Restoration of the Søborg Lake

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Abstract

This report examines the Søborg Lake restoration project owned and undertaken by the Danish Nature Agency and discusses the history, current conditions and the restoration project plan of the lake in detail. We then view said details through the conceptual lens of Ecological and Ecosystem restoration to establish the project as a reflection of said concepts. The information collected for the report has been attained through literature, personal observations and personal communication with Ida Dahl-Nielsen, the restoration project manager. The collected information forms the basis for our Discussion around the question of the project's suitability as either Ecological or Ecosystem restoration given the delineation, goals and implementation. The results of the discussion indicate that Søborg Lake restoration is an example of Ecosystem Restoration due to the larger focus on social infrastructure needs than can be found in Ecological Restoration.

Introduction

Restorative efforts for a degraded landscape have been at the forefront of agendas for several organizations working to preserve biodiversity. It is the natural step after identifying and quantifying the anthropogenically caused ecological impacts on a region.

Denmark is continually remedying its efforts towards the previously initiated loss of biodiversity, deforestation and habitat degradation. The attempts at restoring previously degraded landscapes have been monetarily and legally fueled by the local governing authorities, proactive citizen initiatives and backboned by the scientific and academic communities [1]. This served as motivation to accept our topic for this report.

In the report, we hope to shed light on the lake restoration project operated over the last decade at Søborg Lake, 3230, Græsted, Denmark. The stakeholders of the project aim to restore a lake, which started degradation roughly 2 centuries ago.

The supplementary goals of the project include reclaiming the agricultural lands by compensating the land owners, making the lake a recreational hotspot for the localities, priming the lake and its surroundings for anglers and pedestrian activities, attaining biodiversity enrichment (especially for the avian fauna), and executing a model of the lake that is sustainable in the long run [2]. The benchmark for the project is to get the lake back along its extrapolated trajectory, i.e. to restore the landscape to the conditions in which it would be expected if the lake had not been degraded, within the context of current of social barriers and climatic conditions. These factors serve as motivation for formulating the research question:

Research Question: Is the lake restoration project at Søborg Lake an example of ecological restoration or ecosystem restoration?

The report starts by introducing some key definitions relevant to the research question. Our report firstly discusses the geological, topographical and anthropological history of the project site, as well as its ecological significance for the landscape under the Materials section. This section also covers the basic factual information related to the project's area, operationality and finances. The Methodology section involves collecting primary data by firsthand observations of the project site (collected on 20th Sept. 2024), discussions with the project manager and course instructors, and processing of the secondary data obtained from books, academic and other virtual sources. The Observation and Results section goes into depth about the restoration strategies developed in cooperation with the stakeholders as well as the challenges encountered during establishment of the project and the resulting management strategies that were employed to try to solve some of them. Finally, the Discussion section hopes to consolidate the results and compare them to the definitions in an attempt to answer the research question. The final verdict is presented in the Conclusion as a consequence of the discussion.

There were some limiting factors when putting together the report. Some of the secondary data obtained during data collection phase was encrypted in Danish, requiring specialized inputs to access them. Owing to a lack of time, the report could not have been more comprehensive. A more quantitative analysis of ecosystem services could have provided a better estimation at the form of restoration.

Definitions

Ecological Restoration: "Ecological restoration is the process of assisting the recovery of an ecosystem that has been degraded, damaged or destroyed." [3]

Ecosystem Restoration: "(It is) the process of halting and reversing degradation, resulting in improved ecosystem services and recovered biodiversity. Ecosystem restoration encompasses a wide continuum of practices, depending on local conditions and societal choice." [4]

Materials

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The group visited Søborg Lake on the 20th of September 2024. The description of this site is based on personal observations and personal communication at the location and supplemented by websites and reports.

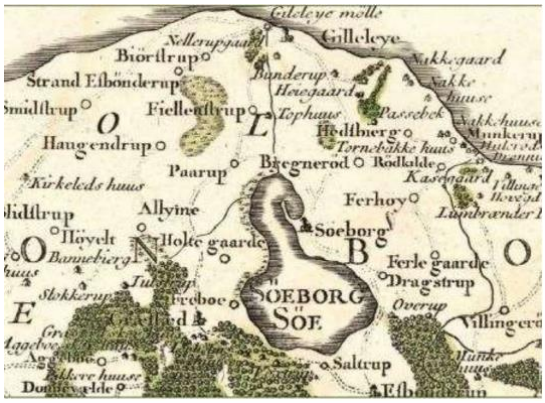

Figure 1 [5]

Søborg Lake was formed by ice and meltwater at the end of the last ice age approximately 11,700 years ago and, for a long period, was a wide fjord with an outlet to the Kattegat Sea near the city of Gilleleje. Over time it became a freshwater lake about 4 meters above sea level (Miljøministeriet & Naturstyrelsen, 2023). The first attempt to drain the lake was made in the 1790s. During this time period, the Søborg Canal was constructed, creating a discharge into the Kattegat (Figure 1).

Since 1945 further improvements to the drainage have been minor (Ibid). The reason for the drainage of Søborg Lake was to obtain agricultural land for local landowners (personal communication, Ida Dahl-Nielsen, 2024). In 2012, three different proposals for the future of Søborg Lake were proposed:

1. Current drainage remains unchanged.
2. New improved main drainage.
3. Restoration of the lake [5]

In 2014, the Nature Council presented a report concerning the restoration of the lake to various landowners and the drainage association, and it received positive feedback (Ibid). The assignment for restoring Søborg Lake was distributed to the Danish Nature Agency in 2017. In 2018, 93 million DKK was allocated for the restoration, and in early 2021, the project was approved by the Danish Environment Agency, also concluding discussions on land distribution (Ibid). Construction started in 2024, and the restoration of Søborg Lake is expected to be completed by late 2025. The budget has since increased to 120 million DKK, and the total land coverage of the restored area will be 600 ha (personal communication, Ida Dahl-Nielsen, 2024).

The lake is divided by the road Holtvej, creating a north pool and a south pool, which are connected by a culvert, (Figure 2). When the group visited the site on the 20th of September, construction for the restoration was underway. The outflow towards the Søborg Lake canal, located in the north pool, was nearing completion (Figure 3 and 4). The dike separating the lake and canal along the western side of the river is also nearing completion (personal communication, Ida Dahl-Nielsen, 2024).

Figure 2 (Personal archive, 2024)

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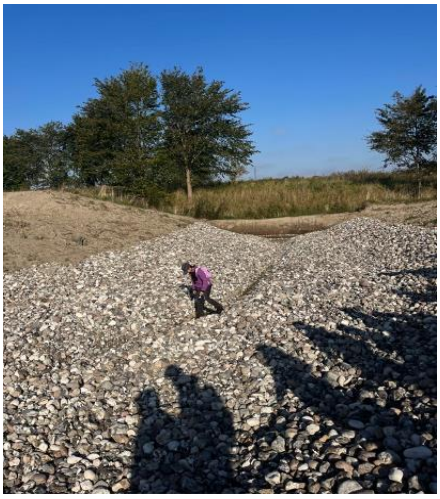

Figures 3 & 4 (Personal archive, 2024)

When the project is finished the lake's primary water sources will be from precipitation, groundwater discharge, a catchment area from the easten side of the lake, and a water channel from Slettemose [5]. The lake will cover an area of 338 ha. A redirection of the Slettemose watercourse into the lake instead of the Søborg canal will be constructed. This will be done using a barrier between the two different watercourses. The Slettemose watercourse enters the lake through the sourthen end. The lake will have an average annual water level of 1 meter and a maximum of 2 meters. The excess water will flow through the outflow at the northern end of the lake into the Søborg Canal, as described above.

This is visible in Søborg Lakes catchment area (Figure 5). The stream into the Søborg canal starts north of Græsted and continues around the northern pool of Søborg Lake, where it will connect with Søborg Lakes outflow, and flow into the Kattegat. As well as the Slettemose watercourse which can be seen entering from the south as a future inflow [5].

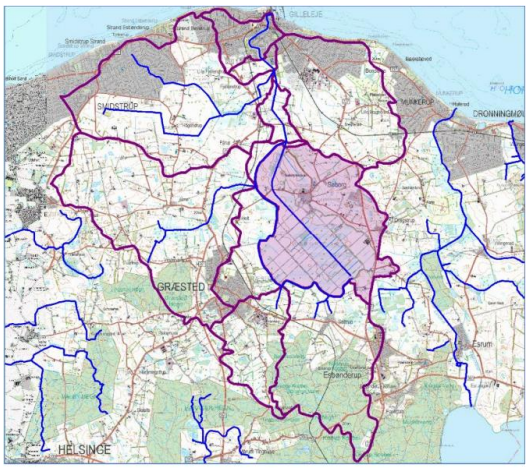

Figure 5 [6]

Some of the areas around the lake will eventually turn into meadows and swamps and will cover 122 ha. These conditions will be described in further detail later in the report. The soil conditions in Søborg Lake consist of gytje, i.e. clay, silt, sand and loamy soil [5], (Personal observations, 2024).

Methods

As this report is mainly based on a field visit to the restoration site of Søborg Lake, the methods used for research rely solely on a qualitative approach. In addition to the field visit, further communication with the project manager of the restoration site was necessary. The gathered information then was expanded on by the technical reports prepared by Danish Nature Agency for a more detailed view of the historical development of the site and restoration project. Finally, the project outlook is compared to theoretical literature developed by the Society for Ecological Restoration (SER) such as the definitions for frameworks of restoration.

Field visit: On the 20th of September 2024 the Søborg Lake restoration site was observed analyzed as a part of a study visit together with the Special Consultant/Project Manager Ida Dahl-Nielsen. During the time span of around 2.5 hours the northern part of the soon-to-be lake area was inspected starting from the pumping station and finishing nearby the pipe connecting the north and south parts of the lake. During this time site was introduced to students and inquiries about the restoration project were answered by Ida Dahl-Nielsen. Additionally, the authors observed the current situation, created photo documentation and participated in a soil auger test complete with a visual and physical soil profile analysis.

Additional communication: In order to acquire additional information – mainly Søborg Lake restoration project details translated in English, additional inquiries were made towards the project team with the help of the course staff, namely Karsten Raulund-Rasmussen.

Literature review: For the purpose of answering the research question proposed in the report, appropriate literature was considered, providing a broader historical and environmental view of the Søborg Lake site. Additionally, Danish Nature Agency has drafted and made available numerous publications considering Søborg Lake restoration project maps, technical specifications, environmental impact analysis and alike, which were taken in account to a limited extent as the information was only available in Danish. In order to try and test this restoration project against existing theoretical frameworks, the definitions published by SER were used as a way to expand on the related content covered in the course lectures. "International Principles and Standards for the Practice of Ecological Restoration, 2nd Edition" published in 2019 can be put forward as the main source for theoretical background on the grounds of which ecological restoration can be compared to ecosystem restoration and vice versa.

Results/observations

Restoration Project Plan:

The Danish Nature Agency has set out a series of goals intended to be achieved by restoring the former Søborg lake [2]. Namely, these are:

Goal 1: To preserve, strengthen, and develop nature and its diversity.

Goal 2: To promote a diverse bird life.

Goal 3: To promote cultural and historical values around the castle ruins.

Goal 4: To create a beautiful landscape and opportunities for outdoor life.

Goal 5: To reduce the emission of greenhouse gases and leaching of nutrients, e.g., nitrogen.

Before work could begin on the project in the field, acquisition of the area from local stakeholders was necessary. The individual steps of the restoration project consist mainly of several categories, namely water- and earthworks for the purpose of establishing

both a new lake inlet and outlet, raising the water level to the agreed upon height and maintaining the chosen boundaries of the lake. Additionally, certain steps of the plan pertain to infrastructure developments in favor of social needs, such as the creation of walkways, support of existing road structure and diversion of certain pathways around the lake area. As the water level rises, islands will emerge within the lake to provide valuable habitats for certain bird species. Certain areas directly adjacent to Søborg lake are to be modified to foster further habitats for an increase in biodiversity. Finally, long-term maintenance and monitoring are included in the plan for adjustments down the line as the restoration nears its completion.

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Table 1: A breakdown of planned activities to be undertaken as part of the project by category [5][7].

Project Step	Step Purpose
Category - Area Preparation	
Land Acquisition	Voluntary selling and swapping of land plots within the delineated target area of the restoration project.
Demolition Work	Several small farm buildings in the target area to be dismantled and cleared from the future lakebed.
Category – Hydrological	
Slettemose Stream Redirection	The stream is to be redirected into the lake to provide the main source of inflowing water into Søborg.
Outlet Creation	A 65m stone strip to be created at the lake outlet into Søborg canal leading out into the sea, for the purpose of dampening water fluctuations and prevention of nutrient-rich canal water and sea water flowing back into the lake during particularly high tide.
Pumping Station Shutdown	The pumping station to be shut down to stop the draining process and allow the lake to be gradually, naturally refilled overtime to desired average water level of 1m.
Category – Earthworks & Infrastructure	
Pipeline Construction	A large pipe and culverts to be placed under the road in order to connect the North and South portions of the lake.
Dike Construction & Reinforcement	Dikes to be constructed around the perimeter of the lake to ensure water is retained within the delineated boundaries. The dikes will be built primarily on the western edge of the lake. These dikes will also serve as a boundary to prevent water from flowing into Søborg Land Canal. Another purpose of the dikes is to ensure the lake is not connected to the land channel to protect fishing interests.
Trail and Recreational Infrastructure Setup	Construction of pathways for walking, cycling and horseback riding around the lake, keeping minimal possible disturbance in mind. This includes a boardwalk in the southern portion of the lake connecting the shoreline to some of the smaller established islands, and the construction of a birdwatching point.
Category – Biodiversity Management	
Island Creation	Several small islands will be created as a result of rising water level, with some of the projected to be free of the influence of Fox in order to protect bird species inhabiting the island.
Grazing Land Management	Maintenance of open meadows through grazing.
Reed Management	Cutting and grazing for controlling the spread of reeds and preserving water areas.
Category – Monitoring	
Water Level Monitoring	Monitoring the water level and managing overflow during storms.
Biodiversity Monitoring	Measurement of biodiversity for the purpose of comparing it with the project's initial goals, as well as tracking of invasive species.

Map of Challenges:

A major challenge, from the beginning of the project, is to decide what reference to use. For this exercise, an SER decision tree could be used.

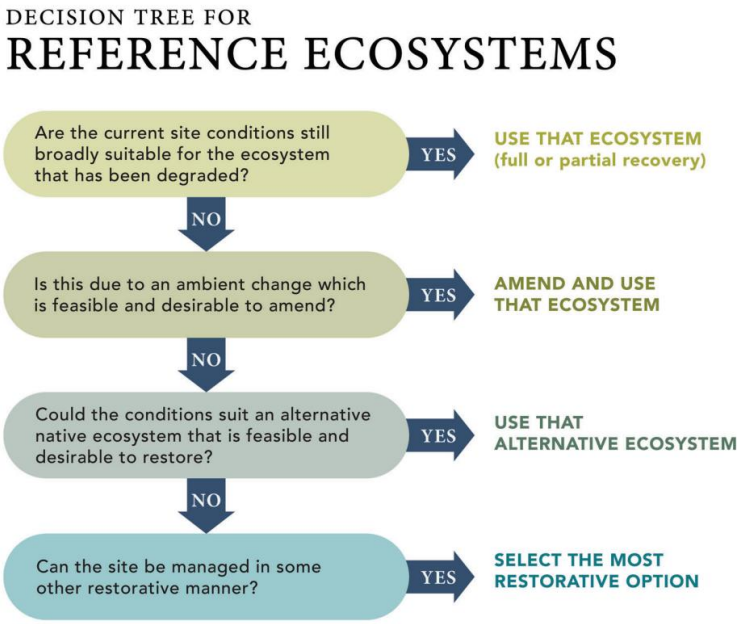

Figure 6: Decision tree to assist selection of appropriate native reference ecosystems for restoration projects [3]

The decision tree inquires if the current site conditions are still suitable for the ecosystem that has been degraded. The former ecosystem was lowland bird and fish habitats (personal communication, Ida Dahl-Nielsen, 2024), but due to social and recreational parameters being valued highly, we cannot restore it to its original state. The next question asks if this is due to ambient change, which is feasible and desirable to amend. While the changes are indeed feasible to amend, certain concessions had to be made due to social barriers.

The project managers needed to take into account if other barriers have risen since the degradation happened. In this case they found a lot of barriers, especially concerning the western catchment area of the original lake. As of now, the western catchment area runs into Søborg land canal and is directed to the Kattegat Sea, since that change was made, two major things have changed. Agriculture has started using artificial fertilizer, leading to pollution in the rivers. Trout reproduction has risen due to a lack of pikes, which can only be present if lakes are present. These two changes are potential barriers to decide if the western catchment area should be connected to Søborg lake which makes up a major_challenge.

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Below we have listed arguments from the excursion and from the reports in the literature for and against the inclusion of the western catchment area in the restoration project.

Table 2: showing arguments for and against the inclusion of the western catchment area.

Arguments **against** the inclusion of the western catchment area.	Arguments **for** the inclusion of the western catchment area.
The catchment area can risk carrying excess fertilizer contamination to the lake, from agriculture fields. Leading to a rise in algae blooming ([8], p. 93).	The water quality has been measured recently, and it showed the same quality that could be expected in Søborg lake. Meaning it would not make a difference to algae blooming ([8], p. 93).
The reproduction of trout will decline if the western catchment area is connected to Søborg lake, harming the angler association (personal communication, Ida Dahl-Nielsen, 2024)	The original steady state would have had a lower reproduction of trout, due to the natural presence of pike ([8], p. 93).
Occasional saltwater would reach Søborg lake due to high tides in Kattegat [5]	The technical report, made by NIRAS, described that a significant salt intrusion will be present in the future climate, even without the inclusion of the western catchment area ([8], p. 104).

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The project managers ended up not including the western catchment area in the reference. A major decision, based on accommodating the angler association and the fear of algal blooming (personal communication, Ida Dahl-Nielsen, 2024).

Social Challenges:

Land ownership: The project based its success on landowners voluntarily selling their land, which had the consequence of the Danish Nature Agency buying the land to market price, making it an expensive project.

Recreational demands: Different stakeholders from the local community were involved in the project, and their wishes for walking, horse riding, fishing, cycling and birdwatching were met and included in the plans [2].

Landscape demands: A portion of the locals desired a deeper lake to secure a better view by having less area for *Phragmites*. This wish was not met, but instead the arguments for grazing being able to provide the same result were brought to their attention (personal communication, Ida Dahl-Nielsen, 2024).

Ecological Challenges:

***Abiotic challenge* - Keeping the water in the lake:** Since the Søborg land canal was constructed to help drain the lake, this canal will keep the water table low. Four sections of dikes are planned to keep the water from flowing into the canal, shown by the yellow lines in picture (NUMBER)

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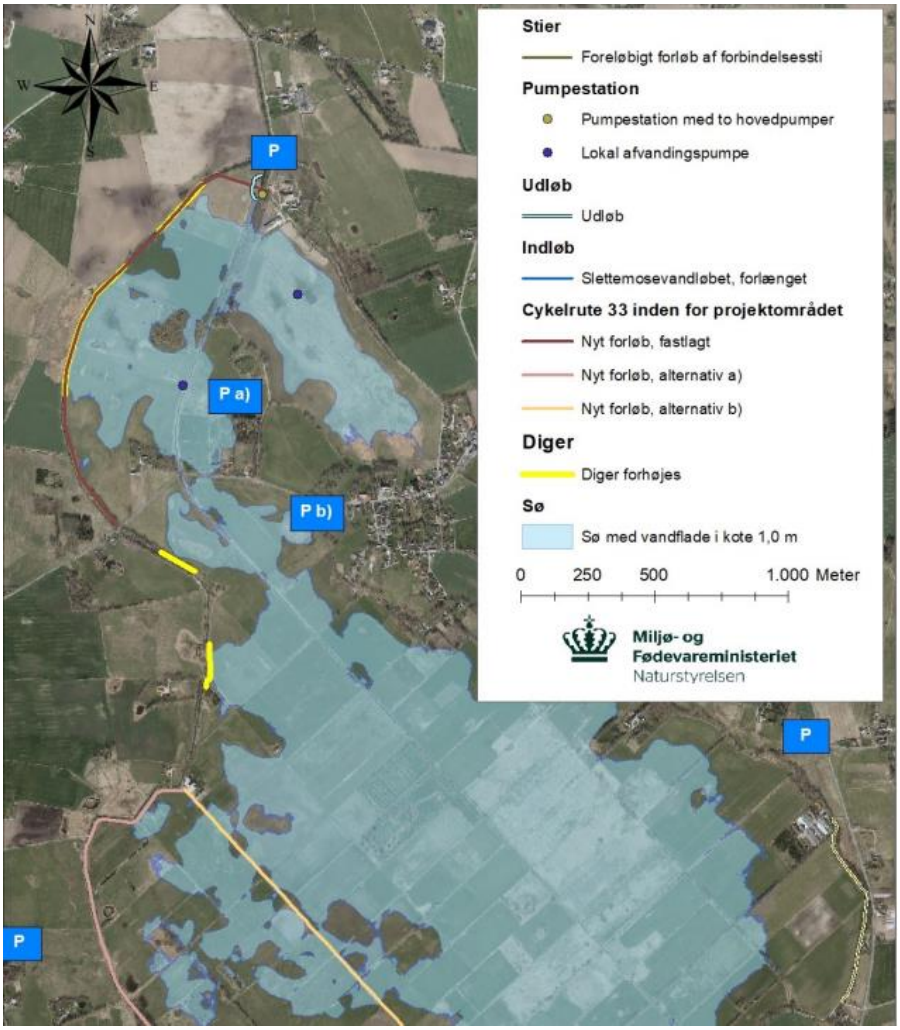

Figure 7: Map showing planned reinforcement of the dykes [9]

***Abiotic challenge* - Algae blooming:** Algae tend to blossom in high numbers when excess nitrogen and phosphorus is present. Since Søborg lake is a former agricultural area, it contains more nutrients and poses a risk of algae blooming. Fortunately, the soil is so nutrient rich that farmers have not used additional nutrients in their practice, thus the measured nutrient levels are not considered a current threat (personal communication, Ida Dahl-Nielsen, 2024). The catchment area to Søborg land canal however is considered to contain a higher concentration of nutrients and therefore, the nature agency had to decide if the larger catchment area with

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agricultural areas to the west should be included or not. They have decided not to include it, and the risk of algae blooming is part of that decision ([8], p. 93).

***Biotic challenge* - Fox free islands:** The project aims to create a large habitat for birds, however in the research leading up to the project planning the threat of foxes to the breeding birds was discovered. The solution has been to create several bird islands, by having higher water levels around the bird islands (personal communication, Ida Dahl-Nielsen, 2024).

***Biotic challenge* - Pike eating trout reproduction in rivers:** The rivers in the former catchment area to Søborg lake are considered to be suitable for the reproduction of trout, and since pike is expected to relocate into Søborg lake once it has been restored, the reproduction of trout is estimated to be reduced. This was a concern to the local angler association, and it has been accommodated by the agency by not connecting Søborg lake to Søborg land canal (personal communication, Ida Dahl-Nielsen, 2024), thereby isolating both the trout and the western catchment area from Søborg lake and the pikes.

Discussion

The first topic to discuss is the core of the restoration project which is the reference. The reason being that the project managers have diverted substantially away from what historically would be considered the reference of this lake. There are very good historical references as to what the lake would have looked like today, had there not been any human interference. But the project aims to exclude the western catchment area, which is more than 2/3 of the original catchment area, from the lake. That begs the question - what were the barriers that discarded the most appropriate reference? The arguments presented earlier show that conflicting statements seem to blur the picture of how big the risk of algae blooming is. Also, social barriers weighed a lot in the decision, specifically the anglers wish for trout rich rivers. Finally, it is not clear if the risk of saltwater in Søborg lake has been a deciding argument for the decision, as it seems to be an important argument in the project description, but in the technical report the risk is accepted. The reference was determined as it is either

because of avoidance of algae blooming, to help local anglers or for avoiding too much saltwater, one social barrier and two ecological barriers.

As specified earlier, the Danish Nature Agency set out five different goals they envision to try and reach with the Søborg lake restoration project. On surface it is possible to consider that several of them might overlap and complement each other (for example: "To preserve, strengthen and develop nature and its diversity" and "To promote a diverse bird life") while others might require substantial recessions from the "textbook" restoration scenarios (for example: "To create a beautiful landscape and opportunities for outdoor life"), in order to fulfill them all. Similarly, some of the defined goals correspond more with the framework behind ecosystem restoration than the one of ecological restoration, while some could be considered a part of both restoration approaches.

Goal 1: To preserve, strengthen, and develop nature and its diversity

This goal directly addresses biodiversity and the integrity of natural systems, making it central to both approaches. Preserving and developing diversity of nature is one of the primary focuses in ecological restoration, where the goal is to restore species composition and ecosystem functions, as well as in ecosystem restoration, where biodiversity supports broader ecosystem services. Thus, with this definition it could be appropriate for both ecological and ecosystem restoration.

Goal 2: To promote a diverse bird life

Promoting diverse bird life directly relates to restoring habitats and species composition, which is a key part of ecological restoration. In the context of ecosystem restoration, bird diversity can also enhance ecosystem services such as pest control, pollination, and seed dispersal. Appropriate for both ecological and ecosystem restoration, but more focused on ecological restoration.

Goal 3: To promote cultural and historical values around the castle ruins

This goal falls under ecosystem restoration because it includes human values and cultural significance, which extends beyond the purely ecological. Restoration projects that integrate historical or cultural elements often focus on creating landscapes that reflect both ecological integrity and human history, such as maintaining traditional land-use practices or protecting historically significant landscapes. Appropriate for ecosystem restoration.

Goal 4: To create a beautiful landscape and opportunities for outdoor life

This goal ties into human well-being, recreation, and aesthetic values. While ecological restoration is more focused on species and ecological processes, ecosystem restoration often takes human engagement into account, aiming to provide access to nature and enhance the quality of life through recreational opportunities and aesthetic landscapes. Appropriate for ecosystem restoration.

Goal 5: To reduce the emission of greenhouse gases and leaching of nutrients, e.g., nitrogen

This goal fits within ecosystem restoration because it involves improving ecosystem services, particularly regulating services like carbon sequestration and water purification. Ecological restoration can also address these aspects by restoring plant and soil communities that capture carbon or prevent nutrient leaching, but ecosystem restoration emphasizes the broader environmental benefits to society. In the case of Søborg lake restoration project the projections of changes in greenhouse gas emissions from the change of land use are still quite approximate and partly will be clear when the project is finalized which does not correspond to some of the core principles of ecological restoration. Appropriate for both ecological and ecosystem restoration, leaning toward ecosystem restoration.

If the restoration of Søborg Lake had been framed as an ecological restoration instead of an ecosystem restoration, the project would have instead focused on returning the lake to its pre-disturbance state before the first drainage in the 1790s. An ecological restoration would have prioritized the integrity and biodiversity of the ecosystem over the societal values, that are abundant in the current restoration plan. But this would severely prohibit human activity in the Søborg Lake area. The recreational areas and Anthropocene infrastructure such as the boardwalk, bike lanes and the road atop the culvert would be removed or limited to the greatest extent possible from the environment. These areas would instead shift towards further re-establishment of native species and the expected pre disturbance habitats. For this to be achieved the natural hydrology would be restored, redirecting the Søborg Lake land canal back into Søborg Lake. Restoring the natural hydrology would allow nature to determine whether the pike would reduce the trout population. But this also allows the possibility for algae blooms in the lake, which might be induced by higher nutrients concentration in the nearby catchment area, due to agriculture. The possible effects of near located modern or conventional agriculture to Søborg Lakes hydrology is not part of the pre disturbed state, which is the goal of ecological restoration. It is, therefore, not possible in ecological restoration to completely ignore the effects of the Anthropocene, but in the case of Søborg Lake they can be diminished further than they currently are.

A possibility could be areas that are off limits for locals/humans in order to protect fragile habitats. With this planning focus Søborg Lake could instead be an “institution” that educates locals or tourists about the significance of restoring and conserving biodiversity and local habitats and not promoting recreational areas. This change in planning strategy would result in a stronger and more resilient ecosystem in Søborg Lake. But it would possibly come at the cost of enraging local communities and reducing cultural values.

Conclusion

For this report we can conclude that Søborg Lake is an example of ecosystem restoration and not ecological restoration. This is due to the planning of the restoration project by the Danish Nature Agency valuing social and recreational parameters highly. This is also reflected in goal 3 and 4 of their five goals for the restoration of Søborg Lake. The restoration plan being so heavily influenced by social values defines it as ecosystem restoration according to the theoretical definition used by the_UN.

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