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Decision Support for Lake Restoration: A Case Study in Swedish Freshwater Bodies

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Abstract: A considerable number of lakes in Sweden have high phosphorus internal loading from the sediments which cause cyanobacterial blooms every summer. Due to potential risks with such blooms for human health, drinking water supply, and ecosystem services, measures need to be taken to control the phosphorus content. Measures to control the phosphorus input from the surrounding land has been in focus. However, the measures have not been sufficient. This is because phosphorus deposited at the bottom of the lakes for many years are finally starting to leak to the water phase when the decomposition of sediments leads to anoxic conditions. In order to determine effective and efficient lake restoration measures, methods for lake restoration decision support by a multi-criteria analysis and the application of a decision analysis are developed. The multi-criteria analysis includes the determination of costs, longevity, and efficacy of six common lake restoration measures to reduce internal phosphorous loads in two lakes selected as a case study. The results show that aluminum treatment combines a highest efficacy with a high-cost efficiency being thus the optimal identified measure. The method involves adding an aluminum solution to the lakes' sediment, which binds phosphorus, preventing it to be released to the water column. The multi-criteria model is integrated to a decision analytical model. The decision analytical model is used to identify the monetary socio-economic and environmental boundaries for the implementation of the optimal lake restoration measure.

Keywords: Bayesian decision analytical model; lake restoration; aluminum treatment; internal phosphorus load

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1. Introduction

In European water policy, the Water Framework Directive (WFD) aims to improve the chemical and ecological quality of European surface waters to achieve good ecological status in all rivers, lakes, coastal, and transitional waters [1]. Currently, more than half of European water bodies are in a degraded condition, and nutrient enrichment [2] is one of the main problems [3]. Eutrophication in lakes often leads to a negative loop, where high levels of phosphorus (P) in the water lead to excessive phytoplankton growth. When the phytoplankton die and fall to the bottom, they are decomposed which requires oxygen which leads to low oxygen levels of the bottom water of the lake. Low oxygen levels in turn releases P from the bottom sediment and makes it available to the phytoplankton. In this way, P added to a lake years ago can cause eutrophication today. This phenomenon is called internal loading [4], and it is a common problem in lake restoration projects when preventing nutrients from land from entering a lake will not be enough to prevent blooms of phytoplankton.

Phosphorus (P) can be released from sediments via several processes. If there is oxygen in the bottom water, P is strongly bound to metals in the sediment, such as iron, aluminum, and calcium. These complexes are difficult to dissolve and make the P unavailable to phytoplankton and other plants, and it does not contribute to eutrophication [5]. However, changes in oxygen and pH can dissolve complexes, making the P bioavailable by diffusion from the sediment to the overlying water column [6]. For example, the binding of P to iron (Fe), is sensitive to low oxygen conditions which lead to a decrease in the reduction-oxidation (redox) potential at the sediment-water interface, causing release of Fe bound P (PFe) from the sediment to the water column via the reduction in ferric Fe (Fe III) to water soluble ferrous Fe (Fe II) [7]. P release from sediment is also affected by pH because the solubility of Fe and Al increases at both low and high pH, whereas the solubility of calcium (Ca) bound P (PCa) decreases at low pH [8]. Elevated P release from Fe and Al complexes during high pH conditions has been observed in several studies [8,9], which is generally caused by excessive photosynthetic activity/phytoplankton growth, which increases the pH by fixation of carbon dioxide during photosynthesis [9].

Many efforts have been done for lake management, such as assessment of external and internal nutrient loading [10], identifying and analyzing existing lake management strategies [11], and lake restoration approaches [12].

There are mainly two ways of reducing P loading, either through removing the P from the lake or lake sediment or through stabilizing P in the sediments. The most studied methods for such lake restoration are aluminum treatment, Phoslock, oxygenation, mixing of the water, dredging, and reduction fishing. Each method with different success rate, longevity, and costs [13,14]. Aluminum treatment, Phoslock, oxygenation, and mixing aim to bind P in the sediments. Dredging and reduction fishing physically remove P [14].

Stora and Lilla Ullfjärden are two lakes situated close upstream to Lake Mälaren, the third largest freshwater lake in Sweden. High P concentrations have been a problem for a long time in this lake system, and it causes phytoplankton blooms every summer. Due to large volumes of toxin-producing cyanobacteria in Lakes Stora and Lilla Ullfjärden, they pose great potential threats downstream in Lake Mälaren, which is used for drinking water for approximately 2 million people [15].

Until now, the external phosphorus load has been reduced by minimizing known sources of P leakage from land, e.g., by better manure management and fields fallowed only during growth season in summer [16,17]. Despite these measures, the P concentration in the lakes remains high due to internal loading of P. The costs for removing P from the lakes are high and local authorities have been hesitating for many years to use such methods to improve status of the lakes more drastically. So far, no standards are available for local decision makers to determine which lake restoration measures to implement in lakes with internal loading of P.

Based on the outlined challenges, this paper aims to develop methods, and to advance scientific understanding for lake restoration decision support by the performance of a multi-criteria analysis and the application of a decision analysis. Both is exemplified through a case study. The multi-criteria analysis encompasses costs, longevity, and efficacy of six lake restoration measures determined by a meta-analysis. Additionally, it is examined whether the cost of the selected treatment can be justified by highlighting the economic values of the lakes. The ecosystem services of the lakes are identified, and each service is assigned an estimated economic value. A Bayesian decision analytical model is used to determine the optimal lake restoration measure and the monetary socio-economic and environmental boundaries for implementation.

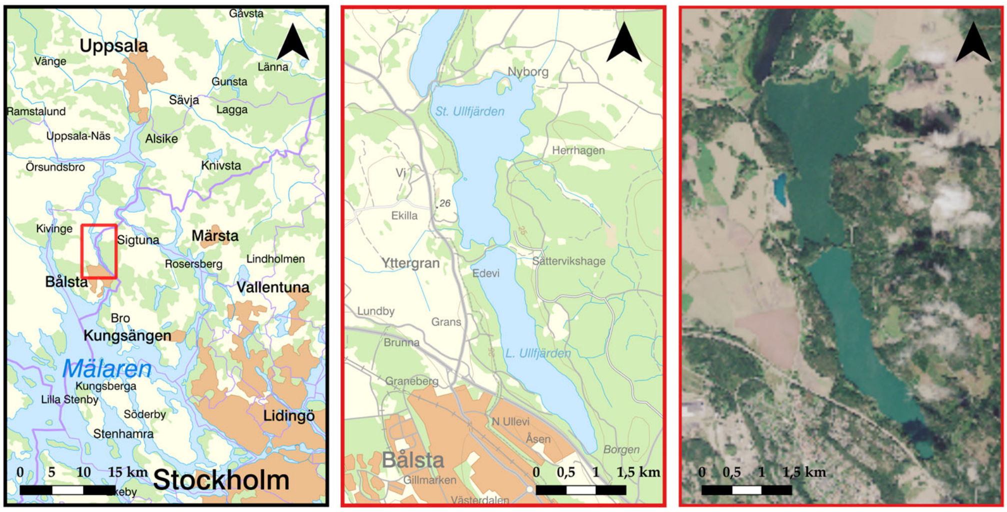
This is, to the knowledge of the authors, the first application of a using multi-criteria model integrated to a decision analytical model for water resources management. The study gives answers to the questions: (i) What is the most suitable lake restoration measure to reduce the internal loading in a specific case regarding costs, longevity, and efficacy? (ii) Can the cost of the selected treatment be justified by highlighting the economic values of the lakes?

2. Materials and Method

2.1. Case Study

2.1.1. Lakes Stora and Lilla Ullfjärden

The two lakes belong to the innermost part of the large, multi-basin Lake Mälaren and are separated by narrow passages, partly from each other, partly from the next basin which eventually empties into the Baltic Sea, with the outlet in central Stockholm, Sweden. Stora and Lilla Ullfjärden can be considered independent lakes, instead of coves to Lake Mälaren, Figure 1. Lilla Ullfjärden is one of the deepest lakes in the multi basin Lake Mälaren system with a maximum depth of 53 m and mean depth of 22 m. The lake area is 1.88 km^2 and the drainage area 8.51 km^2, dominated by forest (69%), and only a small area of farmland and urban area. Stora Ullfjärden has a maximum depth of 27 m and a mean depth of 15.2 m. The lake area is 2.8 km^2 and the drainage area 48 km^2 including the upstream Lilla Ullfjärden. Farmland are dominating (39%) followed by forest (36%), farmland (10%) and urban areas (5%) [16,17]. Both lakes are dimictic and usually covered by ice and snow during winter. The lakes are interesting in many respects. First, the lakes and their surroundings have a high nature value with a nature reserve at the lake shore, the Uppland hiking trail passing by, a public bathing area, and possibilities of fishing. Second, Stora Ullfjärden is home to a highly threatened underwater plant, and the deep Lilla Ullfjärden harbors glacial relicts, i.e., cold-water species that have been trapped and remained here since the ice age [18].



(**a**) (**b**) (**c**)

Figure 1. (**a**) Overview map showing the location of the lakes, shared by Stockholm County and Uppsala County, Sweden © Lantmäteriet; (**b**) Lilla Ullfjärden is an innermost cove of Lake Mälaren entering Stora Ullfjärden which empties into the next basin of Lake Mälaren © Lantmäteriet; (**c**) Satellite image from 31 August 2021 showing dark waters north of Stora Ullfjärden, Stora Ullfjärden with some cyanobacterial bloom, and Lilla Ullfjärden with a strong bloom. Original images: ESA Copernicus Sentinel Data, Syke [19].

2.1.2. Need for Lake Restauration

According to the EU Water Framework Directive (WFD), good ecological status must apply in all lakes [20]. The ecological status based on total P of Stora Ullfjärden is bad (51 µg P/L), and in Lilla Ullfjärden poor (59 µg P/L) which means that measures need to be done to reduce the concentration to around 9 µg P/L, which is a P-level that corresponds to good ecological status based on phytoplankton [5,6,21] and will reduce the problems with cyanobacterial blooms.

2.2. Multi-Criteria Analysis of Lake Restoration Measures

2.2.1. Cost, Longevity and Efficacy

A meta-analysis comprising costs, longevity, and efficacy was performed for the six well-studied measures to reduce internal phosphorous loading. Input data for the analysis can be found in Appendix A, which is based on a literature review. Many references are retrieved from the report Internal load of phosphorus in Swedish lakes [13], but several references were added or removed if they were not considered relevant, such as all lakes with a lake surface area of less than 10 hectares. Included in the analysis are both results from completed studies and estimated results from planned measures.

To compare costs based on studies conducted in different years, inflation information was used to recalculate the cost to a corresponding monetary value in 2021. In cases where cost-information came from a study abroad, the cost was first recalculated to Swedish currency (SEK) using the exchange rate that prevailed in the year the measurement was conducted.

2.2.2. Cost in Long Term

Lake restauration measures have different longevity and thus costs over a considered period accumulate according to inflation and discounting rates. To illustrate this, the total cost was calculated for three different time horizons, 5, 10, and 50 years. A measure that is implemented far in the future will have a lower cost due to discounting. The discount rate used was 1.0225 determined with a discount rate for a public decision maker and the current inflation developments [22].

Since the aluminum treatment has an average longevity of 12 years (Table A1, Appendix A) the cost after 5 and 10 years will be the same as after 1 year, Equation (1). For reduction fishing, with an average longevity of 3 years, the start-up cost will have to be paid twice in 5 years (start year and third year), Equation (2), and 4 times in 10 years (start year, third year, sixth year, and ninth year), Equation (3). For oxygenation and mixing an operating cost is also added each year. For oxygenation with a longevity of 20 years, the start-up cost will have to be paid three times in 50 years (start year, 20th year and 40th year), and the operating cost is paid every year during the 50 years, Equation (4).

Total cost 5 years, Aluminum treatment (longevity 12 years):

$$\text{Total cost} = \text{startup cost} \tag{1}$$

Total cost 5 years, Reduction fishing (longevity 3 years):

$$\text{Total cost} = \text{startup cost} + (\text{startup cost}/1.02253) \tag{2}$$

Total cost 10 years, Reduction fishing (longevity 3 years):

$$\text{Total cost} = \text{startup cost} + (\text{startup cost}/1.02253) + (\text{startup cost}/1.02256) + (\text{startup cost}/1.02259) \tag{3}$$

Total cost 50 years, Oxygenation (longevity 20 years):

$$\text{Total cost} = \text{startup cost} + (\text{startup cost}/1.022520) + (\text{startup cost}/1.022540) + (\text{operating cost} \times 50/1.022550) \tag{4}$$

2.3. Decision Analysis of Lake Restoration Measures

2.3.1. Bayesian Decision Analysis

Bayesian decision analysis constitutes a comprehensive methodology for decision support when the outcomes cannot be predicted with certainty [23]. A recent research effort constitutes connecting the decision theory to environmental impact quantification [24]. Rational decisions are about choosing the option that provides the maximum expected utility or the minimal risk according to the expected utility theorem [25]. In this study, Bayesian decision analysis is based on a risk analysis. Each system state is assigned a probability of occurrence and consequences. Risks are calculated as the product of the probability and the consequences:

$$R(A) = P(A) \times c(A) \quad (5)$$

R is the total risk of system state A, P is the probability that system state A occurs, and c is the expected consequences of system state A. The system state can be modified, in our case with lake restoration measures, r_i. The measures will influence the probability of the system state, i.e., $P(A|r_i)$, and will have costs $c(r_i)$. The total risks and cost for the measure r_i are then calculated with Equation (6):

$$R(A|r_i) = P(A|r_i) \times c(A) + c(r_i) \quad (6)$$

The objective function to determine a decision about a restorative measure is then the minimization of the expected value (operator E) of the costs and consequences overall system states A_j according to the expected utility theorem, Equation (7). The type of decision analysis is called a prior decision analysis.

$$R_{Prior} = \min_{r_i} E_{A_j}\left[c\left(A_j, r_i\right)\right] \quad (7)$$

2.3.2. Probability of Good Ecological Water Status

The probability of good water status in a lake after aluminum treatment is based on a previous project in Lake Växjö, in the south of Sweden [26]. Lake Växjö was treated with aluminum in May to August 2018. Before the lake was treated, reduction fishing was conducted in the lake to stimulate the establishment of underwater vegetation and improve the possibilities of achieving the intended effect with the aluminum treatment [26]. The target value for good water status in Lake Växjö regarding total phosphorus was 15.2 μg/L [27]. The probabilities of achieving good water status in Stora and Lilla Ullfjärden were calculated based on the outcome of the aluminum treatment of Lake Växjö assuring similar success rate (Figure 2). The probability of good ecological water status before measure is 4%, and 92% after aluminum treatment.

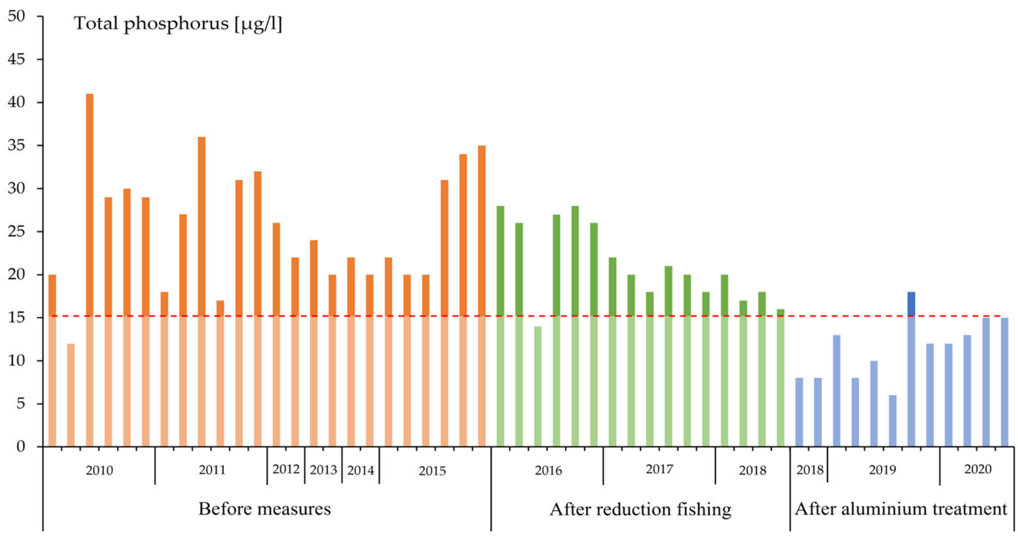


Figure 2. Total phosphorus concentration in Lake Växjö before measures (year 2010–2015), after reduction fishing (year 2015–May 2018) and after aluminum treatment (May 2018–2020) [28]. The red dashed line indicates the limit of good status (15.2 μg/L) in the lake with respect to total phosphorus.

2.3.3. Economic Value of the Lakes

Ecosystem services may be valued economically, not least for activation of resources in society [29]. Listing the services of the specific lakes gives an overview of many aspects that contribute to the value of lakes [30], which is performed based on studies from the same region of Sweden. The various ecosystem services contributions by lakes have an economic value that is either comprehensive (has a market value), can be valued (by using estimates and assumptions), or is not comprehensive (has no market value). In this way, all aspects and attributes surrounding the lakes can be highlighted [30].

2.3.4. Socio-Economic Profitability Assessment of Aluminum Treatment

Restoration of lakes is costly. However, a lake that does not attain good water status also imply consequences and costs. Examples of a bad status are, e.g., increased costs for an adjacent drinking water treatment plant, there may be increased costs for bathing sites located at the lake or reduced value for nearby houses, etc. Since it is difficult to calculate the cost of not having a good ecological status, this study examines what economic consequences need to be surpassed to justify a measure. If the cost of the measure cannot justify the benefit that the measure implies, it is not socio-economic profitable for the measure to be conducted. These consequences are determined with the Bayesian decision analysis. Since there is no value for the cost if good status is not achieved (cost not good status), the Bayesian decision analysis can be used to determine the minimum consequences of a not good lake status to compensate for the costs of the measure.

3. Results

3.1. Multi-Criteria Analysis of Lake Restoration Measures

3.1.1. Cost, Longevity and Efficacy

A summary of the scientific literature-based data in Appendix A is presented in Table 1 and shows the average value for start-up cost, operating cost, longevity, and efficacy for six lake restauration measures focusing on reducing internal phosphorus loading. For more details and the literature sources, please see Appendix A.

Table 1. Average value for start-up cost, operating cost, longevity, and efficacy for the six lake restauration measures to decrease internal phosphorous loading. For the start-up and operating cost, the cost is recalculated to a cost valid in 2021 using an inflation calculator [31].

Measures:	Start-Up Cost	Operating Cost	Longevity	Efficacy
	[SEK/hectare]	[SEK/year/hectare]	[years]	[%]
Al. treatment:	43,300	-	12	90
Phoslock:	139,200	-	30 [1]	60
Oxygenation:	58,900	3700	20 [2]	40
Mixing:	13,600	700	20 [3]	0
Dredging:	185,800	-	2.5	25
Reduction fishing:	36,700	-	3	5

Notes: [1] As the binding capacity does not decrease with time [32] a service life of 30 years is estimated. [2] This is the expected longevity of the pump aggregate to provide oxygen (air), which is expected to be 20 years [13]. [3] Just as for oxygenation, the longevity is assumed to be the expected longevity of the aggregate, which is estimated to 20 years.

3.1.2. Cost in Long Term

Lake restauration measures have different longevity and thus costs accumulate according to inflation and discounting rates over the periods of 5, 10, and 50 years. A measure that is implemented far in the future will have a lower cost due to discounting. In Table 2 the cost of each lake restauration measure of the considered periods are documented.

From Table 2 it is understood that dredging is by far the most expensive option regardless of time horizon. Mixing remains the least expensive option regardless of time horizon followed by aluminum treatment as the second least expensive option.

Table 2. Cost of each lake restauration measure depending on time, based on start-up cost, operating cost, and longevity. A discounting rate of 2.25% have been used.

Measures:	Cost 5 Years	Cost 10 Years	Cost 50 Years
	[SEK/hectare]	[SEK/hectare]	[SEK/hectare]
Al. treatment:	43,300	43,300	136,200
Phoslock:	139,200	139,200	210,600
Oxygenation:	149,100	162,100	332,600
Mixing:	16,700	19,200	39,400
Dredging:	361,500	690,000	2,305,000
Reduction fishing:	71,000	133,200	385,600

3.1.3. Cost-Effectiveness Comparison

To make a cost-effective comparison of the lake restauration measures, a simplified multi-criteria analysis is performed. In Table 3 a ranking (0 to 5) for the efficacy and the costs of a period of 50 years is introduced and the ranks are added.

Table 3. Results of the multi-criteria analysis for possible lake restoration measures to reduce internal phosphorous loading. By efficacy is meant reduction of internal load, making the option with the highest efficacy to receive the rank 5 and the lowest the rank 0, based on Table 1. For the category cost 50 years, a low cost is preferred, making the option with the lowest cost to receive a 5 and the highest cost a 0, based on Table 3. A high total score is desirable.

Measures:	Efficacy	Cost 50 Years	Total
Aluminum treatment:	5	4	**9**
Phoslock:	4	3	**7**
Mixing:	0	5	**5**
Oxygenation:	3	1	**4**
Reduction fishing:	1	2	**3**
Dredging:	2	0	**2**

Aluminum treatment scores the highest in the multi-criteria analysis. This is because it is the method that most effectively reduces the internal phosphorus load and is also the second least expensive method in the long term.

3.2. Decision Analysis of Lake Restoration Measures

3.2.1. Economic Value of the Lakes

To estimate the value of the lakes Stora and Lilla Ullfjärden, all services that contribute to the value are examined and listed in Table 4.

Table 4. Summary of all services contributing to the value of Stora and Lilla Ullfjärden.

Services:	Relevance
Surface water of good quality:	Drinking water production downstream.
Capture nutrients and pollutants:	Bottom sediments act as settling basins for nutrients, metals, and Polycyclic Aromatic Hydrocarbons (PAHs).
Tourism:	Shop at the bathing site Ekillabadet.
Bathing site:	Ekillabadet, public bathing site.
Fishing:	Extensive recreational fishing in the lakes.
Boat life:	Boat club in Lilla Ullfjärden.
Lake view for nearby houses:	Increased property value.

Table 4. *Cont.*

Services:	Relevance
National nature value:	Particularly valuable species occur in the lakes, such as the underwater plant Baltic water-plantain (Alisma wahlenbergii), several species of glacial relicts (Crustacea), and red-listed fish species.
Recreation values:	Lake shore with two Natura 2000 areas next to the lakes. The Uppsala trail passes through the area.
Aesthetic values:	The lakes contribute to emotional well-being.
Scientific values:	The lakes have been the subject of limnological and hydrological research for more than a century (but are more sparingly investigated since the 70s).
Establishment of the WFD:	It states that lakes, watercourses, and coastal waters must reach good ecological and good chemical surface water status. The current water status must not deteriorate in any respect.

In Table 5, each service is qualitatively assigned an expected value. In this way, all aspects and attributes surrounding the lakes can be highlighted. Table 5 shows that the majority of the services do not comprehensibly influence the financial value of Stora and Lilla Ullfjärden.

Table 5. Summary of qualitative expected values for the services of Stora and Lilla Ullfjärden.

Services:	Value [1]	Reduced Value if Good Status Is Not Achieved [2]	Valuing Possibility
Surface water of good quality:	High	Minor	Comprehensible
Capture nutrients and pollutants:	High	High	
Tourism:	Minor	Middle	
Bathing site:	Middle	Middle	Can be valued
Fishing:	Minor	Middle	
Boat life:	Minor	Minor	
Lake view for nearby houses:	High	Minor	
National nature value:	High	Middle	Not comprehensible
Recreation values:	High	Minor	
Aesthetic values:	High	High	
Scientific values:	Middle	Middle	
Establishment of the WFD:	High	High	

Notes: [1] The expected Value is presented on the qualitative scale: "High" (millions of SEK), "Middle" (hundred thousand SEK), "Minor" (less than one hundred thousand SEK). [2] The expected Reduced value if good status is not achieved is presented on the qualitative scale: "High" (75–100% reduced value), "Middle" (25–75% reduced value), "Minor" (less than 25% reduced value).

3.2.2. Socio-Economic Profitability Assessment of Aluminum Treatment

With Bayesian decision analysis, it is possible to determine the economic consequences of a not good lake status by weighting the total risks and expected costs against a good lake status with restorative measures. Figure 3 illustrates finding the tipping point, when the expected not good status consequences with and without the measure are balanced. The balancing is achieved by reducing the probability of a not good status with the measure according to its efficacy.

The inputs needed for the Bayesian decision model to calculate the cost of not achieving good status are the probability of good status and measure cost (start-up cost + operating cost). The lake restauration measure with the lowest total risk is chosen (Equation (7)), which constitutes aluminum treatment, see also Section 3.1.3. The input to the analysis is presented in Table 6.

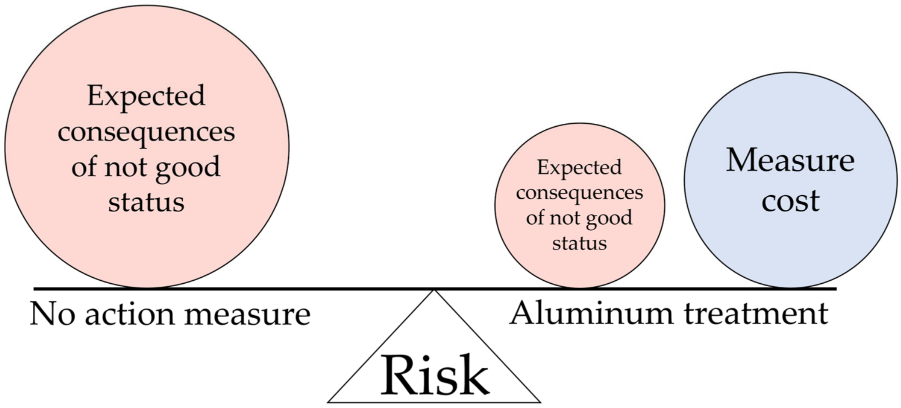


Figure 3. Illustration of the tipping point for when total risks and expected costs is the same for the options "no action measure" and "aluminum treatment".

Table 6. Input data in the Bayesian decision analysis. The cost for aluminum treatment has been multiplied by 500 because the combined lake surface area of Lilla and Stora Ullfjärden is 500 hectares.

Probabilities and Costs:	Probability of Good Ecological Water Status	Areal Cost 12 Years	Total Cost 12 Years
Unit:	[%]	[SEK/hectares]	[SEK]
No measure:	4	0	0
Aluminum treatment:	92	43,300	21,650,000

Figure 4 shows how the input data (Table 6) is used in the Bayesian decision analysis to determine the cost for a not good status, which result in the alternatives "no measure" and "aluminum treatment" to have an equal risk. If the cost of a not good status increases further than shown, aluminum treatment will be the option with the lowest risk.

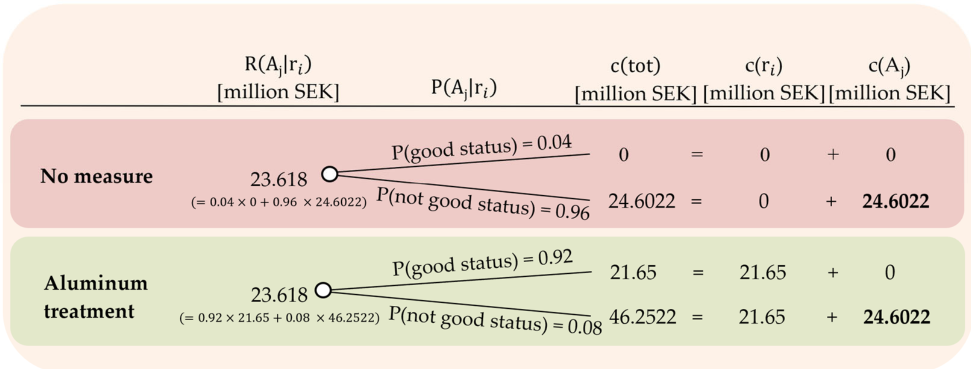


Figure 4. Bayesian decision analysis where the alternative aluminum treatment is compared to the alternative no measure. $R(A_j|r_i)$ is the total risk of system state A_j (good/not good status), for the lake restoration measure r_i (no measure or aluminum treatment), P is the probability and c is the consequences (measure cost and cost good/not good status).

From Figure 4, it can be stated that if the cost not good status is higher than SEK 24.6 million over a 12-year period, the lakes should be treated with aluminum.

4. Discussion and Limitations

The measures presented in this study represent six well-studied measures to reduce internal phosphorus loading. These measures will only have a long-term effect together with continuous efforts to reduce the external phosphorus supply [14].

The six measures to reduce the internal phosphorus loading have different longevities. The costs have been calculated, discounted and accumulated to total costs representative for different time spans. For 10 years, the aluminum method (with a longevity 12 years) only needs to be conducted once, while reduction fishing (longevity 3 years) needs to be conducted four times. Apart from mixing, which according to previous studies does not show a reduction in internal load, the aluminum method is the least costly method, on a 1, 5, 10, and 50 year horizon. It is also the measure that reduces the internal load most effectively.

The probability of good ecological status after a measure is conducted, has been determined based on a previous lake restoration project in Lake Växjösjön, Sweden [26]. From this project there are measurement data for the lake's phosphorus levels before measures, after reduction fishing, and after aluminum treatment. The fact that reduction fishing was conducted before the aluminum treatment may affect the good status probability of the aluminum treatment. Since reduction fishing did not have a high effect and a longevity of only 3 years, it was concluded that the effect of reduction fishing before aluminum treatment can be neglected.

The ecologic societal services of Stora and Lilla Ullfjärden are presented in Tables 4 and 5. The expected value of the services and the expected reduced value if good status is not achieved are based on similar studies. Listing the lake's services in this way is done to give an overview of the various services a lake contributes, to give examples of how the value of different services can be estimated and, above all, to highlight and emphasize the importance of all the lake's services, even services that do not have a market value.

With the help of the Bayesian decision analysis, it can be shown that the lakes should be treated with aluminum if the consequences of poor water status is higher than SEK 24.6 million over a 12-year period. If this cost is compared with Table 5, which shows expected reduced values for all of Stora and Lilla Ullfjärdens' services if good status is not achieved, the decision whether the lakes should be treated with aluminum treatment or not can be supported. It should further be noted that the value of the lakes lies mainly in services that do not have a direct monetary value, such as national nature value including valuable species occurring in the lakes, recreational values, and aesthetic values. However, if the status does not meet a good condition, then this intangible value reduction can be very significant.

Regardless of which measure is chosen for the case study lakes, more site-specific studies need to be conducted to dimension the measure and to confirm the behavior similarities of Lake Växjösjön and the Stora and Lilla Ullfjärden lakes. If aluminum treatment is chosen as a measure, sediment samples need to be taken to investigate which phosphorus fractions are dominating in the sediments, as this affects what dose of aluminum is needed. A dose that is too high can cause aluminum remaining in inorganic form, which is toxic to plants and animals. However, a dose that is too low instead gives a too short-lived result causing continuous summers of toxin-producing cyanobacteria, which it is also toxic to plants and animals. Therefore, a long-term, adequate monitoring program, including proper determination of external loading, is crucial to document the effect of aluminum treatment on sediment phosphorus release and water quality in the lake [33].

We have some further limitations of the study. First, our reference data for the determination of the status probabilities are limited to one lake restoration project in a Swedish lake. Different type of lakes might have other chemical and biological characteristics that might influence the effect of treatment methods. Future work may include different types of lakes. Second, we did not include the external loads effect and how they impact the total phosphorus load and the water quality dynamics.

5. Summary and Conclusions

According to the WFD, good ecological surface water status must apply in all lakes [20]. However, this is not the case in Stora and Lilla Ullfjärden, two lakes close to Lake Mälaren, which is of high value for the capital of Sweden and the surrounding areas. Several measures have already been conducted in the lakes to reduce eutrophication. These measures had the aim of reducing the external phosphorus load, i.e., the nutrient released from surrounding soil. Despite these measures, Stora and Lilla Ullfjärden still suffer from phytoplankton blooms every year. Because the lakes have a long history of external phosphorus loading, phosphorus has accumulated in the bottom sediments and causes internal phosphorus loading. To reach the desired total phosphorus concentration in the lakes, the internal phosphorus load must be decreased by further measures.

In order to determine effective and efficient lake restoration measures, methods for lake restoration decision support by a multi-criteria analysis and the application of a decision analysis are developed and exemplified with a case study. The multi-criteria analysis is developed to determine costs, longevity, and efficacy of six common lake restoration measures to reduce internal phosphorous loads. The multi-criteria model is integrated to a Bayesian decision analytical model. The decision analytical model is used to determine the optimal lake restoration measure and boundaries for measure implementation.

From the study it can be concluded that aluminum treatment is the most reasonable choice to reduce the internal load in the case study lakes Lilla and Stora Ullfjärden. This well-studied method effectively reduces the internal load of phosphorus, and the method is also cost-effective both in the short and long term compared to other measures. However, more site-specific studies are required for dose determination and transferability of measure characteristic underlying this study.

Aluminum treating both lakes, which have a total lake surface area of 500 hectares, is estimated to cost around SEK 21.7 million. However, not achieving good ecological status in the lakes may have monetary consequences and may touch intangible nature values (as discussed). The lakes have a high nature value and contribute to many cultural ecosystem services, such as bathing, fishing, and recreation. With the help of Bayesian decision analysis, a lower boundary value for these socio-economic consequences in the Stora and Lilla Ullfjärden lakes has been established, namely 24.6 million SEK aggregated over a 12-year period.

Future research efforts can be directed towards accounting for measurements to support the restoration measure implementation, which would specifically address the dose determination for aluminum treatment. The performed multi criteria and the decision analyses may also form the basis for the development of a decision support tool in the DiCyano project (funded by VINNOVA).

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Appendix A

Table A1. Aluminum treatment: background data for the multi-criteria analysis.

Source	Lake	Lake Type	Method	Treatment Year	Treated Area	Start-Up Cost	Start-Up Cost	Reduced Internal Loading	Longevity
				[Year]	[Hectare]	[SEK]	[SEK/Hectare]	[%]	[Year]
[34]	Långsjön	Shallow	Sediment injection	2006	29	3,530,756	121,750	90	>9
[34]	Flaten	Deep	Sediment injection	2000	40	3,212,260	80,307	95	>15
[35]	Calhoun	Deep	Hypolimnetic water application	2001	130	1,833,000	14,057	100	>14
[36]	Harriet	Deep	Hypolimnetic water application	2001	47	1,034,687	22,015	85	5
[35]	Cedar	Deep	Hypolimnetic water application	1996	60	1,657,000	27,849	95	13
[13]	Spring	Deep	Hypolimnetic water application	2014	39	3,907,000	23,679		>1
[13]	Long	Deep	Hypolimnetic water application	2009	102	1,360,000	61,818		>6
[13]	Medical Lake	Deep	Hypolimnetic water application	1977	122	934,000	14,594		>40
[13]	McCarron	Deep	Hypolimnetic water application	2005	77	680,000	30,909		>10
[13]	Bryant	Deep	Hypolimnetic water application	2008	74	2,120,000	29,444		>7
[37]	Hjälmaren	Deep	Hypolimnetic water application		20,000	615,000,000	30,750	100	
[26]	Växjösjön	Deep	Hypolimnetic water application and sediment injection	2018	65	5,400,000	69,948	60	
[38]	S.Bergundasjön	Shallow	Hypolimnetic water application and sediment injection	2019	310	15,500,000	35,880		
Average value aluminum treatment:							**43,300 (±31,500)**	**90 (±14)**	**>12**

Table A2. Phoslock: background data for the multi-criteria analysis.

Source	Lake	Lake Type	Treatment Year	Treated Area	Start-Up Cost	Start-Up Cost	Reduced Internal Loading	Longevity
			[Year]	[Hectare]	[SEK]	[SEK/Hectare]	[%]	[Year]
[39]	Lake Rauwbraken	Shallow	2008	4	517,170	129,292.5		
[39]	Lake De Kuil	Shallow	2009	7	1,461,999	208,857		
[13]	The average cost of some small lakes		2013			79,565		
[13]	Summary, Table 10B						30–90	
Average value Phoslock:						**139,200 (±6500)**	**60 (±30)**	**30 ***

Note: * Because the binding capacity does not decrease with time [32] a longevity of 30 years is estimated.

Table A3. Oxygenation: background data for the multi-criteria analysis.

Source	Lake	Treatment Year	Treated Area	Start-Up Cost	Start-Up Cost	Operating Cost	Operating Cost	Reduced Internal Loading	Longevity
		[Year]	[Hectare]	[SEK]	[SEK/Hectare]	[SEK/Year]	[SEK/Year/Hectare]	[%]	[Year]
[13]	Pine Lake	1981	36	765,278	21,258	297,608	8267		
[40]	San Vincent Reservoir	1975	405	7,834,985	19,346	607,211	1499		
[13]	Average 15 lakes	2001	113	20,156,230	178,374	1,004,491	8889		
[41]	Stubbs Bay (Lake Minnetonka)	2004	81	4,336,573	53,538	340,123	4199		
[13]	Tegel	2002	400	32,916,685	82,292	565,759	1414		
[13]	JC Boyle Reservoir	2009	170	3,188,657	18,757	398,582	2345		
[13]	Marston Reservoir	2009	251	19,929,104	79,399	117,343	468		
[13]	Bear Creek Lake	2002	45	2,994,680	66,548	261,925	5821		
[42]	Cherry Creek Reservoir	2002	342	3,492,338	10,212	88,182	258		
[13]	Summary, Table 10B							30–50	20 *
Average value oxygenation:					**58,900 (±52,800)**		**3684 (±3300)**	**40 (±10)**	**20 ***

Note: * The expected lifetime of the aggregate [13].

Table A4. Mixing: background data for the multi-criteria analysis.

Source	Lake	Lake Type	Treatment Year	Treated Area	Start-Up Cost	Start-Up Cost	Operating Cost	Operating Cost	Reduced Internal Loading	Longevity
			[Year]	[Hectare]	[SEK]	[SEK/ Hectare]	[SEK/Year]	[SEK/Year/Hectare]	[%]	[Year]
[43]	Iskmosunden	Shallow	2014	30	332,857	11,095	11,095	370		
[44,45]	Jordan Lake	Water tank	2014	4636	10,856,617	2342	6,263,433	1351	0	
[44]	Lake Houston	Water tank	2006	243	6,680,995	27,494	82,054	338	0	
Average value mixing:						**13,644 (±12,800)**		**686 (±580)**	**0**	**20 ***

Note: * The expected lifetime of the aggregate [13].

Table A5. Dredging: background data for the multi-criteria analysis.

Source	Lake	Lake Type	Treatment Year	Treated Area	Start-Up Cost	Start-Up Cost	Reduced Internal Loading	Longevity
			[Year]	[Hectare]	[SEK]	[SEK/Hectare]	[%]	[Year]
[46]	Finjasjön	Shallow	1991	111	95,985,075	864,730	0	
[26]	Trummen	Shallow	1970	99	21,346,647	215,623	0	
[26]	Växjösjön	Deep	1990	87	45,037,065	517,667	0	
[26]	South Bergundasjön	Shallow	1992	430	50,514,179	117,475	0	
[47]	Lillsesjön alt. 1		2014	55	5,422,886	98,598		
[13]	Clear Lake	Shallow	2009	1468	79,716,418	54,303		
[13]	Half Moon Lake		1991	53,4	256,159	4797		
[13]	Lilly Lake		1991	35,6	366,374	10,291		
[13]	Lenox Lake		1991	13,4	400,959	29,922		

Table A5. *Cont.*

Source	Lake	Lake Type	Treatment Year	Treated Area	Start-Up Cost	Start-Up Cost	Reduced Internal Loading	Longevity
[13]	Nutting Lake		1991	31,6	1,337,916	42,339		
[13]	Collins Park Lake		1991	24,3	2,137,369	87,958		
[13]	Summary, Table 10B						0–50	
[48]	Dongqian Lake, China							2
[49]	Lake Taihu, China							3
Average value dredging:						**185,791 (±268,000)**	**25**	**2.5**

Table A6. Reduction fishing: background data for the multi-criteria analysis.

Source	Lake	Treatment Year	Treated Area	Start-Up Cost	Start-Up Cost	Reduced Internal Loading	Longevity
		[Year]	**[Hectare]**	**[SEK]**	**[SEK/Hectare]**	**[%]**	**[Year]**
[50]	Östhammarfjärden	2011	121.6	1,915,876	15,756		
[51]	Borringesjön		295	1,409,950	4779		
[51]	Yddingesjön		213	1,030,348	4837		
[51]	Havgårdsjön		57	292,836	5137		
[46]	Finjasjön	1993	111	11,192,836	100,836		
[52]	Ringsjön	2005	39,5	6,766,026	171,292		
[53]	Växjösjön	2013	79	5,979,626	75,691		
[53]	Trummen	2013	76	2,184,338	28,741		
[13]	Ryssbysjön	2010			6152		
[13]	Average of four lakes	1989	263	2,375,224	9018		
[13]	Nokomis	2014	81	964,189	11,904		
[13]	Nokomis	2010	81	477,008	5889		
[13]	Summary, Table 10B					0–10	2–5
Average value reduction fishing:					**36,669 (±52,700)**	**5**	**3**

References

1. European Commission. Implementation Report Water Framework Directive and Floods Directive—Questions and Answers. Available online: https://shortest.link/bqgl (accessed on 18 December 2022).
2. ScienceDirect. Available online: https://www.sciencedirect.com/topics/earth-and-planetary-sciences/nutrient-enrichment (accessed on 24 November 2022).
3. Poikane, S.; Kelly, M.G.; Salas Herrero, F.; Pitt, J.A.; Jarvie, H.P.; Claussen, U.; Leujak, W.; Lyche Solheim, A.; Teixeira, H.; Phillips, G. Nutrient criteria for surface waters under the European Water Framework Directive: Current state-of-the-art, challenges and future outlook. *Sci. Total Environ.* **2019**, *695*, 133888. [CrossRef] [PubMed]
4. Pettersson, K. Mechanisms for internal loading of phosphorus in lakes. *Hydrobiologia* **1998**, *373*, 21–25. [CrossRef]
5. James, W.F.; Sorge, P.W.; Garrison, P.J. Managing internal phosphorus loading and vertical entrainment in a weakly stratified eutrophic lake. *Lake Reserv. Manag.* **2015**, *31*, 292–305. [CrossRef]
6. Agstam-Norlin, O. Restoration of Nutrient Rich Lakes Restoration of Nutrient Rich Lakes. Ph.D. Thesis, Swedish University of Agricultural Sciences, Uppsala, Sweden, 2022.
7. Ramm, K.; Scheps, V. Phosphorus balance of a polytrophic shallow lake with the consideration of phosphorus release. *Hydrobiologia* **1997**, *342*, 43–53. [CrossRef]
8. Gomez, E.; Durillon, C.; Rofes, G.; Picot, B. Phosphate adsorption and release from sediments of brackish lagoons: pH, O2 and loading influence. *Water Res.* **1999**, *33*, 2437–2447. [CrossRef]
9. Boers, P.C.M. The influence of pH on phosphate release from lake sediments. *Water Res.* **1991**, *25*, 309–311. [CrossRef]
10. Kowalczewska-Madura, K.; Dondajewska-Pielka, R.; Gołdyn, R. The Assessment of External and Internal Nutrient Loading as a Basis for Lake Management. *Water* **2022**, *14*, 2844. [CrossRef]

11. Mardiatno, D.; Faridah, F.; Listyaningrum, N.; Hastari, N.R.F.; Rhosadi, I.; da Costa, A.D.S.; Rahmadana, A.D.W.; Lisan, A.R.K.; Sunarno, S.; Setiawan, M.A. A Holistic Review of Lake Rawapening Management Practices, Indonesia: Pillar-Based and Object-Based Management. *Water* **2023**, *15*, 39. [CrossRef]
12. Alhamarna, M.Z.; Tandyrak, R. Lakes restoration approaches. *Limnol. Rev.* **2021**, *21*, 105–118. [CrossRef]
13. Huser, B.; Löfgren, S.; Markensten, H. *Internbelastning Av Fosfor I Svenska Sjöar Och Kustområden*; Report 2016: 6; Swedish University of Agricultural Sciences, Water and Environment: Uppsala, Sweden, 2016; Available online: https://pub.epsilon.slu.se/13724/7/huser_b_et_al_161026.pdf (accessed on 5 May 2022).
14. Erlandsson Lampa, M.; Witter, E. *Metod För Påverkanstypen Historisk Förorening—Internbelastning*; Luleå, Härnösand, Västerås, Kalmar, Göteborg: Vattenmyndigheterna i Samverkan, Sweden, 2018. Available online: https://viss.lansstyrelsen.se/ReferenceLibrary/55065/Metod%20Internbelastning.pdf (accessed on 6 May 2022).
15. Drakare, S.; Wallman, K.; Almlöf, K.; Segersten, J.; Sveriges, R. *Fokus På Mälaren 2019-Sammanfattande Resultat Från Miljöövervakning Och Forskningsprojekt Knutna Till Samarbetet Mellan SLU Och Mälarens Vattenvårdsförbund*; Report 2020: 3; Swedish University of Agricultural Sciences, Department of Aquatic Sciences and Assessment: Uppsala, Sweden, 2020. Available online: https://pub.epsilon.slu.se/16975/7/drakare_s_et_al_200514.pdf (accessed on 27 May 2022).
16. VISS Lilla Ullfjärden. Available online: https://viss.lansstyrelsen.se/Waters.aspx?waterMSCD=WA90764558 (accessed on 7 March 2022).
17. VISS Mälaren-Stora Ullfjärden. Available online: https://viss.lansstyrelsen.se/Waters.aspx?waterMSCD=WA47437003 (accessed on 7 March 2022).
18. Gustafsson, A. *Lilla Ullfjärden (Object Data Sheet)*; Naturvatten AB: Upplands-Bro Municipality, Sweden, 2015. Available online: https://www.upplands-bro.se/download/18.56ea77fc1686d89c2f852fa/1548081133208/Sjöar-LillaUllfjärden.pdf (accessed on 10 April 2022).
19. Syke, Tarkka. Available online: http://wwwi4.ymparisto.fi/i4/eng/tarkka/index.html?type=RGB&date=2021-08-31&datespan=1&name=DEFAULT&lang=en&zoom=11.118612663152941&lat=59.64168&lon=17.45038 (accessed on 12 May 2022).
20. The European Parliament and the Council of Union European. Directive 2000/60/EC of the European Parliament and of the Council Establishing a Framework for Community Action in the Field of Water Policy. *Off. J Eur. Commun.* **2000**. Available online: https://eur-lex.europa.eu/resource.html?uri=cellar:5c835afb-2ec6-4577-bdf8-756d3d694eeb.0004.02/DOC_1&format=PDF (accessed on 27 April 2022).
21. Swedish Agency for Marine and Water Management. Available online: https://www.havochvatten.se/vagledning-foreskrifter-och-lagar/foreskrifter/register-vattenforvaltning/klassificering-och-miljokvalitetsnormer-avseende-ytvatten-hvmfs-201925.html (accessed on 26 November 2022).
22. SCB. Inflation i Sverige 1830–2021. Available online: https://www.scb.se/hitta-statistik/statistik-efter-amne/priser-och-konsumtion/konsumentprisindex/konsumentprisindex-kpi/pong/tabell-och-diagram/konsumentprisindex-kpi/inflation-i-sverige/ (accessed on 24 May 2022).
23. Raiffa, H.; Schlaifer, R. *Applied Statistical Decision Theory*; Wiley: New York, NY, USA, 1961; ISBN 047138349X.
24. Dong, Y.; Miraglia, S.; Manzo, S.; Georgiadis, S.; Sørup, H.J.D.; Boriani, E.; Hald, T.; Thöns, S.; Hauschild, M.Z. Environmental sustainable decision making—The need and obstacles for integration of LCA into decision analysis. *Environ. Sci. Policy* **2018**, *87*, 33–44. [CrossRef]
25. Von Neumann, J.; Morgenstern, O. *Theory of Games and Economical Behavior*; Princeton University Press: Princeton, NJ, USA, 1947.
26. Olofsson Madestam, H. *Fosforfastläggning i Växjösjön*; Synlab: Halmstad, Sweden, 2020.
27. VISS Växjösjön. Available online: https://viss.lansstyrelsen.se/Waters.aspx?waterMSCD=WA26248924 (accessed on 26 October 2022).
28. Mörrumsåns Vattenråds Samlade Recipientkontroll (SRK). Available online: http://webstar.vatten.slu.se/db.html (accessed on 17 May 2022).
29. Kinell, G.; Söderqvist, T. *Ekonomisk Värdering Med Scenariometoder—En Vägledning Som Stöd För Genomförande Och Upphandling*; Report 6469; The Swedish Environmental Protection Agency: Stockholm, Sweden, 2011.
30. Morrison, G. *Mälarens Värde*; Chalmers University: Gothenburg, Sweden, 2009. Available online: https://miljobarometern.stockholm.se/content/docs/vp/mal/Malarens_varde_Chalmers_2009.pdf (accessed on 10 May 2022).
31. Ekonomifakta, Räkna på Inflationen. Available online: https://www.ekonomifakta.se/Fakta/Ekonomi/Finansiell-utveckling/Rakna-pa-inflationen/ (accessed on 18 May 2022).
32. Lürling, M.; Faassen, E.J. Controlling toxic cyanobacteria: Effects of dredging and phosphorus-binding clay on cyanobacteria and microcystins. *Water Res.* **2012**, *46*, 1447–1459. [CrossRef] [PubMed]
33. Agstam-Norlin, O.; Lannergård, E.E.; Rydin, E.; Futter, M.N.; Huser, B.J. A 25-year retrospective analysis of factors influencing success of aluminum treatment for lake restoration. *Water Res.* **2021**, *200*, 117267. [CrossRef] [PubMed]
34. Schütz, J.; Rydin, E.; Huser, B.J. A newly developed injection method for aluminum treatment in eutrophic lakes: Effects on water quality and phosphorus binding efficiency. *Lake Reserv. Manag.* **2017**, *33*, 152–162. [CrossRef]
35. Huser, B.J.; Futter, M.; Lee, J.T.; Perniel, M. In-lake measures for phosphorus control: The most feasible and cost-effective solution for long-term management of water quality in urban lakes. *Water Res.* **2016**, *97*, 142–152. [CrossRef] [PubMed]
36. Huser, B. Aluminum application to restore water quality in eutrophic lakes: Maximizing binding efficiency between aluminum and phosphorus. *Lake Reserv. Manag.* **2017**, *33*, 143–151. [CrossRef]

37. Karlsson, M.; Malmaeus, M.; Rydin, E. *Åtgärder Mot Internbelastning Av Fosfor I Hjälmaren*; Report Nr C 381; IVL Swedish Environmental Research Institute: Stockholm, Sweden, 2019. Available online: https://www.ivl.se/download/18.34244ba71728fcb3f3fab6/1591706073502/C381.pdf (accessed on 27 April 2022).
38. Hedrén, A. *Statusrapport Åtgärder Växjösjöarna*; Planning Department Technical Administration: Växsjö Municipality, Sweden, 2019.
39. Spears, B.M.; Mackay, E.B.; Yasseri, S.; Gunn, I.D.M.; Waters, K.E.; Andrews, C.; Cole, S.; de Ville, M.; Kelly, A.; Meis, S.; et al. A meta-analysis of water quality and aquatic macrophyte responses in 18 lakes treated with lanthanum modified bentonite (Phoslock®). *Water Res.* **2016**, *97*, 111–121. [CrossRef] [PubMed]
40. Lorenzen, M.W. *A Guide to Aeration/Circulation Techniques for Lake Management*; Environmental Protection Agency: Portland, OR, USA, 1977. Available online: http://hdl.handle.net/2027/mdp.39015041330062 (accessed on 26 May 2022).
41. Barr Engineering. *Stubbs Bay Feasibility Study*; Barr Engineering: Minneapolis, MN, USA, 2004. Available online: https://minnehahacreek.org/sites/minnehahacreek.org/files/Stubbs%20Bay%20Feasibility%20Study--Final.pdf (accessed on 23 April 2022).
42. Ruzzo, W.P. *Cherry Creek Reservoir Destratification System*; PE, LLC: Denver, CO, USA, 2008. Available online: https://www.cherrycreekbasin.org/wp-content/uploads/2014/04/Cherry-Creek-Reservoir-Destratification-System.pdf (accessed on 26 May 2022).
43. Leander, B. Iskmosundens Syresättningsprojekt. Iskmo, Finland. 2015. Available online: https://iskmosunden.fi/iskmosundens-syresattningsprojekt/ (accessed on 23 April 2022).
44. Town of Cary—Cary Proposes Jordan Lake Aeration System for Improved Water Quality. Available online: https://www.townofcary.org/Home/Components/News/News/10836/715?arch=1&npage=95 (accessed on 16 May 2022).
45. US Army Corps of Engineers. *Finding of No Significant Impact Jordan Lake Aeration System*; US Army Corps of Engineers: Wimlington, NC, USA, 2013. Available online: https://www.saw.usace.army.mil/portals/59/docs/recreation/jordanlake/signed_jordan_demonstraton_project_fonsi_july2014.pdf (accessed on 23 April 2022).
46. Restaurering av Finjasjön. Available online: https://docplayer.se/19147081-Hassleholms-kommun-gatukontoret-restaureringen-av-finjasjon.html (accessed on 19 May 2022).
47. Lillesjön Åtgärdsförslag Och Fortsatta Arbeten. Available online: https://docplayer.se/7346234-Informationsmote-2014-01-28-grimstorp-lillesjon-atgardsforslag-och-fortsatta-arbeten.html (accessed on 19 May 2022).
48. Jing, L.; Bai, S.; Li, Y.; Peng, Y.; Wu, C.; Liu, J.; Liu, G.; Xie, Z.; Yu, G. Dredging project caused short-term positive effects on lake ecosystem health: A five-year follow-up study at the integrated lake ecosystem level. *Sci. Total Environ.* **2019**, *686*, 753–763. [CrossRef] [PubMed]
49. Liu, C.; Zhong, J.; Wang, J.; Zhang, L.; Fan, C. Fifteen-year study of environmental dredging effect on variation of nitrogen and phosphorus exchange across the sediment-water interface of an urban lake. *Environ. Pollut.* **2016**, *219*, 639–648. [CrossRef] [PubMed]
50. Sandström, O. Reduktionsfiske Som Metod För Att Minska Övergödningen I Östhammarsfjärdarna. The Uppland Foundation Report 2011/2, Sweden. 2011. Available online: https://www.upplandsstiftelsen.se/UserFiles/Archive/5417/Rapporter/2011_2_Reduktionsfiske.pdf (accessed on 25 April 2022).
51. Davidsson, T. Börringesjön, Yddingesjön Och Havgårdssjön—Vattenkvalitet Och Åtgärdsförslag. The Ecology Group on Behalf of the Segeån Watercourse Association, Landskrona, Sweden. 2003. Available online: https://segea.se/wp-content/uploads/2020/12/E1_Yddinge_Borringe_Havgard_2003.pdf (accessed on 25 April 2022).
52. Nilsson, R. Projekt Ringsjön—Årsrapport 2006. Höörs Kommun, Sweden. 2006. Available online: https://docplayer.se/23733176-Projekt-ringsjon-arsrapport-2006.html (accessed on 25 April 2022).
53. Förstudie Avseende Förutsättningar Att Med Reduktionsfiske Biomanipulera Sjösystemet Trummen, Växjösjön, S. & N. Bergundasjöarna I Växjö Kommun. Available online: https://docplayer.se/12847907-Forstudie-avseende-forutsattningar-att-med-reduktionsfiske-biomanipulera-sjosystemet-trummen-vaxjosjon-s-n-bergundasjoarna-i-vaxjo-kommun.html (accessed on 17 May 2022).