

## Seasonality of the recreational value of forests in Denmark

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### ABSTRACT

The importance of forest composition and appearance for recreational value is well-known, with a preference for deciduous species over coniferous species in Denmark. Yet, the effect of seasonal variation in appearance of these species on recreational preferences remain underexplored. In this paper, we combine three datasets to examine how seasonality affects people's preferences for forest visits. Using a repeated choice experiment over a one-year period, we find that the Danish public's preference for deciduous over coniferous forests is far more pronounced in spring and summer than in autumn and winter. Using forest visitor data from counting stations across Denmark, we demonstrate that the seasonal variation in visitor numbers is more pronounced for forests with a higher share of deciduous trees. Finally, we use PPGIS data to show that respondents travel to and stay shorter in the forest in the winter. The mode of transport, however, is stable over the year. Thus, out of five elements important for the calculation of welfare estimates, being species preference, travel distance, visit frequency, visit duration and transport mode, we find that the first four vary significantly by season, with no significant seasonal variation for the latter. We conclude that previous valuation studies, primarily based on spring or summer seasons, are upper bounds on the preference for deciduous forests over coniferous forests as well as for travel distance. Future valuation studies on forest recreation should pay closer attention to the effects of seasonality to produce non-biased estimates.

### 1. Introduction

Forests are an important place for recreation in many places in the world. Visiting a forest is a way for people to enjoy nature and to be active. In this way, forest recreation plays a significant role in contributing to societal wellbeing and overall welfare (Eggers et al., 2019; Zandersen and Tol, 2009).

In the past decades, studies have shown that forest management can influence the recreational experience of a forest visit. For example, the choice of tree species, the choice of rotation age that affects the size and/or age of the trees, the variation of tree ages and the choice of leaving deadwood in the forest influence the recreational experience and thus the value (Agimass et al., 2018; Filyushkina et al., 2017; Giergiczny et al., 2015; Gundersen and Frivold, 2008; Nielsen et al., 2007).

However, the effect of seasonality is rarely explicitly considered in studies that deal with forest preferences. The literature either uses a depiction of forests in a single season, often spring or summer, or an aggregate general value over the entire year to estimate the recreational

value or general preferences for forests (Bartczak et al., 2012; Hegetschweiler et al., 2022). Yet, it is easy to imagine that seasonality is particularly important to Northern Europe's deciduous or mixed forests. From the golden colours of the leaves in the autumn, to the first leaves and blossoms in the spring, or the barren branches in the winter, deciduous forests change dramatically in their appearance over the year. Therefore, it seems natural to assume that seasonal variation in forest aesthetics affects the intensity of people's recreational experience. Apart from the forest's appearance, the seasonal variations in weather and light are likely affecting the overall willingness of people to travel to forests. Likewise, seasons could be affecting the frequency of visits, the trip duration, mode of transport, and travel distance. As such, seasonal variations are likely to impact the total recreational value of forests, and studies ignoring this effect are likely to produce biased estimates of the recreational value of (certain types of) forests. Already in 2007, in a review of 20 years of stated preferences (SP) valuation studies of non-timber benefits of forests in Scandinavia, Lindhjem (2007), found some evidence that this is likely to be the case by showing that people

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value forests lower in the autumn and winter than in the spring or summer, despite none of the included studies incorporating this seasonal component explicitly in the study design (Lindhjem, 2007).

To our knowledge, only two previous valuation studies have explicitly incorporated seasonality in their study design. Bartczak et al. (2012) have shown differences in the seasonal value of forest visits in monetary terms, using an on-site travel cost survey in Poland. This study was executed during a single period in the autumn, where respondents were asked about their visiting frequency and travel distance during the entire year. Using these responses, they show significant variation in the value of forest visits during the year, with the highest value in autumn and the lowest in winter. Furthermore, Elsassar et al. (2010) observe a seasonal effect in landscape view preferences in a study utilizing a choice experiment (CE) that focuses on residential location choice. They find a strong preference for broadleaved or mixed forests over coniferous forests in the summer, but no difference in preference in the winter.

In terms of general preferences for forests, a limited number of studies from outside the fields of environmental economics have investigated differences in seasons. Hegetschweiler et al. (2022) show that in Switzerland the overall visual attractiveness of forests is rated higher in summer than winter. Similarly, Koivula et al. (2020) show that in Finland, respondents also rate summer photos of forests higher than winter photos, except for highly logged areas. On the other hand, Tyrväinen et al. (2017) show that winter depictions were generally preferred over summer images for recreation in commercial forests in Finland. The winter depictions in their study showed a clear snow bed, which they indicate is preferred by the respondents, and hence may not hold in more temperate regions (Tyrväinen et al., 2017). In a field study in Southern Germany, Meyer et al. (2019) analyzed the preferences for recreational use of forests and forest benefits such as clean air or peace and tranquility. Here, they show that forest benefits are rated significantly lower in the winter than in summer (Meyer et al., 2019). Therefore, there is a need to better understand how seasonal variation influences forest preferences, particularly in temperate regions.

The present study extends upon previous work on the recreational value of forests tied to seasonality by using a survey design and execution schedule that explicitly follows the seasons in Northern Europe. We utilize three different data sets in our analysis, combining both SP and revealed preference (RP) data. We contribute to the literature by 1) aligning the timing of the data collection with the seasonality respondents are shown in the pictures, 2) sampling the general public rather than only visitors, thereby also targeting those who, potentially, do not visit the forest in certain seasons, 3) focusing on the recreational value of different structural forest attributes, 4) analyzing seasonal differences in the types of recreational trips regarding trip duration, mode of transport and travel distance. Finally, we contribute to the existing literature by 5) combining SP and RP evidence.

In summary, this paper tests the following three implicit hypotheses from the existing forest valuation literature:

1. H0: the relative value of deciduous forests over coniferous forests is stable over the seasons;
2. H0: the type of forest visit in terms of visit duration and transport mode is stable over the seasons;
3. H0: the general value of forest visits is stable over the different seasons.

## 2. Methods

In this study, we combine three datasets to answer our research questions. Rather than having the aim to directly compare the outcomes of the different datasets to each other, we leverage the strengths of the different datasets to provide a comprehensive answer to the question whether the recreational value of forests is seasonal in Denmark. Estimates derived from a CE are known to be sensitive to survey design and the visualization of the choice set (Mariel et al., 2021). To mitigate the

risk of this potential bias, we incorporate a revealed preference dataset, which offers insights based on actual visitation patterns. Both the CE and revealed preference datasets only included information on visiting frequency and stated willingness to travel to forests. To enrich our analysis, we included a third dataset which provides additional metrics relevant to recreational value, such as mode of transport and visit duration, allowing for a more nuanced understanding of forest use across seasons. An overview of the different datasets and methods is provided as Table 1.

The SP data used in this paper thus originates from two sources; The first is data collected in a CE survey executed in Denmark in the period of May 2023 (spring) to February 2024 (winter), and the second data is from a Public Participation Geographic Information Systems (PPGIS) survey, executed during the period May 2022 and April 2023, also in Denmark. The revealed preference data is based on counting station data from across Denmark for a 12-month period starting April 2023.

The two SP surveys were also utilized to answer other research questions related to rewilding and general drivers for outdoor recreation, as reported separately in de Kruiff et al. (2025) and Legarth (2025). All participants in the surveys provided active consent before participating in the survey. Ethical approvals were obtained from the Ethics committee of the University of Copenhagen and are filed under the number j.nr. 504-0298/21-5000 and 504-0298/21-5000.

### 2.1. Forests in Denmark

In this study, we evaluate the seasonality of recreational value of forests in the country of Denmark. In general, approximately 40 % of the total forest area in Denmark is coniferous, 44 % are broadleaved species and approximately 12 % is mixed forests. The final 4 % is temporarily unstocked (Nord-Larsen et al., 2024). Nearly all broadleaved species in Denmark are also deciduous (Bjerreskov et al., 2021).

The Eastern part of the country, covering the island with the capital of Copenhagen, has a somewhat higher share of broadleaved forest, at 66 %, and around 20 % coniferous forests. This is more evenly distributed in the Western part of Denmark, with 46 % coniferous forest and 38 % broadleaved forest. The share of mixed forests is relatively equal over the country. There is no record of age distribution on regions in Denmark. Previous research has shown a general preference of Danes for broadleaved and mixed forests over coniferous forests (Nielsen et al., 2007).

By law, all forests are accessible to the public, irrespective of ownership. However, in privately owned forests, access is only allowed between 6.00 in the morning to sunset and only on established roads and paths. In public forests, there are no restrictions to when and where the public has access. Approximately 70 % of the Danish forest is privately owned, with the rest owned by the state or other public bodies (Johannsen et al., 2019). Visitors may collect mushrooms, berries and other foods in limited quantities for personal use in both private and public forests.

**Table 1**  
Overview the different datasets and methods.

	CE	PPGIS	Counting station
Type of data	Stated preference	Stated preference	Revealed preference
Time period	May 2023 to February 2024	May 2022 to April 2023	April 2023 to March 2024
N	2883 respondents	4784 respondents	127 counting stations
Frequency of data collection	Once per season	Monthly	Aggregated to monthly
Relevant to hypothesis	1 & 3	2 & 3	1 & 3

## 2.2. Stated preference data

This study applied the CE methodology, in which respondents to a survey are repeatedly asked to choose between sets of different forests to visit. The attributes in the CE vary according to an underlying experiment design, allowing for the evaluation of the relative preferences between the attributes. The individual is assumed to maximize their utility by repeatedly choosing their preferred option (McFadden, 1973). Through an analysis of the repeated choices, the analyst can establish the relative preferences for the different attributes with an error for unobserved effects. This analysis is usually executed using different forms of logit models, where the choice of model is primarily driven by the assumed structure of the heterogeneity of preferences of respondents (Mariel et al., 2021). In a Multinomial Logit (MNL) model, preferences are assumed to be homogeneous over the population. In a Mixed Logit (MXL) model, preferences are instead assumed to be heterogeneous over the different respondents, following a certain distribution assumed by the researcher.

Including some form of cost for the respondent, in this case travel distance, allows for a valuation of the relative preference of the attributes vis-à-vis the cost attribute. In most CE applications, the cost attribute is represented by a general tax increase or payment to a general fund. In this survey, we instead used the travel distance to the forest as a measure of costs for the respondent. This measure has the benefit of being more realistic in the context of this CE, which can lead to which can lead to a reduction in protest bidders. This is inspired by the Travel Cost literature, where the expected negative utility of travel distance is used to elicit a recreational value (Freeman III et al., 2014; Matthiesen et al., 2025). Moreover, it emphasizes the recreational nature of the valued good (Whitehead and Wicker, 2018). This maximum Willingness to Travel (WTT) thus represents the ratio between the structural forest and distance attribute. A theoretical challenge when using distance in km as a measure is the unit costs of travel when converting into monetary units (Sælen and Ericson, 2013). In this paper, we refrain from converting WTT to monetary units and instead work in time and distance space. For other applications of WTT in literature, see e.g. Bakhitari et al. (2014) or Christie et al. (2007). For more information on the CE methodology in general, see e.g. Mariel et al. (2021).

In this study, the forests differed in their structural forest attributes (age structure, tree species, forest openness), as well as other attributes related to the presence of herbivores in forests and the distance to the forests.<sup>1</sup> An overview of all attributes and the respective levels can be found in the Supplementary Materials. We adopted a labelled design, where alternatives labelled “Fence” included herbivores and fence attributes, whereas “No fence” alternatives included no herbivores or fences. To avoid confounding with the herbivore and fence attributes, we only analyze the “No Fence” ASC estimates for the analysis of overall trip value in this study. For a more detailed description of the methodology and survey design, we refer to de Kruiff et al. (2025).

As we were interested in the differences in the WTT for structural forest attributes over the seasons, the survey execution schedule closely followed the seasonal pattern. It was sent out in four waves to a representative sample of 20,000 people from Denmark. A total of 2883 respondents completed the survey and were used in the analysis. For the different seasonal waves, the depiction of the deciduous forest attribute changed according to the season.<sup>2</sup> The study used depictions from Anders Busse Nielsen, which have been used in multiple previous studies (Filyushkina et al., 2017; Giergiczyński et al., 2015, 2022; Nielsen et al., 2007). We adapted these in Adobe Photoshop by changing the colour

and presence of leaves on the deciduous trees to reflect the different seasons, but did not include seasonal aspects such as the presence of snow. This is both to avoid confounding effects and because snow is not that prevalent in winter in Denmark.

Additionally, the scenario description of the CE also referred to the seasons and the different depictions of the leaves of the trees. The direct translation to English is available below:

*“Forests can have a different appearance. The trees can be young or old. And the tree species can either be broadleaved or conifer. If there are grazing animals, the forest will also typically become more open. The appearance of the forests will be shown with drawings like the example below. Note that the forest is shown in its [season] state.”*

The colour and presence of leaves and the seasonal state mentioned would match the current season of the data collection. The framing of the question was a forest trip to a large forest “in the near future”, using the following wording translated to English:

*“In the following section, we will describe different forests and ask you to choose which, if any, you would like to visit. All of the forests are large forest areas of approximately 1,000 hectares.” (scenario description).*

*“Imagine that you are planning to take a walk in the woods in the near future. The options below are forests you could possibly visit. Which of them will you choose? You can also choose to visit none of them.” (heading of the choice set).*

As such, we were eliciting the preferences of the respondent contingent on the season at the time of answering, including any seasonal context that could influence forest visit preferences such as day length or temperature, and we align that with showing pictures of trees in that specific season in terms of colour and number of leaves on the trees. Given the limited presence of large contiguous forests in Denmark, we elicited preferences for a particular trip to a forest, and not e.g. an everyday walk with the dog, that happens to be in or near a forest.

Prior to the choice sets, respondents were asked to report on their visit frequency in the last 7 days and in the last year. Here, several respondents provided invalid answers, e.g. providing the year 2024 instead of number of visits. For the analysis of this data, we removed respondents that indicated visiting the forest more than five times a day (0.4 % of all respondents).

The survey was prepared and pretested from November 2022 to May 2023. The attributes and attribute levels included were initially based upon expert assessment. Retrospective think-aloud interviews were used to pretest the survey ( $N = 3$ ), with additional online pretesting of the survey ( $N = 3$ ). Additionally, a pilot study was executed in April 2023 to test and obtain priors for the experimental design ( $N = 73$ ).

We used a multinomial logit model and a mixed logit model, both in Willingness to Travel space, for analysis of the CE data. For the MXL model, we assumed that all random parameters were normally distributed, except for distance, where we instead assumed a negative lognormal distribution. A total of 3000 MLHS draws were used for simulation. All models were estimated in R using the Apollo package and BGW algorithm (Bunch et al., 1993; Hess and Palma, 2019).

## 2.3. PPGIS-survey data

The PPGIS survey method is used to obtain information on spatial patterns from respondents (Brown and Weber, 2011; Fagerholm et al., 2021; Wolf et al., 2018). The PPGIS method relies on respondents self-reporting information regarding spatial behavior, for example pinpointing their latest recreational visit site on a map. The mapped points can then spatially be characterized by the analyst based on geographic attributes, e.g. classifying the site by land cover type, urban proximity etc. (Termansen et al., 2013).

Respondents also reported information on their home address; on trip characteristics such as trip duration and mode of transport and on their socio-economic background. The inclusion of the home address allows the analyst to identify the travel distance for recreational visits. Our survey was sent out to a total of 46,877 respondents, out of which

<sup>1</sup> In this paper we only analyze the attributes related to forest appearance. General results regarding fencing and presence of herbivores are reported in de Kruiff et al., 2025

<sup>2</sup> Visual depictions used in the survey are included in the Supplementary materials as Figure 9,10 & 11.

9169 provided information on the location of their latest nature visit and their current home location. The survey was sent out monthly, on different days over a 7-day period, resulting in 84 distribution rounds, to account for any effects of weekday or weekend recreation (Bertram et al., 2017; Keskinen et al., 2020). The respondents were obtained from a representative sample of the Danish Central Person Register (CPR). Respondents were slightly older and more likely to be female than the Danish national average. The spatial distribution of respondents corresponded closely to the spatial distribution of inhabitants at the municipal level in Denmark, ensuring that the dataset is not only demographically but also geographically representative.

Respondents were asked to provide their home location and the place of their latest visit in nature using the online PPGIS-tool Maptionnaire. Respondents were also asked to provide information on their second to last visit to nature. To ensure high enough detail of the location mapping, respondents needed to zoom into the map to at least neighborhood level before indicating their visit location (Legarth, 2025). Respondents also indicated their frequency of visit, whether the visit was only recreational or multipurpose, and mode of transportation.

For the analysis in this paper, we only drew on the 4784 respondents who mapped their latest visit point within 250 m of a forest area, as classified by a national level land cover map (Levin, 2022). To ensure validity in relation to the time of visit, only visits made within four weeks were included in the analysis. For this dataset, we primarily use the reported information on travel distance, mode of transport and visit duration. The estimations of travel distance between the recreational site and home address were based on Euclidean distance (crow's flight) between the reported points of the respondent. Visit duration and mode of transportation of the latest visit were self-reported by the respondent. Respondents who provided recreational visit locations of >40 km away if visited by foot, >70 km if visited by bike and > 100 km by car were removed. These locations were deemed unreasonably far for a general recreational trip, to not include e.g. long holiday trips. For clarity, we excluded trips made by public transport, given their marginal share in the total number of trips (bus 0.7 %, train 1.4 %). Multi-purpose and multi-destination trips were retained in the dataset. The share of visits where a nature visit was the sole purpose – as opposed to incidental or multi-purpose trips – was relatively stable across all months (around 80 %), indicating no meaningful seasonal variation in their occurrence. Excluding them would therefore not substantially alter seasonal patterns. Moreover, incidental and multi-purpose trips represent an important component of forest recreation demand and contribute to the total recreational value of forest visits, making them relevant to include in the analysis. For more information on this survey and its methodology, we refer to Legarth (2025).

#### 2.4. Revealed preference data

Revealed preference analysis in this study was based on monthly visitor numbers, recorded by the Danish Nature Agency's counting stations across the country. However, data from these stations require assessment of their reliability and representativeness since count data can be influenced by several factors, as trivial as animals passing back and forth in front of the counter, close-by vegetation, direct sunlight into the sensor etc. Furthermore, technical malfunction might occur. A two-step process was applied: First, a loglin regression analysis of the hourly counts, explained by the time of the year (days to Newyear), weekend-days vs weekdays, and presence of daylight and rush-hour (for weekdays) was conducted. Counters with R2 below 20 % were not regarded trustworthy and accordingly disregarded. In the second step, hourly observed counts were compared to predicted values based on the loglin regression. In cases where counts were higher than the 99 % confidence interval of the prediction the observed count was replaced by the prediction. In a similar way, a binominal model was applied to predict the likelihood of zero-counts, which is prominent in recreational areas (typically at night). Observed counts, at hours predicted to be zero, were

replaced. When hourly recordings were missing for periods longer than 24 h, predicted counts were inserted (Skov-Petersen, 2025).

For each of these stations, to test sensitivity to the Modifiable Areal Unit Problem (MAUP), different radius bands were established. The MAUP describes that the analysis of spatial data can depend significantly on the size and boundaries chosen as demarcations. Any outcome or interpretation might depend on these chosen demarcations, instead of a true difference (Wong, 2004). We established the number of square meters of coniferous and deciduous forests in a radius of 250, 500, and 1000 m around the counting station, and used these as separate bands for our analysis. As such, we analyzed the data at different spatial resolutions using the three different radius bands, thereby ensuring robustness. The number of coniferous/deciduous trees in an area was based on Bjerreskov et al. (2021).

Stations with less than 10 % forest cover in a 1000-m radius were further removed, as well as three extreme outliers with over 100,000 visitors per month (52). This resulted in a total of 127 counting stations being included in the analysis. Additionally, in the 250- and 500-m radius bands, there were five and two stations without any trees within the radius. These were removed from the models based on these radii but were included in the 1000-m radius models.

To ascertain the effect of tree species type on the seasonality of visitor counts, we applied a two-way fixed effects model (TWFE), accounting for fixed effects per station and time. A TWFE model utilizes the panel data structure of the data to control for unobserved heterogeneity both at the unit level (counting stations) and period-specific trends (month or season) (Li et al., 2021; Stock and Watson, 2012). In this way, we controlled for general seasonal trends in visitor numbers and general differences per counting station and isolated the effect of tree species type on the seasonality of visitor counts.

We aggregated time at two levels: monthly and by season and estimated different models for each. For the seasonal aggregation, we grouped monthly the counts as follows: December, January, and February into Winter; March, April, and May into Spring; June, July, and August into Summer; and September, October, and November into Autumn. The fixed effects of the season and individual months are included in the tables to provide information on general seasonal trends.

We used the Percentage of Deciduous trees in the total number of trees as the explanatory variable. This way, we measure the impact of an increase in share of deciduous trees in a forest on seasonality of visitor numbers, without having to employ a somewhat arbitrary categorization of each forest into either "deciduous" or "coniferous". To account for the zero-bounded distributional shape of counts across stations and to further mitigate the effects of outliers, we applied a  $\ln(\text{count}+1)$  transformation to the count data. Standard errors were clustered at the counting station level. Additionally, we estimated the model for 250-, 500-, and 1000- m radius bands.

Formally, our regression equations are:

$$\begin{aligned} \text{Log}(y_{im}) = & C + \text{PercentageDeciduous}_i + \text{Month}_m \\ & + \sum_{m=1}^{11} (\text{PercentageDeciduous}_i * \text{Month}_m) + \lambda_i + \varepsilon_{im} \end{aligned} \quad (1)$$

$$\begin{aligned} \text{Log}(y_{is}) = & C + \text{PercentageDeciduous}_i + \text{Season}_s \\ & + \sum_{s=1}^3 (\text{PercentageDeciduous}_i * \text{Season}_s) + \lambda_i + \varepsilon_{is} \end{aligned} \quad (2)$$

Here,  $y$  represents the visitor count,  $C$  is the regression constant,  $\text{Month}_m$  represents a dummy variable for each month  $m$  from February to December,  $\text{Season}_s$  represents a dummy variable for the seasons  $s$  from Spring to Autumn,  $\lambda$  the fixed effect for counting station  $i$ , and  $\varepsilon_{it}$  the random error. As a robustness exercise, we re-estimate the models where "PercentageDeciduous" is calculated according to different radius bands.

### 3. Results

#### 3.1. Seasonality in WTT for a forest visit

##### a. Seasonality in forest type preferences

As can be seen in Tables 2 and 3, showing the results from the CE, deciduous forests are preferred by respondents over coniferous forests. This aligns with results from previous studies on this topic in Denmark (Filyushkina et al., 2017; Nielsen et al., 2007). However, as visualized in Fig. 1, there were significant differences in this preference for forest type over the seasons. In winter, the WTT was the lowest for visiting a deciduous forest over a coniferous forest. This was followed by autumn, and the preference for visiting a deciduous forest over a coniferous forest was most pronounced during summer and spring. There was no significant difference between the two latter seasons. In summer, the WTT for a deciduous forest over a coniferous forest was around 31 km, whereas it was around 10 km in winter.

##### b. Seasonality in travel distance to the forest

Apart from the relative seasonal effect between structural forest characteristics, the overall WTT to the forest might also differ per season. The reported travel distances from the PPGIS dataset provided a strong indication of a seasonal pattern in forest trip distance. As can be seen in Fig. 2, the mean and median travel distances of the latest forest visit were higher in the summer months than in the winter months. Testing for differences between the mean values between the Winter (5.5 km) and Summer (7.3 km) months, based on a two-sided Welch *t*-test, resulted in a *p*-value of <0.001, rejecting the hypothesis that they were the same.

The supporting evidence from the CE data was less strong. In the choice model, the general WTT to visit a forest over the Optout alternative is indicated by the ASC estimate. For coniferous forests, as shown in Fig. 1 and Tables 2 and 3, the overall value of trips was similar over the year, with autumn and winter trips valued slightly higher than Spring and Summer. Based on MNL model results, for deciduous forests, trips were seemingly least valued overall in winter, with autumn valued the highest. This would suggest that, although the relative difference between coniferous and deciduous was the highest in spring and summer, the general WTT to visit a forest was the highest in autumn. However, as shown in Fig. 1, the difference between autumn and the other months was not statistically significant when estimating models

**Table 2**

MNL model in WTT space, with seasonal shifts in Overall trip value and Tree species. For the Choice Experiment data set. Seasonal differences modelled as shifts compared to Winter. Main parameters of interest only, other attributes parameter estimates reported in Supplementary Materials. Overall trip value represented by the ASC No Fence, where values are compared to baseline of Optout ASC. Significance levels: \*\*\**p* < 0.01, \*\**p* < 0.05, \**p* < 0.1.

Parameter	Model 1. MNL
Overall trip value – Coniferous Forest - Winter	28.656 (3.865) ***
Overall trip value – Coniferous Forest - Spring Difference	-6.413 (5.359)
Overall trip value – Coniferous Forest - Summer Difference	-2.772 (5.322)
Overall trip value – Coniferous Forest - Autumn Difference	+6.497 (5.257)
Overall trip value – Deciduous Forest - Winter	39.513 (3.819) ***
Overall trip value – Deciduous Forest - Spring Difference	+10.65 (5.257) **
Overall trip value – Deciduous Forest - Summer Difference	+14.234 (5.322) ***
Overall trip value – Deciduous Forest - Autumn Difference	+16.552 (5.228) ***
Species – Deciduous over Coniferous - Winter	10.857 (1.919) ***
Species – Deciduous over Coniferous - Spring Difference	+17.063 (2.742) ***
Species – Deciduous over Coniferous - Summer Difference	+17.006 (2.772) ***
Species – Deciduous over Coniferous - Autumn Difference	+10.055 (2.698) ***
LL(start)	-25,338.4
LL(final)	-23,069.3
Adj.Rho-squared vs equal shares	0.089
Number of individuals	2883

**Table 3**

MIXL model specification, WTT space with seasonal shifts in Overall trip value and Tree species. For the Choice Experiment dataset. Seasonal differences modelled as shifts compared to Winter. Main parameters of interest only, other attributes parameter estimates reported in Supplementary materials. Overall trip value represented by the ASC No Fence, where values are compared to baseline of Optout ASC. Significance levels: \*\*\**p* < 0.01, \*\**p* < 0.05, \**p* < 0.1.

Parameter	Model 2. MIXL
Overall trip value – Coniferous Forest - Winter – Mean	27.858 (3.954) ***
Overall trip value – Coniferous Forest – Winter - SD	-46.993 (3.194) ***
Overall trip value – Coniferous Forest - Spring Difference	-5.735 (4.714)
Overall trip value – Coniferous Forest - Summer Difference	-7.035 (4.592)
Overall trip value – Coniferous Forest - Autumn Difference	+2.093 (5.132)
Overall trip value – Deciduous Forest – Winter - Mean	38.511 (3.363) ***
Overall trip value – Deciduous Forest – Winter - SD	-51.5 (2.525) ***
Overall trip value – Deciduous Forest - Spring Difference	+7.419 (5.199)
Overall trip value – Deciduous Forest - Summer Difference	+8.287 (4.958) *
Overall trip value – Deciduous Forest - Autumn Difference	+10.03 (5.13) **
Species – Deciduous over Coniferous – Winter - Mean	8.428 (1.636) ***
Species – Deciduous over Coniferous – Winter - SD	27.084 (1.304) ***
Species – Deciduous over Coniferous - Spring Difference	+14.424 (2.456) ***
Species – Deciduous over Coniferous - Summer Difference	+15.034 (2.308) ***
Species – Deciduous over Coniferous - Autumn Difference	+9.175 (2.424) ***
LL(start)	-30,730.3
LL(final)	-19,970.4
Adj.Rho-squared vs equal shares	0.210
Number of individuals	2883

based on seasonal subsets. Similarly, the effects were only significant at a 90 % confidence level in the MIXL model specification. One of the reasons we might observed only a limited effect was due to the large variation for the ASC estimates, which could be caused by other factors captured in the ASC than the overall forest trip value itself.

#### 3.2. Seasonality in the type of forest trip

##### a. Seasonality in visit duration

Fig. 3 shows that the reported mean visit duration of the latest forest visit was the lowest in the winter months (75.8 min) and highest in the summer months (99.8 min). A two-sided Welch *t*-test for differences between these mean values resulted in a *p*-value of <0.001, indicating a highly significant difference.

##### b. Seasonality in the mode of transport

Fig. 4 reports the mode of transport over the different seasons as a relative share of all main forms of transport. As can be seen in this graph, in contrast to the other indicators used for forest visits, the mode of transport of the latest forest visit was seemingly relatively stable over the seasons. Although individual months have a slightly higher share of different transport modes, an overall trend is difficult to ascertain.

#### 3.3. Seasonality of the frequency of forest visits

##### a. Seasonality of visitor numbers over the year

Fig. 5 reports the mean visitor count over the year, per month. This figure shows a clear seasonal pattern, with most visitors in the summer and fewest in winter. It also shows that this followed a smooth trend, without significant peaks, which could e.g. be for autumn mushroom picking or the first spring flowers. Based on the CE survey, the reported last number of visits in the last weeks in Fig. 6 also showed a pattern of lower visitor frequency in winter. No clear pattern could be observed in the reported yearly visitor numbers based on the season in which this question was asked.

The results from the fixed-effects model, as indicated in Tables 4 and 5, indicate a similar pattern. While controlling for factors at the counting

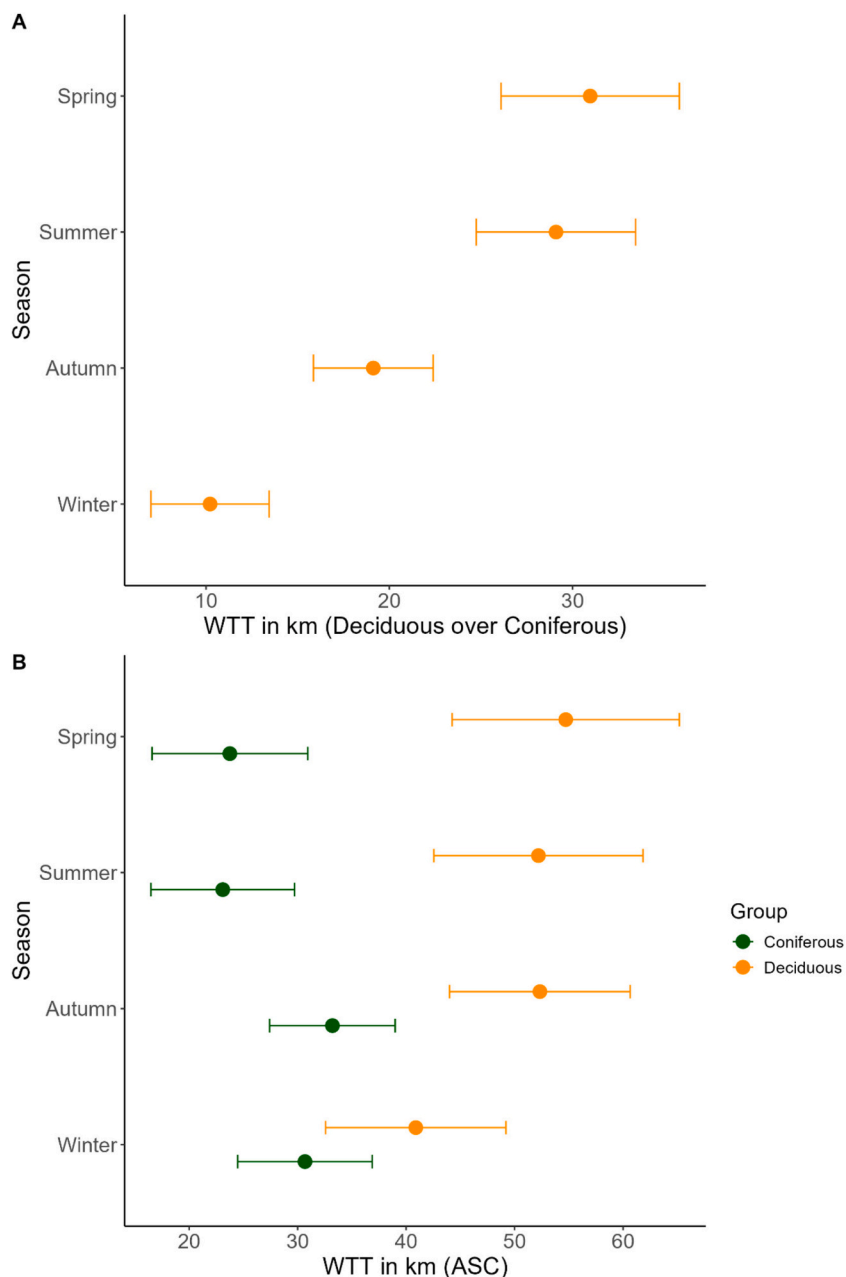


Fig. 1. WTT for different seasons, per attribute, based on the separate MNL models per seasonal subset, as reported in Table 7. Error bars indicate 95 % confidence interval. Standard errors calculated using the Delta method. A. WTT for deciduous trees over coniferous trees. B. WTT to travel to visit a non-fenced forest over the optout (ASC No Fence estimate), for deciduous and coniferous forests.

station level, the highest contribution to visitor numbers was in the spring or summer seasons.

b. Impact of tree species type on seasonal variation in visitor numbers

The results from the two-way fixed effects model, as visualized in Fig. 7, show that the seasonal increase in visitor numbers was larger for forests with a higher share of deciduous forests. This effect was the largest during summer, followed by spring and autumn. As seen in Fig. 8, this effect was relatively smooth over the months and is not driven by a peak in visitor numbers in a specific month. These results are mostly robust to the 500- and 1000-m radius bound. However, at 250 m, the significance level drops considerably. This limitation is discussed in more detail in the next section of this paper.

4. Discussion

4.1. Implications for valuation literature and policy

The results from our paper highlight the importance of seasonality when valuing the societal value of forests and forest attributes. Referring to our first hypothesis, we showed that the stated WTT for deciduous forests over coniferous forests was a factor of three larger in spring and summer than in winter.

This implies that previous valuation studies estimating the value of structural forest characteristics using a single depiction of the forest, often using spring or summer depictions, are likely to have over-estimated the preferences for deciduous over coniferous forests. As is evident from our illustrations, the deciduous forests have a quite different appearance during the winter season compared to a coniferous

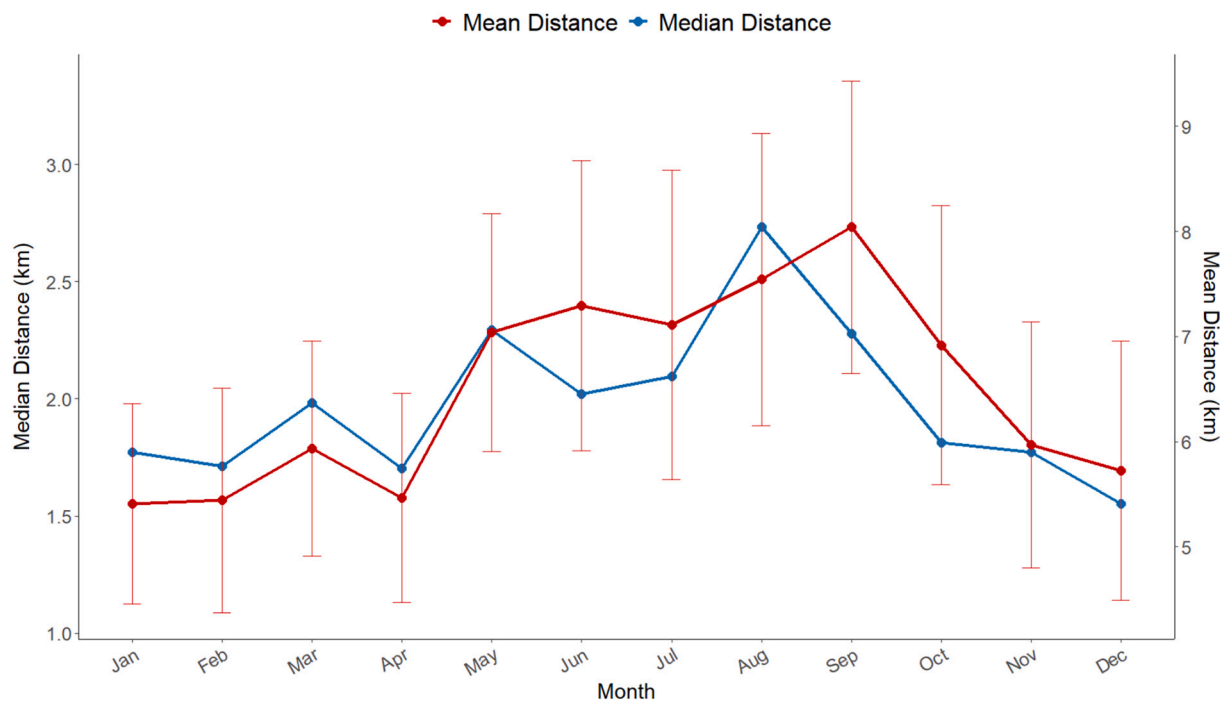


Fig. 2. Reported mean and median Euclidean travel distance per month in PPGIS dataset. Error bars indicate 95 % CI.

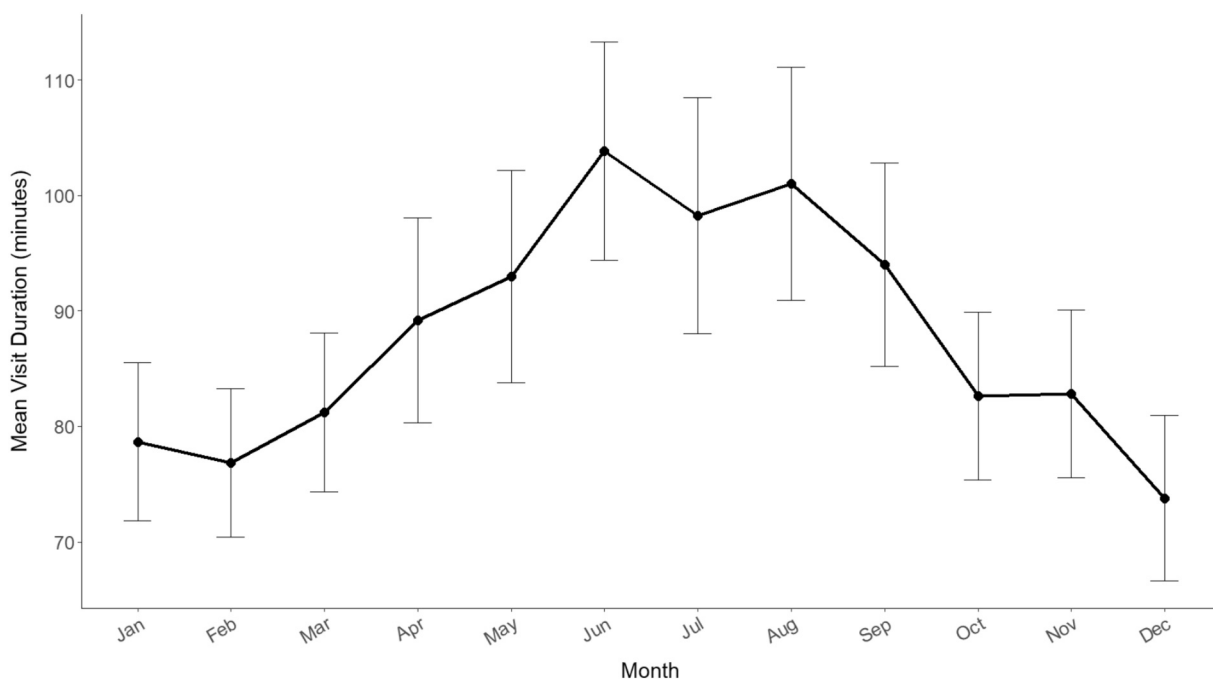


Fig. 3. Mean visit duration of forest visit, based on PPGIS dataset. Error bars indicate 95 % CI.

forest. This might not be evident to the respondent when only asked during the summer season or only shown deciduous trees with the green spring or summer leaves.

We also showed that this seasonal difference in SP was reflected in actual forest visit behavior. Our results showed that the seasonal increase in forest visitor numbers in the summer, spring, and autumn months was higher for forests with a larger share of deciduous trees in Denmark. This provided substantial evidence that the seasonal pattern observed in the SP data was not only due to a difference in visual presentation of the choice set but was also present in realized forest visits.

The above has important implications for previous valuation studies of forests. Table 6 compares the study estimates of the WTT for deciduous forests over coniferous forests to two previous estimates from the literature. Both studies used visual representations of the spring or summer months. Using the ratio between seasons found in this study, we highlight the likely overestimation of the benefits of deciduous forests by not including seasonality patterns. If policymakers base their decisions on such results, they might design policies to plant more deciduous trees than coniferous ones. We show that this effect might be overestimated and, given that most previous stated preference valuation

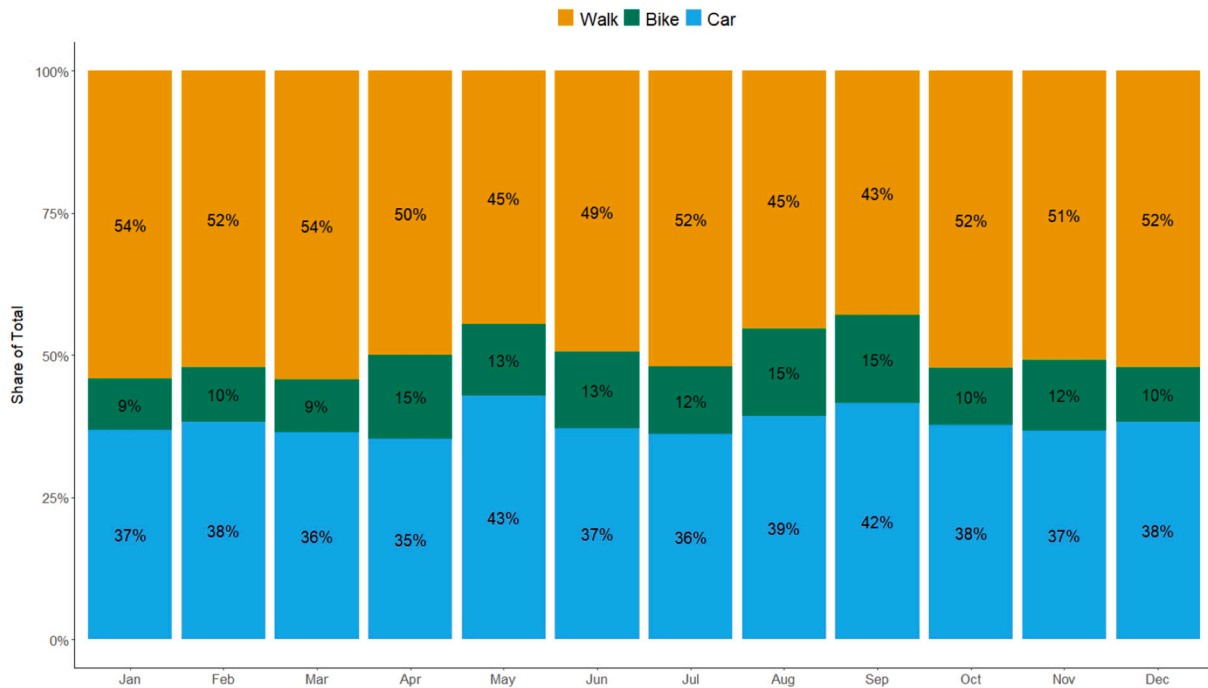


Fig. 4. Relative share of transportation modes for forest visits per month.

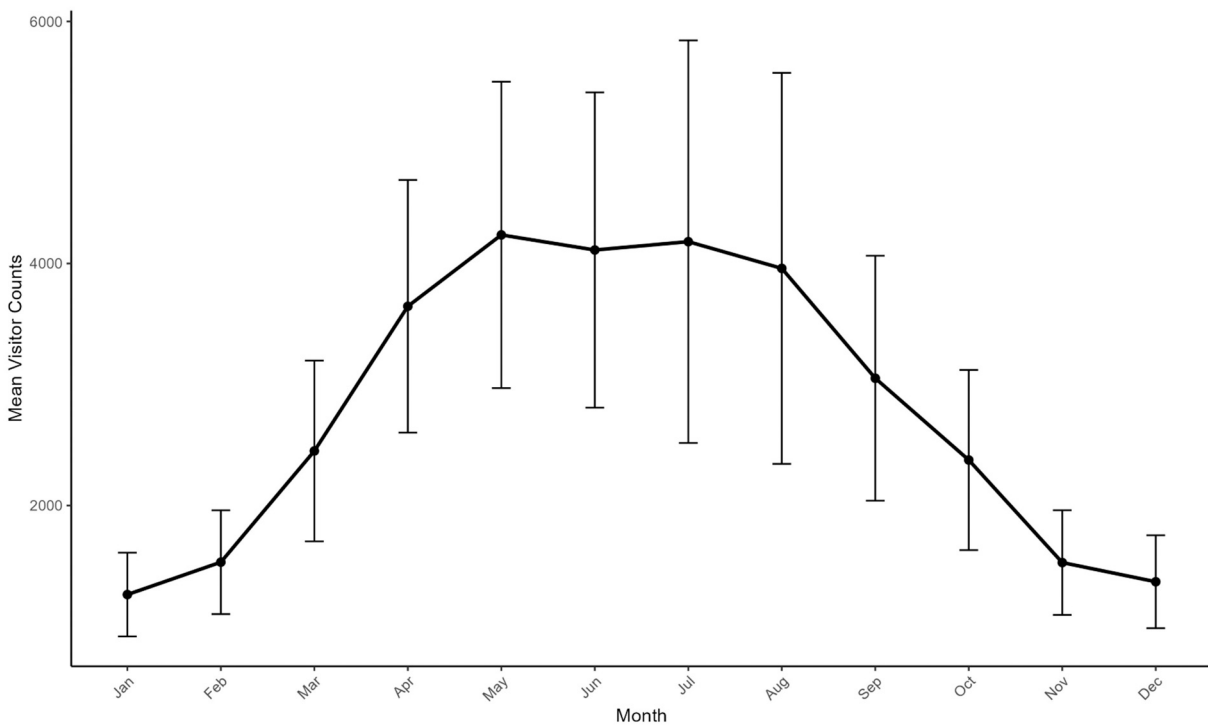


Fig. 5. Mean visitor counts per month, based on counting stations data. Error bars indicate 95 % CI.

studies used summer depictions, that deciduous trees are thus less superior in their recreational value than previously shown.

Regarding our second hypothesis, our results indicated that the trip duration and travel distance was different over the seasons, peaking around the summer months and being the lowest in winter. We found no differences in mode of transport over the seasons, finding no evidence that people e.g. take the bike more often in the summer months.

Finally, regarding our third hypothesis, our results support the notion that the general value of forest visits is different over the seasons.

The CE provided some evidence in favor of rejection of our null hypothesis. This data suggested that the value of coniferous forests differed only slightly over the season, with a slightly lower value in spring and summer. For deciduous forests, the overall WTT was seemingly lower in winter than in the other seasons. However, both of these results were based upon the interpretation of the ASC, which as a constant captures all other factors not included in the model, including study design artifacts (Meyerhoff and Liebe, 2009).

Stronger evidence results from combining the information on the

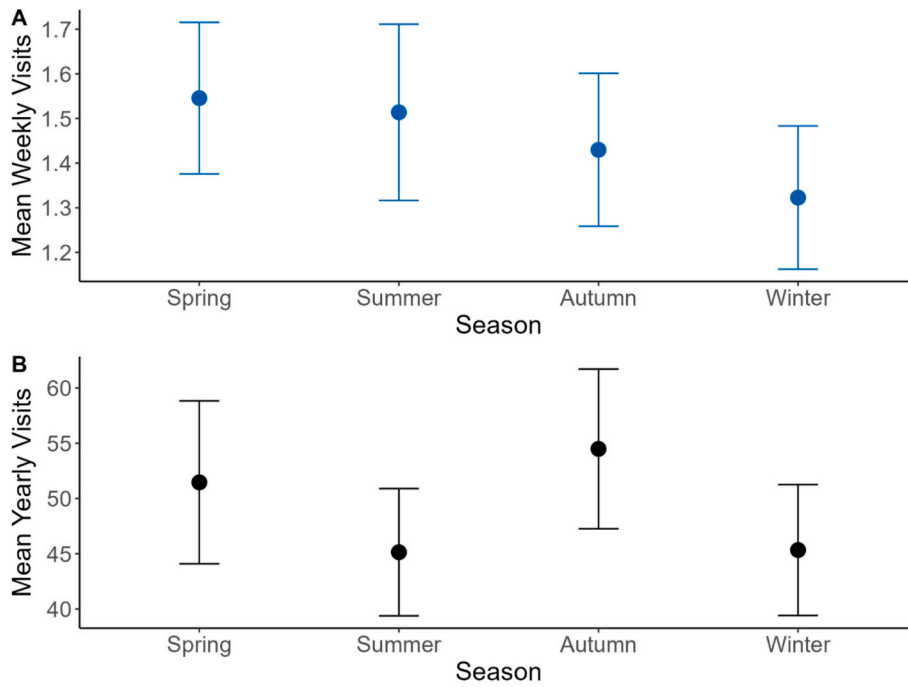


Fig. 6. Reported frequency of visit data in the stated preference dataset, for the last 7 days and last year, per season. Error bars indicate 95 % CI.

Table 4

Estimates from the Fixed effects model on Season level for the revealed preference data. Significance levels: \*\*\* $p < 0.01$ , \*\* $p < 0.05$ , \* $p < 0.1$ .

	250 m	500 m	1000 m
Spring	1.719 (0.331) ***	1.615 (0.356) ***	1.492 (0.383) ***
Summer	1.430 (0.359) ***	1.264 (0.383) ***	1.310 (0.421) ***
Autumn	0.787 (0.214) ***	0.637 (0.213) ***	0.57 (0.235) **
Deciduous:Spring	0.014 (0.008) *	0.018 (0.009) **	0.020 (0.009) **
Deciduous:Summer	0.019 (0.008) **	0.025 (0.009) ***	0.020 (0.009) **
Deciduous:Autumn	0.007 (0.006)	0.013 (0.006) **	0.013 (0.007) *
Observations	480	500	508
Number of stations	120	125	127
Adj R2	0.588	0.589	0.600

type of forest visit as well as the frequency of visits. Differences in mean travel distance, frequency and time naturally relate to the value of the trip. For a back of the envelope estimate to highlight the seasonality in forest value, we combined the mean value of frequency of visits ( $\mu_{if}$ ) per counting station for the Winter and Summer months, and the reported mean travel distance ( $\mu_{td}$ ) in km in these seasons to obtain an estimate of the difference in value between the seasons.

Mean total km travelled per counting station (Winter)

$$= \mu_{if \text{ Winter}} \times \mu_{td \text{ Winter}} = 4165.9 \times 5.5 = 22912.7.$$

Mean total km travelled per counting station (Summer)

$$= \mu_{if \text{ Summer}} \times \mu_{td \text{ Summer}} = 12251.3 \times 7.3 = 89434.3$$

$$\text{Winter as \% of Summer} = \frac{22912.7}{89434.3} \times 100 \approx 26\%$$

(95%CI : 16.3%to42.1%)

Here, we computed the 95% confidence interval using bootstrapped standard errors based on 2000 resamples drawn with replacement. As the above example shows, the mean value of forest recreation in Winter would only be a quarter of the value in Summer. Given the significant differences in both mean travel distance as well as frequency of visits over the seasons, it is apparent that the recreational value of forests is

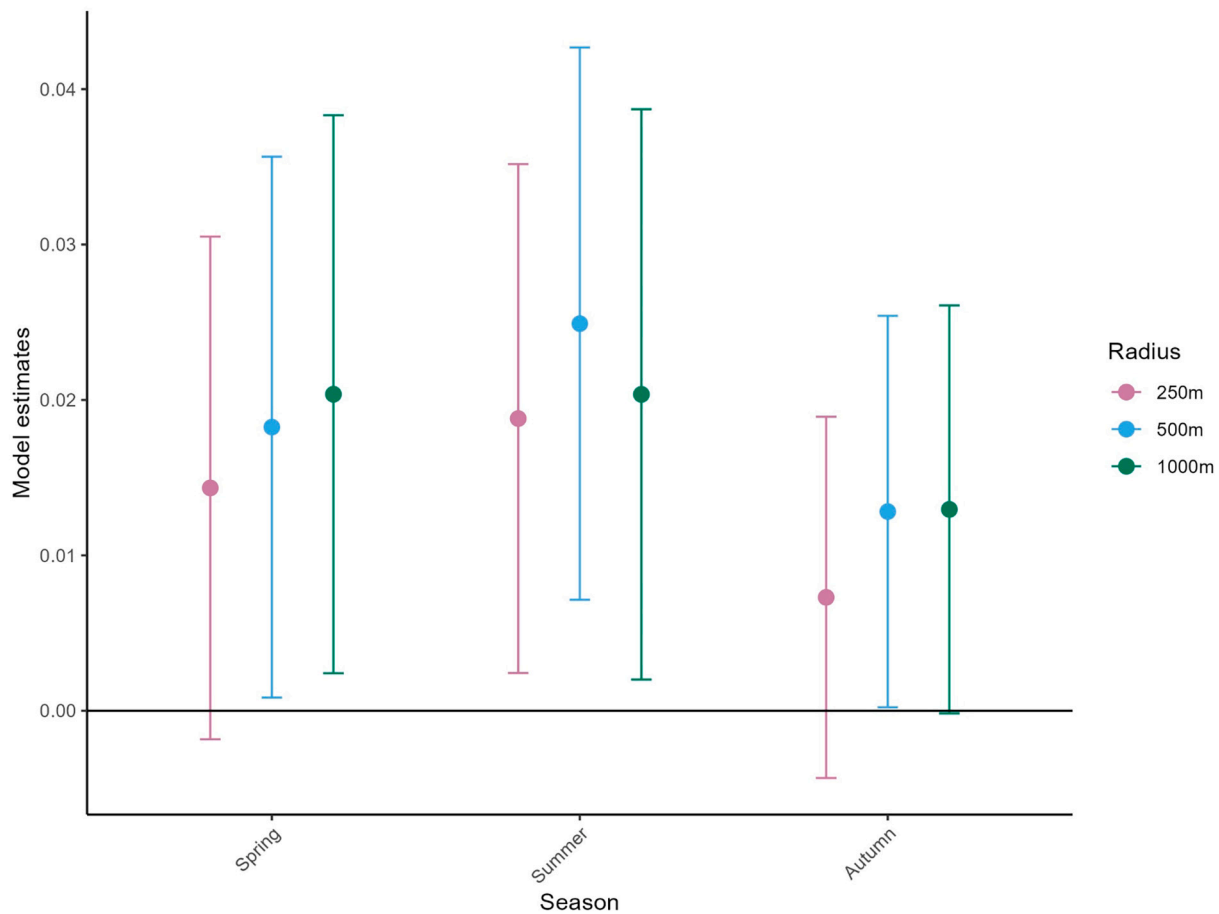
Table 5

Estimates from the Fixed effects model on Month level for the revealed preference data. Significance levels: \*\*\* $p < 0.01$ , \*\* $p < 0.05$ , \* $p < 0.1$ .

	250 m	500 m	1000 m
February	0.051 (0.052)	0.067 (0.054)	0.091 (0.078)
March	0.860 (0.163) ***	0.836 (0.175) ***	0.792 (0.19) ***
April	1.676 (0.292) ***	1.597 (0.313) ***	1.49 (0.338) ***
May	1.657 (0.322) ***	1.541 (0.347) ***	1.524 (0.366) ***
June	1.428 (0.327) ***	1.273 (0.349) ***	1.350 (0.384) ***
July	1.186 (0.293) ***	1.091 (0.315) ***	1.135 (0.341) ***
August	0.966 (0.257) ***	0.787 (0.257) ***	0.751 (0.275) ***
September	0.952 (0.200) ***	0.805 (0.196) ***	0.755 (0.218) ***
October	0.691 (0.164) ***	0.605 (0.175) ***	0.618 (0.202) ***
November	0.240 (0.103) **	0.190 (0.101) *	0.206 (0.116) *
December	0.072 (0.039) *	0.064 (0.040)	0.069 (0.050)
Deciduous:February	0.001 (0.001) *	0.000 (0.002)	-0.001 (0.003)
Deciduous:March	0.008 (0.004) *	0.008 (0.005) *	0.009 (0.005) *
Deciduous:April	0.011 (0.007)	0.015 (0.008) *	0.017 (0.008) **
Deciduous:May	0.014 (0.007) *	0.019 (0.008) **	0.017 (0.008) **
Deciduous:June	0.016 (0.008) **	0.022 (0.008) ***	0.017 (0.008) **
Deciduous:July	0.011 (0.006) *	0.017 (0.007) **	0.014 (0.007) *
Deciduous:August	0.010 (0.006) *	0.016 (0.006) **	0.016 (0.007) **
Deciduous:September	0.007 (0.005)	0.013 (0.006) **	0.012 (0.006) **
Deciduous:October	0.005 (0.005)	0.009 (0.005) *	0.008 (0.006)
Deciduous:November	0.001 (0.003)	0.003 (0.003)	0.002 (0.003)
Deciduous:December	-0.001 (0.001)	0.000 (0.001)	0.000 (0.001)
Observations	1524	1500	1440
Number of stations	127	125	120
Adj R2	0.710	0.708	0.704

different over the seasons. For simplicity, we have not considered the difference in duration of the visits. Given that the mean value of visit duration is higher in summer than winter, the overall difference in value above is a conservative estimate.

Thus, concerning hypothesis three, our results provided evidence that the overall value of forest visits is affected by seasonality, not just the relative value of broadleaved versus coniferous or the type of trip. This aligns well with earlier results from Bartczak et al. (2012). This has important implications for the management of forests. As also highlighted by Bartczak et al. (2012), not including the seasonal variation in valuation studies of forests can hinder the optimal management of



**Fig. 7.** Visualization of the estimates of the Seasonal fixed effects model with winter as the reference for the revealed preference data, per radius band. Error bars indicate 95 % confidence interval. Compared to the Winter season as a base.

forests. Danish forests are multifunctional in use, where other activities such as timber harvesting must be managed in conjunction with recreation. Some of these activities, such as thinning, only take a relatively short time. Timing such activities in the periods with the least recreational value would limit the conflict between forest uses (Bartczak et al., 2012).

#### 4.2. Limitations and future research

Our study estimates of WTT were based on stated preference data. This has allowed us to clearly isolate and identify the effect of deciduous versus coniferous forests over the seasons and compare our results with previous stated preference literature. However, a drawback of this data type is its hypothetical nature, and the sensitivity of the estimates to the visual presentation of the forest appearance over the season. Differences in visual depictions reflecting seasonal changes are known to affect perceived visual attractiveness of a landscape (Kuper, 2013; Xu et al., 2022) and colours or differences in visualizations have also been shown to affect choice experiment outcomes in general (Murwirapachena and Dikgang, 2022). In the pretesting of the CE survey, such observations were also noted by focus group participants, for example with one participant noting that the depiction of winter without colours made them notice this attribute less. Thus, our choices made regarding the seasonal adjustments of visualizations in the choice sets, e.g. in terms of colour, could have affected the difference in stated preferences over the seasons. A notable simplification in the visualization is that the variation in leaf colours within a season is left out. This is likely most notable in the autumn, where the colour of the leaves was a uniform colour in the CE depiction. In other words, any observed effect is the compounded

effect of both the visual appeal of the images, as well as the actual lower preference for visiting a certain type of forest in a certain period. We have attempted to mitigate this potential bias by also including results from revealed preference data, effectively testing for robustness of the stated preference results.

A second potential bias with stated preference data is the potential for self-selection of respondents into the survey. For both the PPGIS and the CE survey, it is likely that those with an interest in forest were more likely to participate and complete the survey. As a result, the sample could be skewed in an unobservable latent interest in forests. This would mean that our estimates in terms of e.g. travel distance or time could be higher than the true population average. However, we argue that this is likely to have a limited effect on the relative value of one season to the other, in that this self-selection due to a higher preference for visiting a forest does not also translate to a structural bias towards visiting the forest in summer over winter. Yet, given that such potential self-selection is inherent to the method, any such bias cannot be fully excluded.

Another limitation of our study is related to the length of the time series of our datasets, in that they each span a total of one-year without repeated seasons or months. Some of the metrics, such as frequency of visits, could potentially be affected by weather. For example, a particularly warm or dry winter could increase the number of visits in this period. Fig. 9 provides an overview of the weather during the period of respective data collections and long-term averages. As can be seen in this Figure, in terms of temperature, the temperatures were relatively close to long-term averages, with winters being slightly warmer, as was the autumn in 2022. Referring to the example calculation in the previous section, as an increase in temperature in winter might relate to higher

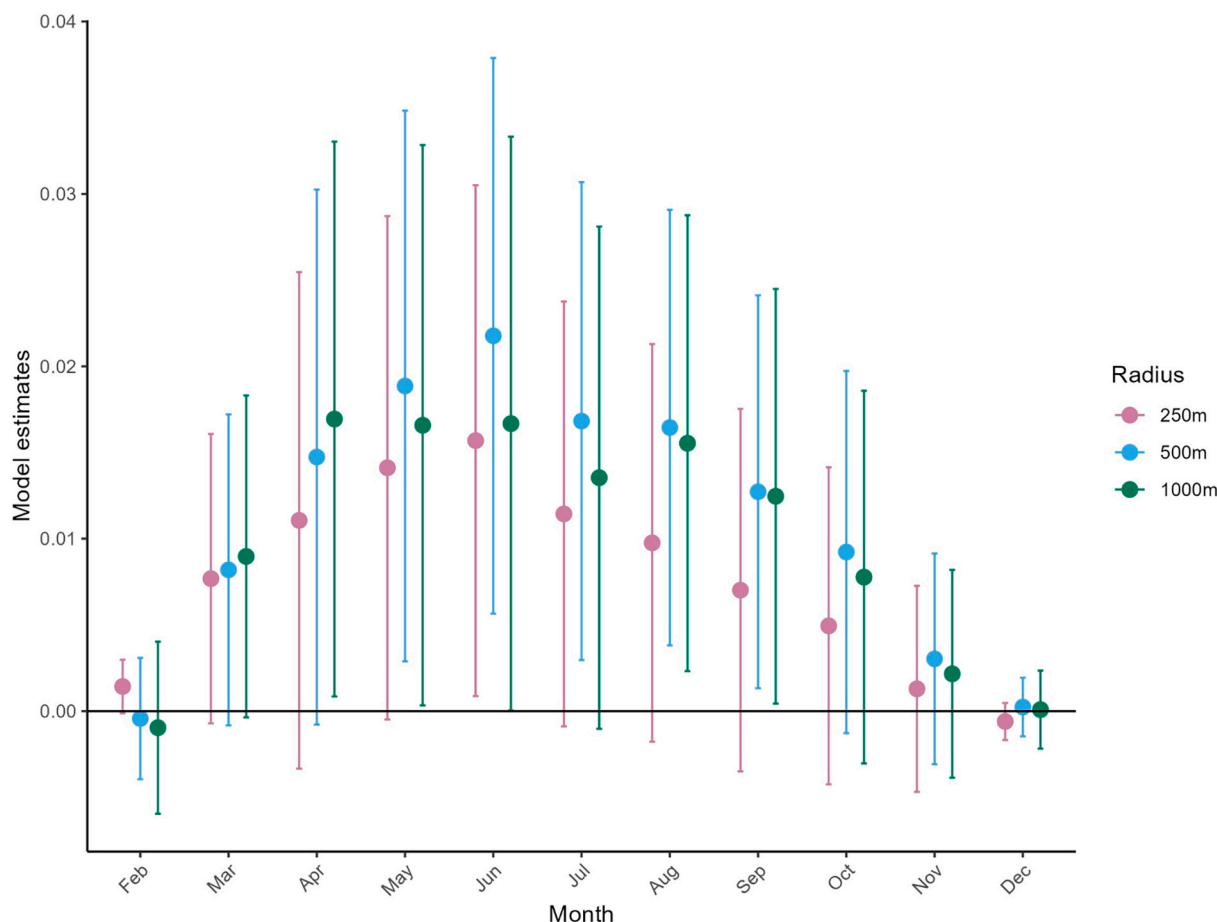


Fig. 8. Visualization of the estimates of the Monthly fixed effects model of the revealed preference data, per radius band. Error bars indicate 95 % confidence interval. Compared to the Winter season as a base.

Table 6

WTT estimates of deciduous forests over coniferous forests of selected studies. WTT in km (WTP in DKK)<sup>b</sup>. For the Choice Experiment data. Cursive are estimated values, based on the ratios between seasons established in this study.

	Study estimates	Filyushkina et al. (2017) <sup>a</sup>	Nielsen et al., 2007
Combined	22 (88)	8 (32)	N/A (556)
Spring	31 (124)	11 (44)	N/A (770)
Summer	29 (116)	10 (41)	N/A (724)
Autumn	19 (76)	7 (27)	N/A (476)
Winter	10 (40)	4 (15)	N/A (254)

<sup>a</sup> Based upon three stands of deciduous forests.

<sup>b</sup> As per Filyushkina et al. (2017), WTP was calculated using a transport conversion factor where 1 km = 4 DKK.

visitor frequency, the calculation is likely more on the conservative side when evaluating this effect over a longer time horizon. Precipitation exhibited greater variability, complicating the assessment of deviations of the long-term average. For example, both summer and winter in 2023 were considerably wetter than average, making it more challenging to evaluate a possible effect. Therefore, given study design, we cannot fully rule out the possibility that our findings reflect seasonal patterns specific to the years studied. Nonetheless, we would argue that the weather during the study period did not deviate substantially from long-term averages.

The one-year period of data collection also means that our WTT estimates could potentially also reflect a trend in preferences for structural forest characteristics over this one-year period. As we did not include a repetition of a season in the distribution schedule of this survey, we

Table 7

MNL model specification, individual model estimates based on data sample subsets, in WTT. Significance levels: \*\*\*p < 0.01, \*\*p < 0.05, \*p < 0.1.

	Spring	Summer	Autumn	Winter
Overall trip value	23.749	23.096	33.205	30.673
-	(4.785) ***	(4.355) ***	(3.924) ***	(4.178) ***
ASC No Fence				
Species –	30.963	29.096	19.125	10.217
Deciduous over	(3.039) ***	(2.668) ***	(1.988) ***	(1.961) ***
Coniferous				
Number of individuals	705	699	736	743
LL(start)	-6196.17	-6143.44	-6468.63	-6530.15
LL(final)	-5654.98	-5532.39	-5823.43	-6039.95
Adj.Rho-squared vs equal shares	0.0849	0.097	0.0974	0.0728

cannot rule out any such trends. However, we argue that the general preferences for types of forest should be stable in the population over the short time span of a year, e.g. that the public over a one year period does not suddenly start disliking coniferous trees more in general. A repetition of the experiment in the same season would provide conclusive evidence on this matter but was not possible within the scope of this study.

In comparison to previous SP studies, we also found a considerably higher WTT, even when comparing similar seasons. A possible reason could be a difference in the context of the choice set, where we elicited WTT estimates for a visit to a large forest. Another possible reason could be a difference in the distance attribute levels that are included in the

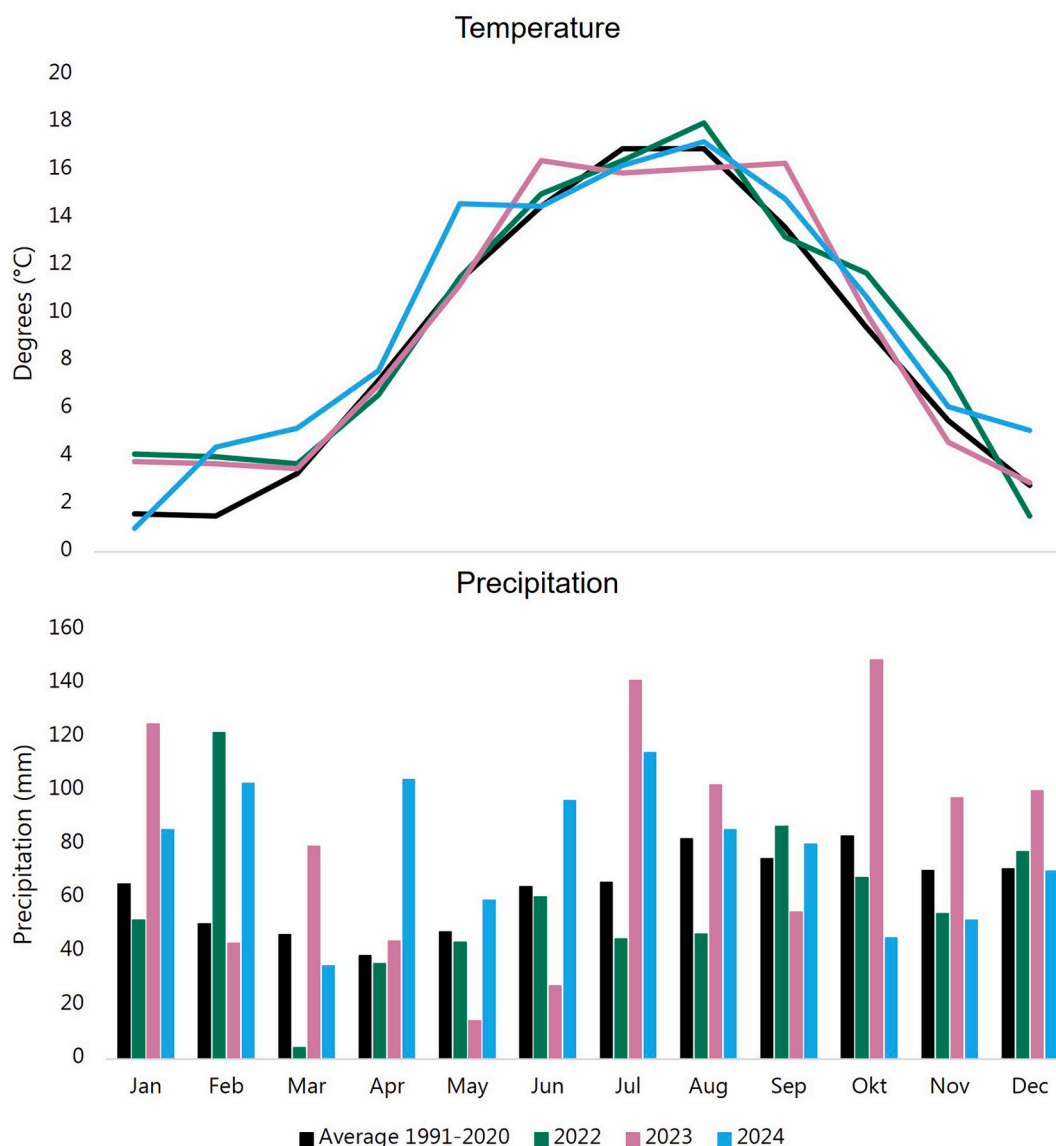


Fig. 9. Weather information over the time period of the study, with long term averages (1991–2020). Data obtained from the Danish Meteorological Institute (DMI, 2025).

study, where our study included considerably higher levels than e.g. the study of Filyushkina et al. (2017). The recreational value of forests has also increased over time, especially post COVID-19 (Bustad et al., 2023; Hansen et al., 2023; Venter et al., 2021). The increase in WTT could at least partly reflect a permanent shift in preferences post COVID-19.

Finally, it is worthwhile mentioning potential limitations regarding the RP data. The observed estimates could be due to different aspects that are inherent to the difference between coniferous and deciduous forests over the year. E.g. it could be related to the difference in visual appearance of the forest or better regulation of heat in deciduous forests during summer (Breil et al., 2023). However, there is also the potential for other factors that are spatially correlated to the type of forest and to seasonality in visitor numbers. We tested several of such possible factors, being the distance to the coast, presence of lakes, slope, recreational areas and accessibility. This model has been included in the Supplementary Materials. Including these factors led to a small drop in significance levels. Overall results were robust. Nonetheless, we cannot identify which factors are specifically driving the difference in seasonality of visitors between deciduous and coniferous forests, beyond that they are systematically related to the forest type.

Second, it should be mentioned that our RP data results were not fully robust to the MAUP. Where all seasons were significant at around 95 % confidence level for 500- and 1000-m radius, the significance for Spring and Autumn decreased at a 250-m band. A possible reason could be that the relative share of broadleaved increases at larger bounds, and that the 250-m radius might be too granular a scale to capture differences in tree species type. As deciduous forests are the dominant type of forest in Denmark, their presence will likely increase more when the analytical bound is increased.

### 5. Conclusion

Based on the prevalence of the seasonality patterns in three datasets, we provided evidence that the recreational value of forests is seasonally dependent in Denmark – a temperate region where deciduous trees lose their leaves before the winter season. This effect was more pronounced for deciduous forests and affected willingness to travel, visiting frequency, travel distance, and time spent during the trip. Thus, our overall conclusion is that several of the current value estimates for forest recreation might be biased, as these are based on a summer season scenario

and illustrations. We suggest that future valuation studies of forests in temperate regions should explicitly account for seasonality, preferably by providing estimates for different seasons to obtain a more unbiased value of forest recreation.

## AI declaration

*During the preparation of this work the author(s) used Microsoft Copilot in order to improve text for readability and conciseness. After using this tool/service, the author(s) reviewed and edited the content as needed and take(s) full responsibility for the content of the publication.*

## CRedit authorship contribution statement

**Tim de Kruijf:** Writing – review & editing, Writing – original draft, Visualization, Software, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Jonas Vester Legarth:** Writing – review & editing, Visualization, Methodology, Investigation, Formal analysis. **Thomas Lundhede:** Writing – review & editing, Supervision, Conceptualization. **Carl-Emil Pless:** Writing – review & editing, Visualization, Software, Methodology. **Hans Skov-Petersen:** Software, Methodology, Investigation. **Jette Bredahl Jacobsen:** Writing – review & editing, Supervision, Methodology, Conceptualization.

## 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.

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## Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.forpol.2025.103607>.

## Data availability

The authors do not have permission to share data.

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