A Comparative Study of Deadwood Quantity, Structure and Management

In Urban, Production, and Natural Beech Forest Landscapes in Skåne

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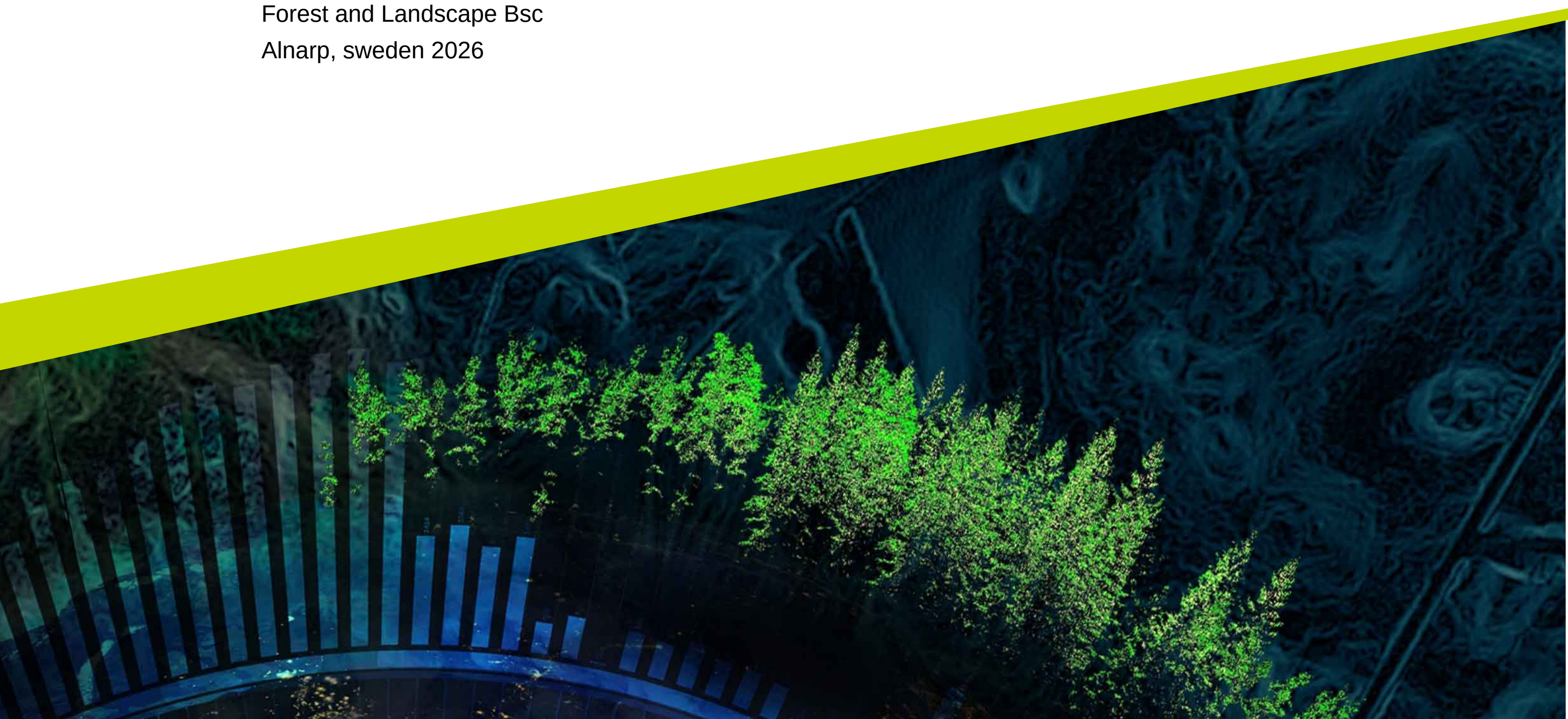

A Comparative Study of Deadwood Quantity, Structure, and Management in Urban, Production, and Natural Beech Forest Landscapes in Skåne

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Abstract

Deadwood is an important structural component of forest ecosystems and supports biodiversity, nutrient cycling, and ecological processes. However, its quantity and characteristics vary across forest types due to differences in management and landscape use.

This study examines standing and downed deadwood in three beech forest types in Skåne, Sweden: an urban forest (Pildammsparken), a production forest (Fulltofta), and a natural forest (Söderåsen). Field data were collected using a full inventory for standing deadwood and line-intersect sampling for downed deadwood. Measurements included diameter, decay class, and number of deadwood pieces. Basal area (m^2/ha) was calculated for standing deadwood, and volume (m^3/ha) was estimated for downed deadwood.

Results showed relatively small differences in the number of downed deadwood pieces across the sites, but clearer differences in diameter, decay stages, and estimated volume. Pildammsparken had larger diameters and the highest volume, influenced by a few large logs. Söderåsen showed greater variation in decay classes and the highest basal area, indicating higher structural diversity. Fulltofta showed intermediate characteristics.

The findings highlight that deadwood structure is as important as quantity. From a landscape perspective, forest management should balance ecological functions with safety and recreational needs.

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Abbreviations

Abbreviation	Full Term
BA	Basal Area
CCF	Continuous Cover Forestry
dbh	Diameter at Breast Height
LIS	Line-Intersect Sampling
m^2/ha	Square metres per hectare
m^3/ha	Cubic metres per hectare
TreMs	Tree-related Microhabitats

Terminology

In this thesis, “snag” refers to standing deadwood, and the two terms are used interchangeably throughout the text.

1. Introduction

Deadwood is an important component of forest ecosystems and plays a key role in supporting biodiversity and ecosystem functioning (Harmon et al., 1986; Stokland et al., 2012). As trees die and decompose, they provide habitat for a wide range of organisms, including fungi, insects, and birds. The ecological value of deadwood depends on its structural characteristics, particularly size and stage of decay, which influence the diversity of species it can support (Stokland et al., 2012).

The quantity and structure of deadwood vary across forest types, largely due to differences in management practices and land use. In natural forests, deadwood is generated through natural processes and retained over long periods, resulting in a wide range of sizes and decay stages. In production forests, activities such as harvesting and thinning can reduce or alter deadwood availability. In urban forests, management often prioritises safety, accessibility, and maintenance, which can lead to the removal of dead or hazardous trees (Paletto et al., 2022). Consequently, both the quantity and structural diversity of deadwood differ between urban, production, and natural forest systems.

This study focuses on three beech forest sites in Skåne, southern Sweden, representing different management contexts. Fulltofta represents a production-oriented forest landscape managed by Stiftelsen Skånska Landskap, where forestry practices influence forest structure and deadwood availability (Stiftelsen Skånska Landskap, 2026). Pildammsparken is an urban park in Malmö, where management prioritises public use, safety, and landscape maintenance (Malmö Stad, 2026). Söderåsen National Park is a protected natural forest where ecological processes are largely allowed to develop with minimal intervention (Sweden's National Parks, 2026). Together, these sites represent a gradient of management intensity, from highly managed urban environments to minimally disturbed natural forests.

Understanding how deadwood varies across forest types is important from both ecological and management perspectives. While deadwood supports biodiversity, it may also be perceived as unsafe or aesthetically undesirable, particularly in urban environments (Paletto et al., 2022). This highlights the need to balance ecological functions with management objectives in different landscape contexts.

1.1 Aim of study

The aim of this study is to examine how forest management influences the quantity, structural characteristics, and management of deadwood across urban, production, and natural beech forest landscapes in Skåne.

1.1.1 Research question/hypothesis

The study is guided by the following main research question:
How does forest management influence the quantity, structural characteristics, and management of deadwood across urban, production, and natural beech forests?

To address this, the study considers the following sub-questions:
• How do the quantity and structural characteristics of deadwood differ between forest types?
• How is deadwood managed in each forest type?
• What factors, such as biodiversity, safety, and recreation, influence management decisions?

It is hypothesised that natural beech forests will contain the greatest quantity and diversity of deadwood due to limited intervention and ongoing natural ecological processes. Urban forests are expected to contain the lowest amount of deadwood, as management often prioritises safety, accessibility, and visual order. Production forests are expected to show intermediate levels, reflecting the influence of active management while still retaining some deadwood pieces

2. Methodology

This study employed a comparative, field-based approach to assess deadwood distribution and structural characteristics, including diameter and decay class, across three forest types: an urban forest (Pildammsparken), a production forest (Fulltofta), and a natural forest (Söderåsen). The study focused on beech-dominated stands to ensure consistent species composition and comparability across sites.

A mixed-methods approach was applied, combining quantitative field measurements of deadwood with qualitative information obtained from site managers through questionnaires and interviews (Stroud et al., 2020). This allowed both a structural assessment of deadwood and an interpretation of management influences across different landscape contexts.

Two complementary sampling methods were used within each study plot. Standing deadwood was assessed using a full inventory approach, where all standing dead trees meeting the inclusion criteria were recorded. Downed deadwood was sampled using the line-intersect sampling (LIS) method, where only deadwood pieces intersecting predefined transects were included (Van Wagner, 1968). Together, these methods provided a comprehensive assessment of both standing and downed deadwood components.

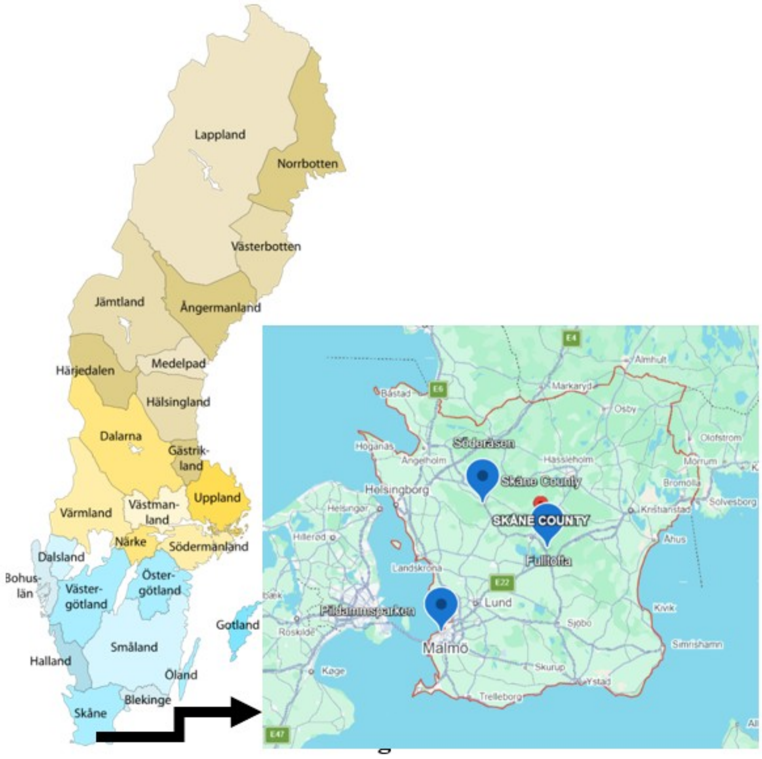
2.1 Study area and site selection

This study focuses on three beech forest sites in Skåne, southern Sweden, representing different management contexts. The geographical locations of the study sites are shown in Figure 1. Site selection was based on beech dominance, representation of urban, production, and natural forest types, accessibility for fieldwork, and suitability for establishing a one-hectare study plot. Aerial photographs of the three study sites are presented in Figure 2.

Pildammsparken is an urban park in Malmö covering approximately 45 ha (Malmö Stad, 2026). Information obtained through communication with the site manager indicated that the sampled beech stand is approximately 75 years old and was established through planting. A one-hectare study plot was selected for deadwood sampling.

The study site in Fulltofta represents a managed forest landscape with multiple management objectives, including timber production, nature conservation, and recreation. The area forms part of the land managed by Stiftelsen Skånska Landskap, which manages approximately 11,000 ha of land across Skåne for forestry, conservation, and outdoor recreation (Stiftelsen Skånska Landskap, 2026). Information obtained from the site manager indicated that the sampled beech stand is approximately 90 years old and was established through planting. A one-hectare study plot was selected for deadwood sampling.

Söderåsen National Park represents a natural forest and covers approximately 1,625 ha (Sweden’s National Parks, 2026). Information obtained from the site manager indicated that the sampled beech stand is estimated to be 80 to 120 years old. According to the site manager, the stand is not a virgin forest and is considered a first-generation forest at the site. However, it could not be confirmed whether the stand originated from planting or natural regeneration. A one-hectare study plot was selected for deadwood sampling.



- Study sites
- Red boundary Skåne County
- Black arrow location of Skåne within Sweden

Figure 1. Location of the three study sites in Skåne, southern Sweden. (a) Location of Skåne County within Sweden. (b) Location of the study sites: Pildammsparken (urban forest), Fulltofta (production forest), and Söderåsen National Park (natural forest). ***Source:*** *Wikimedia Commons (2006), modified by the author*

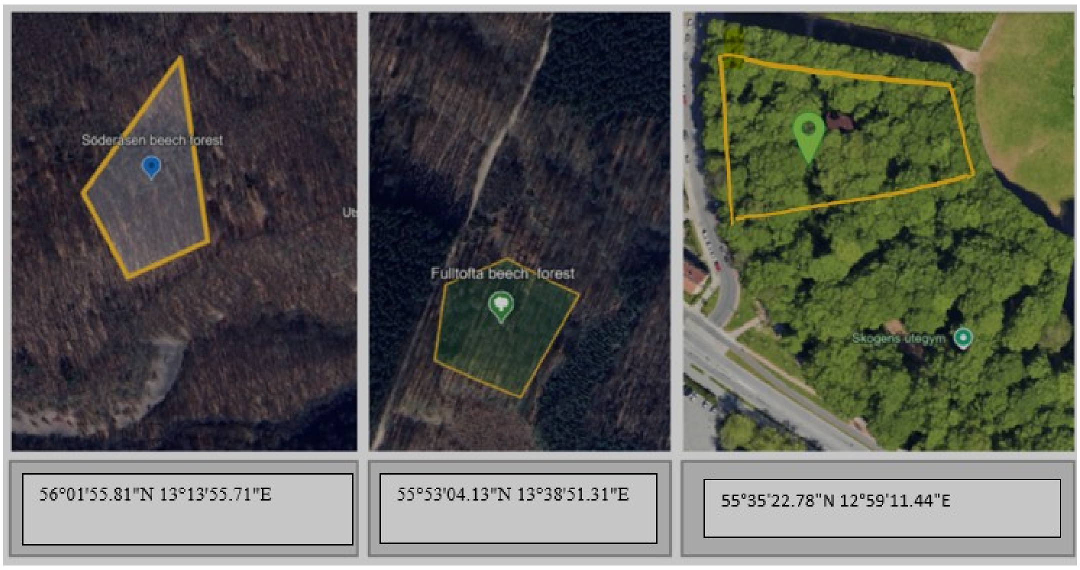


Figure 2. Aerial photographs of the three study sites: Söderåsen (natural forest), Fulltofta (production forest), and Pildammsparken (urban forest).

2.2 Qualitative and data collection

Qualitative information was collected using questionnaires, telephone communication, email correspondence, and interviews.

A common set of questions was used across the three study sites to collect information on management objectives, deadwood management, biodiversity, recreation, and safety.
However, the method of data collection differed between sites. Information for Pildammsparken was collected through telephone communication using the questionnaire framework.

For Söderåsen, information was obtained through a questionnaire and follow-up telephone communication with the site manager.

For Fulltofta, information was collected through a site visit and interviews with the forest manager and other staff members.

The questionnaire used in this study is provided in Appendix 1. The same set of questions was also used during telephone interviews and follow-up discussions when clarification of site-specific information was required.

A summary of the qualitative data collection approach and key themes is presented in Tables 1a and 1b.

Study Site	Forest Type	Respondent Role	Interview Method
Pildammsparken	Urban	Park Manager	Phone interview
Fulltofta	Production	(Verksamhetsansvarig Naturvård)	Phone interview, on-site visit, questionnaire
Söderåsen	Natural	Conservation Manager	Questionnaire, phone interview

Table 1a. Site, respondent role, and data collection method

Study Site	Key Focus Areas	Example Topics Discussed
Pildammsparken	Safety, recreation, management	Removal of deadwood, public safety concerns, and landscape use
Fulltofta	Forest management, biodiversity	Continuous cover forestry, selective retention of deadwood
Söderåsen	Biodiversity, conservation	Deadwood retention, ecological importance of beech forests

Table 1b. Interview focus areas and example topics

One site manager or representative was consulted for each study site. The interviews are described in Table 1a and Table 1b, and the questionnaire and interview guide used in this study are provided in Appendix 1 and Appendix 2. Responses were used to support the interpretation of observed deadwood patterns.

2.3 Plot Delineation

At each site, a study plot of approximately 1 hectare was delineated prior to fieldwork using Google Earth imagery in combination with field-based navigation. Plot boundaries were selected to represent typical stand conditions within each forest type and, where possible, to avoid edges, paths, and highly disturbed areas.

Due to natural variability in terrain and stand structure, plot shapes were not always perfectly regular. However, all sampling was conducted strictly within the defined plot boundaries.

2.4 Sampling of Standing Deadwood

Standing deadwood was assessed using a full inventory approach within each one-hectare plot. This approach ensured that all standing dead trees meeting the inclusion criteria were recorded, providing a complete representation of snag abundance within each site.

All standing dead trees with a diameter at breast height (dbh) ≥10 cm and a length exceeding 1.3 m were included, consistent with standard forest inventory protocols (Jonsson et al., 2016). The measurement procedure is illustrated in Figure 3.

Figure 3. Measurement of the diameter at breast height (dbh) of standing deadwood using a calliper.

For each standing deadwood piece, the dbh and decay class were recorded. Diameter was measured at approximately 1.3 m above ground level using a calliper. In cases where the diameter exceeded the capacity of the calliper, a measuring tape was used to measure stem circumference, which was then converted to diameter. Each measured tree was marked to avoid double-counting.

2.5 Basal Area Calculation

The basal area of standing deadwood was calculated to provide a combined measure of tree size and abundance. The basal area was calculated for each snag using dbh and summed for each study site.

$$BA=\frac{\pi d^2}{4}$$

where:

- **BA** = basal area (m²)
- **d** = diameter at breast height (m)

All diameters measured in centimetres were converted to metres prior to calculation. The total basal area was expressed as square metres per hectare (m²/ha).

2.6 Sampling of Downed Deadwood

Downed deadwood was sampled using the line-intersect sampling method, a widely used and efficient approach for estimating coarse woody debris (Van Wagner, 1968). This method quantifies downed deadwood based on pieces intersecting a transect line. The measurement procedure is illustrated in Figure 4.

Figure 4. Measurement of downed deadwood diameter at the point of intersection along a line transect using the LIS method.

2.7 Transect Layout

Within each study plot, four line transects (U1–U4) were established. The spatial arrangement of transects within each plot is illustrated in Figure 5. Each transect was 20 m in length, resulting in a total transect length of 80 m per site. Transects were arranged parallel to one another and maintained a consistent orientation within each plot to ensure comparability.

One transect was positioned centrally within the plot, while the remaining three were distributed across different areas to capture spatial variation in deadwood distribution. In irregular plots, transects were adjusted to remain within boundaries while maintaining adequate spatial coverage.

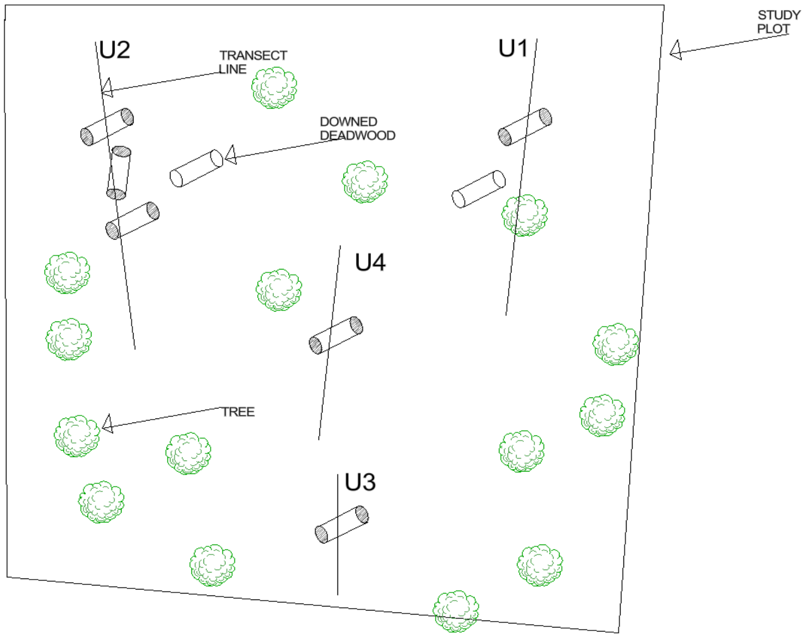


Figure 5. Schematic illustration of transect placement within a study plot, designed by the Author

Only deadwood pieces directly intersecting the transect line were recorded, following standard LIS protocol (Van Wagner, 1968).

2.8 Data Collection and Volume Estimation

All downed deadwood pieces with a diameter ≥10 cm intersecting each transect were recorded. For each intersecting piece, the diameter at the point of intersection and decay class were noted. Only pieces whose central axis was intersected by the transect line were included.

Each piece was recorded once at the point of intersection. Only diameter measurements were required, as deadwood length is not needed in the LIS method.

The recorded diameters were used to estimate downed deadwood volume per hectare (m³/ha) using the LIS method (Van Wagner, 1968):

$$V=\frac{\pi^2 \sum d^2}{8L}$$

where:

- v = volume of downed deadwood
- d = diameter of each intersecting piece (m)
- L = total transect length (m)

Diameters were converted from centimetres to metres before calculation. The total transect length was 80 m per site. Results were expressed as cubic metres per hectare (m^3/ha) to allow comparison across forest types.

2.9 Decay Classification

Deadwood was classified into decay classes based on visual field assessment, representing progressive stages of decomposition from recently dead wood to highly decomposed material.

The classification was adapted from the Swedish National Forest Inventory (2021), which defines decomposition stages based on wood softness and structural integrity. Deadwood was classified into five decay classes, as described in Table 2.

Decay Class	Description
Class 1	Recently deadwood: wood hard, structure intact, bark and/or foliage may be present.
Class 2	Wood mostly hard; minor signs of decomposition, little structural change
Class 3	Early decomposition: 10–25% of wood softened, some structural breakdown
Class 4	Moderate decomposition: 26–75% of wood softened, structure weakening
Class 5	Advanced decomposition: 76–100% of wood softened, structure largely lost

Table 2. Description of decay classes (adapted from Swedish NFI)

3. Results

3.1 Standing Deadwood

The number and structural characteristics of standing deadwood varied across the three study sites and are summarised in Table 3. A total of 7 standing deadwood were recorded in both Fulltofta and Söderåsen, while 2 standing deadwood were recorded in Pildammsparken.

Mean standing deadwood diameter differed among sites. Pildammsparken exhibited the highest mean diameter (47.70 cm), followed by Söderåsen (38.64 cm) and Fulltofta (33.43 cm). The two standing deadwood recorded in Pildammsparken showed substantial variation in diameter (19.0 cm and 76.4 cm).

The basal area of standing deadwood also differed among sites. Söderåsen exhibited the highest basal area (0.89 m²/ha), followed by Fulltofta (0.62 m²/ha) and Pildammsparken (0.49 m²/ha).

Decay class distribution varied among sites and is summarised in Table 4. In Fulltofta, decay classes 2, 4, and 5 were the most frequently recorded, while decay class 3 occurred less often. In Söderåsen, all five decay classes were represented, with decay classes 2 and 3 being the most frequent. In Pildammsparken, only decay classes 2 and 4 were recorded.

Overall, Söderåsen exhibited the widest range of decay classes, indicating greater variation in decomposition stages than the other study sites.

Study Site	Number of snags	Mean Diameter (cm)	Basal Area (m²/ha)
Fulltofta	7	33.43	0.62
Pildammsparken	2	47.70	0.49
Söderåsen	7	38.64	0.89

3.1.1 Table 3. Structural characteristics of standing deadwood across study sites

As shown in Figure 6, Söderåsen exhibited the highest basal area, followed by Fulltofta and Pildammsparken.

Study Site	Recorded Decay Classes
Fulltofta	Classes 2, 3, 4 and 5
Pildammsparken	Classes 2 and 4
Söderåsen	Classes 1, 2, 3, 4 and 5

3.1.2 Table 4. Decay classes recorded for standing deadwood across the study sites.

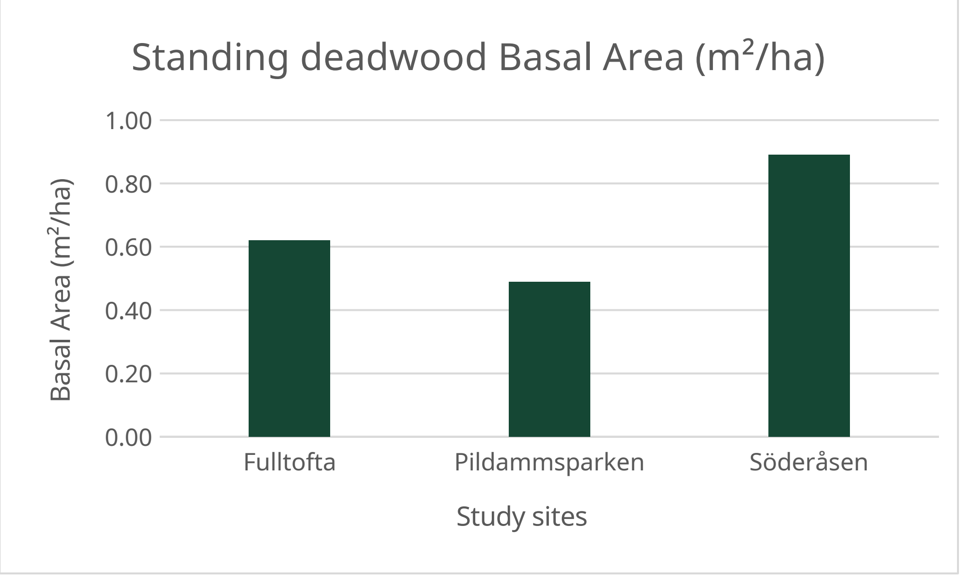


Figure 6. Basal area (m²/ha) of standing deadwood across study sites

3.2 Downed Deadwood

The quantity and structural characteristics of downed deadwood varied across the three study sites. A total of 13 pieces were recorded in Fulltofta, 14 in Pildammsparken, and 12 in Söderåsen. Detailed transect-level data are provided in Appendix 3.
Mean diameter differed slightly among sites. Pildammsparken exhibited the highest mean diameter (27.95 cm), followed by Fulltofta (25.58 cm) and Söderåsen (24.46 cm).

At the transect level, variation in both the number of pieces and mean diameter was observed within each site. In Fulltofta, the number of pieces per transect ranged from 2 to 4, with mean diameters ranging from 15.50 cm to 29.75 cm. In Pildammsparken, the number of pieces ranged from 2 to 7 across transects, with the highest mean diameter recorded in transect U1. Söderåsen showed a more even distribution of both the number of pieces and mean diameter across transects.

Decay class distribution also varied across sites and transects. In Fulltofta, decay class 5 was most frequent in transects U1, U2, and U4. In Pildammsparken, decay class 5 was most frequent in transects U1 and

U2, while decay class 3 was most frequent in transects U3 and U4. In Söderåsen, decay classes ranged from 1 to 5 across transects.

3.3 Downed Deadwood Volume

The estimated volume of downed deadwood across sites is presented in Table 5. The highest volume was recorded in Pildammsparken (231.43 m^3/ha), followed by Fulltofta (141.65 m^3/ha) and Söderåsen (122.56 m^3/ha).

Study Site	**Volume (m^3/ha)**
Fulltofta	141.65
Pildammsparken	231.43
Söderåsen	122.56

3.3.1 Table 5. Estimated volume of downed deadwood (m^3/ha)

As shown in Figure 7, Pildammsparken exhibited the highest estimated volume of downed deadwood**.**

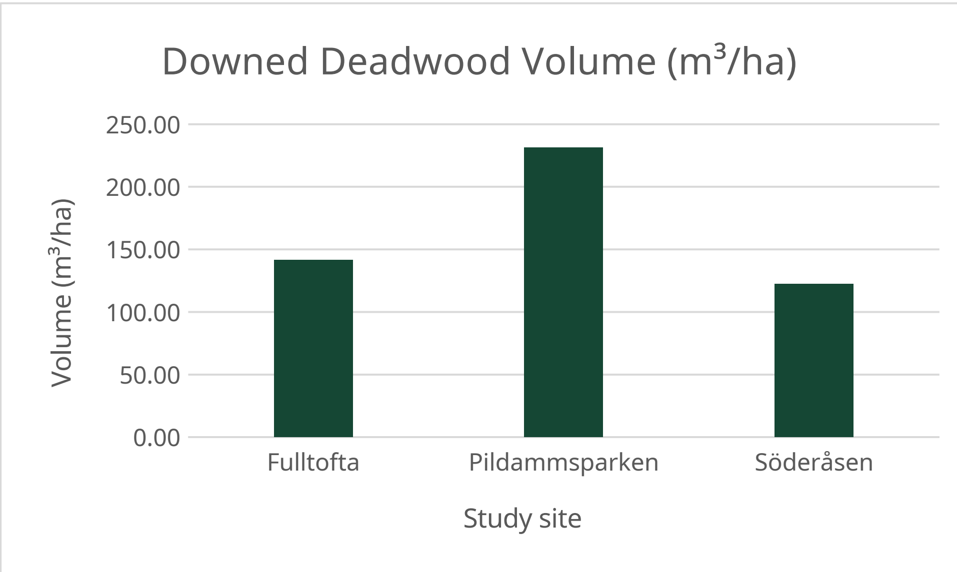


Figure 7. Estimated volume (m^3/ha) of downed deadwood across study sites.

3.4 Questionnaire and Interview Results

From the interviews and questionnaires, all respondents considered deadwood important for biodiversity.
The responses showed that safety was an important management consideration across all study sites, although it was given greater priority in the urban forest because of its recreational function and higher public use. The interviews also highlighted differences in management objectives between the study sites.

Biodiversity conservation was the primary objective in Söderåsen, while Fulltofta combined production, conservation, and recreational objectives.

In Pildammsparken, management focused mainly on recreation and public safety. Overall, the responses indicated that deadwood management is influenced by a balance between biodiversity, safety, and site-specific management objectives.

3.5 **Summary of Results**

Across all sites, differences were observed in both standing and downed deadwood characteristics. The number of downed deadwood pieces was similar across sites, while variation was evident in mean diameter, decay class distribution, basal area, and estimated volume. Pildammsparken exhibited higher mean diameter and volume values, Fulltofta showed a higher occurrence of advanced decay stages, and Söderåsen displayed a broader range of decay classes.

4. Discussion

4.1 Standing Deadwood

The study revealed clear differences in the quantity and structural characteristics of standing deadwood across the three sites, reflecting variations in forest management and landscape context. Fulltofta and Söderåsen contained more snags than Pildammsparken, consistent with differences in management objectives. In urban forests such as Pildammsparken, trees that pose potential safety risks are often removed, leading to reduced levels of standing deadwood. This pattern is generally consistent with previous findings that managed and urban forests tend to contain lower amounts of deadwood due to human intervention (Jonsson et al., 2016; Korhonen et al., 2020).

In contrast, Söderåsen exhibited a broader range of diameters and decay classes, indicating greater structural variability typical of forests where natural processes dominate. This pattern is further supported by basal area results, which showed that Söderåsen had the highest basal area despite not having the largest mean diameter. This highlights the importance of considering both tree size and abundance when assessing the structure of standing deadwood.

Standing deadwood was also observed to contain tree-related microhabitats (TreMs), including cavities and fungal-associated structures, as shown in Figure 8. Although these features were not systematically recorded, their presence reinforces the ecological importance of retaining standing deadwood, as these structures provide habitat for a wide range of organisms (Löfroth et al., 2023).

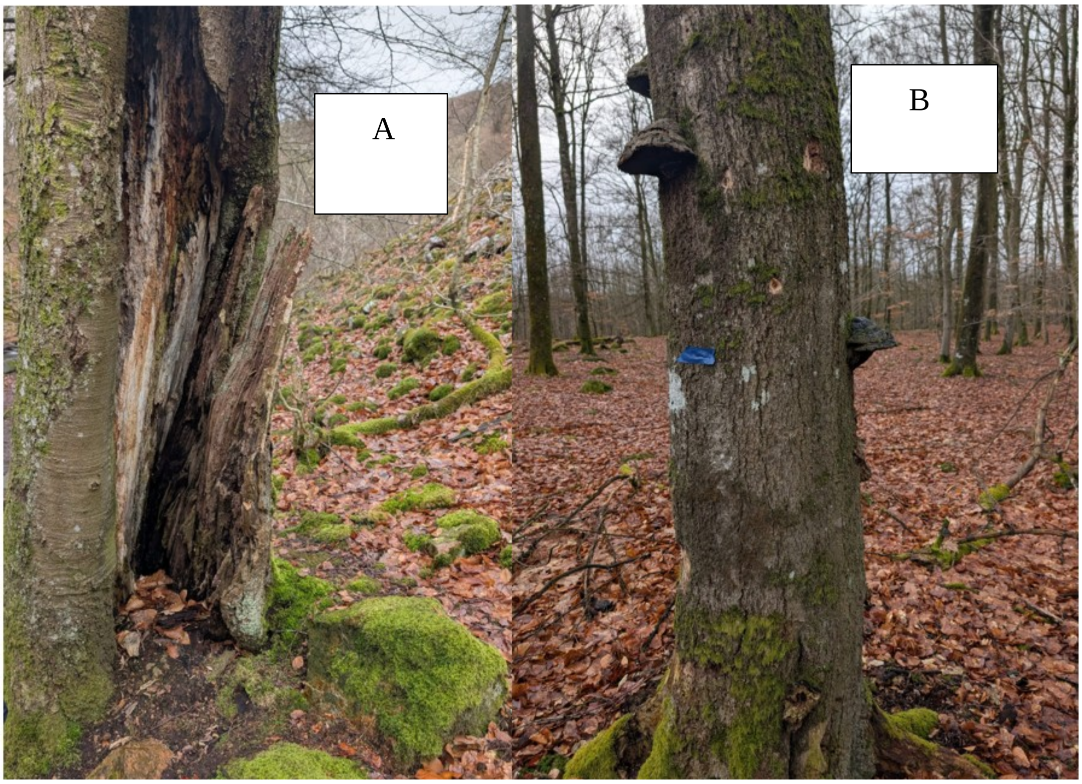


Figure 8. Examples of tree-related microhabitats (TreMs) observed during fieldwork. (A) Cavity formed by advanced decay in standing deadwood in Söderåsen. (B) Fungal fruiting bodies and associated structural features on a standing dead tree in Fulltofta. Source: Author.

Differences between sites may also be influenced by stand characteristics such as forest age and management system. Fulltofta is managed under the CCF, and all three sites consist of different management objectives and site conditions. While not directly analysed, these factors likely contribute to variation in deadwood structure and availability.

4.2 **Downed Deadwood**

The number of downed deadwood pieces was relatively similar across all sites; however, differences in structural characteristics indicate that quantity alone does not adequately describe deadwood patterns. Variation in diameter, decay class, and volume suggests differences in distribution and ecological function between sites.

Pildammsparken recorded the highest mean diameter and volume of downed deadwood. However, this result should be interpreted with caution. In this study, the high volume appears to be influenced by a small number of large deadwood pieces rather than by consistently high deadwood abundance. Although urban forests are generally expected to contain lower amounts deadwood due to management practices

(Korhonen et al., 2020), the relatively high volume observed in Pildammsparken differs from what would normally be expected in an urban forest setting.
To better understand this result, the estimated downed deadwood volume in Pildammsparken (231.43 m^3/ha) was compared with values reported in previous Swedish studies. Fridman and Walheim (2000) reported an average deadwood volume of 6.1 m^3/ha for managed productive forestland in Sweden. This prompted a closer examination of the field observations and the sampling method used.

Although the number of downed deadwood pieces recorded in Pildammsparken was similar to those recorded in Fulltofta and Söderåsen, several large-diameter logs were present within the sampled area. The largest recorded diameter in Pildammsparken was 60.0 cm, compared with 40 cm in Fulltofta and 36 cm in Söderåsen.

One possible explanation relates to the characteristics of the Line Intersect Sampling (LIS) method. The Van Wagner (1968) equation estimates volume using squared diameters, meaning that larger logs have a greater influence on the final volume estimate than smaller pieces. Previous studies have shown that LIS estimates may be influenced by local deadwood distribution and stand conditions (Woldendorp et al., 2004). Similar findings were reported by Rousseau et al. (2024), who noted that LIS is sensitive to log clusters and large logs. This provides a possible explanation for the high volume estimate observed in Pildammsparken.
Fulltofta showed a higher proportion of deadwood in advanced decay classes, indicating that some material is retained long enough to reach later stages of decomposition. This pattern likely reflects retention practices within production forestry, where maintaining some deadwood is increasingly recognised as important for supporting ecological functions (Bače et al., 2019).

In contrast, Söderåsen exhibited a more even distribution across both diameter and decay classes, suggesting a continuous input and turnover of deadwood. This pattern is characteristic of forests where natural ecological processes are not heavily disturbed and contributes to structural complexity and biodiversity (Stokland et al., 2012; Löfroth et al., 2023).

The spatial variability observed across transects is expected, as deadwood distribution is influenced by localised processes such as tree fall and disturbance. The line-intersect sampling method used in this study is designed to capture this variability and provide reliable estimates of downed deadwood (Van Wagner, 1968).

4.3 Decay Class Distribution

Differences in decay-class distribution further highlight the influence of management practices. Fulltofta was characterised by a higher occurrence of advanced decay classes, suggesting that deadwood remains in the forest long enough to decompose further.

Söderåsen showed different stages of deadwood decay, suggesting that new deadwood is continuously added while older deadwood continues to decompose.

In contrast, Pildammsparken exhibited a more limited range of decay classes, likely reflecting the removal of deadwood before it reaches advanced stages. This pattern is consistent with urban forest management practices, which prioritise safety and maintenance.

The presence of multiple decay stages remains important for biodiversity, as different species depend on specific stages of wood decomposition (Jonsson et al., 2016; Stokland et al., 2012).

4.4 Influence of Forest Management and Landscape Context

The observed differences in deadwood quantity and structure across the three study sites can largely be explained by contrasting management objectives and landscape contexts. In Pildammsparken, management primarily focuses on recreation, accessibility, aesthetics, and public safety. As a result, deadwood is often removed, particularly near paths and frequently used recreational areas. The park manager explained that standing and fallen deadwood may be removed when they pose a potential safety risk or are visually unsuitable in the urban park environment. This likely contributes to the lower quantity and reduced structural diversity of deadwood observed at the site.
However, urban green-space management is often influenced by public expectations, aesthetic preferences, safety considerations, and practical maintenance requirements, which may affect the retention of biodiversity-related features such as deadwood (Randrup et al., 2017; Brocki et al., 2025).

In Fulltofta, management practices such as thinning and harvesting influence both the quantity and structure of deadwood. The conservation manager at Fulltofta explained that continuous cover forestry is used as part of the forest management approach to maintain forest continuity while still allowing timber production. According to the manager, selected deadwood pieces are intentionally retained to support biodiversity and ecological functions within the managed forest landscape. Although forestry operations still affect deadwood availability, the retention of some standing and downed deadwood reflects increasing recognition of the ecological importance of deadwood in managed forests (Bače et al., 2019). This also highlights the multifunctional nature of production forests, where timber production, biodiversity conservation, and recreational values must be balanced within the same management framework (Bače et al., 2019).

In contrast, Söderåsen is managed primarily for conservation, allowing ecological processes such as natural tree mortality and decomposition to occur with minimal human intervention. The conservation manager emphasised the importance of retaining deadwood to support biodiversity and maintain ecological continuity within the forest ecosystem.
Field observations from Söderåsen also suggested that safety was managed through limited intervention rather than extensive removal of deadwood. As shown in Figure 9, downed deadwood was retained within the forest environment while walking paths remained generally accessible. This indicates a management approach that prioritises ecological processes while maintaining visitor access and basic trail safety.
This management approach likely contributes to the broader distribution of deadwood sizes and decay stages observed at the site. The greater structural diversity found in Söderåsen is consistent with characteristics commonly associated with more natural forest systems and contributes to habitat complexity and ecological stability (Stokland et al., 2012; Löfroth et al., 2023).

Figure 9. Retained downed deadwood adjacent to a walking path in Söderåsen National Park, illustrating limited intervention management where ecological processes are maintained while visitor access remains possible. Source: Author

At the same time, deadwood also influences how forest landscapes are perceived and experienced by visitors. From a landscape architecture perspective, deadwood contributes not only to ecological processes but also to the spatial character, visual identity, and sense of naturalness within forest environments. In recreational landscapes such as

Pildammsparken, management decisions are often shaped by visitor expectations regarding safety, accessibility, maintenance, and visual order. Consequently, deadwood retention may sometimes be reduced despite its recognised ecological importance (Randrup et al., 2017; Brocki et al., 2025), as public preferences in recreational landscapes are often influenced by perceptions of aesthetics, order, and safety (Qiu et al., 2021; Paletto et al., 2022).

However, the presence of deadwood in more natural environments such as Söderåsen may strengthen perceptions of ecological continuity, wilderness character, and natural forest dynamics. The wider range of deadwood structures and decay stages observed in Söderåsen contributes not only to biodiversity but also to the visual and experiential qualities of the forest landscape (Stokland et al., 2012; Paletto et al., 2022).

4.5 Future Management Scenarios

Future management strategies could further increase deadwood availability while still reflecting the main function of each forest type. In Pildammsparken, selected standing and downed deadwood could also be retained in locations where safety risks are limited, helping to increase ecological value while still maintaining accessibility and park management objectives (Randrup et al., 2017; Brocki et al., 2025)
In Fulltofta, future management could increase deadwood retention during thinning and harvesting operations. Retaining larger logs, snags, and trees with visible habitat structures may improve structural diversity and provide habitat continuity within the production forest landscape. Certain parts of the forest could also be managed with increased deadwood retention, especially in less intensively harvested areas, while still allowing timber production to continue (Bače et al., 2019).

In Söderåsen, continued limited intervention would likely maintain natural deadwood accumulation over time. Future management could also focus on monitoring long-term deadwood development and protecting areas with high structural diversity from unnecessary disturbance. Maintaining variation in deadwood size and decay stages may further support biodiversity and ecological continuity within the forest ecosystem (Stokland et al., 2012; Löfroth et al., 2023).

These management approaches demonstrate that increasing deadwood availability does not necessarily conflict with recreation, timber production, or conservation objectives, but instead depends on how management strategies are adapted to different landscape contexts.

4.6 **Contribution of the Study**

The findings align with previous research showing that natural forests generally contain higher volumes and a wider range of deadwood compared to managed forests. For example, Korhonen et al. (2020) reported that deadwood levels in urban forests are typically lower than in more natural systems, although they may still support biodiversity depending on management practices. Similarly, Bače et al. (2019) noted that production forests often contain reduced deadwood levels due to harvesting, despite the increasing emphasis on retention.

In addition, the findings indicate that volume-based measurements of deadwood may be influenced by the presence of large-diameter pieces, particularly in sites with uneven deadwood distribution. This suggests that both structural characteristics and sampling sensitivity should be considered when interpreting deadwood data, as volume alone may not fully represent overall deadwood availability.
This highlights the importance of combining quantitative measures with structural interpretation when assessing deadwood in different forest contexts.
The higher structural diversity observed in Söderåsen can be attributed to limited human intervention, allowing natural processes such as tree mortality, decay, and accumulation to occur over time. In contrast, the lower levels and more restricted decay stages observed in Pildammsparken reflect urban management priorities related to safety and aesthetics.

By focusing on a single dominant species, European beech, and applying a consistent sampling method across sites, this study reduces variability. It provides clearer insight into how forest management influences deadwood quantity and structure.
This contributes to a more integrated understanding of deadwood dynamics across urban, production, and natural forest landscapes.

4.7 Limitation

Several limitations were encountered during field data collection that may have influenced the results.

First, establishing precise transect starting points within the one-hectare plots was sometimes challenging, particularly in irregularly shaped areas lacking clear reference points. This may have affected the consistency of transect placement across sites.

Second, there was occasional uncertainty in applying the line-intersect sampling (LIS) method. In particular, difficulty arose when deadwood pieces were located close to, but not directly intersecting, the transect line, which may have introduced minor variation in the inclusion or exclusion of some downed deadwood pieces.

Third, during the full inventory of standing deadwood, there was a risk of confusion in determining whether individual snags had already been recorded. Although marking tape was used to reduce this risk, the possibility of double-counting or omission cannot be entirely ruled out.

Fourth, the study focused only on beech (Fagus sylvatica) deadwood with a diameter of at least 10 cm. Smaller deadwood and material from other tree species were not included, which may limit the representation of total deadwood availability within the study sites.

Fifth, the sampling design used for estimating downed deadwood volume may have influenced the results. The LIS method is sensitive to large logs because larger diameters have a greater influence on the volume calculation. In addition, the total transect length used in this study was 80 m. Previous studies have shown that longer transects and a higher number of deadwood intersections can improve the accuracy of volume estimates (Brown, 1974; Woldendorp et al., 2004). Therefore, the reported deadwood volumes should be interpreted as estimates for the sampled sites and may not fully represent the deadwood volume of the entire forest area.

Finally, the study used a sample area of one hectare at each site. While this allowed for detailed field measurements, it may not fully capture the variability of deadwood distribution across larger forest areas.

Despite these limitations, the same methods were applied consistently across all study sites, allowing meaningful comparison of deadwood characteristics among the different forest types.

5. Conclusion

This study examined how deadwood quantity and structure differ across urban, production, and natural beech forests. The results showed clear differences between the three forest types, mainly influenced by how each forest is managed.

Standing deadwood was more common in Fulltofta and Söderåsen than in Pildammsparken. Although Pildammsparken had the highest mean diameter, this was based on only two trees and does not represent a consistent pattern. Söderåsen showed greater variation in diameter and decay stages, as well as the highest basal area, indicating a more complex and natural deadwood structure.

For downed deadwood, the number of pieces was similar across all sites, but differences were found in diameter, decay stage, and volume. Pildammsparken had the highest volume, mainly due to a few large logs. Söderåsen showed a more even distribution across decay stages, reflecting continuous natural processes. Fulltofta showed intermediate conditions, where some deadwood is retained despite active forest management.

Overall, the results show that forest management strongly influences deadwood characteristics. Urban forests tend to have less deadwood due to safety and maintenance concerns. Production forests are shaped by harvesting but may still retain some deadwood. Natural forests, with minimal human intervention, support a wider range of deadwood structures and ecological processes. This is consistent with previous research highlighting the importance of natural forests for maintaining deadwood diversity (Stokland et al., 2012).

Deadwood is an important component of forest ecosystems because it supports biodiversity and provides habitat for many organisms (Löfroth et al., 2023). This study shows that not only the amount of deadwood matters, but also its structure, including size and stage of decay. However, the results suggest that keeping some deadwood in forests can support biodiversity, even in small amounts. This can be done without affecting the forest's primary use, such as recreation or timber production. In urban forests, management could aim to balance safety with the ecological benefits of retaining deadwood.

Future research should include more sampling sites and larger areas to better represent each forest type. Including other tree species and smaller deadwood would give a more complete picture of deadwood availability. It would also be useful to measure tree-related microhabitats more thoroughly and to apply statistical analysis to strengthen comparisons between sites.

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Appendix 1. Questionnaire used in the study

Questionnaire – Deadwood Management in Beech Forests
Bachelor Thesis – SLU
Basic Information

- Name: ___________________________
- Organization: _____________________
- Role/Position: ____________________
- Forest type: ☐ Urban ☐ Production ☐ Natural

1. Management Purpose

1. What is the main purpose of this forest area?
   ☐ Recreation ☐Timber production
   ☐ Biodiversity conservation
   ☐ Other: _______________________

2. Deadwood Management

2. How is deadwood usually handled in this area?
   ☐ Mostly left ☐ Partly removed
   ☐ Mostly removed
3. What types of deadwood are typically removed?
   ☐ Fallen trees
   ☐ Branches
   ☐ Standing dead trees
   ☐ Other: _______________________

3. Biodiversity

4. How important is deadwood for biodiversity in this area?
   ☐ Very important
   ☐ Important
   ☐ Less important
5. Are there guidelines or policies for retaining deadwood?
   ☐ Yes
   ☐ No
   If yes, please describe briefly:

4. Recreation and Safety

6. Does deadwood create safety concerns?
   ☐ Yes
   ☐ No
   If yes, how?

7. How do visitors generally perceive deadwood?
   ☐ Natural
   ☐ Untidy
   ☐ Dangerous
   ☐ Other: ______________________

5. Reuse and Management

8. Is deadwood removed, or reused in any way?
   ☐ Yes
   ☐ No
   If yes, how?

9. What factors most influence your decision to remove or keep deadwood?
   (e.g. safety, policy, cost, biodiversity)

6. Final Reflection

10. In your opinion, what is a good balance between biodiversity, safety, and management?

Optional

Would you be open to a short follow-up discussion if needed?
☐ Yes ☐ No

Appendix 2. Interview guide.

The questionnaire presented in Appendix 1 was used as the basis for telephone interviews and follow-up discussions with site managers.

Additional questions used for clarification included:

1. What is the approximate age of the forest stand?
2. Can you provide any additional information about the site, and under what circumstances is deadwood removed from the forest?

Appendix 3. Raw data for standing and downed deadwood.

DOWNED DEADWOOD (LIS)

Fulltofta

Transect	**Piece ID**	**Diameter (cm)**	**Decay Class**
U1	1	30	4
U1	2	29	5
U1	3	31	5
U1	4	29.	5
U2	1	19.5	1
U2	2	29.1	5
U2	3	27.0	5
U3	1	12	2
U3	2	19	2
U4	1	29	5
U4	2	22	4
U4	3	16	5
U4	4	40	1

Pildammsparken

Transect	**Piece ID**	**Diameter (cm)**	**Decay Class**
U1	1	45.40	5
U1	2	60	5
U1	3	60	5
U2	1	25.30	5
U2	2	10	5
U3	1	10	3
U3	2	11	3

U4	1	21	3
U4	2	22.5	3
U4	3	24	3
U4	4	45	3
U4	5	16	3
U4	6	12.3	3
U4	7	28.8	3

Söderåsen

Transect	Piece ID	Diameter (cm)	Decay Class
U1	1	30	5
U1	2	14	5
U1	3	36	5
U1	4	19	5
U2	1	22	2
U2	2	32	2
U2	3	30	2
U3	1	10	3
U3	2	25	3
U3	3	28.5	3
U4	1	32	1
U4	2	15	1

STANDING DEADWOOD (SNAGS)

Fulltofta

Snag ID	Diameter (cm)	Decay Class
1	35	3
2	32	4
3	30	4
4	40	5
5	30	5
6	35	2
7	32	2

Pildammsparken

Snag ID	Diameter (cm)	Decay Class
1	76.4	2
2	19.0	4

Söderåsen

Snag ID	Diameter (cm)	Decay Class
1	50	2
2	16.2	3
3	39.3	4
4	50.5	1
5	35.3	3
6	47.2	2
7	32	5

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