DEPARTMENT OF BIOLOGICAL AND
ENVIRONMENTAL SCIENCES

CREATING TEACHING RESOURCES FOR JUNIOR HIGH SCHOOL STUDENT'S THROUGH WETLAND INVESTIGATIONS

Enhancing the ecological and societal value of wetland forests

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Photo by Carlos Parra Arevalo (September 25, 2025)

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Abstract
Having worked as a biology teacher at the junior high school level, I acknowledged a need for hands-on learning materials that support the study of ecology and biodiversity through fieldwork. I explored how such materials could be designed for studying forests in Sweden. Using a standardized method for measuring ecological parameters in wetland forests (such as lower vegetation species, water coverage and lying deadwood logs using FAS), I collected data from three sites along Sweden's west coast, Rya Skog (Gothenburg), Näverkärr and Havstensfjorden (near Lysekil). The aim was to create a toolkit aligned with the Swedish biology curriculum for years 7-9 (Lgr22), while highlighting interdisciplinary connections between subjects such as mathematics and geography. I also compared some of my collected data with results from studies performed in Näverkärr and Havstensfjorden during spring 2024. The results suggest wide possibilities to develop pedagogically relevant teaching materials aligned with the curriculum. The methodology resulted in a structured toolkit for investigating wetland forests, or other types of forests, opening possibilities for interdisciplinary collaboration. The water coverage on both sites was absent/barely visible during my visit (week 39-40), a difference with earlier studies where a bigger extent was documented. Biodiversity was higher in Näverkärr during this autumn investigation than during spring of 2024, whereas in Havstensfjorden it was almost aligned with the results of the earlier studies. A certain level of error should be acknowledged, though the timeframe and method for identification of plant species could be improved to get more representative results. The deadwood sampling method (FAS) opens possibilities to future research on specific insects, fungi, and the carbon cycle. This study can also be continued by education institutions, where its effectiveness is tested and evaluated. To increase the knowledge of ecological/societal values and biodiversity of these habitats for the students may help the sustenance of these valuable environments into the future.

Sammanfattning
Efter att ha arbetat som biologilärare på högstadienivå insåg jag ett behov av praktiska läromedel som stödjer studiet av ekologi och biologisk mångfald genom fältbaserad undervisning. Jag undersökte hur sådana material kunde utformas för att studera skogar i Sverige. Genom att använda en standardiserad metod för att mäta ekologiska parametrar i alkärrskogar (såsom låg växtlighet, vattenspeglar och död ved med hjälp av FAS), samlade jag in data från tre platser längs Sveriges västkust Rya Skog (Göteborg), Näverkärr och Havstensfjorden (nära Lysekil). Syftet var att skapa ett verktyg som är i linje med kursplanen i biologi för högstadiet (Lgr22), och uppmärksammar ämnesövergripande kopplingar till exempelvis matematik och geografi. Jag jämförde även låg växtlighet och vattenspeglar med tidigare studier som utförts i Näverkärr och Havstensfjorden under våren 2024. Resultaten visar goda möjligheter att utveckla pedagogisk relevanta undervisningsmaterial i linje med kursplanen i biologi. Metoden resulterade i en strukturerad verktyg för att undersöka alkärrskogar, eller andra typer av skogar, och främja samarbete mellan ämnen. Vattenspeglar på båda platserna var i stort sett frånvarande eller knappt synliga under mitt besök (vecka 39–40), en skillnad med tidigare studier där en större utbredning dokumenterats. Biodiversiteten var högre i Näverkärr, medan det i Havstensfjorden låg nära resultaten från tidigare studier. En viss felmarginal bör beaktas vid tolkningen av dessa resultat då tidsramen och metoden för identifiering av växtarter kan förbättras för att få mer representative resultat. Metoden för provtagning av död ved (FAS) var mer tidskrävande än de andra parametrarna, men öppnar möjligheter för framtida forskning kring specifika insekter, svampar samt kolets kretslopp. Studien kan även fortsättas av utbildningsinstitutioner, där dess effektivitet testas och utvärderas. Att öka elevernas kunskap om alkärrskogar ekologiska och samhälleliga värden samt biologisk mångfald i dessa livsmiljöer, kan bidra till att bevara dessa värdefulla miljöer i framtiden.

Keywords: Wetland forest, lower vegetation, deadwood logs, water coverage, Fixed Area Sampling (FAS), Linear Intersect Sampling (LIS).

Introduction

Background

Having worked as a biology teacher at the junior high school level, I bring valuable experience in helping students understand the crucial role different natural habitats and their different species play in our ecosystems. We used to have biology lessons in a forest near our school and explore the variety of ecosystems that can exist withing a relatively small area. Thanks to this, I acknowledge a need for hands on teaching materials for outdoor biology lessons, a type of material that is structured to specifically study ecosystems and ecology. I want also to emphasize how rewarding it is to study biology more often in the forest itself, where life unfolds in real time. This study is therefore designed to support biology teachers in junior high school by providing material for conducting lessons and projects in forest environments. It can serve as a practical toolkit for outdoor biology education, focusing on ecosystems and ecology. For this study I want to focus on wetland forests, their remarkable biodiversity and the richness of life that exists across multiple scales. But above all, I want to highlight how educational it can be to spend time in such an environment during school hours, experiencing firsthand what textbooks only describe. Due to time constraints, I will not include mangrove forests in this study. Instead, I will focus on other type of wetland forests (*Alnus glutinosa* dominated) located in the west coast of Sweden, one in Gothenburg and two others near Lysekil, north on Gothenburg (Fig. 1).

The importance of wetlands

Paudel *et al.,* (2023) classify the type of forests investigated in this study as hardwood forested wetlands, since their tree coverage (*Alnus glutinosa* dominated) is higher than 30%. These ecosystems can function as natural buffers, helping to regulate groundwater runoff and reduce the impact of flooding (Jeglum *et al.,* 2011). They also provide habitats for bird species and other wildlife, contributing to regional biodiversity (Paudel *et al.,* (2023). Hörnberg *et al.,* (1998) reports in a study how a small water covered area in a forested wetland in northern Sweden (close to the Arctic circle) provided habitat to 21 % of the regional population of a specific type of beetle. Moreover, wetland forests may function as carbon sinks, making them essential in efforts to mitigate climate change (Jeglum *et al.,* 2011). Hansson *et al.,* (2005) highlighted that wetland forests were historically undervalued during industrialization due to their unsuitability for agriculture, leading to widespread drainage across Europe and Noth America. In Sweden wetlands environments are regarded as highly important for biodiversity and for mitigating the effects of eutrophication, therefore many previously drained wetlands have been restored to support ecological recovery (Åhlén *et al.,* 2020). Bystrom (2000) suggests that wetlands have a 30% effectiveness in sequestering excess nitrogen from agricultural activities near the Baltic Sea. This could help reduce eutrophication in a relatively natural way.

Strand & Weisner (2013) made important observations regarding the positive impact of constructed wetlands in Sweden on bird and amphibian populations, where their findings suggest that these wetlands contributed to increased numbers of both birds and amphibians. Notably, several bird species that use the constructed wetlands for breeding were listed on Sweden's red list due to declining populations. In addition, Strand & Weisner (2013) conducted measurements using water samplings over a period of 1.5 to 9 years to analyze the wetlands capacity to absorb excess nitrogen from nearby agricultural fields. Strand & Weisner (2013) results suggest a nitrogen absorption capacity of about 1000 kg N/year per wetland (seven constructed wetlands) over an area of around 3,5 hectares ha in total. Restoration and conservation of wetland forests could thus yield promising positive results in reducing eutrophication, while simultaneously supporting the reestablishment of red listed species in Sweden.

In my opinion, projects and studies like this could be shared to a bigger extent with both the public and students. They demonstrate that change is possible, and that efforts to protect and restore red listed species can truly make a difference. Educating young people about such ecosystems is essential for fostering environmental awareness and responsibility.

Education and wetland forests

Smith (2025) conducted a comparative study on what they refer to as place-based education, focusing on forest schools in Canada and Sweden. Smith (2025) suggest that spending more time in the forest, for example having school lessons can develop not only knowledge on biology but also have positive effects on cognitive and emotional development. Fägerstam & Blom (2012) suggests that having biology several lessons outdoors, such as in a forest, can have a positive effect on learning about ecology. Their results suggest that this type of outdoor practice helped junior high school students retain information for a longer period, compared to a control group that received just a few biology lessons outdoors. Drawing on John Deweys pedagogical perspective of pragmatism, where "*learning by doing"* is central (Säljö, 2022), this type of educational approach shows great promise in cultivating a generation that both values and understand the vital role of nature in sustaining life.

I will be comparing some of my collected with data from earlier studies conducted in two of the three wetland forests selected for this study (Näverkärr and Havstensfjorden Nature Preserves near Lysekil). Schmith (2024), Medin (2024) and Tupala (2024) investigated these two sites from three different perspectives, where they collected data using a standardized method for measuring parameters in wetland forests., I will adapt some of the of the methods for measuring parameters in this study, to develop a toolkit for investigating wetland forests that is aligned with the current curriculum for compulsory school in Sweden.

Aim

The aim of this project is to develop an educational toolkit to support junior high school biology teachers in their teaching about ecosystems, with a broader aim of inspiring students, educators, and the wider community to appreciate and care for nature. In addition, this project aims to showcase its results as a model for outdoor educational activities that can be carried out by junior high school students, promoting environmental awareness and hands on learning in natural settings. As named in the introduction, a standardized method will be applied to assess various parameters in coastal wetland forests (from Schmidt, 2024; Medin, 2024; Tupala, 2024). A method for calculating deadwood volume called Fixed Area Sampling (FAS) will be integrated as a new parameter (from Rondeux *et al.,* 2012; Rousseau *et al.,* 2024; Ahmad *et al.,* 2020). The study sites selected for analysis were identified in contact with Sara Braun (from Braun *et al,* accepted in AmBio Oct 2025). With this project I also want to inspire junior high school students to pursue studies in natural sciences at university level.

Additionally, this project aims to highlight the connection between biology, mathematics and socially oriented subjects in junior high education (e.g. geography, history). I want to emphasize the importance of interdisciplinary studies in addressing contemporary societal issues such as climate change. This study will be framed in relation to relevant points in the current Swedish national curriculum for compulsory school quoted in the textbox bellow.

Relevant points from the curriculum's biology and mathematics core content for year 7-9:

Biology:

Nature and environment

- *Local and global ecosystems. The relationships between populations and available resources. Photosynthesis, cellular respiration, material cycles, and energy flows,*

- *Human impact on nature locally and globally, and how to promote sustainable development at the individual and societal level. The importance of biodiversity and ecosystem services (*Curriculum for compulsory school, preschool class and School-Age Educare [Lgr22], 2025, p. 163*)*

Systematic investigations and evaluation of information

- *Field studies and experiments using both analog and digital tools. Formulation of research questions, planning, performance, evaluation of results, and documentation with images, tables, diagrams, and reports,*

- *The relationship between biological investigations and the development of concepts and explanatory models. The historical development, applicability, and changeability of biological explanatory models,*

- *Searches, critical evaluation, and use of information related to biology. Argumentation and position-taking on current environmental and health issues (*Curriculum for compulsory school, preschool class and School-Age Educare [Lgr22], 2025, p. 163*).*

Mathematics

Probability and statistics

- *Tables and diagrams, and to describe the results of investigations, both with and without digital tools. Interpretation of data in tables and graphs (*Curriculum for compulsory school, preschool class and School-Age Educare [Lgr22], 2025, p. 61*).*

Geometry

- *Methods for calculating area, perimeter and volume of geometric objects, and related unit changes (*Curriculum for compulsory school, preschool class and School-Age Educare [Lgr22], 2025, p. 61*).*

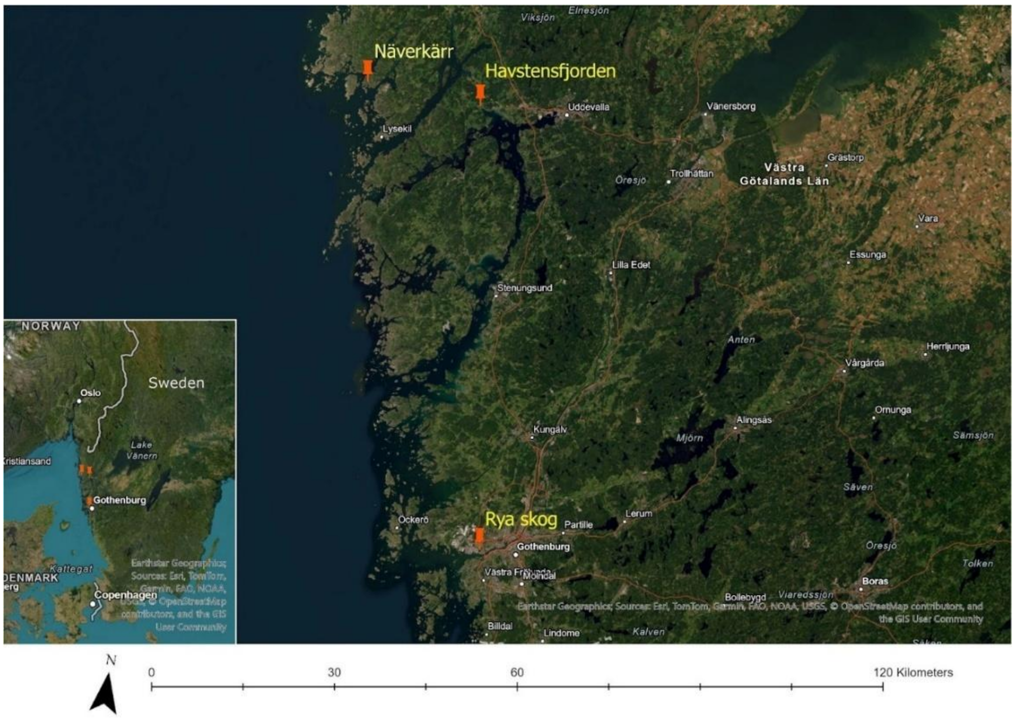

Figure 1. *The figure illustrates the investigated coastal wetland forests (Map created in ArcGIS Pro using author's GPS data and Esri Imagery Hybrid basemap).*

Research questions:

- How can an investigation of wetland forests contribute to the development of teaching materials that are pedagogically relevant, and aligned with the current biology curriculum in today's school content?

- How can outdoor learning experiences in wetland forests foster interdisciplinary connections between biology, mathematics and socially oriented subjects?

- What temporal measures are easily compared in and between wetland forests, in this case which differences in biodiversity (e.g. dominant lower vegetation species) and water coverage are evident in the Näverkärr and Havstensfjorden wetland forests when compared to findings from spring 2024?

Material and method

This section is designed to serve as a toolkit for outdoor activities, lessons and projects, primarily within the subject of biology for junior high school students. At the same time, it creates an opportunity for interdisciplinary collaboration in mathematics and subjects such as geography, physical education and even history, as many of the visited sites have a background of struggle to become nature preserves. Working across subjects provides a broader perspective on the thematic unit of ecology and ecosystems. It allows students to explore the topic from multiple angles, scientific, social, and historical, making the learning experience hopefully more meaningful and connected to the real world.

Recommended approach when working with students

1. **Introduction (prior to the fieldwork)**

a. Discuss ecosystems, biodiversity, human impact, ecological sustainability and why it is important.
b. Plan the time you all will dedicate to the project. You can simulate a real-life project, for example pretending to be a research group working for Gothenburg city.

c. Give lessons about types of wetlands and discuss how they may help regulate the climate.

d. Watch relevant documentaries on threatened species, discuss relevant news articles that talk about environmental disasters caused by humans.

e. Test Google Earths functions. Use the measuring tools, practice how to start a project and save it.

f. Introduce the standardized parameters described in *Table 1*. These parameters provide essential data for studying forest biodiversity at a basic level, for example by identifying lower vegetation species and measuring their coverage. This data also enables us to detect threatened plant species, as well as invasive ones that may hinder the survival of native flora. All the parameters that will be measured are related to the subject of ecology and ecosystems.

g. Divide students into small groups. It is recommended working in groups of at least three students, or even in pairs. This method of working is the most effective for learning when working in groups (Jensen, 2022). It also makes it possible to create more groups, which can then establish additional plots throughout the forest.

2. **Fieldwork (nearby wetland forest)**
   a. Visit at least two forests to compare the collected data. Each group collects data on one parameter (Tab. 1).

3. **Data entry and analysis (Guided Google Sheets lesson at school)**
   a. Students input the collected data using Google Sheets. With the supervision of the teacher students can start to create simple graphs and tables.

   b. Do necessary calculations in Google Sheets.

4. **Discussions and reflections**
   a. Recommended questions for discussion:

      i. What patterns did they find? Were there relevant differences between forests? How might human activity affect these ecosystems

5. **Students' presentations**
   a. Each group will prepare and deliver a short presentation showcasing the results of their projects.

Table 1. *The table presents the parameters included in the standardized method, along with the recommended digital and analog tools for analyzing each one. Tasks 1 and 2 should be completed in the computer lab or classroom prior to the fieldwork, whereas tasks 3 to 7 are intended to be carried out in the field.*

Task	**Parameter**	**Method**	**Tool**	**Working environment**
1	**Total area of each site (m^2 or ha)**	Measurement of the estimated area of each forest (m^2 or ha). This task can also be performed in the field by marking GPS points around the forest using Google earth measuring tools.	Google earth in a PC or Chromebook.	School
2	**Proximity to shoreline or open water (m)**	Measured as the shortest distance from the forest edge to the nearest shoreline, to discover potential marine influence in the water coverage.	Google earth in a PC or Chromebook.	School
3	**Water coverage (m^2)**	Mark several points around the edge of the water coverage, then use this points to draw a polygon in Google earth. This will give you an estimated area of a potential water covered area in the forest.	GPS tracking with Google earth on a smartphone.	**Field**
4	**Forest density ($trees/ha$)**	Count the trees within each **10 x 10 m deadwood plot**. Record the observations in an analog notebook (recommended). This data will give you an estimate of the density of the investigated area in $trees/ha$	Small notebook (paper and pencil).	**Field**
5	**Volume of lying deadwood logs (m^3/ha)**	Measure the diameter and length of the lying deadwood logs within the **10 x 10 m plot.** Measure only logs with a **diameter** $\geq$ **10** cm **at midpoint** and a **length** $\geq$ **1** m. This data will be used to calculate an estimated volume of deadwood within each plot. This data will be used to calculate an estimated volume of deadwood across the investigated area of the forest.	Caliper and measuring tapes (5 m or 30 m)	**Field**
6	**Salinity levels in the forests water covered areas (ppm)**	Measure the salinity level with the salinity measuring device. This will assess the degree of marine influence across the forest.	Salinity measuring device	**Field**
7	**Species coverage (Shannon Index)**	Estimate ground and lower vegetation species and their abundance in at least two mini plots (1 x 1 m) within each deadwood plot (10 x 10 m). The more data you have the better for estimating biodiversity.	Combination of the smartphone applications *Flora Incognita* and *Picture This.*	**Field**

Detailed fieldwork preparations and analysis of data

I will present this section as a workflow, outlining my recommended steps from start to finish in a step-by-step guide.

The following workflow was applied:

1. Identifying the wetland forests to be investigated.
2. Gathering materials needed for the field study.
3. Creating layouts to be filled in the field.
4. Visiting the sites and collecting data.
5. Digitalizing and analyzing the data using Google Sheets. This part will result in several diagrams, graphs and pie charts that will be then discussed and presented at the end of the project.

1. **Identifying the wetland forests to be investigated.**
   Identifying and selecting a suitable wetland forest takes time, which is why it constitutes the first step in the methodology. The identification process for this study was made possible in communication with Sara Braun (from Braun *et al.,* accepted in AmBio Oct 2025). This communication, along with my supervisor's support, enabled me to choose two sites near Lyseklil, **Näverkärr** (Fig. 2) and **Havstensfjorden** (Fig. 3), as well as a mixed wetland forest in Gothenburg called **Rya Skog** (Fig. 4). I therefore recommend dedicating time for online research to find a suitable place to investigate.

2. **Gathering of the materials needed for the fieldwork**
   I measured five parameters in the field (Tab.1), which required the following tools:

   i. **Power banks -** at least two small ones to charge smartphones, as the Google Earth app uses a big amount of battery power.

   ii. **PVC-pipes or wooden sticks** (at least 50 cm in length) – I used these as corner markers for the 10 x 10 m deadwood plots.

   iii. **Measuring tapes -** one 30 m and one 5 m**.** These tapes were used for the 10 x 10 m deadwood plots.

   iv. **Caliper (46 cm) –** to measure the diameter of lying deadwood logs.

   v. **Folding rulers** – I used two 2-m folding rulers to create a 1 x 1 m square mini plot for species identification. They are easy to carry in a backpack and take little space. I recommend using this method, although it is also possible to construct a 1 x 1 m square using four 1 m PVC-pipes and four L-joints.

   vi. **Garmin GPS (optional)** – if more precise points are desired, otherwise Google earth is sufficient to get estimated positions.

   vii. **Salinity measuring device –** to measure salinity in the water covered areas of each wetland forest (measured in ppm).

   viii. **Rubber boots** – very important to bring, as all selected sites are wetlands or contain wetland areas.

   ix. **A good rain jacket –** in case of rain.

   x. **Food and water supplies** – very important to stay hydrated and with energy to walk around the forest. Bring a bag to dispose of the trash.

3. **Creating layouts to be filled out in the field**
   These layouts will save precious time when collecting data in the forest. I recommend using paper and pencil to save battery power on smartphones. Two types of layouts were used in this study. One for lower vegetation species and their abundances (Tab.2), and another for the remaining parameters to be measured (Tab. 3).

Table 2. *The table presents the layout used for identification of lower vegetation within the 1 x 1 m Mini plots. The percentage coverage must be an estimate of the species' actual coverage within the Mini plot.*

Plot ID	Mini plot ID	Plant species scientific name	% Cover	Red list label

Table 3. *The table presents the layout used within each 10 x 10 m plot for measuring deadwood logs (minimum diameter 10 cm and length 1 m), recording GPS coordinates, Date of measurement, Number of trees within the plot and salinity of water covered areas in ppm.*

Plot ID	GPS coordinates	Date	Number of trees	Salinity (ppm)
Log ID	**Length (cm)**	**Midpoint Diameter (cm)**	**Notes**	

4. **Visiting sites and collecting data**
   I measured five field parameters at all sites (Tab. 1), all of which are suitable for junior high school students. I recommend that all measurements are carried out, and that small groups of students rotate between different measuring methods so that all students can try a field measurement technique.

5. **Digitalizing and analyzing the data using Google Sheets and Google Earth**
   This part of the method is essential, as digitizing the data using Google Sheets facilitates the calculations required for data analysis. Based on the layouts used in the field, we will now create a Google Sheet containing all the data. Google Earth has a free online version that is suitable for use in junior high school. I used it to measure the area of water covered areas, create GPS points for each deadwood plot (10 x 10 m) and for measuring the distance to the nearest shoreline.

   The following headers were used to analyze the data in Google Sheets:

   - Forest Name
   - Total area in hectares, ha
   - Water coverage, m^2
   - Plot ID (1, 2, 3 etc.)
   - GPS Latitude (Deadwood plots coordinates in Google Earth)
   - GPS Longitude (Deadwood plots coordinates in Google Earth)
   - Tree Count

- Forest Density, $(\frac{trees}{ha})$
- Distance to Shoreline, m
- Salinity of water coverage, ppm
- Log ID (L1, L2, L3 etc.)
- Log length, m
- Log diameter at midpoint, cm
- Log volume, m^3
- Total log volume per plot, m^3
- Estimated deadwood volume per hectare, $\frac{m^3}{ha}$

Calculation of the estimated deadwood volume per hectare
To calculate the deadwood volume I applied Fixed Area Sampled (FAS), following a combination of the methodology from Ahmad *et al.,* (2020), Rousseau *et al.,* (2024) and Rondeux *et al.,* (2012). A simplified version of the method was applied, focusing on deadwood in the form of lying logs with a minimum diameter at midpoint of 10 cm and a minimum length of 1 m. No additional methods were employed to document deadwood, to keep the process straightforward and accessible to junior high school students. This method is time consuming, and it also requires a level of mathematics corresponding to year 9. Therefore, I recommend refraining from including this parameter in lessons for years 7 and 8.

The estimated deadwood volume was calculated using a version of the Hubers formula provided by Ahmad *et al.,* (2020), shown in the workflow described below:

a. The above suggested formula (from Ahmad *et al.,* 2020, p.23) was used for calculating the volume of each lying log of deadwood:

$$V_{log} = f \times L \times (dM)^2$$

Where:

$$V_{log} = Log\ volume\ in\ m^3$$

$$f = 0{,}00007854$$

$$L = Log\ lenth\ in\ m$$

$$dM = Log\ diameter\ at\ midpoint$$

b. In the column **Total log volume per plot, m^3**, I summed the volumes of each log within plot (10 x 10 m) to obtain the total log volume per plot.

c. Next, calculate the average of these total volumes using the AVERAGE formula in Google Sheets. This step should be practiced beforehand in mathematics or biology lessons, so that students are familiar with the method.

d. Based on the calculated average, you can now calculate an estimated total volume of deadwood per hectare $(\frac{m^3}{ha})$, by multiplying the average volume by 100 because:

i. $1\ hectare\ (ha) = 10000\ m^2$

ii. $Each\ plot\ for\ deadwood\ measuring\ had\ an\ area\ of\ 100\ m^2$

iii. $\boldsymbol{V_{m^3/_{ha}}} = V_{average} \times \frac{10000\ m^2}{100m^2} = \boldsymbol{V_{average}} \times \mathbf{100}$

iv. $\boldsymbol{V_{m^3/_{ha}}} = \boldsymbol{V_{average}} \times \mathbf{100}$

Calculation of the estimated Forest Density per hectare

In the column with the header **Forest Density,** ($\boldsymbol{trees/_{ha}}$), I calculated the estimated forest density using the following formula below (from Baliton *et al.,* 2020 p. 709):

1. $1\ hectare\ (ha) = 10000\ m^2$
2. $Each\ plot\ for\ deadwood\ measuring\ had\ an\ area\ of\ 100\ m^2$
3. $Forest\ density_{Trees/_{ha}} = Counted\ trees \times \frac{10000\ m^2}{Sample\ area\ in\ m^2}$
4. $Forest\ density_{Trees/_{ha}} = Counted\ trees \times \frac{10000\ m^2}{100\ m^2}$
5. $\boldsymbol{Forest\ density_{Trees/_{ha}}} = \boldsymbol{Counted\ trees} \times \mathbf{100}$
6. $Calculate\ forest\ density\ for\ each\ plot, and\ then\ the\ average\ of\ all\ the\ values$
7. $This\ average\ is\ your\ \boldsymbol{Estimated\ Forest\ density}$

Calculating Shannon-Wiener Diversity Index (optional)

Ortiz- Burgos (2016) define the Shannon Diversity Index as *"one widely used index for comparing diversity between diverse habitats"* (p. 572-573). I calculated it to compare my results with the results from earlier studies (from Tupala, 2024) made in the two of the three sites investigated in this study (Näverkärr and Havstensfjorden). The Shannon-Wiener index was calculated using R, and the corresponding plot was also generated in R (Fig. 16.) These calculations can be made in Google Sheets or Excel using the following formula (from Ortiz-Burgos, 2016 p. 572; Nolan & Callahan, 2006 p. 334):

$$H' = -\sum_{i=1}^{s} p_i \times \ln p_i$$

$Where:$

$H' = Shanon - Wiener\ Diversity\ Index$

$s = number\ of\ species\ (estimated\ percentage\ coverage\ in\ this\ study)$

$p_i = proportion\ of\ individuals\ related\ to\ the\ total\ number\ of\ counted\ species$

$\ln p_i = Natural\ logarithm\ \ of\ p_i$

Coverage of lower vegetations species with Mini plots

This parameter is measured through establishing 1 x 1 m mini plots within the 10 x 10 m deadwood plots. The idea is to establish at least two mini plots per deadwood plot. You will try to get an estimate of the coverage of each species of lower vegetation and identify it through combining the apps *Flora* Incognita and *Picture This* with a smartphone. You will fill in the layout for species coverage (Tab. 2).

Find if the species is threatened using SLU databanks website (recommended), where you can find useful information on a great variety of plant species across Sweden (SLU Artdatabanken, 2025). This parameter also will be compared with the results from studies conducted in two of the three sites investigated in this study (Näverkärr and Havstensjorden). The generated charts will be presented in the results section.

Create charts and tables to visualize and present your data

Once you've digitalized all your data using Google Sheets, it is time to visualize your data using a type of chart suitable for what you want to present. This will provide a general overview of the lower vegetation diversity in the area investigated of the forest. All the charts from this study will be presented in the results section.

I recommend performing this step as a guided lesson at school. It will make the lesson dynamic and give open for discussion of the data in class.

Creating maps using Google Earth web

I will present the maps I created using Google Earth in the results section. As an optional method I also created maps using ArcGIS pro online, which is a powerful software to analyze geographic data in different ways. To create these maps, I used the GPS points on each deadwood plot (10 x 10 m) taken on a Garmin GPS device and downloaded them into ArcGIS pro online.

To create maps using Google Earth you just need to log in and create a new project. You will then be able to navigate through the entire planet earth virtually, and add GPS points, measure distances, calculate area and much more. It is also possible to present your project as a story animation. One reason to create maps of the site using Google Earth is to show the dispersion of the plots around each forest investigated. I took screenshots on the Google Earth project to show them in results section, mostly because the Goggle Earth pro version is required to download the maps. As mentioned before, I recommend planning a couple of lessons prior to the fieldwork to test the measuring tools in Google Earth web, as well as to create a new project.

Description of the sites investigated

Rya Skog Nature Preserve (Forest a)

Coordinates: **11,8858973°*E* 57,6955136°*N***

Located in Gothenburg and surrounded by oil industry tanks and pipes, as well as constant heavy vehicles traffic (Fig. 2), this nature reserve has an area of approximately **20 hectares**. The forested area consists of two alder dominated swamp areas, and one oak dominated area across the middle part of the forest. Within the forest, an invasive plant species with high risk of spreading has been identified, *Impatiens parviflora* (SLU Artdatabanken, 2025).

The forest was at the center of a debate during the 1950s due to the rapidly growing industrial sector in the city. During those years, the authorities planned to build a water treatment plant in the forested area, but the public and biologists across the city opposed the initiative (Billing, 2023). Even so, a water treatment called Ryaverket was constructed in 1958 at the edge of the forested area, taking away a considerable part of the forest (Billing, 2023). The water treatment area is situated east of the forested area (Fig. 2), and on occasions the wind transports the smell of sewage water across the forest.

There are small pathways that allow you to walk around the entire nature reserve, making it practical to establish mini plots and identify lower vegetation species (Fig. 3) at well distributed points throughout the area (Fig. 2). The site was relatively dry because I hadn’t rained in the weeks leading up to my visit. As a result, the water coverage was limited to a small area (barely visible) south of the Nature reserve (Fig. 4).

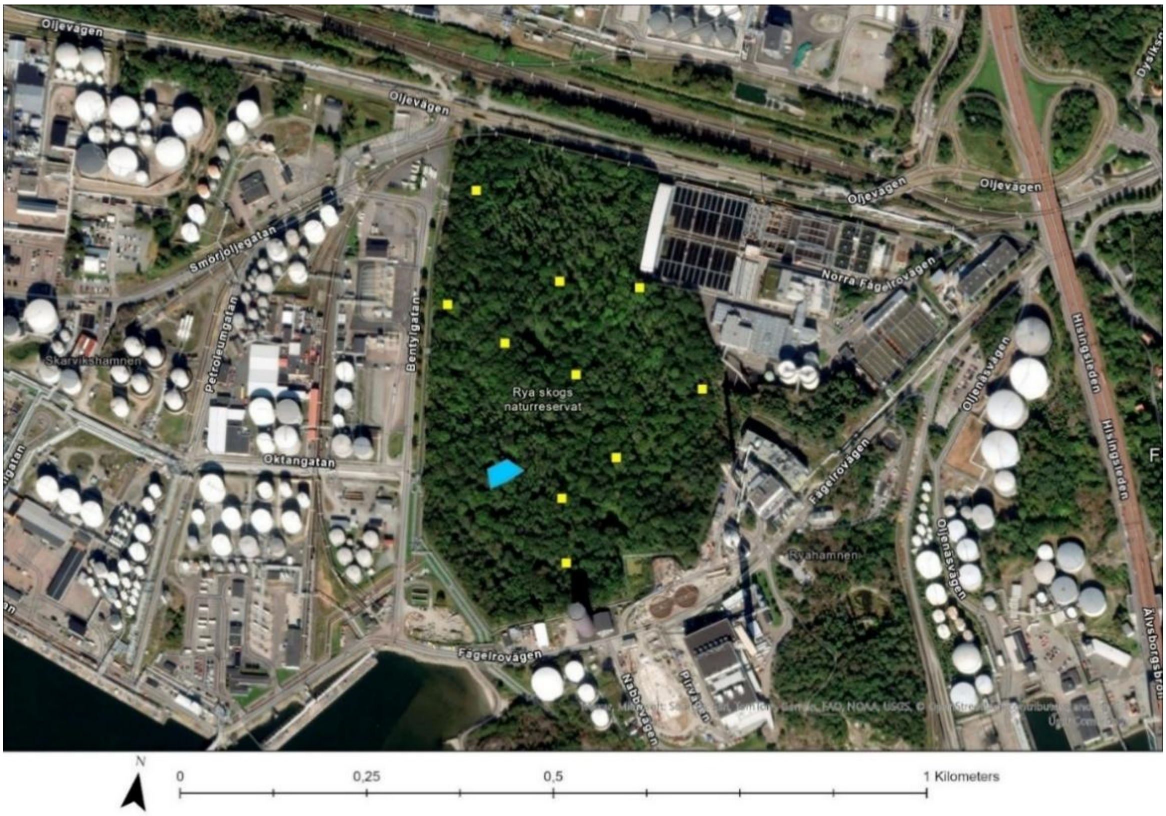

Figure 2. The figure shows Rya Skog in Gothenburg (Forest a). The yellow squares indicate the locations of ten plots where data on deadwood, lower vegetation species and tree density were collected. The blue polygon represents an area of limited/barely visible water coverage (Map created in ArcGIS pro online using author’s GPS data and Esri Imagery Hybrid basemap).

 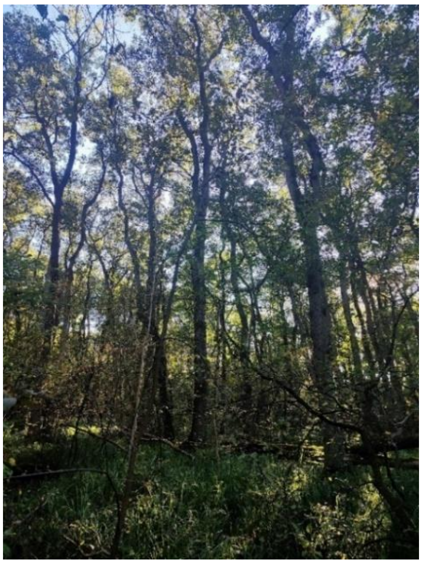

Figure 3 (left) and 4 (right). Figure 3 shows a 1 x 1 m mini plot used to identify lower vegetation species, with help pf the apps Picture This and Flora Incognita. Figure 4 shows an overview of an Alnus dominated area that should have been covered by water at the time of my visit to Rya Skog. Although the ground was saturated, a barely visible amount of water was present.

Näverkärr Nature Preserve (Forest b)
Coordinates: $11,3733822°E$ $5835000701°N$
Situated near Karlsvik beach, this wetland forests is rich in trees up to 200 years old (Västkuststiftelsen, 2025). The area I investigated covered around **6,5 hectares** (Fig. 5), while the entire reserve spans approximately 235 hectares (Länsstyrelsen Västra Götaland, 2025), including a small island. In the north plots the dominant species observed were *Mercularis perennes* (skogsbingel) and filipendula ulmaria (älggräs). In the southern plots, *Pleurozium schreberi* (väggmossa) and *Hepatica nobilis* (blåsippa) were also present to a significant extent. During my visit I observed a big woodpecker that was making a hole in one of the many standing dead trees close to the southern plots (Fig. 5). The reserve is signed with pathways that allow visitors to walk around the reserve, making the establishment of mini plots (1 x 1 m) (Fig. 6) for lower vegetation species identification less problematic.

In the 1950s, this wetland forest was att risk of being exploited by the timber industry. However, its owner, Signe Benjour, together with Magnus Fries, descended from a known family of botanists, won a legal battle, and in 1964 the forest was designated as a nature reserve (Fig. 6) (information sign at the reserves parking area, 2025).

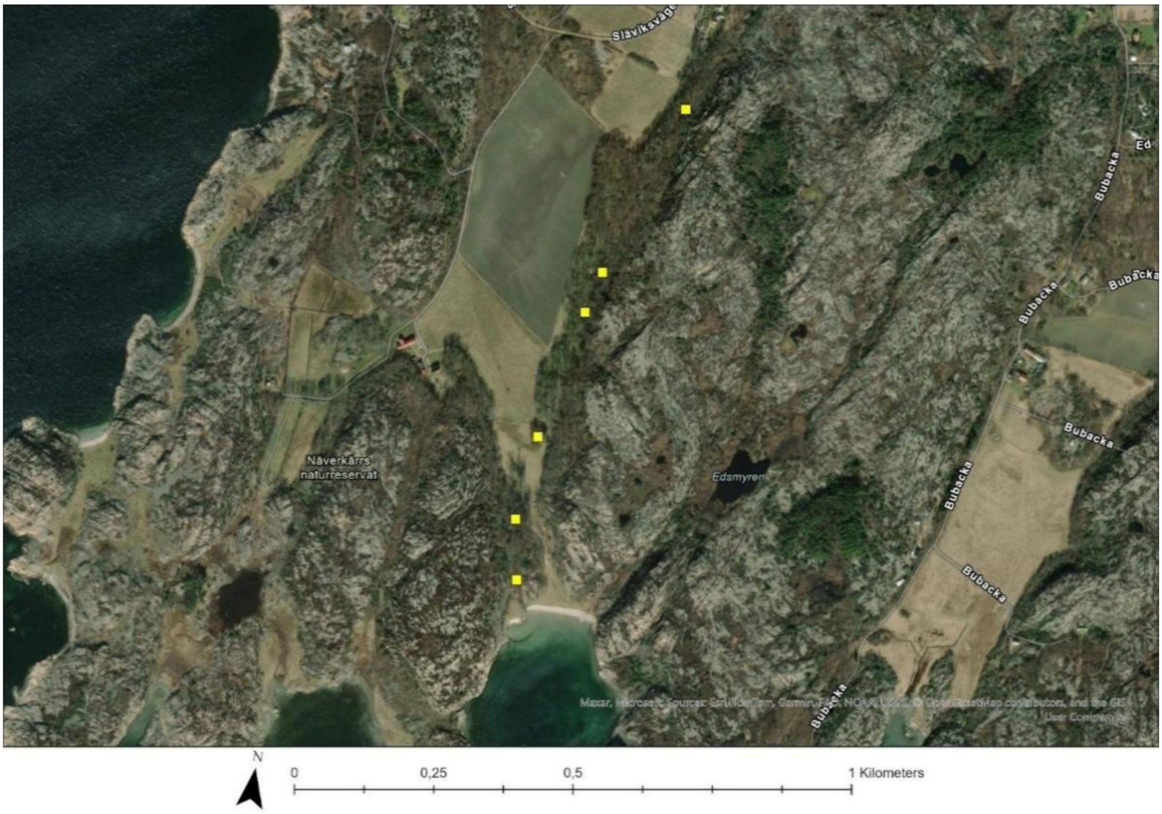

Figure 5. *The figure shows the investigates site at Näverkärr Narure Reserve (Forest b). The yellow squares indicate the locations of six plots where data on deadwood, lower vegetation species and tree density were collected (Map created in ArcGIS pro using author's GPS data and Esri Imagery Hybrid basemap).*

Figure 6 (left) and **7 (right).** *Figure 6 shows the information sign in the reserves parking area. In the black and white picture can we see Näverkärr's forest saver Signe Benjour. Figure 7 shows a mini plot (1 x 1 m) depicting the strong presence of the species Mercurialis perennis (skogsbingel).*

Havstensfjorden Nature Preserve (Forest b)

Coordinates: $11,3733822°E\ 5835000701°N$

This wetland forest edge is located close to the shoreline (around 26 m) (Fig. 10). Due to the lack of rainfall prior to my visit (week 39-40), visible water coverage was largely absent, although small patches of standing water were present in some areas (Fig. 25). The measured salinity of the few water-covered areas was 199 ppm, which represents very low salinity and more a less no influence of coastal waters salinity. A small creek flows into the sea, west on the forested section of the nature reserve (Fig. 8), and the water coverage withing the investigated area may originate from this creek. This could explain the measured salinity levels in the wetland forest, which is densely populated with trees. The salinity may be influenced by groundwater seeping in from the creek.

Trees of the genus *Alnus* (klibbal) dominated the area (Fig. 11), making it a textbook example of an alder swamp forest. A smaller area was also dominated by coniferous trees. The investigated area covered around **2,5 hectares**, representing part of the tree-covered section of the reserve (Fig. 8). This is a small part of the reserves total area, which is around **1932 hectares** (Länstyrelsen Västra Götaland, 2025). Due to the dense vegetation in most of the area investigated, as well as the water saturated conditions of the soil, it was challenging to establish mini plots for species identification (Fig. 9). The dominant lower vegetations species was Mnium hornum (skuggstjärnmossa), with a considerable presence of *Scirpus sylvaticus* ((skogssäv) and *Carex digitata* (vitspärr). The information sign, located at the parking area near the reserves entrance, explains that a large portion of the reserve lies underwater, which contributes to a rich variety of fish in its deepest areas. In the southern part of the reserve, there is a dedicated birdwatching tower. I recommend bringing water resistant clothing and rubber boots to explore the wetland forest area. A wooden ramp also runs through the forest, making the area accessible to strollers and wheelchairs.

Figure 8. *The figures show the investigated area in Havstensfjorden Nature Reserve. The yellow squares represent the four plots (10 x 10 m) where I collected data on deadwood, tree density, salinity of water covering (mostly not visible) and lower vegetation species coverage. The red line represents the shoreline (Map created in ArcGIS pro using author's GPS data and Esri Imagery Hybrid basemap).*


Figure 9 *(left) and* ***10*** *(right). Figure 9 shows one of the mini plots (1 x 1 m) where lower vegetation species were identified. Note the high density of lower vegetation. Figure 10 shows the proximity of the forest edge to the shoreline.*

Figure 11*. The figure shows an area in Havstensfjorden reserve dominated by trees of the genus Alnus (klibbal)*

Results

Visualization of all parameters

The results are presented in tables and charts to facilitate their visualization. Species coverage across different mini plots will be presented in a summarized bar chart created using Excel (Fig. 12). All other charts were created in Google Sheets (Fig. 17, 18 and 19).

Lower vegetation species coverage

Rya Skog (20 replicates total), Näverkärr (12 replicates) and Havstensfjorden (8 replicates)

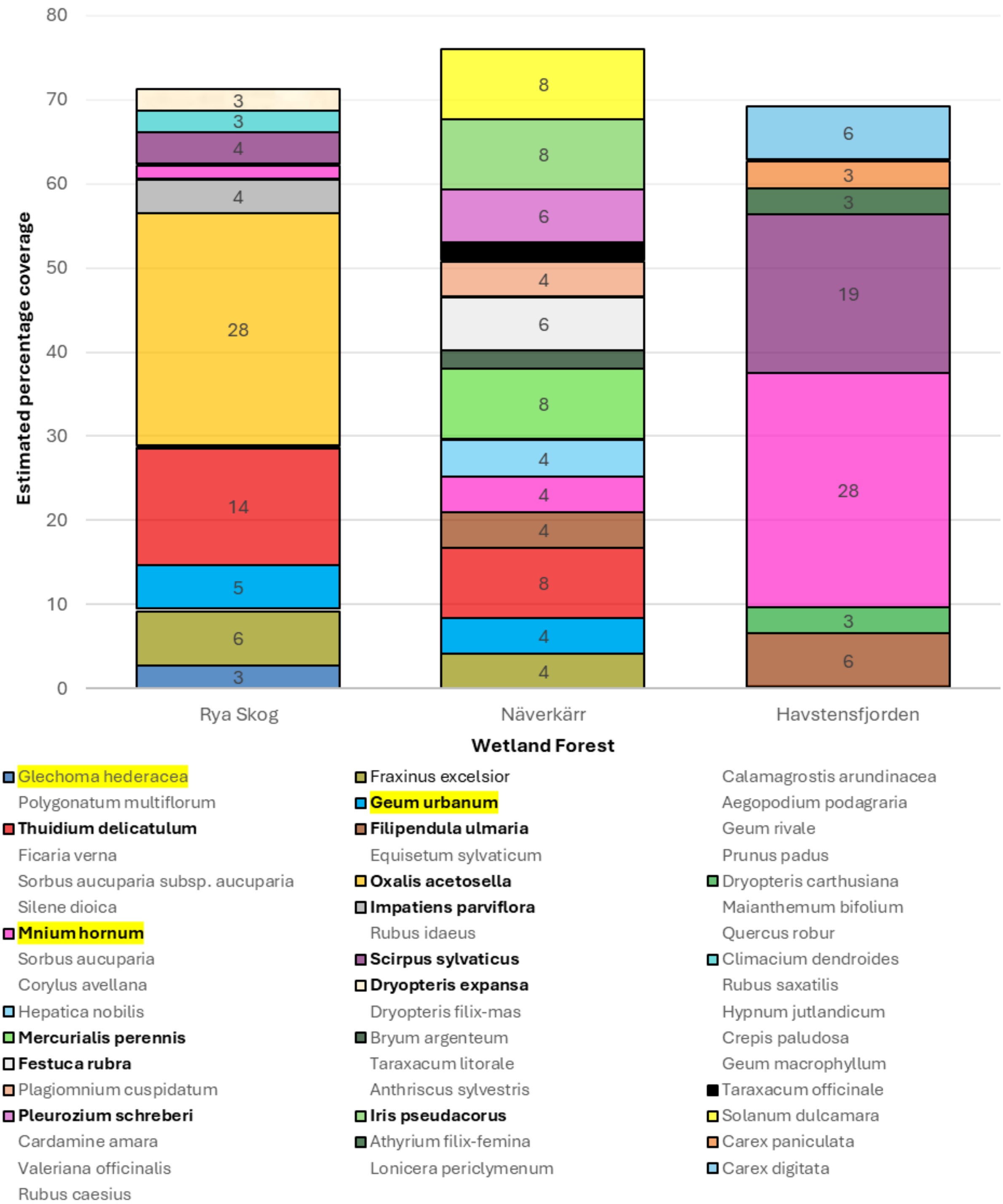

Figure 12. *The figure shows a bar chart depicting the identified lower vegetation species in the* ***mini plots*** *(each 1 x 1 m) measured in Rya Skog Nature Preserve (Forest a), Näverkärr (Forest b) and Havstensfjorden (Forest c). Note the dominance of the species depicted with its data label. The values represent the estimated mean percentages of the species coverage in each study site. Values* $\leq 2\%$ *were ignored though the aim was to show the most dominant species. Species highlighted in yellow were present in all three sites Rya Skog has a mean percentage coverage of Mnium hornum (skuggstjärnmossa)* $= 1 \pm 1\%$ *(20 replicates), whereas in Havstensfjorden the same species have a mean value of* $28 \pm 8\%$. *Näverkärrr has a mean value of Mnium hornum* $= 4 \pm 2\%$.

Estimated Shannon-Wiener Index in Forest a (10 replicates), Forest b (6 replicates) and Forest c (4 replicates)

To compare biodiversity in the three forests I performed a Shannon-Wiener diversity index calculation in R using the sampled data on lower vegetation species coverage (Fig. 16). Rya Skog had the highest species richness of the three forests (Fig. 16). The species richness in *Forest b* (Näverkärr) and *Forest c* (Havstensfjorden) in this autumn study was further compared with an earlier study performed in spring 2024 (Tupala (2024). The estimated results show a close similarity to Tupala (2024) findings for Havstensfjorden, where this study's estimated mean was 0.73, compared to around 0.70 in Tupala (2024) results. For *Forest b* (Näverkärr), however, the results differ more. This study yielded an estimated index of 0.74 compared to around 0.25 in Tupala (2024) results.

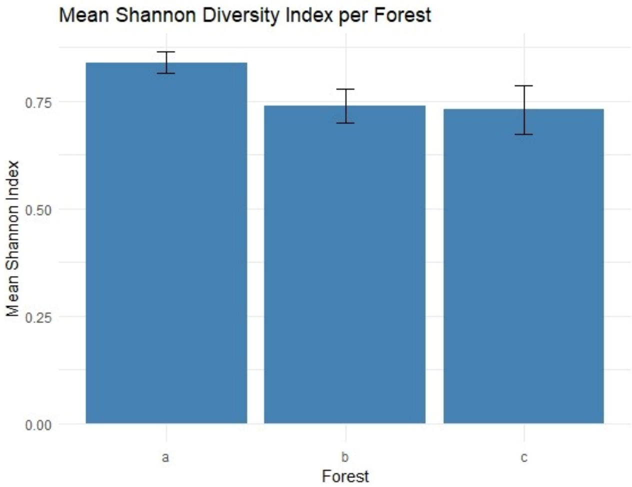

Figure 16. *The figure presents the estimated mean Shannon-Wiener Index in each study site of the current study: Forest a (Rya Skog), Forest b (Näverkärr) and Forest c (Havstensfjorden).*

Estimated deadwood volume in Forest a (10 replicates), Forest b (6 replicates) and Forest c (4 replicates)

Using a modified version of Huber's formula (from Ahmad *et al.,* (2020), and following the protocols by Rondeux *et al.,* (2020) and Rousseau *et al.,* (2024) for measuring lying deadwood logs using Fixed Area Sampling (FAS), I obtained the estimated results shown in figure 17. All calculations and creation of the bar charts were made using Google Sheets.

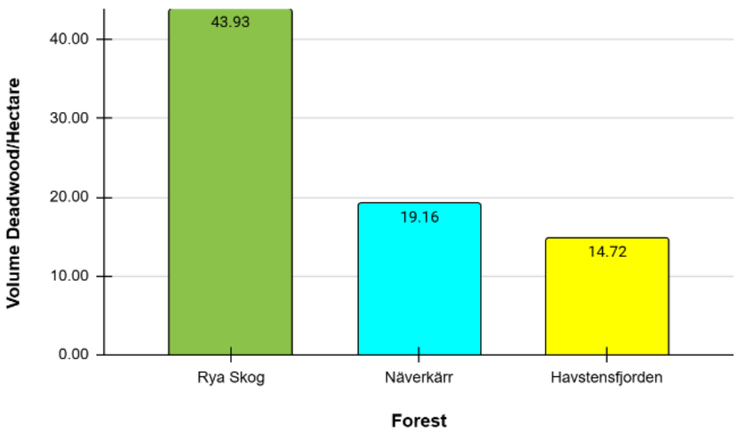

Figure 17. *The figure presents an estimate of the volume of lying deadwood in each wetland forest. Note the differences between Forest a (Rya Skog), and the other two study sites Forest b (Näverkärr) and Forest c (Havstensfjorden).*

Estimated Forest Density in Forest a (10 replicates), Forest b (6 replicates) and Forest c (4 replicates)

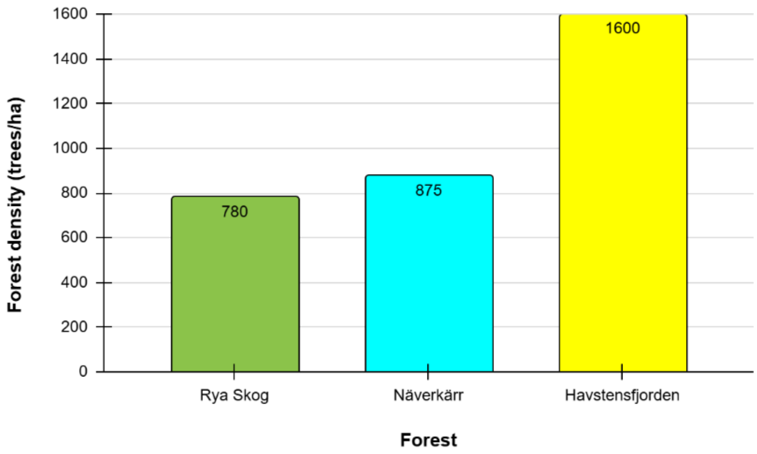

Figure 18. *The figure presents the estimated forest density (trees/ha) in each wetland forest. Note the difference between Forest c and the other two study sites Forest a (Rya Skog) and Forest b (Nänerkärr). The bar chart was created using Google Sheets, as well as the required calculations.*

Measured salinity levels and area of water coverage present on each site in ppm (3 replicates)

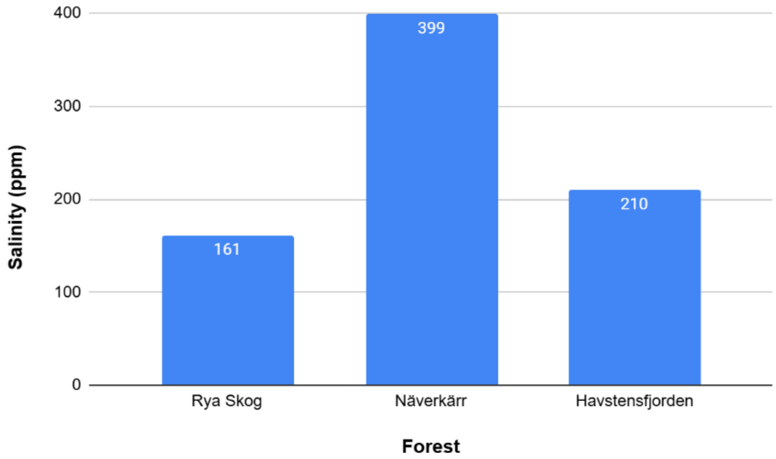

Figure 19. *The figure shows the measured salinity level (ppm) obtained using a salinity measuring toll in the limited water covered areas at each wetland forest. Note the slightly higher salinity level in Forest b (Näverkärr), compared to Forest a (Rya Skog) and Forest c (Havstensfjorden).*

Area of water coverage

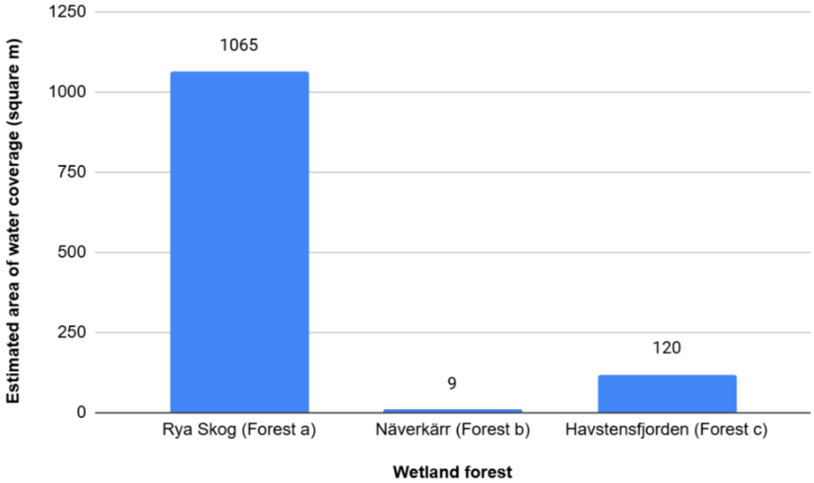

Figure 20. *The figure shows the estimated area of water coverage in each study site. Note the difference between the water covered areas in each site, although visible water was mostly absent. The water covered area for Forest a is a rough approximation based on high saturation of water in the soil since, as mentioned above, visible water was limited.*

Measured distance to the nearest shoreline and area of each study wetland forest

Rya Skog Nature Preserve (Forest a) - Coordinates: 11,8858973°E 57,6955136°N

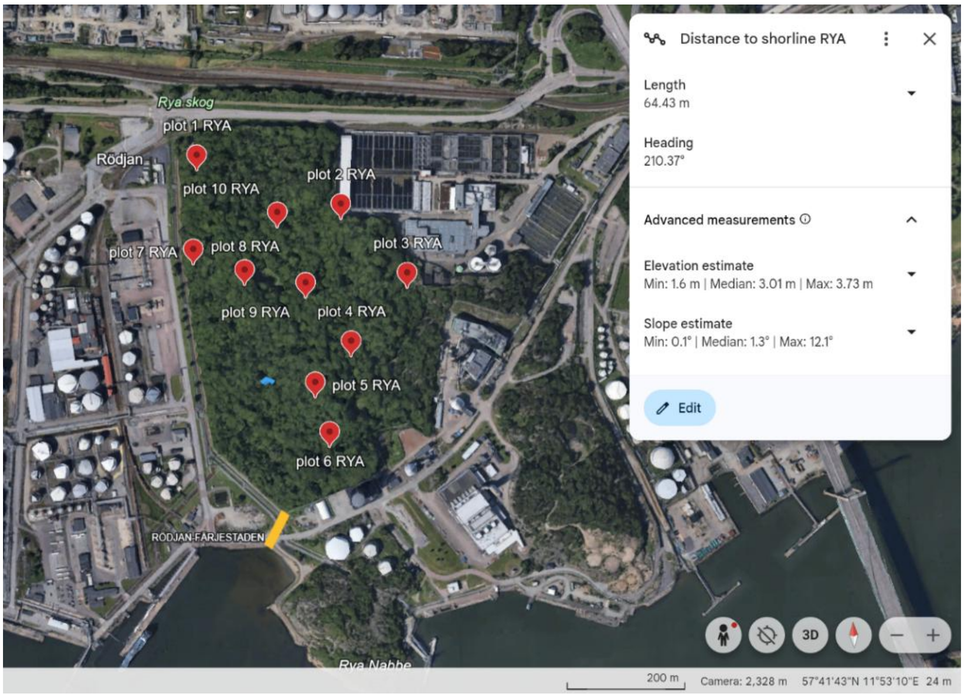

Figure 21. *The figure shows the estimated distance from Forest a edge (Rya Skog) to the nearest shoreline (yellow line). Note the value of the estimated distance in the white square window (around 64.43 m). The figure also shows the distribution of the deadwood plots around the wetland forest (Map created using Google Earth Web, Satellite basemap, 2025).*

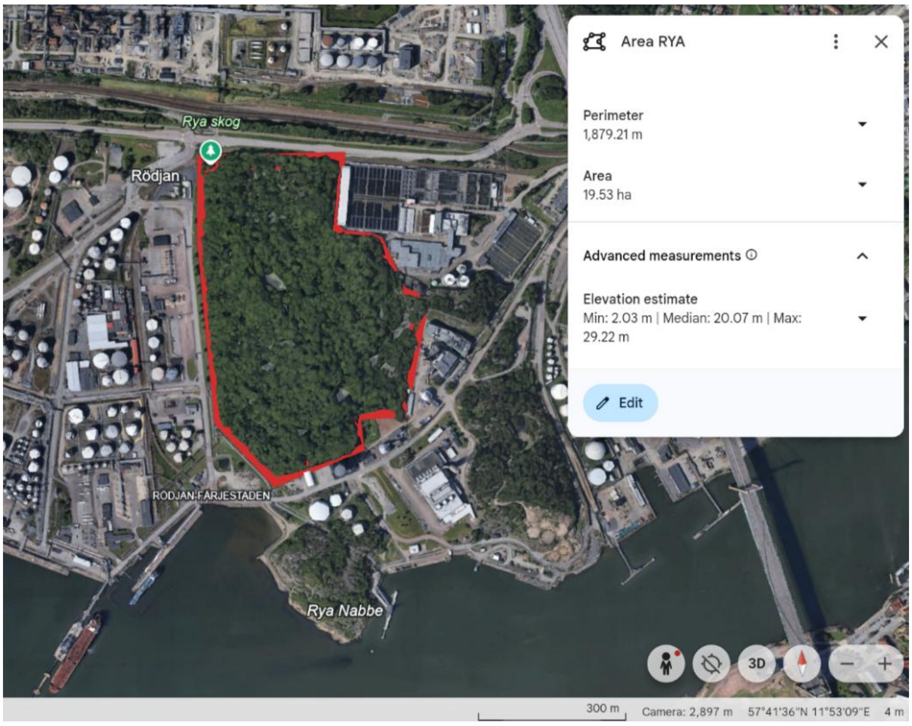

Figure 22. *The figure shows the estimated area of Forest a (Rya Skog) depicted with the red polygon. Note the value of the estimated area in the white square window (around 19,53 ha). (Map created using Google Earth Web, Satellite basemap, 2025).*

Näverkärr Nature Preserve (Forest b) - Coordinates: 11,3733822°E 5835000701°N

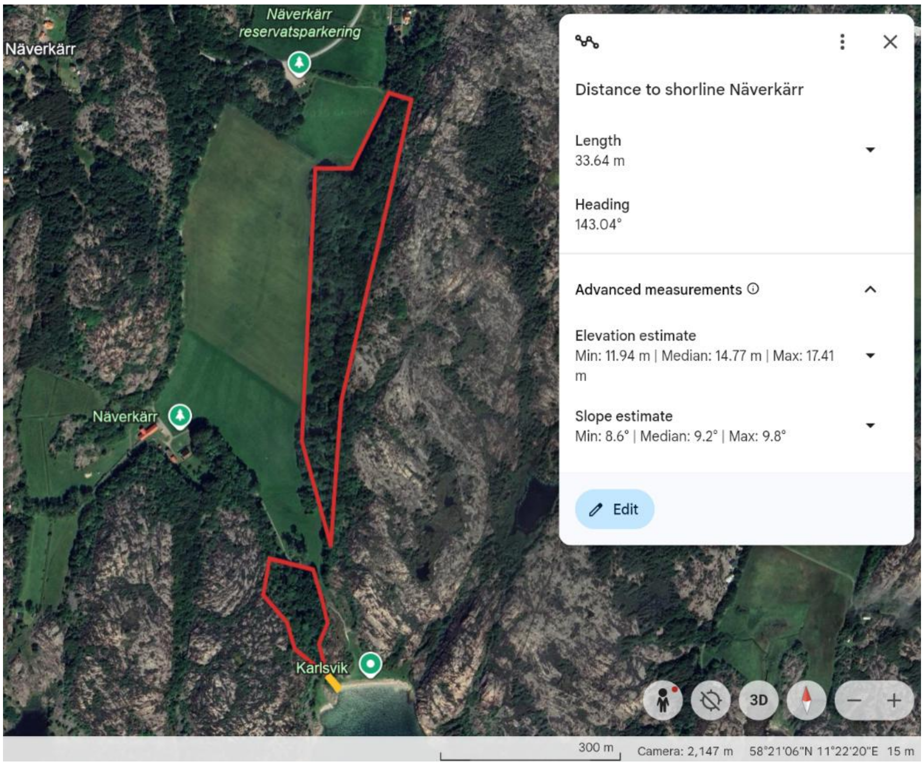

Figure 23. *The figure shows the estimated distance from Forest b edge (Näverkärr) to the nearest shoreline (yellow line). Note the value of the estimated distance in the white square window (around 33.64 m). The two red polygons represent the area investigated, which has an estimated area together of 6,22 ha (Map created using Google Earth Web, Satellite basemap, 2025).*

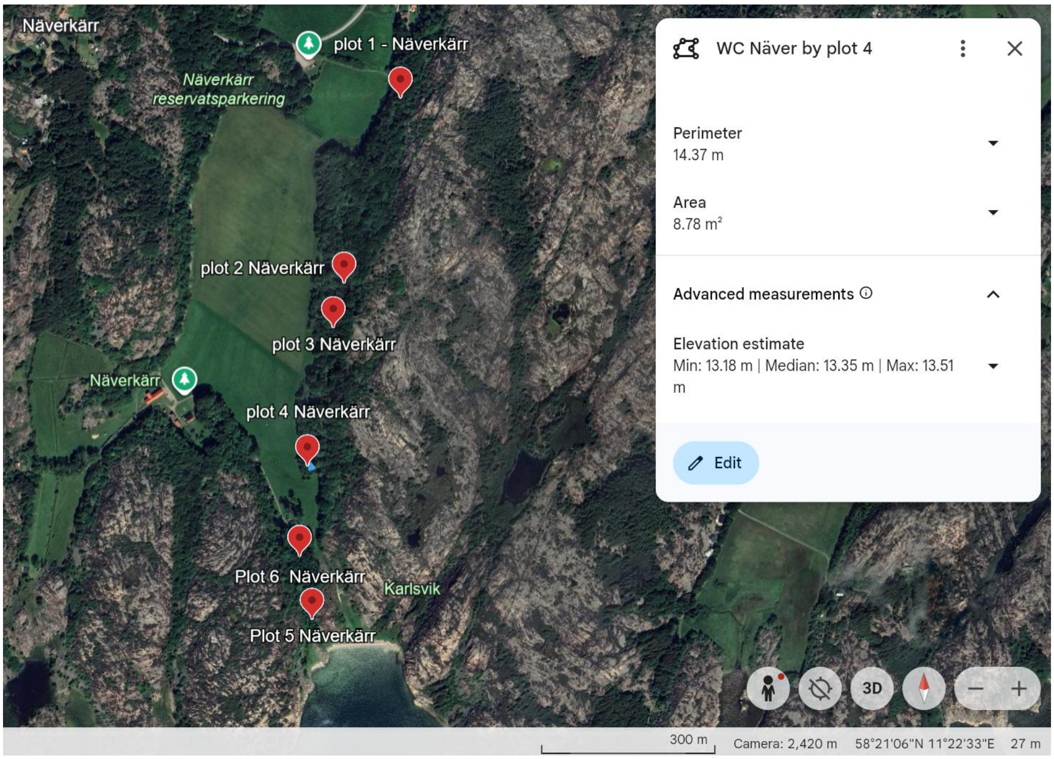

Figure 24. *The figure also shows the distribution of the deadwood plots around the wetland forest, as well as the limited water coverage within deadwood plot 4. The area of the water coverage shown in the white window is a rough estimation, though it was barely visible, and had a salinity level of 399 ppm (Map created using Google Earth Web, Satellite basemap, 2025).*

Havstensfjorden Nature Preserve (Forest b) - Coordinates: $\mathbf{11,3733822°}\boldsymbol{E}\ \mathbf{5835000701°}\boldsymbol{N}$

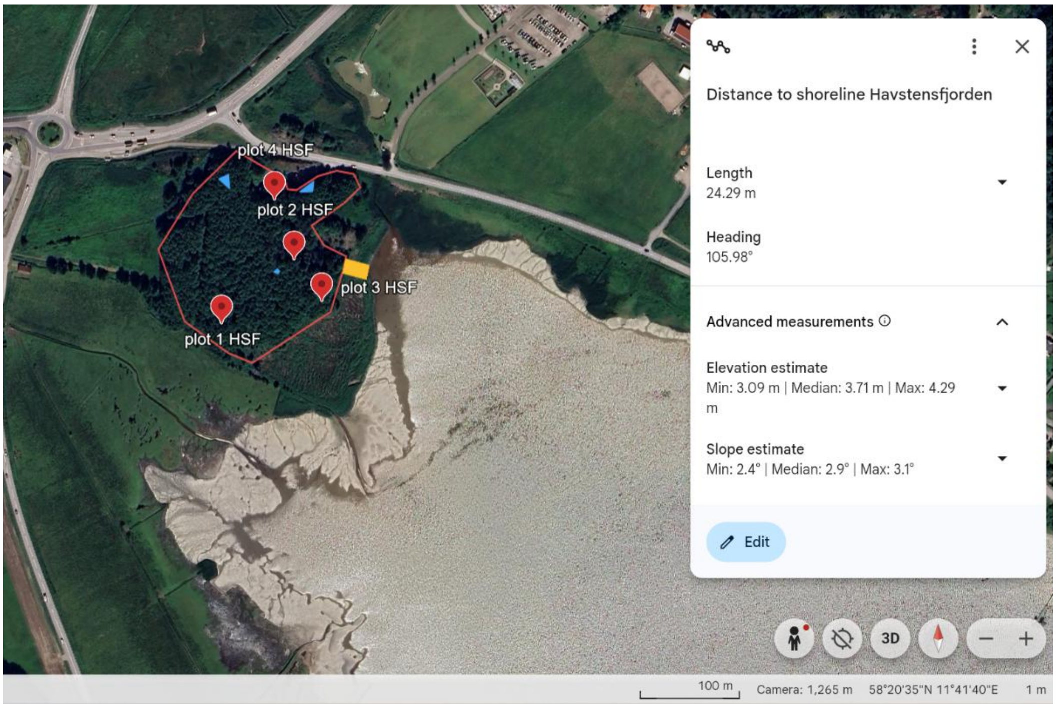

Figure 25. *The figure shows the estimated distance from Forest c edge (Havstensfjorden) to the nearest shoreline (yellow line). Note the value of the estimated distance in the white square window (around 24.29 m). The red polygon represents the area investigated, which has an estimated area of 2.48 ha. The blue polygons represents the limited visible water coverage (Map created using Google Earth Web, Satellite basemap, 2025).*

Discussion

Central aim overview

A central aim of this project was to explore how the study of wetland forests can support the development of teaching materials that are aligned with Sweden's current biology curriculum for junior high education. This was made possible by integrating various parameters into the study of wetland forests (Schmidt, 2024; Medin, 2024; Tupala, 2024), shown in *table 3*. From a junior high school student perspective, one could probably wonder how all this work in the forest is going to serve as a learning tool, but more importantly what am I going to learn about measuring all this?

Learning possibilities from deadwood volume and forest density parameters

This study introduces a new parameter to the standardized procedure, a method for measuring lying deadwood logs using Fixed Area Sampling (FAS), along with a technique for calculating deadwood volume (from Ahmad *et al.,* 2020; Rousseau *et al.,* 2024; Rondeux *et al., 2012*). This study's results show an estimated volume of deadwood of 43.93(10 replicates) cubic meters/hectare in Forest a, 19.16 (6 replicates) in *Forest b* and 14.72 (4 replicates) in Forest c (Fig. 17). It could be suggested that the higher volume in *Forest a* is explained by the amount of data sampled, which was greater than that sampled in the other sites (*Forest a* 10 plots, *Forest b* 6 plots and *Forest c* 4 plots). Here, students could discuss what this result tells us.

This parameter opens opportunities for teachers to discuss the ecological role of deadwood, such as its function as a habitat for various insects and other organisms that contribute to nutrient recycling in the soil (Paletto *et al.,* 2012). The curriculum's core content in biology states that students should receive teaching contents such as ecosystems, biodiversity and nutrient cycles. Therefore, this parameter serves as a bridge to give students the opportunity to learn about the subject in a practical manner, and to train mathematical subjects such as geometry. Volume calculations can though be done in practical way, in the forest. Students can learn about volume and area in the forest, with deadwood logs and plot establishments. In that way the teacher put the mathematical content in a clear real-world context.

The estimated forest density results were 780 trees/hectare for *Forest a*, 875 for *Forest b* and 1600 for Forest c. A possible trend that suggests that the less volume of deadwood, the greater the forest density values. Bayraktar *et al., (*2020) suggests that forests with many old trees use to have higher volumes of deadwood. Thus, this study's results could mean that *Forest a* has a larger number of old trees, compared to *Forest b* and *c.* It should be considered that in *Forest b* a considerable number of standing dead trees were observed but not included in the calculations of deadwood in this study thou the focus was on lying deadwood logs. Bayraktar *et al.,* (2020) also highlights the importance of deadwood as a key parameter for studying ecological factors in forests, as it is part of the IPCCs carbon stocks pool. While a teacher can explain the importance of deadwood in a classroom setting, experiencing it firsthand in a forest environment can make the topic more engaging and meaningful for students.

Learning possibilities from water coverage comparison and its salinity

Prior to visiting the study sies, I anticipated encountering extensive water coverage, however this was not the case. Only in *Forest c* was a more visible extent of water coverage documented, although most of it not visible in the area investigated. Studies from spring 2024 reported a visible water coverage of 1093 hectares in *Forest b,* respective 1193 hectares in *Forest c.* The results of this study show an estimated water coverage area of 8,78 square meters (visible water) in *Forest b* and around 119,7 square meters in *Forest c* (Fig. 22), mostly not visible (Fig. 25), which is an evident difference from the earlier studies. This estimation is based on the observation that most of the soil throughout the area was saturated with water, resulting in very waterlogged conditions.

However, visible water was only present in a few small spots scattered across the site (Fig. 25), except for a small, elevated area located near the parking lot/place, north of the study site, where no water was present at all.

This result suggests that there seems to be a clear difference in water coverage between spring and autumn seasons. This data opens opportunities to discuss the role of water coverage in wetland forests. A wetland forest is characterized by having water available all/most of the year, due to a *"water table at or near the soil surface"* (Paudel *et al.,* 2023, p. 1). Paudel *et al.,* (2023) highlights that the water coverage dynamic affects the chemistry of the soils in wetlands forests, affecting plant growth and thus the overall ecology of the forest. This information is directly related to the junior high curriculum point on ecosystems. The curriculum highlights photosynthesis and material cycles as some of key processes that students should learn about in years 7-9 (See Text box 1) (Lgr 22). Our results thus show the dynamics of the water table in *Forest a* and *b* when comparing spring and early autumn seasons in these specific sites.

The highest measured salinity in this study was recorded in the limited water coverage of *Forest b* which was 399 ppm (Fig. 19), specifically within deadwood plot 4 (Fig. 24) – coordinates: $11{,}3738400°E\ 58{,}3514940\ °N$. Water with this level of salinity can be classified as slightly brackish (Li *et al.,* 2020; Millar *et al.,* 2016). Millar *et al.,*2016 highlights that it is more difficult for plants to absorb water with high salinity, compared to freshwater. However, it is unclear whether this salinity level is caused by sea water spray from the nearby shore (Fig. 23). This discussion can be carried out with students, where terms such as water hardness, as well as how plants absorb water through their roots. Another process that can be discussed is the water cycle which is an essential part of the ecosystems.

Learning possibilities from biodiversity and lower vegetation comparison
I calculated species diversity using the Shannon-Weaver index to compare my results with those reported by Tupala (2024) in spring 2024. This study shows a mean Shannon-Wiener index of 0,738 for *Forest b*, and 0,730 for *Forest c* (Fig. 16). Tupala (2024) results for *Forest b* were 0,25, and 0,65 for *Forest c*. The differences with *Forest c* are relatively small, whereas more evident for *Forest b.* But how can the results of this parameter be used to teach students about ecology and biodiversity? Baliton *et al.,* (2020) highlights that the Shannon- Wiener index give us an estimate of *"the variation of populations of different species in an ecosystem"* (p. 709). Having this in mind, biologists can thus record fluctuations in the diversity of species in different forests investigated. Hrivnák *et al.,* 2020 highlights that *Alnus glutinosa* dominated forests are among the most important types of forest to be protected due to its hydrological complexity, which explain the high biodiversity among forests in Europe. The results from this study suggest that it may be clear seasonal differences in lower vegetation diversity (spring 2024 and early autumn 2025) in Näverkärr, whereas a more constant diversity of this species in Havstensfjorden.

The species coverage results in this study also suggest a seasonal difference in the dominant species in *Forest b* and *c*, compared with earlier studies (Schmidt, 2024). The dominant species in *Forest b* (Näverkärr) in spring 2024 was Anemone nemorosa (vitsippa) and Lesser celandine, with some presence of Hepatica nobilis (blåsippa) (Schmidt, 2024). This autumn 2025 (September) species such as Mercularis perennis (skogsbingel) are relative more dominant (Fig. 12), and the species reported in spring 2024 were not observed, besides Hepatica nobilis (blåsippa). These results can help students see seasonal differences in species composition, as well as an estimate of their coverage (Fig. 12). In forest c dominant species recorded in this study was Mnium hornum (skuggstjärnmossa) and Scirpus sylvaticus, which also differ from the study conducted in spring 2024 where *Filipendula ulmaria* was dominant (Schmidt, 2024).

This information opens possibilities for discussing biodiversity's importance for the different habitats in wetland ecosystems. A term that can be introduced in this context is ecosystem services. As presented in the introduction section, wetland forests play an important role in regulating groundwater run off (Jeglum *et al.,* 2011). We discuss also how the water table dynamic plays a crucial role in the growth rate of plants and the chemistry of the soil in these forests (Paudel *et al., 2023).* We can discuss with students the connections between parameters such as water coverage and species diversity.

Development of pedagogically relevant teaching materials

This study demonstrates that investigation of wetland forests can contribute to the development of pedagogically relevant teaching materials. These materials are aligned with the curriculum for compulsory school in Sweden (Lgr22), specifically with the subject of biology but also mathematics as it required different types of calculations, as well as to create and interpret tables and diagrams. One of the curriculum's main goals is to support students in developing their "*abilities to conduct systematic investigations in biology"* (Lgr22, p. 161). The method used in this study was designed to be adaptable across educational levels, starting with junior high school students, but also suitable for high school instruction trough the integration of different forest types and more advanced calculations. Furthermore, the study reflects the curriculum's emphasis on systematic working methods. It requires students to consider what aspects of nature to be investigated. In this case, focusing on biodiversity and ecology. As mentioned above, such investigations also demand mathematical skills, for example calculating species diversity and volume of deadwood. In addition, the use of mapping tools and geographic systems such as Google Earth links the study to the subject of geography, reinforcing interdisciplinary learning across natural science, mathematics and geography (or even other social study subjects such as civic and history).

Fägerstam & Blom (2012) highlights that outdoor lessons are not commonly practiced in Sweden. The same study pointed out that learning biology outdoors may have positive outcomes when it comes to students learning about ecology. Jeronen *et al.,* (2016) conducted a study on the effectiveness of learning methods in biology and sustainability education. Their findings suggest that approaches involving active group work among students were one of the most effectives for learning these subjects. The list of studies demonstrating the positive effects of various learning methods is extensive. In today's world, it is more important than ever to promote teaching approaches in biology where outdoor activities are a natural and regular part of instruction.

Limitations

The most prominent limitation in this study was the timeframe. A study like this kind could be conducted on a larger scale to collect more data that would be more representative of the parameters measured. As my results showed, there was almost no visible water coverage during my visit. Due to time constraints, I was unable to conduct a second (or even third) visit following a period of precipitation, which would have provided a more representative assessment of this parameter. However, I discovered that the investigated wetland forests have fluctuations of water coverage, which suggest that this parameter is highly influenced by precipitation events during longer periods. To improve this time limitation, it is recommended to involve other subjects in the project. In this way a detailed and structured interdisciplinary project could be planned so that the thematic covers the curriculum in those subjects. I recommend at least two whole school day visits for fieldwork, distributed in a two-week period. Mathematics, geography, civics and even physical education teachers could attend to the fieldwork. This project could also be conducted every school year, something that can lead to a considerable amount of ecological data to be sampled over a period of several years. One year's data can then be analyzed and compared with data from the previous year and so on. Subsequently it could turn out to be a comprehensive ecological study over a specific wetland forest.

Another limitation to consider is the method used for identifying plant species, which may not always be entirely accurate at all times, specifically for identifying moss species. In many cases, I receive different results from the two identification apps *Flora Incognita* and *Picture This.* To improve accuracy, I recommend allocating more time for species identification, including taking detailed photographs and analyzing them in a PC lab setting. This would likely lead to more representative results. The accuracy of species identification may have influenced the calculation of the diversity index. Additionally, I conducted all the fieldwork alone, which could also be considered a limitation. Working in pairs or in a group would likely have made the sampling process more efficient, particularly when setting up plots for identifying plant species and recording deadwood.

Forest density in this study was measured by counting trees within the 10 x 10 m lying deadwood plots. To improve this method, identifying tree species could offer a broader understanding of the forests tree species composition. Although, the selected sites were largely dominated by trees of the genus *Alnus,* which was already known prior to the field visit. There is another technique for measuring deadwood logs called Line Intersect Sampling (LIS). This method is more efficient but may be less accurate than FAS (Teissier Du Cros & Lopez, 2009). Thus, it could be suggested that a more extent area for deadwood sampling (Fig.22, Fig. 23, Fig. 25) could be covered using LIS in future research.

Possible future research

This study opens possibilities for future work aimed at testing the toolkit with students in junior high school. In subsequent research, one or two parameters could be selected to evaluate the effectiveness of outdoor lessons and group based practical activities. The goal would be to assess not only the impact on academic performance, but also on students' attitudes toward biology, particularly in areas such as ecology, biodiversity and sustainability. Another possibility for future research is to focus on one or two parameters and perhaps including specific species of insects and fungi that act as decomposers of deadwood, and in that way enter a broader field of ecological studies.

Conclusions

The study shows promising possibilities for developing teaching material for junior high biology education through wetland investigations. It also suggests a wide variety of adaptabilities for interdisciplinary connections with mathematics, as well as social study subjects such as geography and even civics, history and physical education. This study suggests higher biodiversity in Forest b (Näverkärr), and almost similar in Forest c in comparison with studies conducted in spring 2024 (Tupala, 2024). It also suggests evident seasonal differences in water coverage (lower) in Näverkärr and Havstensfjorden, in comparison with earlier studies conducted in spring 2024 (Schmidt, 2024; Tupala, 2024; Medin, 2024). To increase knowledge of ecological and societal values of wetland forests among junior high school students may help the sustenance of these valuables' habitats into the future.

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