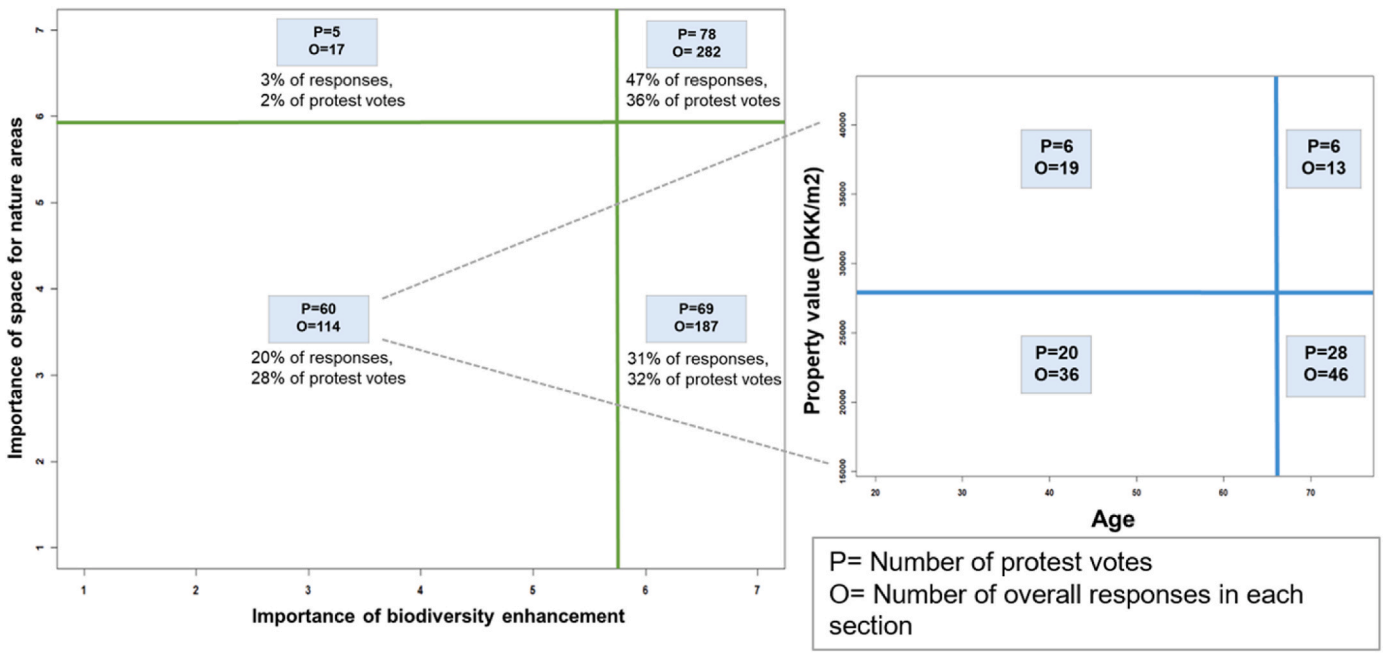

Fig. 4. Visual representation of the respondents' protest vote data divided according to the relevant variables from the logistic regression model (see Table 4). Within each area of the graph it is shown the number of protest votes and the overall responses (i.e. protest and non-protest votes) for the respondents with those characteristics (i.e. older than 60 years old and living in an area with property value below average).

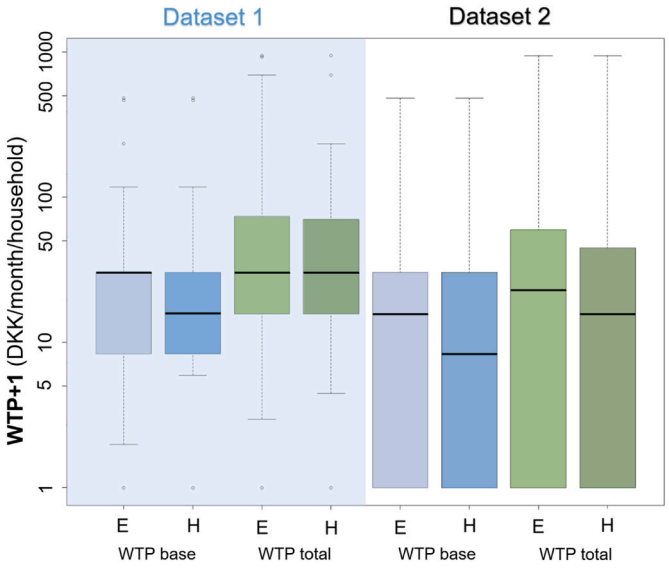

Fig. 5. Representation of the different WTP in datasets 1 (excluding all protest votes) and 2 (re-introducing some protest votes), classified by area (E for Lake Egå or H for Hovmarksparken) and by first and final bids (base and total).

residents (e.g. shorter visits, just passing by). Therefore, our results seem to uncover how the area's physical characteristics appear to influence what the respondents identify as an area worth valuing. Specifically, in the case of the Aarhus NBS sites, the larger, peri-urban site appears to be more likely to be identified as an area of particular interest for recreation or nature enhancement. On the other hand, the smaller site seems to struggle to be recognized as relevant infrastructure for contributing to the same benefits. The influence of size on the value attribute to NBS has also been observed in other studies (e.g. Liebelt et al., 2018; Skrydstrup et al., 2022). Nevertheless, such perceptions do not appear to be reflected in the quantitative valuation of our study sites, as the difference between WTP bids for the two sites was not deemed statistically significant (Fig. 5, SI Table S4).

4.2. *Effect of personal preferences on WTP*

The "raw" outcomes on background preferences were relatively homogeneous (Fig. 3, SI Fig. S7-12), but the queries on the nature benefits of NBS were the most divisive. Specifically, respondents that attributed a higher importance to nature were answering (i.e. were willing to express a value) for both sites, whereas those who did not value nature as highly were more likely to choose to answer only for the urban NBS site. This seems to suggest that Hovmarksparken is not perceived as an area particularly relevant for the improvement of nature quality.

In terms of quantitative valuation, the mean WTP values in the two datasets appeared to follow the same patterns, despite the lower average of dataset 2, due to a higher number of zero bids. WTP bids significantly increased across sites when the elements enhancing biodiversity were introduced into the hypothetical valuation scenario (Fig. 5, SI Table S2). This finding suggests that the improvement of nature is seen as a positive addition worth paying more for, independently from which site is considered. The relevance of people's preferences regarding the benefits of NBS for nature is also reflected in the results of our models (Table 5), where the importance given to areas set aside for nature is the only variable influencing the WTP present across all 12 models. Despite the unclear influence of some variables, the models seem to paint a quite cohesive picture: people's preferences are the drivers of valuation, followed by variables describing the recreational uses of the respondents, and finally, socio-demographic characteristics, which have a more marginal effect.

4.3. *Evaluating method applicability*

The proposed holistic assessment proved useful in solidifying the importance of using multi-dimensional approaches when assessing NBS. In relation to our first research objective, our method was able to capture a wide range of uses and perceptions of the areas, and our results support the claim that economic valuations alone are insufficient to clearly represent all the non-market benefits of NBS. Our results thus match the outcomes of other preference studies conducted in similar contexts

Table 5
Linear regression model results for the expressed WTP base, WTP nature and WTP total for Lake Egå (E) and for Hovmarksparken (H) using both datasets 1 and 2 (only the variables that were significant in at least one model were reported. For the results including the complete list of variables, see Table S5 in the SI). *p < 0.05 **p < 0.01 ***p < 0.001.

Independent variables	Dataset 1 (excluding all protest votes)						Dataset 2 (partly re-integrating protest votes)					
	WTP base		WTP nature		WTP total		WTP base		WTP nature		WTP total	
	E	H	E	H	E	H	E	H	E	H	E	H
Intercept	1.057***	1.565***	−0.306	2.086***	1.232*	1.609***	−0.936**	−0.462	−0.799	0.330	−1.095**	−0.825*
Importance of no access "nature for nature" areas	0.179***	0.236***	0.150**	0.292***	0.139**	0.254***	0.373***	0.511***	0.303***	0.462***	0.419***	0.598***
Importance of biodiversity enhancements	–	–	0.241**	–	0.192**	–	0.196**	–	0.198**	–	0.235***	–
Visiting the area to enjoy nature	0.581***	–	–	0.443*	0.441**	0.406*	–	–	–	0.381*	–	–
Visiting the area to practice sport	–	–	0.493**	–	–	–	0.455**	–	0.572***	–	0.554***	–
Passing by the area	–	–	–	–	–	0.443*	–	–	–	–	–	–
Distance to the area	–	–	–	–	−0.011*	–	–	–	–	–	–	–
Household income	1.146e-06***	–	9.418e-07***	–	1.258e-06***	–	–	–	–	–	–	–
Importance of avoiding flood in private property	–	–	0.114*	–	–	–	–	–	0.088*	–	–	–
Importance of avoiding flood in public property	–	–	−0.191***	−0.272***	−0.096*	–	–	–	−0.149**	−0.145*	–	–
Indirect experience with flooding	–	–	–	–	–	–	–	–	–	–	–	0.461*

(Anderson et al., 2022; Ando et al., 2020; Bernath and Roschewitz, 2008; Derkzen et al., 2017; Hérivaux and Le Coent, 2021; Reynaud et al., 2017; Schaich, 2009), with the additional novelty of having conducted a comprehensive ex-post assessment taking into consideration all the factors influencing valuation.

What clearly emerges from our study is that non-tangible benefits of NBS are positively valued by the users of these areas, regardless of their use. For example, the option of an increase in benefits for nature was preferred, and a high interest in biodiversity enhancements and "space for nature" areas was registered. Therefore, in order to ensure continuous support in NBS uptake, it is fundamental that the multiple benefits of NBS are not only produced, but also highlighted and shared with the population, at least in a Danish context. These are crucial assessments for decision-makers and stakeholders (e.g. municipalities) striving for the creation of NBS, and therefore worth pursuing for more effective and successful implementations.

We were able to show a strong link between personal preferences and the value attributed to the NBS; however, a clear connection between the latter and the physical characteristics and uses of the NBS could not be found. This may be due to a number of reasons, both methodological (e.g. most of the respondents live very close to the two sites, and many of them completed the survey for both NBS), and contextual (e.g. Danish welfare state, widespread awareness of the population to climate adaptations). Therefore, a suggestion for future research on this approach could be to replicate it on other NBS sites (of different sizes, completion ages and cultural contexts) to further test and evaluate these findings. Through such a replication, it will be possible to obtain a wider array of data on uses, preferences and benefits of NBS, which the literature calls for (e.g. Venkataramanan et al., 2020) to achieve more genuinely comprehensive and holistic NBS implementation frameworks. Our questionnaire was successfully adapted to register responses for two different sites, and the co-design procedure used with Aarhus Municipality could be replicated with stakeholders from different NBS, obtaining a series of similar datasets allowing for quick and accurate comparisons across NBS.

4.4. Limitations of the methods

CV methods have their shortcomings. Collecting data through a questionnaire makes it easy to incur in-sample selection bias. Our distribution was random, but our collected sample shows, for example, a bias towards older people. This could be because retired people can allocate more to answering surveys. Nevertheless, the over-representation was not deemed so critical that it needed a sample correction. However, given the tendency of older people to protest against the valuation scenario (Fig. 4), it is essential to keep in mind that the obtained WTP values could be slightly lower than in reality.

Another possible bias in our sample could be the hypothetical bias, i.e. running into unreliable estimates due to the respondents' having to evaluate an imaginary scenario (Schläpfer et al., 2004). Another source of hypothetical bias is the protest answers. The scenarios we proposed (i.e. having to pay a fee to maintain the study sites) could be why people stated protest bids, rather than not approving the NBS project. However, we tried to reduce the protest bias by clearly stating the imaginary nature of the queries and eliciting a WTP for two projects that have already been implemented. Moreover, it is fair to point out that the additive, two-step valuation approach could be partly responsible for the difference seen in the bids "for nature". However, the fact that not all respondents initially stating a WTP >0 also did so for the second question seems to indicate that the second valuation question provided enough of a distinction to stimulate truthful additive bids.

Regarding the analysis of the WTP values, the non-significant

difference between the WTP of Lake Egå and Hovmarksparken could be because this specific analysis had to rely on the respondents that answered for both sites (which led to smaller subsamples in both datasets 1 & 2). Overall, at least this subset expressed approximately the same value for both areas.

It is also necessary to address how the data collection nature could have influenced the analyses. The data was collected through multiple choice questions, with the options often presented as intervals. It may be that the chosen intervals were not entirely fitting for this specific case. As an example, the vast majority of the respondents indicated to be living between 1 and 5 km from Lake Egå. Therefore, a more fitting set of intervals, i.e. with smaller increments, could have made a difference in the outcome of our analyses. Nevertheless, the overlap between relevant variables across models confirms their influence on the respondents' WTP regarding Aarhus's study sites.

5. Conclusions

We co-created a novel CV method for assessing the interconnections between the characteristics, perception and valuation of NBS, which was applied to two study sites. Based on our analyses of the results, we conclude the following.

- The physical characteristics of NBS sites influence people's perceptions and uses of the site. In our study site, the larger, peri-urban NBS is visited for longer periods of time, and more often, the purpose of the visits is to enjoy its nature. Moreover, it appears to be perceived as a better site for the improvement of the quality nature. However, these differences in perception did not lead to a statistically higher WTP for the larger area, suggesting that variables other than size and placement come into play to influence valuation.
- In the context of this study, people's expressed valuation of the NBS closely reflected their interest in improvements benefitting mostly nature (i.e. no-access "space for nature" areas). This suggests that our respondents' valuation links to their personal preferences rather than, e.g. their socio-demographic characteristics or the physical features of the NBS. Thus, highlighting the multiple benefits of NBS and actively involving citizens in their creation seem plausible approaches to support their prioritization and increase their uptake.

Our findings underline the importance of including benefits for nature both in the planning and the assessment phases as a key to successfully implementing NBS projects. The connection to nature benefits appears to increase the valuation, making these projects more appealing, also in comparison with traditional gray solutions. Moreover, publicizing the nature benefits that a particular NBS could introduce to an area appears to be a desirable choice, as the public seems to show a positive attitude towards "greener" solutions. Overall, this research demonstrates the importance of adopting a multi-dimensional approach in the economic valuation of the non-tangible benefits of NBS. Understanding the different dimensions that influence these strategies' valuation can further support the planning of more purposefully designed and efficient solutions.

Credit author statement

Martina Viti: Conceptualization, Writing – original draft, Investigation, Methodology, Data curation, Visualization. **Roland Löwe**: Conceptualization, Writing – review & editing, Methodology. **Hjalte J. D. Sørup**: Writing – review & editing, Methodology, Visualization. **Jacob Ladenburg**: Writing – review & editing, Visualization, Validation. **Oliver Gebhardt**: Conceptualization, Writing – review & editing. **Signe Iversen**: Writing – review & editing, Validation. **Ursula S. McKnight**: Conceptualization, Supervision, Writing – review & editing, Validation. **Karsten Arnbjerg-Nielsen**: Conceptualization, Supervision, Writing – review & editing, Methodology, Project Management, Funding acquisition.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jenvman.2023.117498.

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