Master’s thesis

Master’s Programme in Applied Environmental Science – Ecosystem Services and Nature Resource Management, 60 credits

Assessing the Ecological and Social Impact of Wind Farms:

A Comprehensive Study

Environmental Science, 22.5 credits

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Agnes Rottbers

HALMSTAD UNIVERSITY

Potential Bias Statement

While conducting this research, I have utilized data from Arise AB, where I am currently employed. I acknowledge that my position within the company could be perceived as a source of bias. However, I affirm that all efforts were made to ensure the integrity and objectivity of the research. Data analysis and interpretation were conducted with rigorous adherence to academic standards and ethical guidelines. To mitigate any potential conflict of interest, the study's methodology was independently reviewed and validated by impartial reviewers. My employment status has not influenced the study's design, data collection, analysis, or conclusions.

Abstract

Addressing climate change necessitates a shift towards sustainable energy systems, with wind farms emerging as vital renewable energy sources. However, the implementation raises concerns about ecological and social effects. This study examines the potential effects of onshore wind farms in Sweden through a comparative analysis before and after their construction. Ecological impacts on birds and lepidopterans were assessed using a retrospective case-control study, while social effects were evaluated through a descriptive survey distributed to nearby residents.

The results indicate no significant difference in bird or lepidopteran populations before and after wind farm construction. However, there was considerable variation between wind farms on the effects on birds and lepidopterans. The perceived effects by residents correlate closely with their attitudes towards wind energy, with negative attitudes associating with negative perceived effects across all phases of wind farm development.

Long-term investigations are warranted to comprehensively understand potential impacts on avian and lepidopteran species, especially including local conditions. Further, wind farm developers are advised to prioritize community engagement and communication to foster positive attitudes and mitigate residents' perceived impact.

Keywords: wind farm, ecological, social, impact, birds, lepidopterans, distance, attitude

Abbreviations

Commissioning	When something is brought into operation
Post-construction	The time after something is constructed
Pre-construction	The time before something is constructed
SLU	The Swedish University of Agricultural Sciences
SPSS	The Statistical Package for the Social Sciences
SSOS	The Swedish Species Observation System

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Introduction

The 17 Sustainable Development Goals (SDGs) was an action to address climate change and attain sustainable development for the people and planet, adopted by the United Nations in 2015 to be achieved by 2030. As of today, only 15% of the targets are on track with six years left to the deadline (United Nations, 2023). The annual average anthropogenic emissions of greenhouse gases (GHG) between 2009 and 2019 are the highest on record, despite the international target of limiting global temperature rise to 1.5°C compared to pre-industrial temperature (IPCC, 2022).

SDG number 7 - Affordable and Clean Energy aims to ensure access to affordable, reliable, modern, and sustainable energy for all. Some progress has been made, but not merely enough considering 675 million people still do not have access to energy at all (IEA, et al., 2023). Additionally, the total global energy demand is expected to increase due to climate change, in sectors such as agriculture, industry, and residential because of, for example, changes in technologies for irrigation in food production and increased need for cooling/heating systems in buildings (van Ruijven, De Cian, & Wing, 2019). Meanwhile, the sector with the highest global emissions is electricity and heat production, which in 2022 reached its highest emissions on record, 14.6Gt CO_2 (IEA, 2023). It is crucial to reduce fossil fuel use and increase renewable energy technologies to reduce CO_2 emissions (Wang & Wang, 2015; Yang, et al. 2022), and in Europe, the most common way to mitigate climate change while still promoting economic growth is to develop renewable energy (Abid, et al., 2023). In 2022, around 69% of Swedish electricity production was from renewable sources, of which 19% was from wind energy (Statistikmyndigheten, 2023).

There are many uncertainties regarding land-use and land-use change emissions with great annual variations (IPCC, 2022). However, all exploitation has an ecological and social impact associated with it and wind energy is no exception (Coppes, et al., 2020; IPCC, 2022; Wang & Wang, 2015), which means that the combined challenges of climate change and energy security necessitate the adoption of renewable technologies in the future to minimize societal and ecological impacts (Wang & Wang, 2015).

Biodiversity

The establishment of wind farms alternate land use and lead to a minor reduction in habitat space, either directly by the presence of towers on land or indirectly as species tend to avoid their surroundings (Coppes, et al., 2020; Gasparatos, et al., 2017). Wind farms' most apparent impact on the habitat and biodiversity of birds and bats is direct impact through collision with the turbine. Wind turbines can also create negative barriers and biotope destruction (Coppes, et al., 2020; Gasparatos, et al., 2017; Wang & Wang, 2015). Generally, bird species that are rare, endangered, or have long lifespans and slow reproductive rates face the greatest risk when wind turbines are installed in their habitats (Gasparatos, et al., 2017; Rydell, et al., 2017), and raptors can be especially vulnerable (Dohm, et al., 2019). On average, a wind turbine is the cause of death of between five and ten birds per year. However, this heavily depends on the turbine size and placement and the richness of birds in the area. It also varies greatly between bird species (Rydell, et al., 2017).

While the degree of habitat loss resulting from wind farm establishment seems generally modest in many instances, animal displacement could be observable across extensive distances surrounding the wind farm (Coppes, et al., 2020). Displacement occurs when animals avoid areas in the proximity of individual turbines or the entire wind farm and relocate from previously used habitats. Physical displacement can occur due to the destruction of habitats, but this impact is often considered minor regarding wind farm development (Dohm, et al., 2019). Thus, possible causes of displacement are often both site and species-specific. The effects are dependent on factors such as habitat type (forests or grasslands), wind turbine characteristics (noise pollution and shadows due to height, size, design of wind farm), increased human presence (construction, maintenance), and traits associated with a particular species (sensitivity to disturbance, antipredator responses) (Coppes, et al., 2020). The review by Gasparatos, et al., (2017) indicates that studies have found only minimal changes in occurrence or sightings of avian species as a result of wind farms. However, long-term studies on wind farm disturbance on birds have not yet been conducted (Rydell, et al., 2017).

Lepidopterans are an order comprising both moths and butterflies, containing almost 150,000 species in the world, out of which only 12% are butterflies (SLU, 2024). In Sweden, there are almost 2700 species of lepidopterans, and only around 4% are butterflies (Pettersson & Arnberg, 2023: SLU, 2024). Lepidopterans contribute to many ecosystem functions and due to their sensitivity to land use change, they act as an indicator of the ecosystem health (European Environment Agency, 2024; Ghazanfar, et al., 2016). Lepidopterans are vital for a range of ecosystem services, including pollination, and provide food for other organisms. Additionally, they act as biological pest control. Loss or destruction of habitats has a negative impact on distribution and abundance (Ghazanfar, et al., 2016). The design of modern wind turbines reaches high enough into the air to interfere with the migratory movements of insects, suggesting that insects are attracted to or affected by the presence of wind turbines. This can potentially lead to altered behaviours or adverse effects from collisions with the turbine blades (Rydell, et al., 2010).

Sweden has committed to 16 environmental quality objectives in their work towards the Agenda 2030. The objectives are used to define the aim that societal decisions must steer towards to reach a sustainable society. One of these objectives is “Functioning forests”, which implies preserving and developing biodiversity in forests (Naturvårdsverket, 2024a). The follow-up report from 2024 stated that the development of this objective is negative (Naturvårdsverket, 2024a). One index used to monitor the progress is the index for population development of nesting birds which includes 16 species chosen since they spend most of their adult life in the monitored environment (Appendix 1). The monitoring over the last two decades shows that the average change for the constituent species is very small (Naturvårdsverket, 2024b).

A second environmental quality objective Sweden has committed to is “A rich agricultural landscape”. The grassland butterfly index, a European index monitoring the change in population abundance of 17 butterfly species is used as an indicator to this objective. Of the 17 grassland butterfly species monitored, 12 are found in Sweden (Appendix 1) (Naturvårdsverket, 2024c). In 18 European Union member states, this long-term monitoring shows a decline of 29.5% in populations between 1991 and 2020 (European Environment Agency, 2024). On the other hand, the indicator for woodland butterflies has been stable between 1991 and 2018. This indicator is based on 10 species that occur more in woodlands than in other types of habitats (Appendix 1) (Van Swaay, et al., 2020). The long-term monitoring of woodland butterflies in Europe shows that the trend is stable, with an average decline at the start of the period followed by an increase. Increased forest areas and quality as efforts against climate change can be a possible cause for more and larger suitable habitats for woodland species (Van Swaay, et al., 2020).

Between 2010 and 2022, the Swedish trend of grassland butterflies is stable while the trend of woodland species is increasing, moderately but significantly (Pettersson & Arnberg, 2023). The trends of bird and butterfly populations can be an indicator of environmental health (European Environment Agency, 2021). The purpose of this study is to investigate if and how biodiversity in the area has been negatively affected after the construction of the wind farm.

Local Impact on Humans

The development of wind farms that are needed for the transition towards a sustainable energy system is hindered by, for example, social acceptance, minimum distance requirements, and conflict of interest leading to local and political opposition (Ruddat, 2022). Social acceptance is essential for expanding wind energy. However, it is complex and includes factors such as the proximity to turbines, visual effects, trust in involved actors, and conception of possible risks and benefits and perceived fairness associated with the project (Ruddat, 2022). The lack of local social acceptance and opposition is often associated with a concept called "Not In My Backyard" (NIMBY) (Enevoldsen & Sovacool, 2016; Jones & Eiser, 2010; Lindén, Rapeli, & Brutemark, 2015; Ruddat, 2022). NIMBY means "[...] that people have positive attitudes towards something (wind power) until they are actually confronted with it, and that they then oppose it for selfish reasons" (Wolsink, 2007, p. 1199). This means that the attitude towards wind energy in general can be positive, but the attitude towards facilities in the immediate vicinity is negative (Enevoldsen & Sovacool, 2016; Lindén, Rapeli, & Brutemark, 2015). This concept has been criticized for being too simplistic (Ek, 2005; Ruddat, 2022; Wolsink, 2007). A study in Sweden showed no evidence to support the NIMBY hypothesis (Ek, 2005) and another study found that NIMBY should be considered along with other factors, such as general attitude towards wind power, to understand public opinion (Lindén, Rapeli, & Brutemark, 2015).

Hammarlund (1997) concludes that the initial general attitude towards wind energy plays a major part in their perception of impact factors, especially noises, after development. At this stage, there has also been a demonstrated shift towards a positive outlook on wind energy within the nearby residents. Generally, people seeing a wind farm with rotating wind turbines are often more positive towards it, compared to if turbines are standing still (Krohn & Damborg, 1999).

The purpose of this study is to investigate if and how the local communities' expected and perceived impact of a wind farm is affected by; distance to the wind farm, if the resident moved to the area before or after it was constructed, and their attitude towards wind power in general.

Aim

This study aims to investigate the impact of constructed onshore wind farms in forest ecosystems in Sweden, and how it has changed from before construction to today. The study focuses on two aspects: ecological and social. The change in biodiversity in proximity to the wind farm, as well as the residents' expected and experienced impact of the wind farm, is analysed.

Research Questions

1. Has diversity in the proximity of the wind farm been reduced after establishment, regarding:
    a) Birds?
    b) Lepidopterans?
2. Is the expected and experienced impact of the wind farm affected by:

a) Distance?

b) If the resident lived in the area before the wind farm was constructed?

c) Attitude towards wind power?

Material and Methods

The impact of wind farms on local biodiversity was studied with a retrospective case-control study. In addition, social sustainability was investigated in a descriptive survey that was sent to nearby residents. The commissioning year of each wind farm determined the breaking point in time to understand the potential impacts due to the establishment of wind farms.

To understand the environmental impact of a wind farm in terms of biodiversity, paired sample t-tests, the Pearson correlation Coefficient, Chi-2 test of independence and Shannon's diversity index were used. For the social aspect, the expected and experienced impact of individuals was analysed using Fisher's Exact test.

Study Objects

Ten onshore wind farms constructed and/or commissioned by Arise AB were selected for the study. The wind farms are grouped into five study objects (henceforth referred to as "sites") due to geographical proximity. All sites were located in forest ecosystems in Central and South Sweden (figure 1). The number of wind turbines at each site ranged from six to twenty-three and the wind farms in the study were commissioned (put into operation) between 2009 and 2020 (table 1). The heights of the turbines vary from 150m to 195m.

Table 1. The study objects size and commissioning year.

Study object	Number of wind farms	No. of turbines	Max. height of turbine (m)	Commissioning year	Pre-construction period	Post-construction period
Site 1	2	19	150	2009	–2008	2009–
Site 2	3	23	150	2011	–2010	2011–
Site 3	3	23	195	2011	–2010	2011–
Site 4	1	6	150	2011	–2010	2011–
Site 5	1	9	180	2020	–2019	2020–

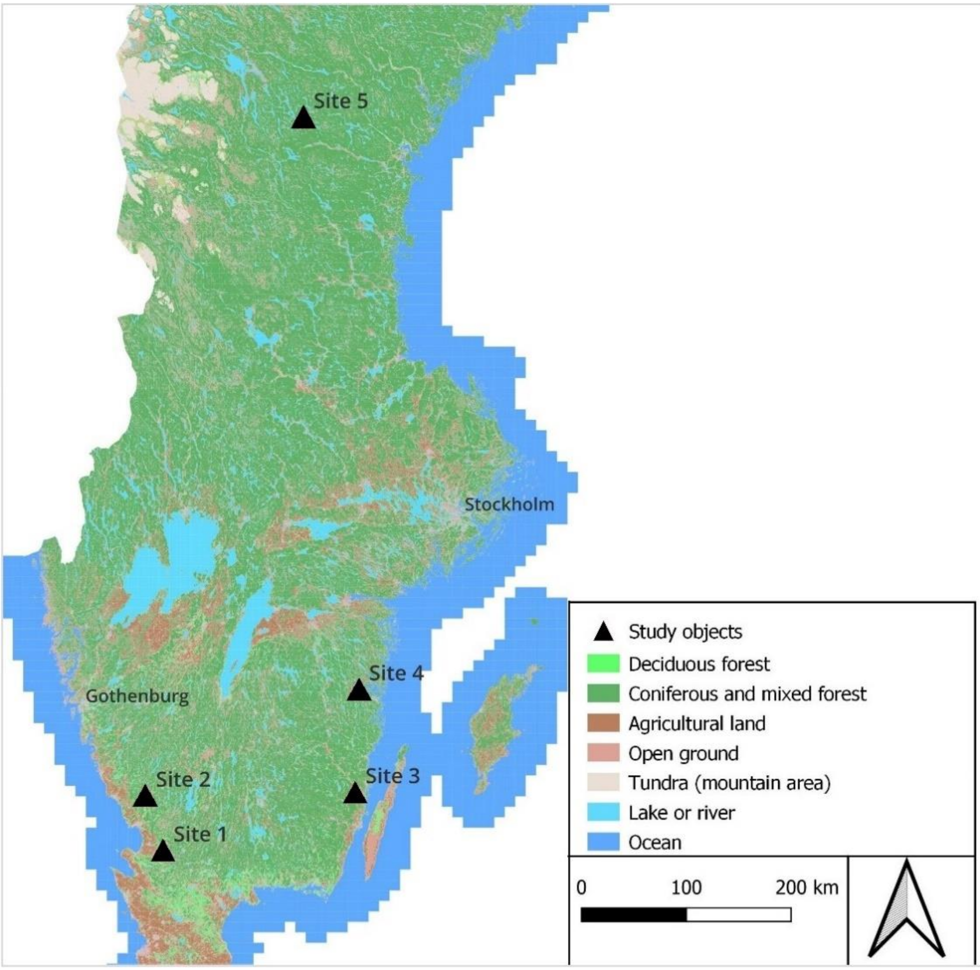

Figure 1. Map showing the study objects location in Sweden. (Lantmäteriet, Geotorget).

Study of Effects on Biodiversity

Biodiversity is described as the richness and variety of species present in an ecosystem (Methorst, et al., 2021). To investigate potential effects on biodiversity, previously reported observations of birds and lepidopterans were used. Both systematic inventories and citizen science data were included as separate datasets in this study.

Data on birds were obtained from the Swedish Species Observation System (SSOS) and, where accessible, from inventories pre- and post-construction. The SSOS is a national program organized by the Swedish Environmental Protection Agency that enables citizens to report observations on all types of wild species. The data for this study was obtained from their public database www.artportalen.se. Additionally, data was retrieved from inventories conducted on behalf of the project developer within 2 years before construction, and 3 years after construction at three wind farms (sites 1 and 2). They were conducted by an experienced ecologist and ornithologist using systematic inventory methods. (Swedish University of Agricultural Sciences, 2023)

Two sources were used to obtain data on lepidopterans. Data was obtained from SSOS from their public database www.artportalen.se, similar to the data used for the analyses on birds. In addition, data on butterflies from the national inventory programs by the Swedish University of Agricultural Sciences (SLU) were used. These data were obtained from standardized inventories performed by persons with experience in identifying butterflies.

In the early 2000s, the Swedish Agricultural Agency implemented a program called 'Quality follow-up of meadows and pastures' to measure natural values, biodiversity, and progress towards national objectives (www.slu.se) (Swedish University of Agricultural Sciences, 2023). The SLU has since 2006 organized annual inventories of butterflies and bumblebees as part of the program. The inventory routes are divided into five-year laps and selection is made by random sampling, meaning that an inventory is usually carried out every five years per route (Swedish University of Agricultural Sciences, 2023). Therefore, this study includes systematically collected data on lepidopterans from 2006 at the earliest.

Citizen data rely on citizens who are interested in species groups and report from an actual location, and as a result, data is therefore not systematically collected. This means that the reported data can vary with time and may not be available at all sites during all years during the period included in this study (2000 and 2023) (Appendix 2). Due to inconsistency in the reporting years in each period, all data from SSOS was therefore calculated to an average (Appendix 2).

Local Impact on Humans

To assess nearby resident's expected and perceived impact of a wind farm, a quantitative survey was conducted. At each site, 30 participants were identified within a radius of 5km, resulting in a total of 150 potential participants (table 2). Only permanent residents were included, meaning that any vacation residencies were excluded. The actual number of respondents was 67.

The questions in the survey were structured to understand the potential impact concerning the three drivers of distance to the wind farm, potential disturbances pre- and post-construction, and the general attitude towards wind power. To investigate the impact of the wind farm on the resident's distance to the site, three zones with different distances to the wind turbines were created (figure 2) (table 2). The shortest distance to a resident from the turbines was approximately 0.5km and therefore, a decision was made to add 0.5km to distance group A. A question was asked to differentiate pre- and post-construction (Appendix 3). Depending on the answer to this question, the respondent was asked to answer two or three unique questions respectively.

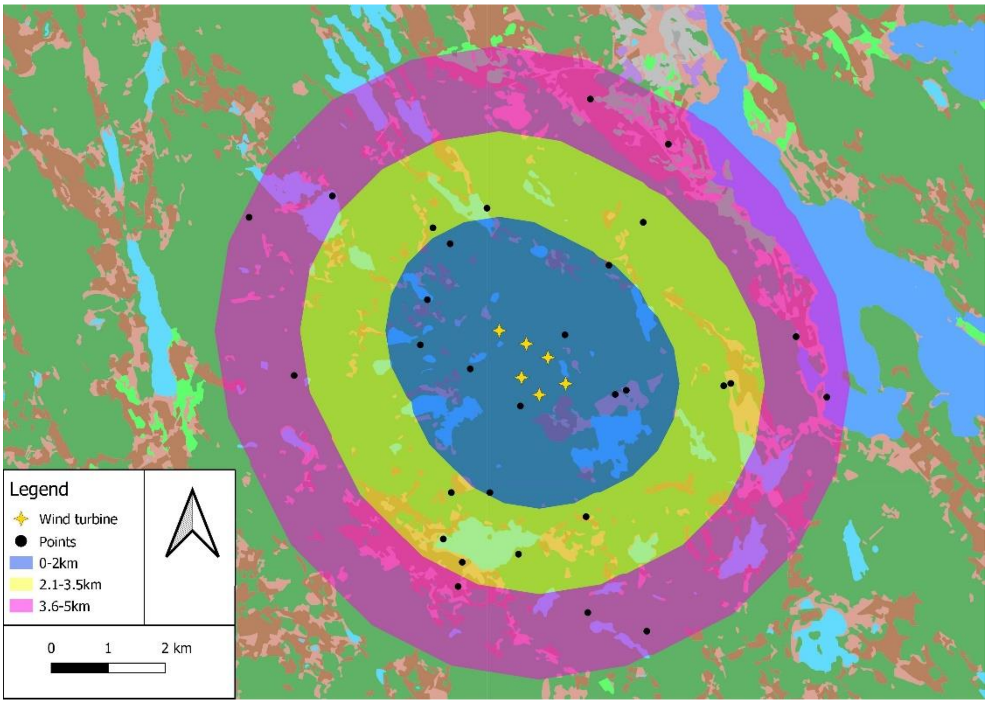

Figure 2. Distance groups and random points placed using QGIS in Site 4. Forest areas are green. Forests are symbolised by green colour, agricultural land or open ground by brown/beige colour and water by blue colour. (Lantmäteriet, Geotorget)

Table 2. Total number of targeted participants per distance group.

Distance group	Distance from turbine (km)	Number of potential participants
A	0 – 2	50
B	2.1 – 3.5	50
C	3.6 – 5	50

After the generic demographic questions about gender, age and occupation, the respondent's general attitude towards wind power was asked. This was done to improve objectivity in the response regarding attitude. Otherwise, there may be a risk that respondents were influenced by subsequent questions regarding impact. This might pose a risk for anchoring, where the attitude sets the tone for the replies to subsequent questions (Gehlbach & Barge, 2012). However, since wind power is a topic where people often are engaged (Krohn & Damborg, 1999; Ruddat, 2022), the decision was taken to place the overall question on attitude first to avoid as much influence on this reply as possible.

The survey was created in Microsoft Forms and consisted of eighteen questions in total, with sixteen multiple-choice questions and two open questions, where the respondents had the opportunity to elaborate on their answers (Appendix 3). Persson (2016) describes the answers to open questions as more difficult for the researcher to interpret compared to multiple-choice questions, and more demanding for the respondent to answer, potentially leading to a reduced number of answering respondents. However, a strength is that answers to open questions often provide more detailed and in-depth information which was the aim of this enquiry. Multiple-choice questions are easier for the respondent to answer and for the researcher to interpret, given that the choices are well thought out and cover all potential alternatives (Persson, 2016).

Actions were taken to comply with the principles of research ethics for social studies set up by the Swedish Research Council regarding information, consent, confidentiality, and data usage (table 3). Since it is important to protect the respondent's personal information to prevent any form of violation (Dimenäs & Björkdahl Ordell, 2007), the importance of each question concerning personal information was evaluated and only those considered important enough for this study were included in the survey.

Table 3. Research ethics principles followed during the study.

Requirements (Dimenäs & Björkdahl Ordell, 2007)	**How it was applied**
Information Inform respondents about the project's aim	The enclosed information letter explains the aim of the project
Consent The respondent can choose to take part in the project	Respondents were given information about the study being voluntary and that consent was given by choosing to take part in the study
Confidentiality Information about all respondents must be handled confidentially and stored where unauthorized people do not have access	Respondents were anonymous and it is unknown who of the targeted respondents answered the survey
Usage Information collected about individuals can only be used for research purposes	The data collected was only used for this study and was destroyed afterwards

Before the survey was distributed a pilot study was conducted. The survey was sent to a test group consisting of seven individuals not connected to the study to receive feedback on the structuring and clarity of the questions. Based on this feedback, the order and wording of one question were revised.

Data Collection

Biodiversity

A radius of 3km from the wind turbines was used to obtain data on lepidopterans and birds from SSOS. Each search was used with boundaries:

- species: birds and butterflies
- year: 2000-2023

Using ‘butterflies’ in the SSOS resulted in data on lepidopterans, meaning that both butterflies and moths were included. This resulted in one data set for birds and one for lepidopterans for each site, resulting in a total of ten data sets for the five sites.

In the analyses, data from pre- and post-construction inventories of birds from two of the sites were compared.

For the SLU inventories of butterflies, a 5km buffer was used. There was one site identified within the study sites that had data for both the pre- and post-construction years and was used for analyses (Swedish University of Agricultural Sciences, 2023).

Local Impact on Humans

The survey was distributed as a printed letter by post. The postal envelope included an information letter describing the study, contact information for the researcher, the survey, and a franked reply envelope (Appendix 4). The survey was also accessible in a digital format through Microsoft Forms, where the participants were encouraged to use a printed QR code to access the online survey.

The survey was sent to the residents on March 4th, 2024, with a deadline of March 31st, giving the respondents approximately 3 weeks to respond. This was decided due to the Swedish postal distribution system where postal delivery is every other weekday, thus the actual delivery date could differ between the areas. I also wanted to give the residents enough time to answer it thoroughly and return it. The survey was estimated to take about five to ten minutes to respond.

The received printed responses were manually transferred to Microsoft Forms and all data were compiled in one data set. All data was then extracted and processed in Excel.

Geographical Information Systems

QGIS, a software for geographical information systems (GIS) was used to set the geographical boundaries and collect data. Polygon shapefiles were created in QGIS to retrieve data on species observations. Additionally, buffer zones were created for each distance group and the function of placing random points was used within each buffer to identify survey participants (figure 2). For each random point, the nearest address was identified and selected for participation in the survey.

Statistical Analysis

SPSS 29.0 (The Statistical Package for the Social Sciences) was used to analyse all data.

Biodiversity

The Pearson Correlation Coefficient test was used to investigate the potential correlation between the number of species found and the number of visits to the study sites. The Chi-2 Test of Independence was used to test the potential difference before and after wind farm construction when the variable contained a single value. Paired sample t-tests were used to test for potential differences before and after wind farm construction for the following factors:

- Number of visits (by individual observers)
- Species richness
- Presence of indicator species (Appendix 1)
  - Nesting birds in forests
  - Grassland butterfly
  - Woodland butterfly

The potential change in biodiversity between pre- and post-construction was analysed using Shannon's diversity index (Shannon, 1948). The index is a measure used to quantify the diversity of a community and accounts for the number of species in a habitat (richness) and their relative abundance (evenness). A higher value indicates a higher number of species and/or a higher evenness of their abundance. Shannon's index of diversity (H') is defined as:

$$H' = -\sum[(pi) \times \log(pi)]$$

Where:
$p\mathrm{i} = \frac{n}{N}$ = proportion of individuals of i-th species in a whole community

n = individuals of a given species
N = total number of individuals in the community

Local Impact on Humans

To analyse the relationship between two or more categorical values the Fisher's Exact Probability test was used. The test evaluates whether a non-random association is found between the categorical variables. A high Fisher

Exact value indicates a greater difference between the expected and observed data (Pallant, 2020). In case of a significant result (p <0.05), the adjusted residual was used as a post-hoc test to identify which groups were larger or smaller than expected. An adjusted residual of +/- 2 is considered significant, where a positive residual indicates a larger group than expected while a negative residual indicates a smaller group (Pallant, 2020; Sharpe, 2019). The Fisher's Exact Probability test is defined as:

$$p = \frac{\binom{a+b}{a}\binom{c+d}{c}}{\binom{N}{a+c}}$$

a = the number of observations in the first group in the first category

b = the number of observations in the first group in the second category

c = the number of observations in the second group in the first category

d = the number of observations in the second group in the second category

As a post-hoc-type comparison, Cramer's V test was used to test the effect of significant associations following Fisher's Exact Probability test, indicating if the effect between the variables was weak, medium, or strong. The three thresholds of Cramer's V are determined by the number of categories, expressed as degrees of freedom (df*) (table 4). Degrees of freedom (df*) is the smallest value of either the number of categories in the row variables minus one (R-1) or column categories minus one (C-1) (Gravetter & Wallnau, 2016; Pallant, 2020).

Table 4. Thresholds for interpreting the effect of Cramer's V (Gravetter & Wallnau, 2016).

	Small effect	Medium effect	Large effect
df* = 1	0.10	0.30	0.50
df* = 2	0.07	0.21	0.35
df* = 3	0.06	0.17	0.29

Results

Biodiversity Results

Birds

SYSTEMATIC INVENTORIES

The average number of bird species detected in the systematic inventories was relatively similar in the pre-construction years, 58 species per site, compared to the post-construction, 56 species per site. The t-test did not show a significant difference in the number of species between the time periods (t= 0.078, df=2, p=0.945). The total number of bird species detected in the pre-construction phase was 99, and 94 in the post-construction phase.

Out of the three inventory sites, the number of bird individuals (which is needed to calculate the Shannon diversity index) was only reported for both the pre- and post-construction phases at one site. For this site, Shannon's diversity index (described in Material and Methods) on birds was H' = 2.3 in the pre-construction years and H' = 2.4 in the years after the wind farm construction.

THE SWEDISH SPECIES OBSERVATION SYSTEM

The number of reported findings of birds from the citizen science data in the SSOS varied between study sites and time periods (Appendix 2). In 2000, a total of 342,426 findings of birds in Sweden were reported using SSOS. In 2023, the reported findings had increased to 4 643,880. An increase was also shown at the study sites, where the number of reported findings was 6 in 2000 and 571 in 2023.

Findings of birds were reported at the study sites in 87% of the years included in this study (2000-2023) (Appendix 2). In the pre-construction phase, birds were reported in 76% of the years and in the post-construction phase, 98% of the years. However, the difference in bird findings was not significant between the two time periods (t= -2.730, df=4, p=0.052) (Appendix 2).

REPORTED VISITS

The data from SSOS showed that a total of 2438 visits were registered by 431 individual bird observers at the five study sites. The visits were distributed as 921 visits in the pre-construction years and 1517 visits in the post-construction years.

The result appeared to show an increase in average visits at all sites in the post-construction years compared to the pre-construction years (table 5). An increase was shown at three sites and a decrease was shown at two sites. The largest increase was in site 4, from 1.4 visits per year in pre-construction to 17.6 visits per year in post-construction. However, the result of the t-test did not show a significant difference between the visits in the pre-construction years and the post-construction years (t= -1.611, df=4, p=0.182) (table 5).

Table 5. Results of the SSOS data presented as annual average.

		Site 1	Site 2	Site 3	Site 4	Site 5	Total
Visits	Pre	8.5	16.1	45.2	1.4	15.6	**17.4**
	Post	7.7	19.3	68.0	17.6	13.8	**25.3**
Number of species	Pre	16.0	10.5	13.4	0.6	7.3	**9.6**
	Post	8.1	9.6	12.5	9.3	21.3	**12.1**
Diversity index (H')	Pre	3.8	4.0	3.7	0.5	3.4	**3.1**
	Post	3.6	1.4	4.3	4.2	3.0	**3.3**
Forest nesting bird species	Pre	1.3	1.1	1.3	0.0	0.6	**0.9**
	Post	0.8	0.9	1.0	0.9	1.8	**1.1**

SPECIES RICHNESS

During the pre-construction years 9.6 species per year were reported and 12.1 species during the post-construction years (table 5). The average number of species per year showed a decrease at three sites and an increase at two after the wind farm was constructed. A total of 210 bird species was reported at the five study sites during the entire study period, distributed 175 during pre-construction and 194 post-construction. There was no significant difference in the number of bird species before the wind farm was constructed compared to after the wind farm was constructed (t= -0.663, df=4, p=0.543) (table 5).

There was no significant difference in either the number of bird species reported or the number of visits from the pre-construction years to the post-construction years. However, there was a significant positive correlation between the annual number of bird species and the annual number of visits reported in SSOS between 2000-2023 (r(24) = 0.956, p<0.001) (figure 3).

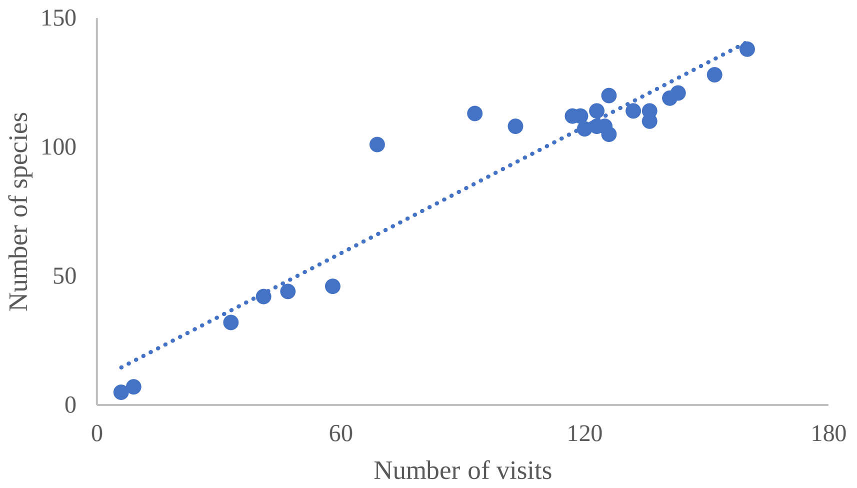

Figure 3. The relationship between the annual number of visits and the number of bird species. (*N*=24).

DIVERSITY

The results showed an average Shannon's diversity index (H') of 3.1 in the pre-construction years and H = 3.3 in the post-construction years (table 5). The index showed increases at three sites and decreases at two sites, though not statistically tested.

NESTING BIRD SPECIES IN FORESTS

The results showed an increase in the average number of species observed from the pre-construction years to the post-construction years, from 0.9 to 1.1 species per year (table 5). The average number of species increased at two sites and decreased at three sites. However, the difference in the number of nesting bird species in the pre-construction years for all sites compared to the number of species in the post-construction years was not significant (t= -0.623, df=4, p=0.567) (table 5).

Out of the 16 forest nesting bird species monitored for the national indicator on nesting birds in Sweden (Appendix 1) (Naturvårdsverket, 2024b), at most 13 were reported at one site, site 3, in both the pre- and post-construction years. During the pre-construction years, ≤8 species were reported at two sites and ≥9 at three sites. During the post-construction years, ≤8 species were reported at one site and ≥9 at four sites. The greatest difference was seen at site 4, where 0 species were reported in the pre-construction years and 11 in the post-construction years.

There were 202 reported visits for the observance of nesting bird species in the pre-construction years and 316 in the post-construction years. However, the t-test did not show a significant difference between the two periods (t= -1.148, df= 4, p= 0.315).

Lepidopterans

SYSTEMATIC INVENTORIES

One inventory was conducted by SLU during the pre-construction years and two during the post-construction years. The systematic inventories showed that 18 species of lepidopterans, a total of 298 individuals, were found at the site in the pre-construction years (N=1). In the post-construction years, 26 species were found with a total of 396 individuals. The Chi-2 test showed no significant difference in the number of species between the periods χ^2 (1, N=44) = 1.455, p=0.228, but there was a significant difference in the number of individuals χ^2 (1, N=694) = 13.839, p<0.001. Further, the Shannon's diversity index (H') was 2.1 in the pre-construction years and H = 2.2 in the post-construction years.

THE SWEDISH SPECIES OBSERVATION SYSTEM

The number of reported findings of lepidopterans from the citizen science data in the SSOS varied between study sites and time periods (Appendix 2). In 2000, a total of 16 587 findings of lepidopterans in Sweden were reported using the SSOS. In 2023, the reported findings had increased to 363,878. An increase was also shown at the study sites, where the number of reported findings was 4 in 2000 and 857 in 2023.

Findings of lepidopterans were reported at the study sites in 67% of the years included in this study (2000-2023) (Appendix 2). They were reported in 50% of the years in the pre-construction phase and in 85% of the years in the post-construction phase. However, the difference in findings was not significant between the time periods (t= -2.402, df=4, p=0.074) (Appendix 2).

REPORTED VISITS

The data from SSOS showed that a total of 659 visits were registered by 115 individual lepidopteran observers at the five study sites. The visits were distributed as 147 visits in the pre-construction years and 512 visits in the post-construction years.

The result showed an increase in average visits for reporting lepidopterans at all sites in the post-construction years compared to the pre-construction years (figure 4). An increase was identified in all sites, with the greatest in sites 3, 4 and 5 (table 6). The increase from 3.6 visits per year in the pre-construction years, to 11.2 visits post-construction was significant (t= -2.873, df= 4, p= 0.045) (figure 4).

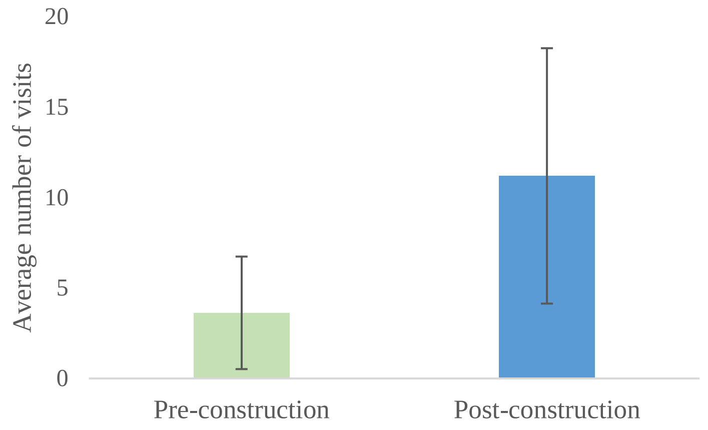

Figure 4. Average (±SD) number of visits for the pre-construction years and the post-construction years at the studied wind farm sites. (N=5).

Table 6. Results of the SSOS data presented as annual average.

		Site 1	Site 2	Site 3	Site 4	Site 5	Total
Visits	Pre	1.0	2.3	4.6	1.0	9.3	**3.6**
	Post	2.0	4.7	12.4	15.6	21.3	**11.2**
Number of species	Pre	1.0	7.0	12.0	4.0	8.5	**6.5**
	Post	2.7	9.0	41.7	6.9	21.5	**16.4**
Diversity index (H')	Pre	0.7	1.9	4.0	1.9	2.8	**2.3**
	Post	1.8	2.2	3.2	3.5	3.8	**2.9**
Grassland butterfly species	Pre	0.0	0.1	0.2	0.0	0.5	**0.2**
	Post	0.1	0.2	0.8	0.8	0.8	**0.5**
Woodland butterfly species	Pre	0.0	0.3	0.1	1.5	0.9	**0.5**
	Post	0.3	0.4	0.7	0.8	1.8	**0.8**

SPECIES RICHNESS

During the pre-construction years 6.5 species per year was reported and 16.4 species during the post-construction years (table 6). The result showed an increase in all sites, with the greatest increase at sites 3 and 5. During the entire study period, a total of 685 species of lepidopterans were reported at the five study sites, of which 244 species were reported in the pre-construction years and 600 in the post-construction years. However, there was no significant difference in the number of species between the periods pre- and post-construction (t= -1.834, df= 4, p= 0.141) (table 6).

There was no significant difference in the number of lepidopteran species reported, but there was a significant difference in the number of visits from the pre-construction years to the post-construction years. However, there was a positive correlation between the annual number of lepidopteran species and the annual number of visits (r(24) = 0.854, p <0.001) (figure 5).

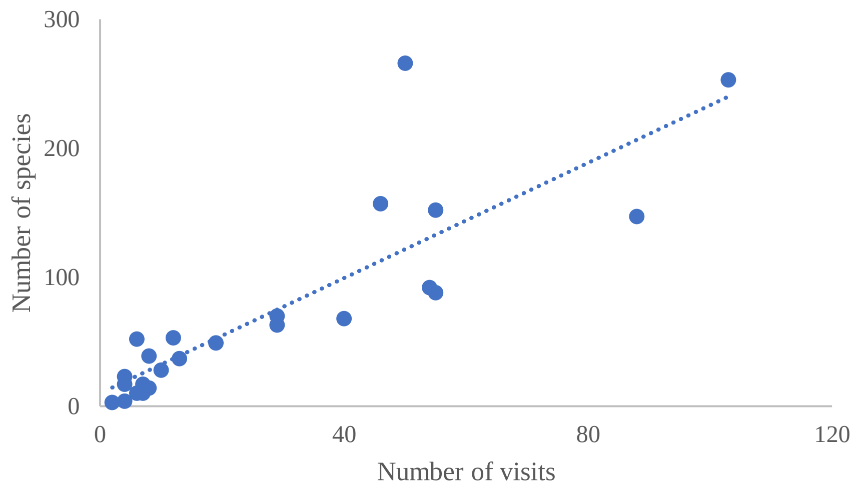

Figure 5. The relationship between the annual number of visits and the number of lepidopteran species. (N=24).

DIVERSITY

The result showed an increase in the average Shannon's diversity index (H) from the pre-construction years to the post-construction years, from 2.3 to 2.9 (table 6). There were indications of increases at four sites, with the largest increase at site 1, though, not statistically tested.

GRASSLAND BUTTERFLY SPECIES

The results showed that an average of 0.2 grassland butterfly species was reported at the sites per year in the pre-construction years (table 6). During the post-construction years, the number of species increased to 0.5 per year, which is an increase of 271%. At most, 0.8 species per year were reported at sites 3, 4 and 5 during the post-construction years (table 6).

Out of the 12 grassland butterfly species (Appendix 1), 10 species were reported at two sites in the post-construction years, while less than 4 species were reported at all five sites in the pre-construction years as well as at three sites in the post-construction years. There was no significant difference in the number of grassland butterfly species between the pre-construction years and the post-construction years (t= -2.540, df= 4, p= 0.064) (table 6).

There were 12 reported visits for the observance of grassland butterfly species in the pre-construction years and 176 in the post-construction years. However, the t-test did not show a significant difference between the two periods (t= -1.278, df= 4, p= 0.270).

WOODLAND BUTTERFLY SPECIES

The result showed that an average of 0.5 woodland butterfly species per year was reported at the sites during the pre-construction years and 0.8 per year during the post-construction years (table 6). At most, 1.8 species per year were reported at site 5 during the post-construction years.

Out of the 10 woodland butterfly species (Appendix 1), ≥7 species were reported in four time periods, at one site during the pre-construction years and at three sites during the post-construction years. All 10 woodland butterfly species were reported at site 4 during the post-construction years. Additionally, ≤5 was reported in the other six time periods, at four sites during the pre-construction years and at two sites during the post-construction years. There was no significant difference in the number of woodland butterfly species between the pre-construction years and the post-construction years (t= -0.841, df= 4, p= 0.448) (table 6).

There were 25 reported visits for the observance of grassland butterfly species in the pre-construction years and 228 in the post-construction years. However, the t-test did not show a significant difference between the two periods (t= -1.268, df= 4, p= 0.274).

Survey Results

Background Information

Out of the 150 surveys sent out, 67 responses were received. One incomplete response was received and discarded; therefore, the result is based on 66 responses. This makes the response rate 44%, which can be considered low. In voluntary surveys it is often hard to get a response rate over 60%, and to get a rate over 40% usually requires extra effort (Arundel, 2023). Since no additional effort was made to increase the response rate in this study, 44% is acceptable (Arundel, 2023).

Almost half of the respondents were between the ages of 61-75 years and just almost a third were 46-60 years (figure 6A). Regarding gender, 59% identified as male, 39% as female and a low percentage as another option (figure 6A). The respondents' occupations varied, but the largest groups were 'Retired' (39%), 'Working away' (32%), and 'Working from home' (24%) (Appendix 5). The top three answers to the question 'What are the main reason/reasons you live in this area?' were 'Outdoor life', 'Being from the area' and 'Animals' (Appendix 5).

The respondents distributed by distance were fairly even, though a slightly larger number of responses were received from distance group A (figure 6B). However, a larger imbalance was shown between the groups of pre- and post-construction, where 76% of the respondents belong to the pre-construction group while only 24% are post-construction (figure 2) (figure 6C). Meaning that a majority of the respondents lived in the area before the wind farm was constructed.

In terms of the respondents' general attitude towards wind power, 49% of the respondents answered that they were 'Positive', 33% 'Neutral' and 18% 'Negative' (figure 6D). At the national level, the corresponding shares are 72% positive, 11% neutral and 17% negative (Novus, 2023).

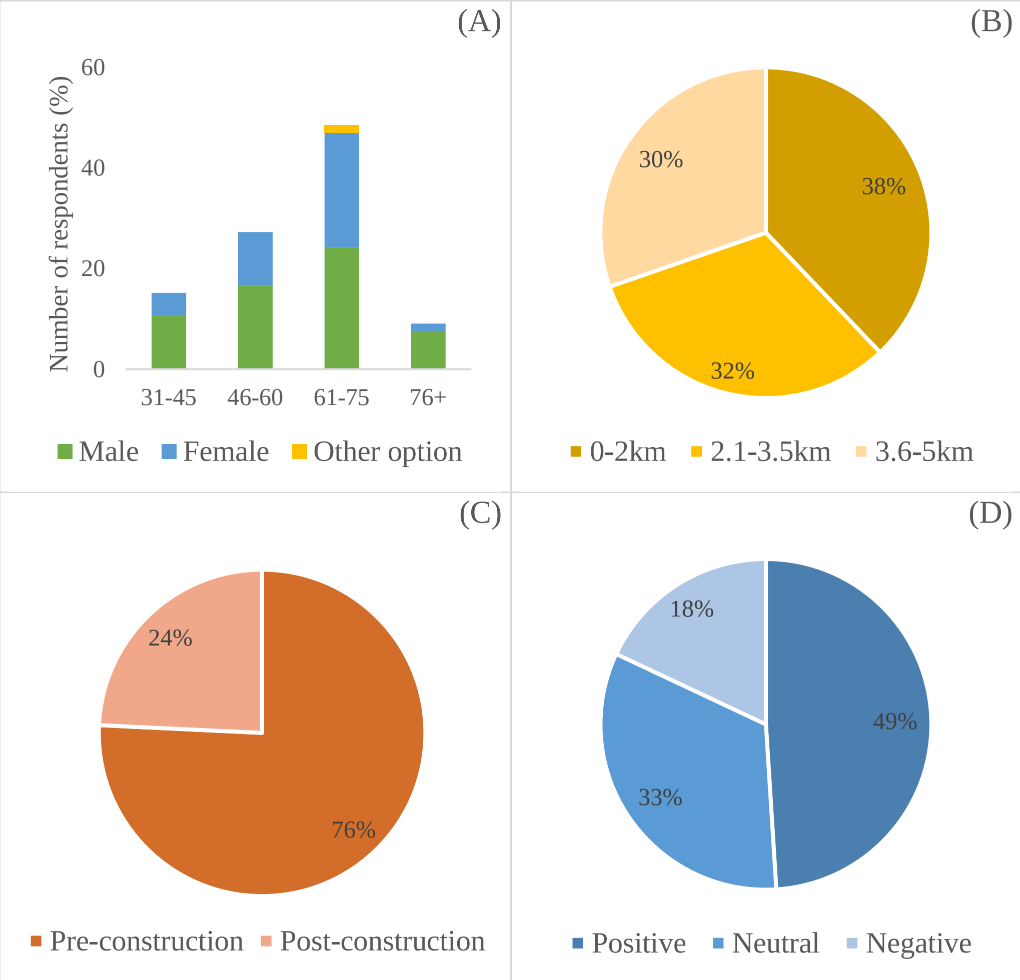

Figure 6. Demographic background of the respondents. The gender distributed by age (A); and respondents distributed by distance (B); pre- and post-construction (C); and attitude (D). (*N*= 66).

The association between the three factors distance to wind farm, pre- and post-construction groups, and the attitude towards wind power was investigated. The Fisher's test did not indicate a significant association between distance to the wind farm and pre- and post-construction groups (p=0.428), or the attitude towards wind power (p=0.774). Neither was there a significant association between the pre- and post-construction groups and their attitude towards wind farms (p=0.102). Indicating that there is no evidence that either of the three factors is related to one another.

BEFORE CONSTRUCTION

When asked how they expected the wind farm to impact their everyday life, 68% answered that they would be impacted to some level and 32% answered that they would not be impacted (figure 7A). Most respondents (83%) expected no or little impact on their everyday life. The lowest share of respondents (3%) expected a very big impact.

When the wind farm was taken into operation, 65% of the respondents perceived a change to some degree, while 35% replied that no change had occurred (figure 7B). A higher degree of change was perceived by 23% of the respondents.

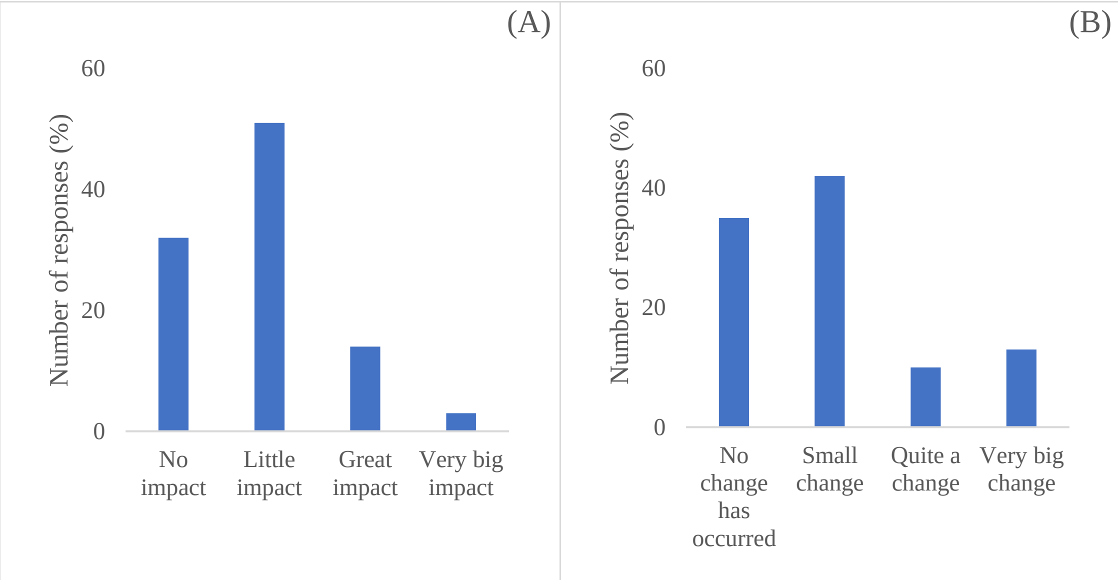

Figure 7. The respondent's expected impact of the wind farm before it was constructed, or before the respondent moved to the area (A) (*N*=66); and the perceived change in the local environment due to the construction of the wind farm (B) (*N*=48).

A majority of the respondents 85% expected to be affected by the wind farm in their everyday life to some degree, and therefore the potential impact on aesthetics, health, household animals, climate, and the local environment was further investigated (figure 8).

The dominant positive effect was that on the climate (figure 8). The most negative effects were expected to be on aesthetics, animals, and the local environment, where over 40% of the respondents expected negative effects. The impact on health was expected to be neutral by half of the respondents and to be negative by 29%.

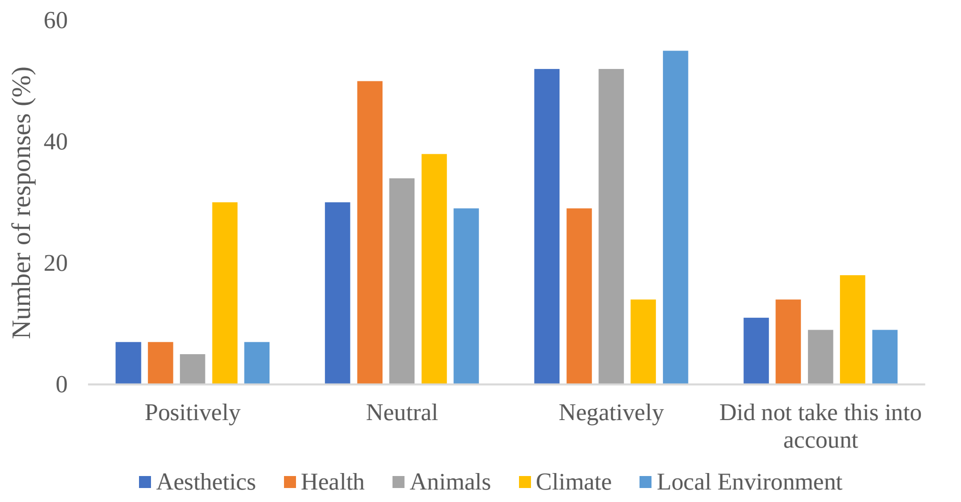

Figure 8. The response distribution of the respondent's expected impact on five factors (survey question 8). (*N*=56).

DURING CONSTRUCTION

To understand the perceived impact of the construction phase, respondents were asked about potential disturbances from heavy transport, groundwork, increased traffic in the area, noises, and lights from the construction work (figure 9). This question was only applied to the respondents who lived in the area during the pre-construction years and did not apply to respondents in the post-construction group.

The dominant response was that none of the activities was perceived as disturbing (figure 9). A small disturbance was shown in activities such as transport, increased traffic, noises, and lights. A lower share of respondents perceived the activities as a higher level of disturbance.

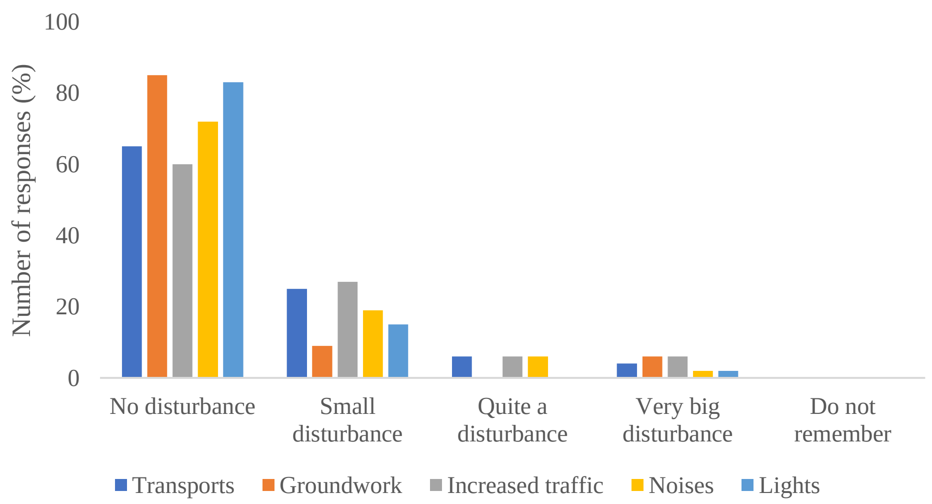

Figure 9. The response distribution of the respondent’s experienced impact of constructional activities (survey question 14). (*N*=48).

DURING OPERATION

To understand the perceived impact in the operational phase of the wind farms, respondents were asked about potential disturbances from noises from wind turbines, shadows from rotor blades, changed landscape, sleep disorder, and the warning lights on the turbines (figure 10).

A majority answered that there was no disturbance from shadows or warning lights, and no sleep disorder was experienced (figure 10). Regarding noises and a changed landscape, 36% respectively 27% of the respondents perceived a small change. The largest disturbance was the changed landscape which was perceived as most disturbing throughout and had the highest shares in the categories of quite or very big disturbance, in total 38%.

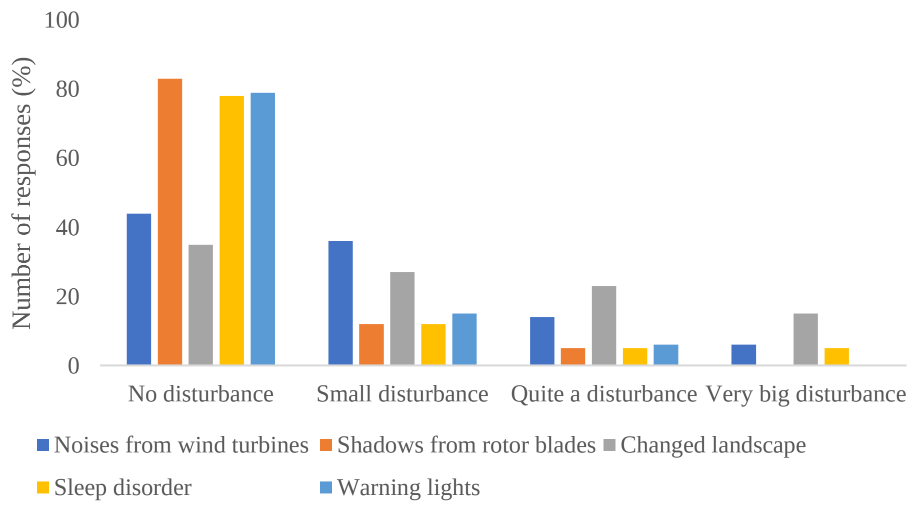

Figure 10. The response distribution of the respondents experienced disturbance of factors during the operational phase (survey question 10). (*N*=66).

In one of the open questions, 23 respondents described how the local environment had changed in their opinion. The predominant aspects were visual changes (39%) (flickering lights, moving turbines, and changed landscape), and noise (33%). The noise was described as especially disturbing during certain wind conditions. The respondents wrote, “VERY disturbing during certain wind directions and strengths”, “I hear the wind turbines a few times a month – once a week. But I am only bothered with it a few times a year”, and “During forest walks, the wind turbine becomes visible, even lights in the evening”. Additional negative changes that were mentioned only once were that the wind farm is too close to residents, the impact on nature, limited mobility in the area and that the area has been transformed into an industrial area. One respondent replied that they “Rarely walk or ride in the area, which I used to do often. Only if there is a good mushroom supply. No enjoyment of nature there anymore. It is an industrial area”.

The access to new roads that were constructed for the wind farm was mentioned as a positive change by 11% of the respondents, who commented "New roads have been constructed and, of course, the environment has changed, but the benefits outweigh", and "Wasn't as bad as we thought, we choose other paths".

Distance to Wind Farm

A majority of the respondents, irrespective of distance, expected the wind farm to have little impact on their everyday lives (figure 11A). When comparing between the distance groups, the largest difference can be seen in the categories of no impact and great impact. More respondents in distance groups B and C expected no impact compared to distance group A. While more respondents in distance group A expected a greater impact compared to distance group B and C. The result of the Fisher's test (p =0.856) did not indicate a significant association in the relationship between the distance groups and their expected impact.

The majority of the respondents in distance group C perceived that no change had occurred in their local environment, followed by a small change (figure 11B). In distance groups A and B, the majority of the respondents perceived a small change followed by no change. A greater share of respondents in distance group A perceived a very big change, compared to distance groups B and C. The Fisher's test (p=0.237) did not indicate a significant association between the distance groups and their perceived change in the local environment.

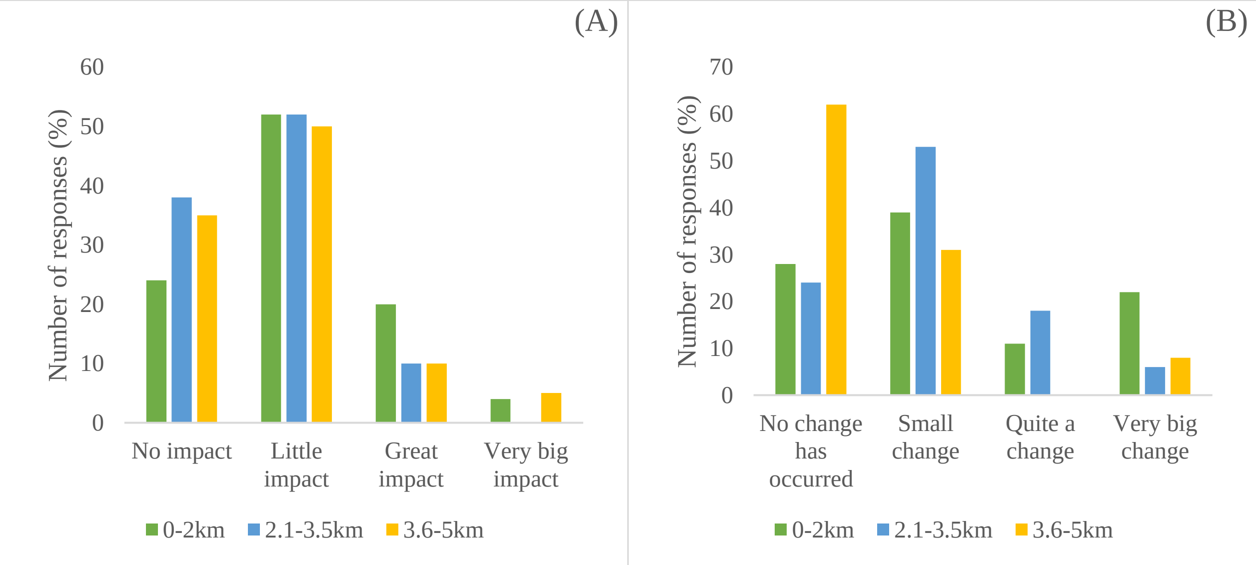

Figure 11. The respondent's expected impact (A) (N=66); and perceived change in the local environment (B) (N=48), in percentage per distance group.

BEFORE CONSTRUCTION

The result on the potential impact on aesthetics, health, household animals, climate and the local environment showed that the majority of the respondents in distance groups A and B were expecting a negative impact, followed by a neutral impact, while in group C it was the opposite (figure 12). In groups A and C, the positive impact was ranked the lowest.

The dominant negative impact was found in aesthetics and the local environment for all distance groups. Additionally, animals were found to have a negative impact in distance groups B and C. The most positive impact was found in climate for all distance groups. Health was expected to have the most neutral impact.

The result of the Fisher's test did not indicate a significant association between the distance and the expected impact in any of the five factors (Appendix 6).

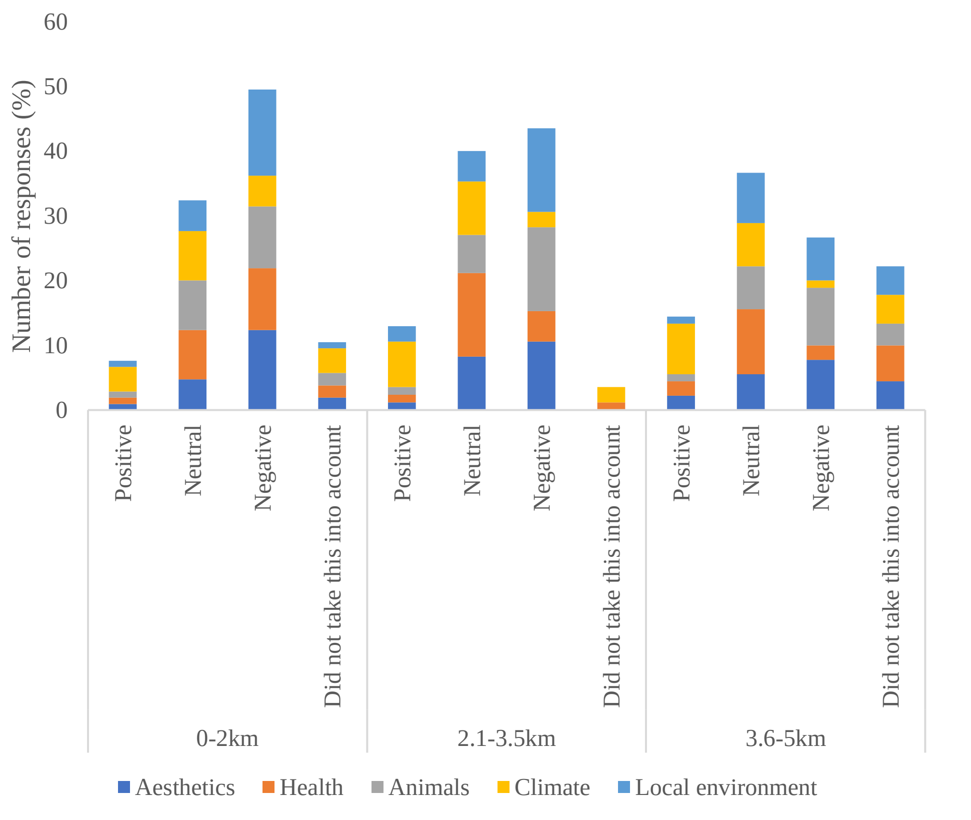

Figure 12. The response distribution of the respondent's expected impact on five factors (survey question 8). (N=56).

DURING CONSTRUCTION

The responses on the activities during the construction phase showed a consistent result as not disturbing for all distance groups (figure 13). Disturbance was perceived at all levels in groups A and B, but in group C only a small disturbance was perceived. Transports, increased traffic, and noises were perceived as most disturbing in all groups.

The Fisher's test did not indicate a significant relationship between distance and the experienced impact in any of the activities during the construction phase (Appendix 6).

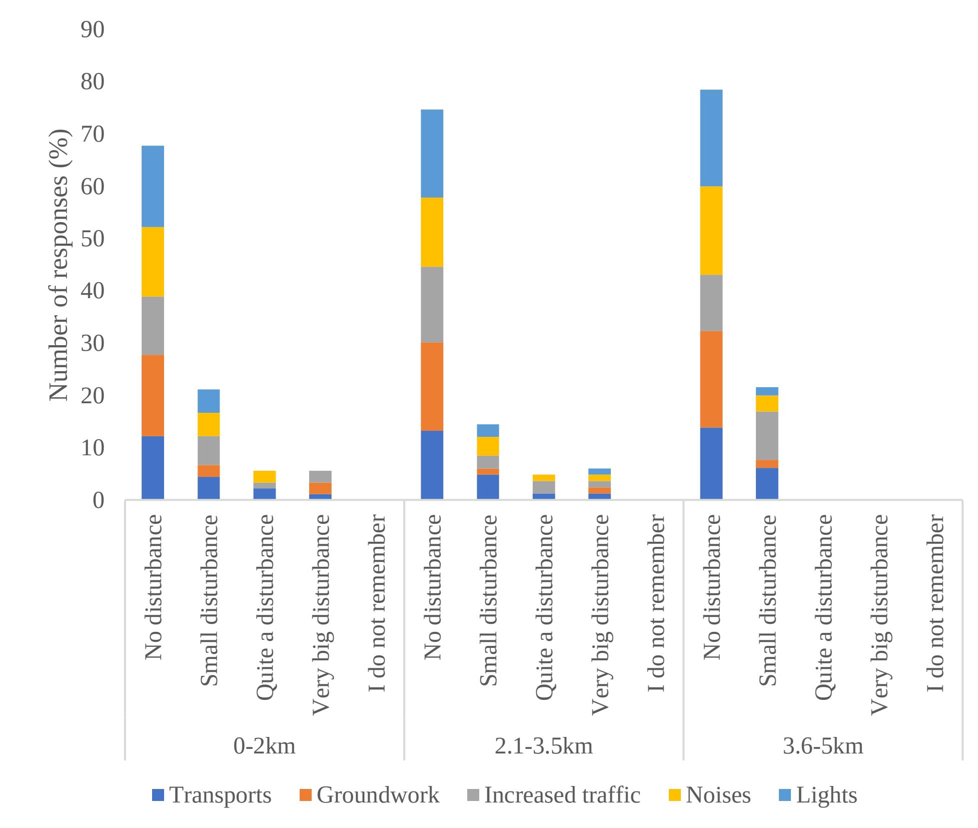

Figure 13. The response distribution of the respondent's experienced impact of constructional activities (survey question 14). (*N*=48).

DURING OPERATION

The majority of respondents in all distance groups did not perceive disturbance from any of the factors during the operational phase (table 7). The changed landscape was identified as the most disturbing factor, as well as noises. Shadows were a disturbing factor in distance group A, but not in groups B and C. Overall, the level of disturbance decreased with increased distance.

The Fisher's test shows that distance to wind farm had a significant association between noises from wind turbines (p=0.018, Cramer's V=0.327) as well as shadows from rotor blades (p=0.001, Cramer's V=0.350) (table 7). The positive residuals were found in distance group A experiencing quite a disturbance and in group C experiencing no disturbance. Added, a positive residual was found regarding shadows in group A experiencing a small disturbance. Both noises and shadows have negative residuals in group A experiencing no disturbance, while in group C they are found in the categories of quite a disturbance or small disturbance. However, three of the factors (changed landscape, sleep disorder, warning lights) did not indicate a significant relationship with the distance to the wind farm (table 7).

Table 7. The response distribution of perceived impact during the operational stage in relation to the distance, of all factors in survey question 10. The grey-marked values are significantly higher or lower than expected. (N=66).

Factor	Distance	Perceived impact operational phase				***p*-value**	**Cramer's V**
		No disturbance	Small disturbance	Quite a disturbance	Very big disturbance		
Noises from wind turbines	0-2km	6 (-2.5)	10 (0.5)	7 (2.7)	2 (0.5)	0.018	0.327
	2.1-3.5km	10 (0.4)	9 (0.7)	2 (-0.7)	0 (-1.4)		
	3.6-5km	13 (2.3)	5 (-1.3)	0 (-2.1)	2 (0.9)		
Shadows from rotor blades	0-2km	15 (-4.0)	7 (3.1)	3 (2.3)	-	0.001	0.350
	2.1-3.5km	20 (1.8)	1 (-1.3)	0 (-1.2)	-		
	3.6-5km	20 (2.4)	0 (-2.0)	0 (-1.2)	-		
Changed landscape	0-2km	6 (-1.4)	9 (1.2)	6 (0.2)	4 (0.2)	0.674	0.176
	2.1-3.5km	7 (-0.2)	6 (0.2)	5 (0.1)	3 (-0.1)		
	3.6-5km	10 (1.7)	3 (-1.5)	4 (-0.3)	3 (0.0)		
Sleep disorder	0-2km	17 (-1.7)	5 (1.5)	1 (-0.2)	2 (1.1)	0.662	0.184
	2.1-3.5km	18 (0.9)	2 (-0.4)	1 (0.1)	0 (-1.2)		
	3.6-5km	17 (0.8)	1 (-1.2)	1 (0.1)	1 (0.1)		
Warning lights	0-2km	20 (0.2)	4 (0.2)	1 (-0.5)	-	0.984	0.072
	2.1-3.5km	16 (-0.4)	3 (-0.1)	2 (0.8)	-		
	3.6-5km	16 (0.2)	3 (0.0)	1 (-0.2)	-		

Adjusted residuals in brackets.

Before and After Wind Farm Construction

Out of the respondents in the pre-construction group, 74% expected their everyday life to be impacted to some degree (figure 14). The corresponding share for the respondents in the post-construction group was 50%. Meaning that a larger share of the respondents in the post-construction group expected no impact from the wind farm compared to the pre-construction group.

When comparing the answers between the three impact levels, the pre-construction group had a majority in the two lower impact levels. However, more respondents in the post-construction group expected a very big impact, compared to the pre-construction group.

The Fisher's test (p=0.194) did not indicate a significant association between the pre- and post-construction groups and the expected impact of the wind farm. Additionally, when asking the post-construction group if they took the wind farm into account when deciding to move to the address, 100% of the respondents answered that they did not.

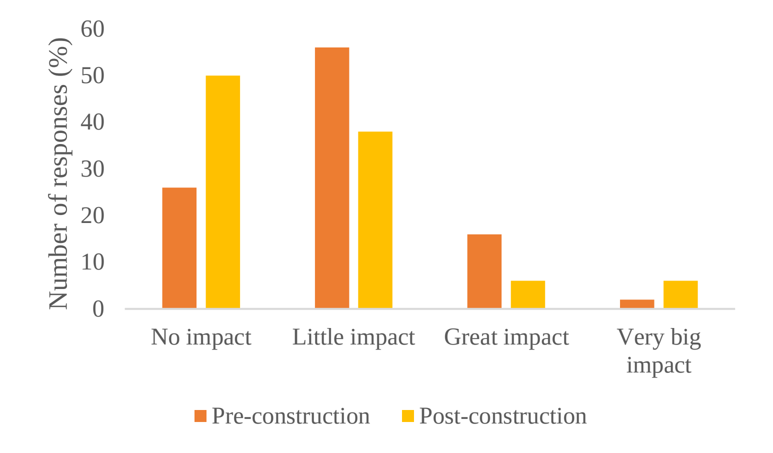

Figure 14. The respondents' expected impact in percentage per pre- and post-construction group. (*N*=66).

BEFORE CONSTRUCTION

The result showed that the respondents in the pre-construction and the post-construction groups expected a negative impact, mainly on the factors of aesthetics, animals, and the local environment (figure 15). A neutral impact was expected on factors such as health and climate. The most positive impact was found in climate. The Fisher's tests did not indicate a significant association between the factors and pre- and-post-construction (Appendix 6).

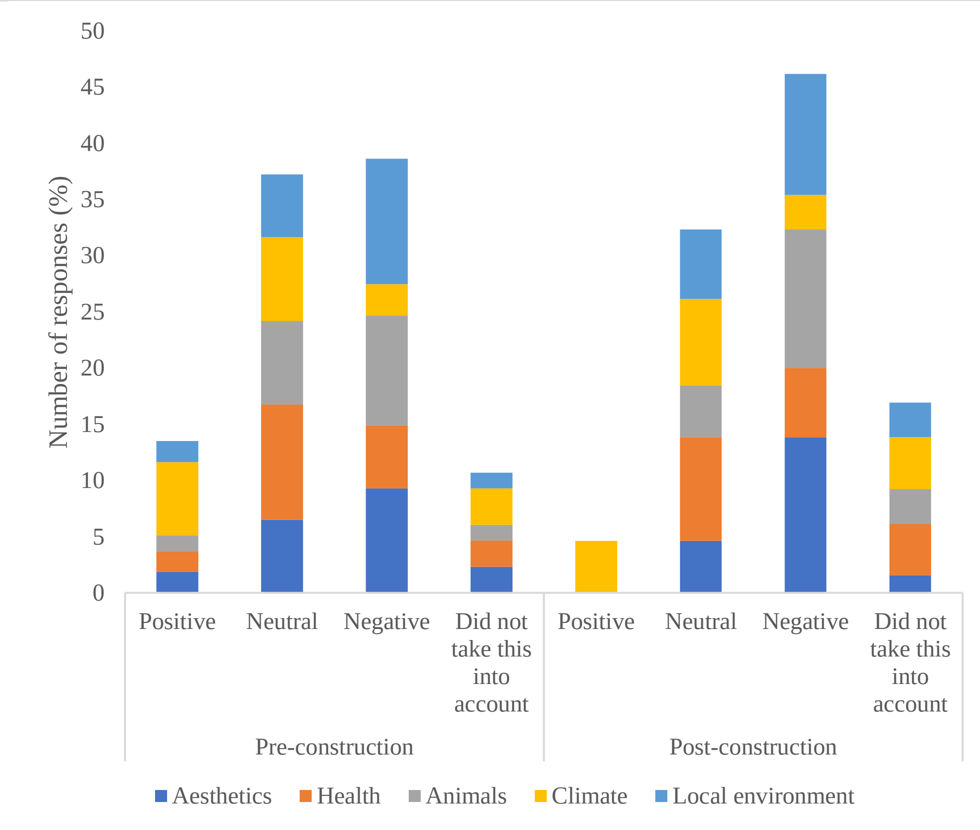

Figure 15. The response distribution of the respondent's expected impact on five factors (survey question 8). (*N*=56).

DURING OPERATION

The responses showed that a majority of the respondents in both pre- and post-construction groups perceived the activities during operation as not disturbing, 62% and 70% respectively between pre- and post-construction (figure 16). Out of the disturbance levels, most respondents in both groups have perceived a small disturbance. The most disturbing factors were noise and the changed landscape.

The result of the Fisher's test shows that none of the factors during the operational phase had a significant association with the pre- and post-construction groups (Appendix 6),

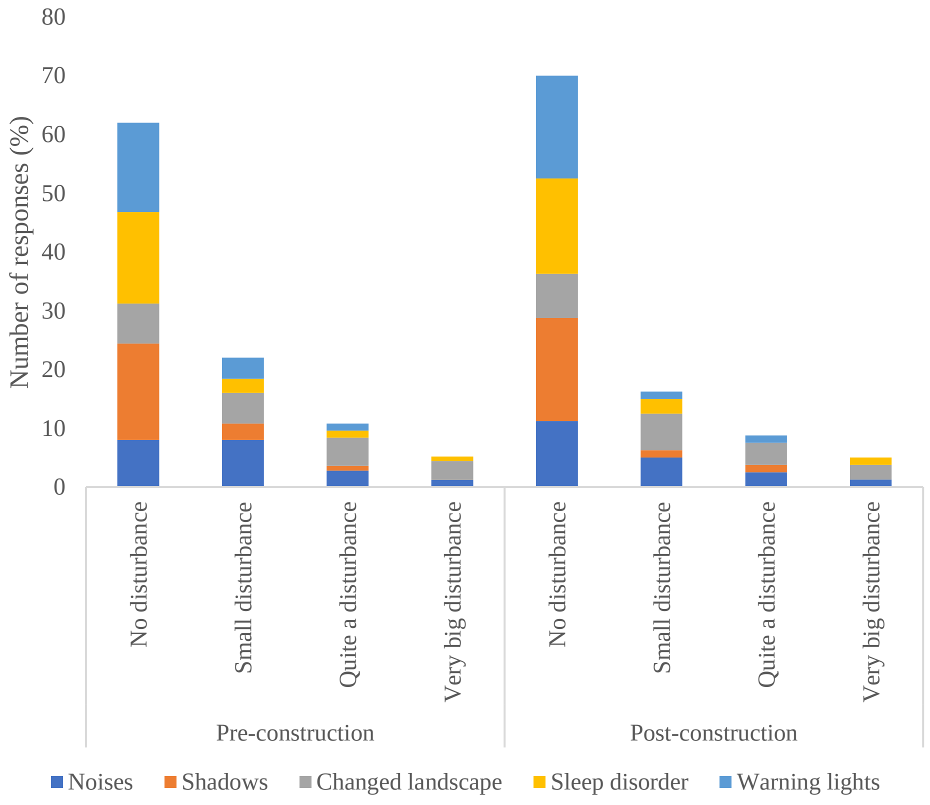

Figure 16. The response distribution of the respondents experienced disturbance of factors during the operational phase (survey question 10). (*N*=66).

Attitude Towards Wind Power

When asked how the respondents expected the wind farm to affect their everyday lives, 44% of the respondents with a positive attitude expected no impact (figure 17A). The corresponding share of those with a neutral attitude was 18% and a negative attitude was 25%. The majority of respondents expecting a small impact had a positive or neutral attitude, while the majority of respondents expecting a higher level of impact had a negative attitude.

The result of the Fisher's test (p=0.006, Cramer's V=0.364) indicated a significant strong association, with significant residuals in multiple variables.

The positive residuals were found in the variables of ‘No impact/Positive attitude’, ‘Little impact/Neutral attitude’ and ‘Great impact/Negative attitude’ (figure 17A). The negative residual was found in ’Little impact/Negative attitude’.

When asked how the respondents perceived that their local environment had changed since the wind turbines were put into operation, 50% of the respondents with a positive attitude did not perceive a change and 36% perceived a small change (figure 17B). All of the respondents with a negative attitude perceived a change to some degree, in a descending scale from highest to lowest degree of change. A small change was perceived by respondents with a neutral attitude.

The result of the Fisher’s test (p=0.002, Cramer’s V=0.462) indicated a significant strong association between multiple variables. Positive residuals were found in the variables ‘No change has occurred/Positive attitude’, ‘Small change/Neutral attitude’, ‘Quite a change/Negative attitude’, and ‘Very big change/Negative attitude’ (figure 17B). No significant negative residuals were found, though, the residuals of ‘No change has occurred/Negative attitude’ and ‘Quite a change/Positive attitude’ was just below the threshold at -1.9 (Appendix 6).

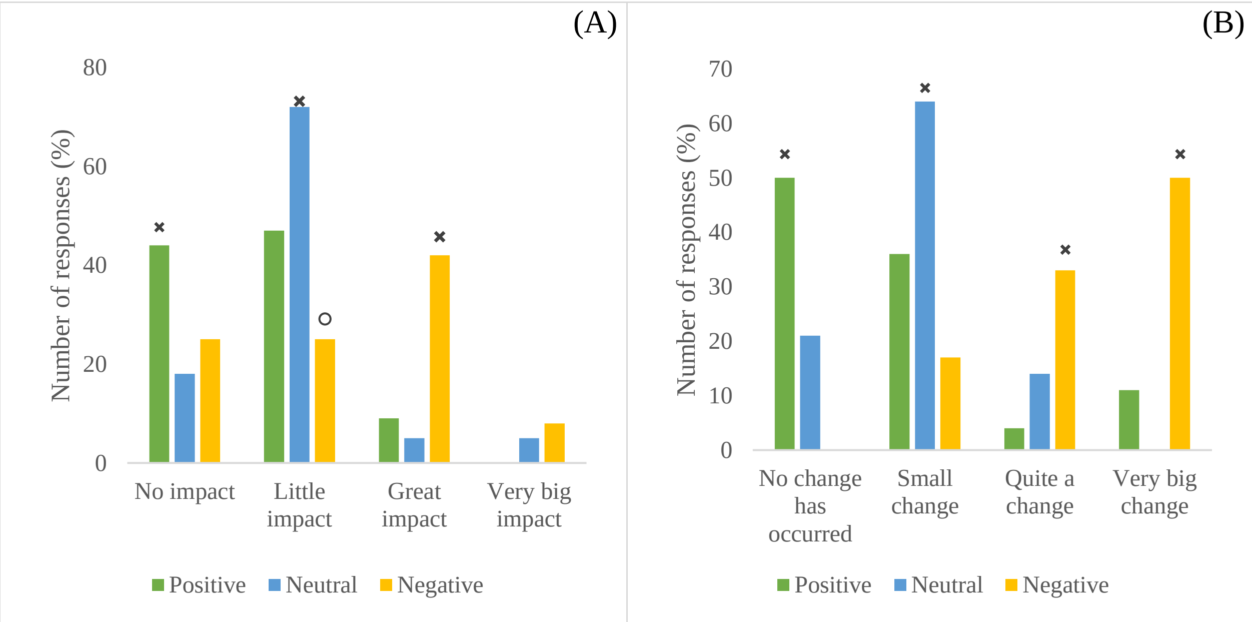

Figure 17. The number of responses in relation to attitude in terms of expected impact (A) (N=66); and perceived change in the local environment (B). (N=48).

× = positive residual

∘ = negative residual

BEFORE CONSTRUCTION

The result showed that the majority of the respondents with a positive attitude expected a neutral impact on the aesthetics, health, household animals, climate, and the local environment, followed by a positive and negative impact in that order. The majority of the respondents with a negative or neutral attitude expected a negative impact, followed by a neutral impact. The most positive impact was expected from respondents with a positive attitude. The climate was the factor that most respondents expected a positive impact on, irrespective of attitude.

The Fisher's test shows that four out of the five factors had a significant strong association with the respondents' attitude (table 8). The significances were found between attitude and aesthetics (p=0.018, Cramer's V=0.394), health (p=0.041, Cramer's V=0.392), animals (p=0.010, Cramer's V=0.408), and local environment (p=0.028, Cramer's V=0.364). No significance was found between attitude and climate (p=0.063).

In three of the four significant factors (health, animals, local environment), a positive residual was found in the group of 'Negatively impact/Negative attitude' (table 8). Additionally, another set of positive residuals was found in the group with a positive attitude expecting a positive or neutral impact. In all four factors, the negative residual was in the group of 'Negatively impact/Positive attitude'.

Table 8. The response distribution of expected impact in relation to the respondent's general attitude towards wind power, of all factors in survey question 8. The grey-marked values are significantly higher or lower than expected. (N=56).

Factor	Attitude	Expected impact on everyday factors				***p*-value**	**Cramer's V**
		Positively	Neutral	Negatively	Did not take this into account		
Aesthetics	Positive	3 (2.2)	8 (2.2)	5 (-3.3)	2 (0.4)	0.018	0.394
	Neutral	0 (-1.5)	2 (-1.9)	14 (2.2)	2 (0.4)		
	Negative	0 (-0.9)	2 (-0.3)	7 (1.4)	0 (-1.0)		
Health	Positive	3 (2.2)	10 (1.0)	3 (-2.2)	2 (0.0)	0.041	0.392
	Neutral	0 (-1.5)	9 (0.4)	6 (-0.3)	3 (1.0)		
	Negative	0 (-0.9)	2 (-1.6)	7 (3.0)	0 (-1.2)		
Animals	Positive	2 (1.8)	10 (2.9)	5 (-3.3)	1 (-0.2)	0.010	0.408
	Neutral	0 (-1.2)	3 (-1.7)	13 (1.6)	2 (1.0)		
	Negative	0 (-0.7)	1 (-1.4)	8 (2.1)	0 (-0.9)		
Climate	Positive	8 (1.6)	6 (-0.3)	1 (-1.5)	3 (-0.2)	0.063	0.410
	Neutral	5 (-0.4)	8 (1.0)	1 (-1.5)	4 (0.6)		
	Negative	1 (-1.4)	2 (-0.9)	5 (3.7)	1 (-0.6)		
Local environment	Positive	2 (1.8)	8 (2.2)	7 (-2.9)	1 (0.3)	0.028	0.364
	Neutral	0 (-1.2)	4 (-0.6)	13 (0.9)	1 (0.3)		
	Negative	0 (-0.7)	0 (-2.0)	9 (2.5)	0 (-0.7)		

Adjusted residuals in brackets.

DURING CONSTRUCTION

The majority of the respondents, irrespective of attitude, perceived no disturbance from the constructional activities' transports, groundwork, increased traffic in the area, noises and lights (table 9). Out of the respondents with a positive attitude, 14% expected a disturbance to some degree. For the respondents with a negative and neutral attitude, 47% respectively 46% expected a disturbance to some degree. None of the factors showed a deviant pattern in disturbance in comparison to the others.

The result of the Fisher's test shows strong significance in the relationship between attitude and groundwork (p=0.032, Cramer's V=0.282), noises (p=0.005, Cramer's V=0.388), and lights (p=0.011, Cramer's V=0.314) (table 9). The Fisher's test did not indicate an association between attitude and transport (p=0.083), or increased traffic (p=0.124).

In all three activities, positive residuals were found in the group of 'No disturbance/Positive attitude' (table 9). The negative residuals were not consistent throughout the activities, they were all found in positive attitudes but in different levels of disturbance. Regarding noises, another set of residuals was found, with the positive in 'Small disturbance/Negative attitude' and the negative in 'No disturbance/Negative attitude'. In terms of lights, a negative residual is found in 'No disturbance/Neutral attitude'.

Table 9. The response distribution of perceived impact during construction in relation to the respondent's general attitude towards wind power, of all activities in survey question 14. The grey-marked values are significantly higher or lower than expected. (N=48).

Activity	Attitude	Perceived impact during construction				p-value	Cramer's V
		No disturbance	Small disturbance	Quite a disturbance	Very big disturbance		
Transports	Positive	22 (2.4)	5 (-1.4)	1 (-0.9)	0 (-1.7)	0.083	0.318
	Neutral	6 (-2.0)	5 (1.1)	1 (0.2)	2 (2.3)		
	Negative	3 (-0.8)	2 (0.5)	1 (1.1)	0 (-0.5)		
Groundwork	Positive	27 (2.6)	1 (-1.5)	-	0 (-2.2)	0.032	0.282
	Neutral	9 (-1.9)	2 (1.0)	-	2 (1.6)		
	Negative	4 (-1.4)	1 (0.8)	-	1 (1.1)		
Increased traffic	Positive	20 (1.8)	7 (-0.4)	1 (-0.9)	0 (-2.1)	0.124	0.283
	Neutral	6 (-1.6)	5 (0.9)	1 (0.2)	2 (1.5)		
	Negative	3 (-0.6)	1 (-0.6)	1 (1.1)	1 (1.1)		
Noises	Positive	25 (3.2)	3 (-1.8)	0 (-2.2)	0 (-1.2)	0.005	0.388
	Neutral	7 (-1.8)	3 (0.4)	2 (1.6)	1 (1.6)		
	Negative	2 (-2.3)	3 (2.1)	1 (1.1)	0 (-0.4)		
Lights	Positive	27 (2.9)	1 (-2.6)	-	0 (-1.2)	0.011	0.314
	Neutral	9 (-2.3)	4 (1.8)	-	1 (1.6)		
	Negative	4 (-1.2)	2 (1.4)	-	0 (-0.4)		

Adjusted residuals in brackets.

DURING OPERATION

The result on the perceived impact on the factors during the operational phase showed that the respondents, irrespective of attitude, did not perceive any disturbance (table 10). Out of the respondents with a positive attitude, 26% perceived a disturbance to some degree. For the respondents with a negative and neutral attitude, 60% respectively 38% perceived a disturbance to some degree. All of the respondents, irrespective of attitude, perceived the disturbance in a descending scale from lowest to highest level of disturbance. All respondents perceived the noises and changed landscape as the most disturbing, while shadows and warning lights were the least disturbing.

The Fisher's test result showed a strong significant relationship in the association between attitude and three of five factors, noises from wind turbines (p=0.025, Cramer's V=0.317), changed landscape (p=0.012, Cramer's V=0.352), and sleep disorder (p=0.011, Cramer's V=0.339) (table 10). The Fisher's test did not indicate an association between attitude and shadows from the rotor blades (p=0.155), or warning lights (p=0.106).

Regarding noise and changed landscape, the positive and negative residuals imply that one with a positive attitude perceives the noise and changed landscape as not disturbing, while one with a negative attitude perceives a higher level of disturbance. Regarding sleep disorder the positive and negative residuals indicate that someone with a negative attitude is prone to perceive a higher level of disturbance.

Table 10. The response distribution of perceived impact during the operational stage in relation to the respondent's general attitude towards wind power, of all factors in survey question 10. The grey-marked values are significantly higher or lower than expected. (N=66).

Factor	Attitude	Perceived impact operational phase				*p*-value	Cramer's V
		No disturbance	Small disturbance	Quite a disturbance	Very big disturbance		
Noises from wind turbines	Positive	18 (2.0)	11 (-0.3)	1 (-2.4)	2 (0.1)	0.025	0.317
	Neutral	9 (-0.4)	9 (0.5)	4 (0.8)	0 (-1.5)		
	Negative	2 (-2.1)	4 (-0.2)	4 (2.2)	2 (1.7)		
Shadows from rotor blades	Positive	29 (1.5)	3 (-0.7)	0 (-1.7)	-	0.155	0.220
	Neutral	18 (-0.2)	3 (0.3)	1 (0.0)	-		
	Negative	8 (-1.7)	2 (0.5)	2 (2.2)	-		
Changed landscape	Positive	17 (3.0)	8 (-0.4)	6 (-0.7)	1 (-2.6)	0.012	0.352
	Neutral	4 (-2.0)	8 (1.2)	6 (0.6)	4 (0.5)		
	Negative	2 (-1.5)	2 (-0.9)	3 (0.2)	5 (2.8)		
Sleep disorder	Positive	28 (1.7)	2 (-1.4)	1 (-0.5)	1 (-0.5)	0.011	0.339
	Neutral	19 (1.1)	3 (0.3)	0 (-1.3)	0 (-1.3)		
	Negative	5 (-3.5)	3 (1.5)	2 (2.2)	2 (2.2)		
Warning lights	Positive	27 (1.1)	3 (-1.3)	2 (0.1)	-	0.106	0.256
	Neutral	18 (0.4)	2 (-1.0)	2 (0.7)	-		
	Negative	7 (-1.9)	5 (2.8)	0 (-1.0)	-		

Adjusted residuals in brackets.

Discussion

Overview

The results of the study on bird and lepidopteran diversity before and after the construction of the wind farm provide relevant insights into the potential impact of such establishments on local biodiversity. The systematic inventories showed an increase in individual lepidopterans found in post-construction and the SSOS showed an increase in number of visits regarding lepidopterans in post-construction. Additionally, there was a positive correlation between visits and the number of bird and lepidopteran species. There were no indications of differences in the number of bird and lepidopterans species or diversity between pre- and post-construction, suggesting that, within the limitations of this study, the wind farm did not have a significant negative impact on the diversity of the species.

The expected and experienced effects from wind farms on the local community are not imminently affected by distance. Disturbance in the form of noises and shadow flickering is found to be related to distance, resulting in an increasing disturbance with decreasing distance. Whether the respondent moved to the area before or after the wind farm was constructed does not determine their expected or experienced impact. No significant associations could be identified, regardless of the influencing factor. This means that the level of impact is not perceived as higher, or lower, by someone who lived in the area before the wind farm was constructed compared to someone who moved there after the wind farm was constructed. The attitude is distinctly related to both the resident's expected and experienced impact of wind farms, as well as significant in relation to multiple influencing factors at different phases over a wind farm's lifetime. A negative attitude is related to a higher level of impact or disturbance from the wind farm, while a positive attitude is related to a lower level of impact or disturbance.

Biodiversity

Null hypothesis (H_0): there is no difference in bird diversity between pre- and post-construction of the wind farm.

Alternative hypothesis (H_1): there is a difference in bird diversity between pre- and post-construction of the wind farm.

Regarding bird observations, the systematic study did not find any significant difference in the number of species before the wind park was constructed compared to after construction. In addition, the results differed from results from previous studies that have reported a decrease in the number of bird species (Coppes, et al., 2020; Gasparatos, et al., 2017). Although the data in our study were relatively close to significance, the reduction in species was relatively minor with two species. The results from the SSOS were not significant either. One difference is that there was a close to significant increase in the number of years when birds were reported, with 98% of the years covered post-construction compared to 76% before the wind farm was installed. A better resolution of data is important to be able to conclude changes in bird diversity. Additionally, regarding forest nesting birds, there was no difference in the number of species or visits between the pre- and post-construction years. However, the study found a positive correlation between the number of visits and the number of species found, suggesting that increased human activity in the area may have contributed to the observed increases in the number of species. The study failed to reject the null hypothesis (H_0), suggesting that there is no difference in bird diversity between pre- and post-construction of the wind farm.

Null hypothesis (H_0): there is no difference in lepidopteran diversity between pre- and post-construction of the wind farm.

Alternative hypothesis (H_1): there is a difference in lepidopteran diversity between pre- and post-construction of the wind farm.

The study found that there was a significantly higher number of visits of lepidopteran observers after the wind farm was constructed. The reason behind this could be due to increased awareness of being a popular place to find lepidopterans or increased accessibility due to new roads, which was also mentioned by the survey respondents. However, the actual reason behind this is unknown. In four out of five sites, the pre-construction period ended in 2010 or earlier. The Swedish Butterfly Monitoring Scheme started in 2010, which can explain the lower number of visits found in the pre-construction years, compared to the post-construction years. The study failed to fully reject the null hypothesis (H_0), suggesting that there is no difference in lepidopteran diversity between pre- and post-construction of the studied wind farms. Further, regarding both grassland and woodland butterflies, there was no significant difference found in the number of species or visits between the time periods. There was a possible, but not significant, tendence for an increase in the number of grassland species, and therefore future studies might investigate if the resulting change in landscape from clearing forests to erecting wind turbines might have any effect on the functional groups of butterflies locally. The results might suggest that not only overall butterfly diversity but also changes in species composition may be important to monitor in future follow-ups of wind farm effects.

The Shannon's diversity index on birds indicated a large decrease and increase in sites 2 and 4, respectively. At site 2 post-construction, a total of 10,162 Brambling (*Fringilla montifringilla*) were reported as observed, with

10,000 on one occasion. Brambling has been observed in large flocks of up to two million individuals (Jenni, 1987), and therefore this finding was kept in the data set. Whereas, at site 4 only 3 species at a sum of 6 individuals are reported as observed during the pre-construction years. In the post-construction years, there are 112 species reported and 1,405 individuals.

The species richness of birds and lepidopterans from the SSOS data hinted at an increase in post-construction, but there was no significant difference between the periods. However, there were differences in the response between the sites. Site-specific variations on birds can be identified, for example at site 4 where all variables increased after construction. Further, the positive correlation found for both birds and lepidopterans between the number of species and visits indicates that it not necessarily was a lower number of species in the areas during the earlier time period, but instead a lower number of visits. Additionally, the higher number of visits in post-construction can explain the hinted increase in the other variables as well, though, none were found significant. Prior research has indicated that wind farms can have adverse effects on bird populations (Coppes, et al., 2020; Gasparatos, et al., 2017; Rydell, et al, 2017). However, this study did not observe such an impact. The variation in response between the sites is worth noting and further studies of which factors might cause such differing responses (area, type of species involved, other factors). Typically, the effects of wind farm construction are determined for individual wind farms. The contrasting responses found in the present study indicate the importance of a more overall analysis to further improve the understanding of the placement of future wind farms.

Studies have found that site-specific characteristics are a determining factor in the effects on species diversity, with affecting factors such as design and placement of turbines, as well as species richness in the area (Coppes, et al., 2020; Gasparatos, et al., 2017; Rydell, et al., 2017). This may act as a reason for the differing observed response between the sites, since height and the number of turbines shifted.

Linear structures such as power-line corridors (PLCs) can influence the diversity and abundance of butterflies in adjacent habitats. Positive effects on butterfly richness and abundance have been noted up to a distance of 500m on both grassland and woodland butterfly species. Adding these structures in forested landscapes is beneficial for butterfly conservation while highlighting the importance of monitoring and conservation strategies to minimize any potential negative effects (Berg, et al., 2016). Developing wind farm installations in forested areas adds linear structures and can potentially be beneficial for local wildlife. Although no significant difference was found in the diversity of lepidopterans, the indication of an increase in grassland butterfly species during the post-construction years could possibly hint at a weak positive trend for grassland butterflies in forest ecosystems that are opened up by wind farm development. However, this trend was not significant in our study (p= 0.064).

While hill topping lepidopteran species may be vulnerable as many insects are killed by collisions with wind turbines each year, the potential impact on biodiversity and insect populations, and as a consequence predators in the food web, remains certain (Dhunny, et al., 2019; Voigt, 2021). While some individual insects or birds might be affected, the overall risk to populations is low (Osman, et al., 2023), which is consistent with the findings of this study. However, it should be noted that potential changes in populations or the arrival and disappearance of species have not been investigated.

Using multiple wind farms as study objects strengthens the findings by providing a comprehensive understanding of the effects, accounting for variability across different locations and conditions. Though, it should be acknowledged that this study only accounted for the establishment of the wind farm as an environmental change, thus not considering other activities or changes within the study areas, for example potential deforestation or other land-use changes. Although the long-term perspective is at the centre of this study, the uncertainties with citizen data need to be considered when interpreting the results. Forward, it is suggested that systematic monitoring is needed to understand the potential ecological impact of wind farms from such a perspective.

Local Impact on Humans

Null hypothesis (H_0): there is no association between distance to and the expected or experienced impact of the wind farm.

Alternative hypothesis (H_1): there is an association between distance to and the expected or experienced impact of the wind farm.

The results showed that the expected and perceived change in the local environment due to the wind farm is not affected by the distance between the individual and the wind farm. Further, no relationship was found between any of the everyday life factors or constructional activities and the respondent's distance to the wind farm. Two significant relationships were found regarding distance during the operational phase, suggesting that some audible and visual factors have a higher level of disturbance at a decreased distance. Although significant relationships between distance and noise and shadows, there were no significant relationships between the expected and perceived impact of the wind farm and, consequently, the null hypothesis (H_0) cannot be fully rejected.

Null hypothesis (*H_0*): there is no association between whether the resident lived in the area before the wind farm was constructed or moved there later, and the expected impact of the wind farm.

Alternative hypothesis (*H_1*): there is an association between whether the resident lived in the area before the wind farm was constructed or moved there later, and the expected impact of the wind farm.

The study shows that no investigated relationships were associated with whether or not the individual lived in the area before the wind farm was constructed or moved there later, the null hypothesis (H_0) was therefore failed to be rejected. Meaning, for example, that the expected impact of an individual who lived near the wind farm before it was constructed, does not differ from someone who moved there later.

Null hypothesis (*H_0*): there is no association between attitude towards wind power and the expected or experienced impact of the wind farm.

Alternative hypothesis (*H_1*): there is an association between attitude towards wind power and the expected or experienced impact of the wind farm.

The result showed that one's general attitude towards wind power had a strong association with the expected and perceived impact of a nearby wind farm, rejecting the null hypothesis (H_0). Specifically, a negative attitude is related to negative perceptions of the wind farm and its characteristics, while a positive attitude shows the opposite. Two-thirds of the factors or activities before and during construction and during the operational phase, are significant with attitude. Added, they all show the same pattern in the relationship between the level of impact and attitude, strengthening the hypothesis that one with a negative attitude is more likely to experience a negative impact, while the opposite is proved for someone with a positive attitude.

Additionally, no significant relationships were found between the three drivers' distance to the wind farm, whether the respondent moved to the area pre- or post-construction, and general attitude towards wind power. Studies have shown that individuals living closer to the wind farm generally are more positive (Krohn & Damborg, 1999), which is an association not found in this study. However, we did not find the opposite either, since there was no significance between the respondent's attitude and distance to the wind farm.

Noises from constructional activities such as groundwork are often disturbing for nearby residents (Folkhälsomyndigheten, 2019; Tolga & Budayan, 2016), implying that activities reasonably would be more disturbing closer to the wind farm. Though the result did not indicate that any constructional activities were associated with distance, they were with attitude. Implying that, as for other impact factors from the wind farm, a negative attitude is correlated with a higher level of experienced impact.

The effects in the operational phase in the form of noises and shadows have a significant correlation with distance, and both factors are the most mentioned when respondents explain how their local environment has changed. The low-frequency sound and infrasound generated by wind turbines can negatively affect human health and cause sleep disorders (Abbasi, et al., 2015; Ageborg Morsing, et al., 2018; Leventhall, Pelmear, & Benton, 2003). However, due to the distance required between residents and a wind farm in Sweden, which is 500m to isolated houses and 1000m to urban areas (Dalla Longa, et al., 2018), there is a lack of evidence that the infrasound generated by wind turbines have negative health effects (Naturvårdsverket, 2020).

A significant relationship has been found between sleep disorder and distance (Abbasi, et al., 2015), though this study did not. However, significant relationships are found between sleep disorder and attitude as well as noise and distance. This means that, since noises and sleep disorders are related, distance can indirectly be a decisive matter in terms of sleep disorder, where a reduced distance increases the human health impact (Frieberg, et al., 2019). Apart from noises, annoyance by direct visibility, shadows and blinking lights seem to be the most common causes of sleep disorder, while there are conflicting results on whether the visibility of the turbines, without audible noise, is a cause (Bakker, et al., 2012; Freiberg, et al., 2019).

Beyond the correlation with distance, a relationship between annoyance and attitude is observed in the perception and annoyance of shadow flickering among individuals living within 2km of a wind farm (Haac, et al., 2022). Additionally, the annoyance correlates with other factors such as the turbine visibility, educational level, and age (Haac, et al., 2022). This supports the correlation of shadows with both distance and attitude found in this study. Haac, et al., (2022) found a difference in perceived shadows between someone who moved to the area before the wind farm was constructed and someone who moved there after. Someone who moved there before had a greater likelihood of perceiving flickering shadows. The contradictory results found between our studies may be because of the difference in distance delimitations between this study and the one by Haac, et al. (2022), 5km vs 2km. Meaning that this study included more respondents that likely not would perceive shadows at all, irrespective of when they moved to the area, since the intensity of shadows from rotor blades decreases with an increasing distance (Haac, et al., 2022; Peri & Tal, 2021). However, interestingly, there was no significant correlation found between the annoyance of shadows and their exposure to them (Haac, et al., 2022). This shows that there is a possibility for a correlation between pre- and post-construction and shadows, but in this case, it may be dependent on the distance boundaries of the study.

However, since no respondent answered that shadows were a very big disturbance, it cannot be considered as the major disturbing factor of a wind farm.

The largest local opposition against wind farms is found in the planning phase (van der Horst, 2007) which is also where the attitude drops to be more negative (Ruddat, 2022). The reason for this may be that the residents have excessive expectations of the negative impacts of the wind farm (Ruddat, 2022). Our study found that the respondents' expectations of the wind farm were more negative before it was constructed and that the overall experienced disturbance was lower. Further, a respondent implied that the change in the local environment due to the wind farm was not as bad as they thought.

Studies have found that the effect on aesthetics, animals, health, and local environment is associated with attitude (Freiberg, et al., 2019; Katsaprakakis, 2012). The perception of the effects on aesthetics and the local environment is also related to other parameters, such as the structure of the surrounding landscape, the number of turbines, and their height (Freiberg, et al., 2019; Katsaprakakis, 2012). This indicates that apart from attitude being an influencing factor, this impact can be more site-specific.

The level of annoyance with factors such as noise and landscape change due to wind farms is determined by the individual's attitude towards wind power. A higher level of knowledge of energy technologies is linked to a positive attitude, and thereby a lower annoyance (Krohn & Damborg, 1999). Further, noise annoyance is correlated with the visual opinion of wind turbines and how well the individual considers the wind turbine to fit into the landscape, where the turbine can be viewed as more protruding in a flatter scenery (Pedersen & Larsman, 2008). One's perception of the landscape change is strongly related to their attitude (Ladenburg & Möller, 2011; Pouta, et al., 2024). The same associations are found in this study, that both noises and changed landscape are correlated with attitude where someone with a negative attitude is more likely to perceive the aspects to have a more negative effect.

There is a difference in the general attitude towards wind power of the respondents in the study compared to the national averages (Novus, 2023). There is a lower share of respondents with a positive attitude and a higher share of respondents with a neutral attitude. We do not know for sure if this is a coincidence or a result of the local impact of the wind farm. Since a potential change in attitude was not studied, it cannot be decided if the level of impact is the result of the attitude, or vice versa. However, irrespective of which is the driving factor, the relationship between the variables remains. To understand which is the driving factor, I recommend this to be investigated in future studies.

The attitude towards and acceptance of wind power in general can differ from that of wind farms, especially local wind farms, and wind power in general. Some may be positive towards wind power and its benefits as a renewable energy source but be negative towards the actual wind turbines in their proximity (Lindén, Rapeli, & Brutemark, 2015). This may be related to the positive impact seen in the rating of climate, which, however, did not have a significant relation to any driving factor. Since the survey was sent to only nearby residents of wind farms and asked about their potential impact from that wind farm, the answers on their general attitude towards wind power could be influenced by their attitude and opinion of the local wind farm. Which could result in a more negative attitude compared to the national average (Novus, 2023). Climate was the factor rated as the highest positive effect, meaning that the respondents may be positive towards wind power in general and have knowledge of the climate change challenges and thereby value the impact on climate as positive.

It is essential that local residents have a more positive attitude towards the project to enable renewable energy expansion, specifically wind farms (Ruddat, 2022), but also to ensure a lower negative effect. A changed landscape is unavoidable, and noise and light analyses are performed to ensure that limit levels are not exceeded (Naturvårdsverket, 2020), meaning that other aspects may need to be considered. How the number of turbines has an impact on the attitude is inconsistent, where results have shown a reduction in positive attitude when one sees more than five turbines, but also an increased positive attitude with an increased number of turbines (Krohn & Damborg, 1999; Pouta, et al., 2024). Additionally, the annoyance can be affected if the resident receives an economic benefit from the wind farm (Firestone, et al., 2018; Janssen, et al., 2011), which can decrease the noise annoyance, while the visibility of the turbines increases the annoyance (Janssen, et al., 2011). However, no such correlations were analysed in this study. Forward, it is recommended that the project developer take measures to make the project beneficial for the local community to promote a positive attitude while mitigating their negative effects. By accommodating the citizen's needs with close communication, for a greater understanding and involvement in the project, and offering economic funds to the community (Firestone, et al., 2018; Janssen, et al., 2011).

The key takeaway from this survey is that the experienced effect among the residents is highly related to their attitude towards wind power. The noted effect is dominantly perceived as small or non-existent, meaning that the wind farms do not have a widespread negative impact on the local community.

Methodology Discussion

Biodiversity

There is a risk that the usage of citizen data can affect the reliability of the result as there are a lot of uncertainties regarding that type of data. However, as the study ranged over a time period of 24 years, the possibility of more available data could increase. The decision was made due to a lack of sufficient data at the chosen sites, and therefore citizen data was considered good enough with the support of systematically collected data.

Survey

Due to the chosen methodology of the study, there was an unknown number of targeted participants between the groups of pre- and post-construction, resulting in a 1:4 ratio of post-construction respondents. The participant selection was random and hence should be representative of the population, however, there is a risk that the distribution is skewed. The ratio can be a cause of pre-construction individuals having more, and stronger, opinions and feelings towards the wind farm and therefore are more likely to answer the survey.

The question order, specifically concerning question 6 (Appendix 3), was carefully thought out. However, this posed a risk for anchoring, where the attitude sets the tone and influences the respondent to answer accordingly in the latter questions (Gehlbach & Barge, 2012). Having in mind that many have opinions on their local surroundings (Lindén, Rapeli, & Brutemark, 2015) and therefore the wind farm, there was a risk that the other questions would have influenced their answer on question 6 if it was placed later in the sequence. Since question 6 acted as the basis for one of the driving factors investigated in the study, I do believe that this was the right sequence.

Conclusions

Wind farms primarily impact avian species through collisions with turbines, creating barriers and destroying habitats. Rare and endangered bird species, especially raptors, face the greatest risk. For birds, our study found no significant difference in species diversity before and after wind farm construction, contrasting with previous studies. Increased human activity correlated with more species observed, suggesting more visits rather than an actual increase in diversity. For lepidopterans, observer visits increased post-construction, possibly due to increased awareness and accessibility, but this did not result in a significant difference in diversity. Site-specific variations were notable, with some sites showing increased variables post-construction. The positive correlation between species and visits suggests that a lower number of species in pre-construction years might be due to fewer observations rather than an actual lower number of species. Overall, the study did not find significant changes in bird or lepidopteran diversity due to wind farm construction. Further research is needed to refine strategies for wind farm placement and management to minimize potential long-term impacts on local wildlife.

The impact of local wind farms on communities is closely intertwined with residents' attitudes towards wind power in general. A negative attitude is often related to the perception of a negative impact, while a positive attitude tends to result in the perception of a more positive or neutral impact. The effects are observed across all phases of wind farm development, with prominent effects observed in health concerns, aesthetics, landscape change, and noise and shadow disturbances. Further, the distance from the wind farm influences the level of disturbance experienced during its operational phase, particularly regarding noise and shadow flickering. As distance decreases, so does residents' tolerance for these disturbances, highlighting the importance of considering proximity in wind farm development. Interestingly, whether the resident moved to the area before or after the wind farm was constructed does not significantly change their expectations or experiences of its impact. Going forward, it is crucial to further examine the relationship between attitudes towards wind power and the experienced effects of local wind farms. Understanding whether attitudes drive perceptions or vice versa, can provide insights for developing more effective strategies for community engagement and impact mitigation. In summary, this study highlights the importance of adopting diverse strategies in wind farm development, that prioritize the communities' attitudes and their concerns. By engaging residents in decision-making processes to accomplish a positive relationship with the community, we can better navigate the renewable energy expansion while striving to mitigate adverse effects on local communities.

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Appendices

Appendix 1

Table 11. Species observed in Sweden.

Nesting birds in forests	Grassland butterflies	Woodland butterflies
Tetrao urogallus	*Ochlodes sylvanus*	*Ochlodes sylvanus*
Tetrastes bonasia	*Erynnis tages*	*Gonepteryx rhamni*
Columba oenas	*Anthocharis cardamines*	*Callophrys rubi*
Picus viridis	*Cupido minimus*	*Nymphalis antiopa*
Dryobates minor	*Phengaris arion*	*Melitaea athalia*
Picoides tridactylus	*Polyommatus semiargus*	*Argynnis paphia*
Aegithalos caudatus	*Polyommatus icarus*	*Coenonympha arcania*
Periparus ater	*Lycaena phlaeas*	*Pararge aegeria*
Lophophanes cristatus	*Euphydryas aurinia*	*Aphantopus hyperantus*
Poecile palustris	*Coenonympha pamphilus*	*Erebia ligea*
Poecile montanus	*Maniola jurtina*	
Poecile cinctus	*Lasiommata megera*	
Certhia familiaris		
Perisoreus infaustus		
Nucifraga caryocatactes		
Pyrrhula pyrrhula		

Appendix 2

Table 12. Reported findings of birds and lepidopterans in the Swedish Species Observation System, presented in total number of years within each time period (pre- and post-construction) and years with available data points in each period.

Study object	**Pre-construction**	**Total no. of years**	**Available data points (years)**		**Post-construction**	**Total no. of years**	**Available data points (years)**	
			Birds	Lepidopterans			Birds	Lepidopterans
Site 1	2000–2008	9	6	2	2009–2023	15	15	7
Site 2	2000–2010	11	11	8	2011–2023	13	13	13
Site 3	2000–2010	11	10	11	2011–2023	13	13	12
Site 4	2000–2010	11	5	2	2011–2023	13	12	13
Site 5	2000–2019	20	15	8	2020–2023	4	4	4

Appendix 3

Survey

* Obligatoriskt

Thank you for taking the time to contribute to my thesis!

The questionnaire takes about 10 minutes to answer. The data is handled confidentially and you as a participant are anonymous. Collected material will only be used for this study. For questions, contact me via email: agnrot20@student.hh.se

As a participant, you have the right to cancel your participation at any time during the survey if desired, you can edit your answers until you close the web tab.

1. What gender do you identify as? *

- ◯ Woman
- ◯ Man
- ◯ Another option
- ◯ Prefer not to say

2. Age? *

- ◯ 16-30
- ◯ 31-45
- ◯ 46-60
- ◯ 61-75
- ◯ 76+

3. In which sector do you describe yourself? Select one option. *

- ◯ Student
- ◯ Working from home
- ◯ Working away
- ◯ Currently not working
- ◯ On parental leave
- ◯ Retired
- ◯ Other

4. What is the main reason/reasons you live in this area? Select one or more options. *

- ☐ Work
- ☐ Economy
- ☐ From the area
- ☐ Closeness to family and friends
- ☐ Agriculture
- ☐ Outdoor life (visiting the natural landscape)
- ☐ Hunting and fishing
- ☐ Garden and cultivation
- ☐ Animals
- ☐ Health and sports
- ☐ Annat

5. What is your general attitude toward wind power as a renewable energy source? Select one option. *

- ◯ Positive
- ◯ Neutral
- ◯ Negative

6. What year did you move to your current address? *

- ◯ 2010 or earlier
- ◯ 2011 or later

7. How did you expect the wind farm to affect your everyday life? Select one option. *

- ◯ No impact
- ◯ Little impact
- ◯ Great impact
- ◯ Very big impact

8. If you expected to be affected, how did you rate the following aspects? Select one option per line.

	Positively	Neutral	Negatively	Did not take this into account
Aesthetics	◯	◯	◯	◯
Health	◯	◯	◯	◯
Animals	◯	◯	◯	◯
Climate	◯	◯	◯	◯
Local environment	◯	◯	◯	◯

9. Were your expectations met? (Unchanged = 5) *

0	1	2	3	4	5	6	7	8	9	10

Not fulfilled at all — Fulfilled completely

10. How do you experience the following factors from the wind farm in your surroundings today? Select one option per line. *

	No disturbance	Small disturbance	Quite a disturbance	Very big disturbance
Noise from the wind turbines	○	○	○	○
Shadows from the rotor blades	○	○	○	○
Changed landscape	○	○	○	○
Sleep disorder	○	○	○	○
Warning lights	○	○	○	○

11. How many wind turbines from the "Site 2" wind farm can you see from your home? Answer in numbers. *

12. How many days do you spend outdoors (within 1km) in the vicinity of the wind turbines during a week? Select one option. *

- ○ I do not spend time in the area
- ○ Once a week
- ○ 2-3 times a week
- ○ 4-6 times a week
- ○ Every day

13. If you spend time in the vicinity of the wind turbines, which activities do you engage in? Select one or more options.

- ☐ I live in the area
- ☐ Physical activity (exercise, sports)
- ☐ Animals
- ☐ Outdoor life
- ☐ Hunting and fishing
- ☐ Berry and mushroom picking
- ☐ Annat

Questions 14 to 16 are **only** answered by you who moved to the address in **2010 or earlier.**

If you moved to the address in 2011 or later, go directly to question 17.

14. How did you experience the following activities during the construction period? Select one option per line.

	No disturbance	Small disturbance	Quite a disturbance	Very big disturbance	I do not remember
Transports	◯	◯	◯	◯	◯
Groundwork	◯	◯	◯	◯	◯
Increased traffic	◯	◯	◯	◯	◯
Noises	◯	◯	◯	◯	◯
Lights	◯	◯	◯	◯	◯

15. How do you feel that your local environment has changed since the wind turbines were put into operation? Select one option.

- ◯ No change has occured
- ◯ Small change
- ◯ Quite a change
- ◯ Very big change

16. If you feel that your immediate environment has changed, describe in what way.

Questions 17 to 18 are **only** answered by you who moved to the address in **2011 or later.**

If you moved to the address in 2010 or earlier, you are now done with the survey. Thank you for your participation. Go to the bottom of the page and click "send" if you are completing the survey digitally.

17. Did you take the wind farm into account in your decision to move to the address?

○ Yes

○ No

18. If yes, describe in what way.

Appendix 4

Information letter attached to the survey sent to all residents.

HÖGSKOLAN I HALMSTAD

Halmstad, 29 February 2024

Hi!

My name is Agnes Rottbers, and I am studying the master's program in Applied Environmental Science - Ecosystem Services and Natural Resource Management at Halmstad University. I would appreciate it if you would take a few minutes to answer my survey about 'NAME' wind farm. The goal is for the study to contribute with data and guidance for future establishment of wind farms.

I am writing my thesis in collaboration with Arise AB on the impact of wind farms on people and nature. The purpose of my study is to map and analyse how the perceived impact of wind farms changes over time. This survey is used to collect data on the impact on people. The survey is aimed at randomly selected people living around the 'NAME' wind farm. It takes about 10 minutes to answer and includes questions about how you experience your immediate environment.

The data will be handled confidentially, and participating respondents will not be named in the work. You as a participant are anonymous. Collected material will only be used to do my thesis and the data material will be destroyed after completion of work. If you have questions, you are welcome to contact me via email: agnrot20@student.hh.se

You are welcome to fill in the survey digitally by scanning the QR code with your mobile camera. If you would rather use the paper survey, that is just as well, please return it in the enclosed reply envelope by March 31, 2024, at the latest.

Thank you very much for taking the time to contribute to my thesis!

Best regards,
Agnes Rottbers

By answering and sending this survey, you agree that I (Agnes Rottbers) may use the collected data for my degree project.

Appendix 5

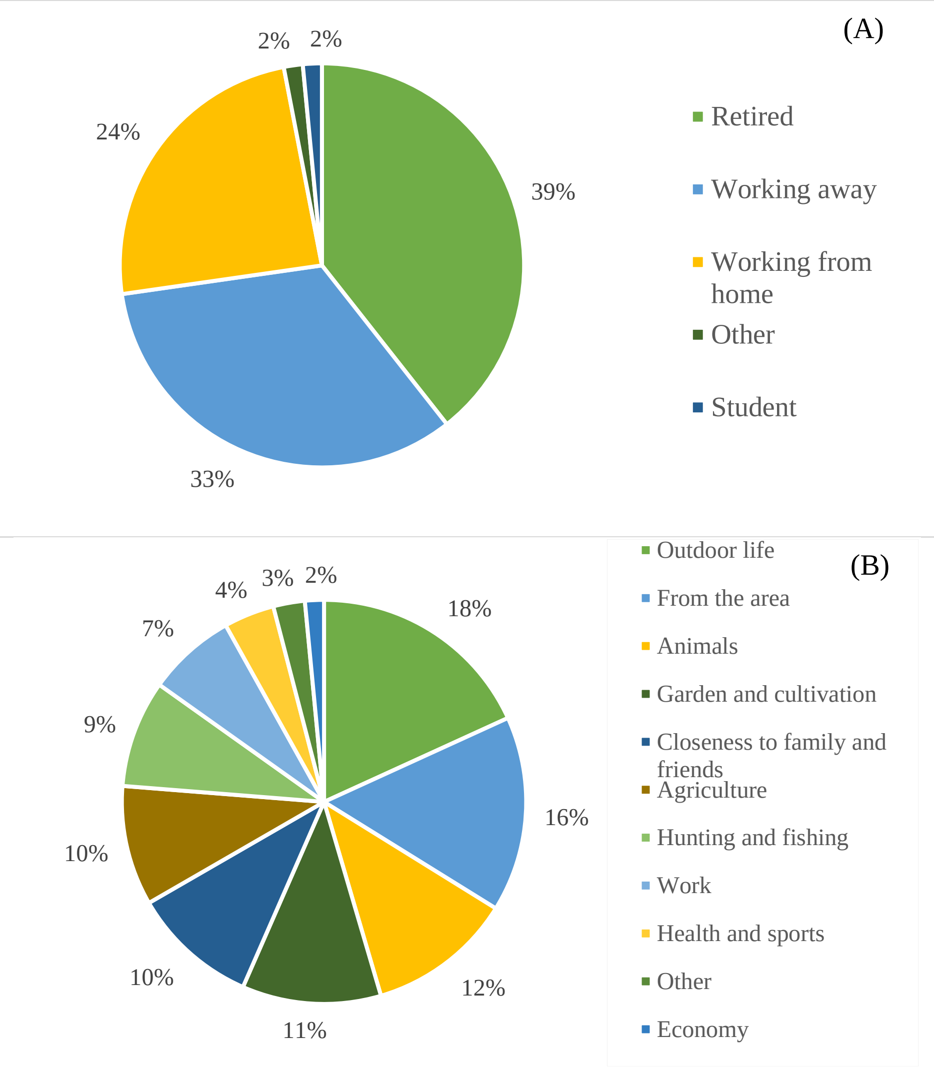

Figure 18. The resident's occupation (A) and their main reasons for living in the area (B). (*N*=66)

Appendix 6

Table 13. Results of Fisher's test of the relationship between survey questions 8, 10 and 14 and distance to the wind farm, the pre- and post-construction groups, and attitude towards wind power in general.

Survey question	Factors	**Distance** Fisher's value	**Pre/post-construction** Fisher's value	**Attitude** Fisher's value
8. If you expected to be affected, how did you rate the following aspects?	Aesthetics	4.529	2.448	12.427*
(negative, neutral, positive, did not take this into account)	Health	6.355	1.296	11.206*
	Animals	3.968	5.760	13.175*
	Climate	3.739	1.652	11.168
	Local Environment	6.639	.152	10.946*
10. How do you experience the following factors from the wind farm in your surroundings today?	Noise from the wind turbines	13.675*	1.676	12.895*
	Shadows from the rotor blades	13.230*	.923	5.750
(no disturbance, small disturbance, quite a disturbance, very big disturbance)	Changed landscape	4.199	.479	15.270*
	Sleep disorder	4.512	1.082	12.772*
	Warning lights	.974	1.248	6.821
14. How did you experience the following activities during the construction period? [1]	Transports	2.650	-	9.351
	Groundwork	1.944	-	8.554*
(no disturbance, small disturbance, quite a disturbance, very big disturbance, do not remember)	Increased traffic	6.214	-	8.675
	Noises	3.710	-	14.408*
	Lights	3.004	-	9.976*

[1] Question only answered by pre-construction group.

* Symbolises significant results.