Cost-benefit analysis of the costs and benefits of Saimaa ringed seal conservation

Our Saimaa Seal-LIFE: Deliverable in D4 cost-benefit analysis, 2023

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Contents

1 INTRODUCTION

The Saimaa ringed seal (*Pusa hispida saimensis*) is a highly endangered seal subspecies that inhabits only in the Lake Saimaa in Finland. Major threats to the recovery of the Saimaa ringed seal population include fishing by-catch mortality, climate change, disturbances from human activity during the breeding season, and the population's small size and fragmentation (Metsähallitus 2023). In the 1980s, the population reached its lowest point, with fewer than 200 individuals. Today, Finland is committed to protecting the seal in accordance with the European Union Habitats Directive (Saimaannorpan suojelutyöryhmä 2022), and thanks to conservation efforts, the population has slowly increased to its current level at approximately 480 seals. The conservation measures include fishing restrictions to prevent by-catch mortality, piling-up snowdrifts and development of artificial nests to support seals nesting during winters with limited snow and ice cover, limiting shoreline construction, and motorized vehicle use to reduce human caused disturbance.

While the seal population has slowly increased, the species is spreading back to its former range and its population is recovering in previously deserted parts of the lake (Metsähallitus 2023). The species is still endangered and there has been debates on whether conservation measures should be increased. In particular, there has been debate about extending the closure period of the ban on gillnet fishing from current (the end of June) to the end of July (Paloheimo 2020).

While Finns generally regard the conservation of the Saimaa ringed seal as important, the methods proposed for its conservation have sparked debate and opposition for decades, especially among the local communities around Lake Saimaa (Tonder & Jurvelius 2004). These debates have largely centered on tensions between people with conflicting interests, focusing on the suitability, acceptability, and local involvement in various conservation strategies. Interest in these debates extends beyond the local residents, with the broader public expressing diverse opinions on the problem and potential solutions. The fishing restrictions introduced to strengthen conservation efforts have been a key issue of contention (Salmi et al. 2013).

To support decision making on future measures and to ensure their social acceptability, it is important to understand the impacts of these measures to different groups of people (Bennett et al. 2017). One way to assess the socio-economic impacts of the conservation efforts is the environmental cost-benefit analysis (CBA) (OECD 2018). CBA aims at evaluating the economic efficiency of projects or policies from the society's perspective. It compares increases in human well-being (i.e. benefits) due to a project to the reductions in that well-being (i.e. costs) due to the project. CBA is well applicable approach in evaluating the socio-economic impacts of the Saimaa ringed seal conservation in particular due its aim to evaluate the impacts of polices or projects to all relevant beneficiaries and losers instead of focusing on a single goal or single group of people (OECD, 2018).

In this report, we apply CBA to the conservation of Saimaa ringed seal. We use benefit estimates for changes in the seal population, including both the existence values (Tienhaara et al. 2024) and changes in recreation benefits (Lankia et al. 2024). The costs of conservation include the actual implementation costs of the conservation measures and the opportunity costs to commercial fishing due to the decreased fish catch. The uncertainty of conservation measures' impact on the seal population is illustrated using a Bayesian Network model based on expert assessments. The benefit-cost comparisons for different conservation scenarios support conservation actions in majority of the evaluated scenarios.

2 METHODOLOGY

2.1 Cost-benefit analysis

Cost-benefit analysis (CBA) is designed to assess the economic efficiency of projects or policies from a societal viewpoint. It aims at offering a structured and transparent method for identifying and valuing the benefits and costs of projects over their entire lifespan (Boardman et al. 2017, OECD 2018). For a project to be deemed successful, its net benefits must be positive, meaning that the benefits must outweigh the costs. The outcomes of a well-executed CBA can provide valuable support for science-based policy decisions.

The general steps involved in a CBA are as follows (adapted from Boardman et al. 2017):

1. Identify alternative projects
2. Determine whose benefits and costs are relevant
3. Identify and categorize impacts, and select measurement indicators
4. Quantitatively predict impacts over the project's life
5. Monetize all impacts
6. Discount benefits and costs to present value
7. Calculate the net present value (NPV) of each alternative
8. Conduct a sensitivity analysis
9. Make a recommendation

CBA involves identifying and monetizing the project's impacts throughout its duration and discounting these benefits and costs to their present values. Benefits and costs are assessed in terms of changes to human welfare, with policy outputs valued based on willingness to pay or accept compensation, and inputs valued based on opportunity costs (Boardman et al. 2017). After determining the net present value, a sensitivity analysis is typically performed on key assumptions and impacts, such as biophysical impacts, monetary values, and discount rates.

Environmental CBA refers to the economic appraisal of policies and projects that have the aim of improving the provision of environmental services, or actions that might affect the environment as an indirect consequence (Atkinson et al. 2008). Environmental CBA integrates the valuation of environmental benefits and costs in the analysis (Atkinson and Mourato 2008). In principle, environmental CBA enables a systematic and transparent evaluation of the impacts of biodiversity conservation policies at the societal level (Markandya 2016).

Comparing the benefits and costs in environmental CBA requires assigning a monetary value also to benefits and costs for which no market price exist. Stated preference methods (see Johnston et al. 2017) enable the valuing of nonmarket goods and services by using surveys to assess respondents' preferences and reveal their willingness to pay for environmental improvement. These methods allow for a rather detailed description of an environmental good in question before valuation. Especially choice experiments (CE) allow valuation of programs with different environmental attributes and their levels, such as biodiversity impacts, and it has been regarded as the most suitable valuation techniques for biodiversity (Bartkowski 2017).

Despite its widespread use, environmental CBA also faces criticism. Critics argue that the theoretical foundations and practical applications of CBA are flawed. Issues such as the concept of efficiency, distributional concerns, and the valuation of environmental impacts are often highlighted (Adler & Posner 1999, Pearce et al. 2006, Turner 2007, Nyborg 2014). To address these challenges, it is important to incorporate various valuation methods and consider alternative decision-making frameworks alongside CBA. For instance, multi-criteria analysis (MCA) allows for the inclusion of both qualitative and quantitative data. Additionally, engaging stakeholders can help ensure that diverse perspectives are taken into account. Moreover, the inherent uncertainty in predicting future states and impacts necessitates robust methods for addressing uncertainty in CBA. Techniques such as scenario analysis, and sensitivity analysis can help estimate the range of possible outcomes and their probabilities, providing a more comprehensive understanding of potential risks and benefits.

Applying CBA to inform policies targeted to safeguard biodiversity involves many uncertain elements. Conservation measures, their implementation, and impact on the state of biodiversity possess considerable uncertainties (Markandaya 2016). In addition, the valuation of biodiversity has several methodological challenges (Bartkowski 2017) such as the non-market nature of components of biodiversity, high levels of uncertainty involved in the understanding of the relationship between biodiversity and human well-being and the abstractness and complexity of biodiversity. Furthermore, the uncertainties concerning the preferences of individuals apply also in valuation of biodiversity (e.g. Voltaire et al. 2013).

In conclusion, although CBA is a valuable tool for policy analysis, it should be applied carefully and supplemented with other methods to provide a more holistic and equitable evaluation of projects, especially those with significant environmental impacts.

2.2 Applying CBA in the case of Saimaa ringed seal conservation

As a first step of CBA, we *identified the alternative projects* that we call here conservation scenarios as they are future-oriented and include uncertainty of the impact of conservation. We describe the scenarios with conservation attributes defined in the choice experiment study to measure preferences for Saimaa seal conservation (Tienhaara, Lankia & Pouta 2024). The attributes include conservation result, i.e. Saimaa seal population, and key conservation measures, i.e. duration of the springtime net fishing ban, motor vehicle ban on ice and building sites available for construction along the shoreline. The attributes defined in Table 1 were chosen to reflect the conservation efforts of the Saimaa ringed seal as realistically as possible. Existing conservation measures were used as a basis for attribute selection. The attributes were determined in cooperation with experts from Natural Resources Institute Finland, Metsähallitus, and the North Savo ELY Centre, who are working in the field of Saimaa ringed seal conservation. In addition to the conservation measures outlined in the scenarios, it is assumed that smaller-scale efforts, such as providing artificial nests and constructing snow piles to support seal breeding, will continue at their current level.

Table 1. Attributes for scenarios.

Attribute	Description
Size of the Saimaa ringed seal population	The Saimaa ringed seal is a highly endangered subspecies of the seal that lives only in Finland, in the waters of Saimaa. At its lowest point, the population was less than 200 individuals in the 1980s.
Duration of the net fishing ban	By banning gillnet fishing in the most important habitats for Saimaa ringed seal cubs, the number of deaths due to gillnets is reduced.
Motor vehicle ban on ice	Saimaa ringed seals are particularly sensitive to disturbances during the reproduction and fledging phase, especially motor vehicles are harmful to nesting in snow lair shelters for birthing, nursing and/or resting.
Building sites available for construction along the shoreline	The construction of the shores of Lake Saimaa causes disturbances for the Saimaa ringed seal, and the constructed shores are not suitable for nesting areas. So far, approx. 30% of the seal's potential nesting area has been lost as a result of shoreline construction.

Since the impact of conservation measures to seal population is uncertain, we selected combinations of conservation results and measures for the scenarios of CBA. The conservation results included increase in seal population to 1.5-fold, 2-fold and 2.5-fold corresponding approximately 600, 800 and 1000 individuals. All the key conservation measures were set on moderate or on a high level. The combinations are presented in Table 2.

Table 2. Scenarios for CBA.

Scenarios		Conservation result, population		
Conservation measures		1.5-fold	2-fold	2.5-fold
Moderate level	Gillnet fishing ban until end of July	M1.5	M2	M2.5
	Motor vehicle ban on ice 200 km2			
	Reduction of building sites by quarter			
High level	Gillnet fishing ban year-round	H1.5	H2	H2.5
	Motor vehicle ban on ice 400 km2			
	Reduction of building sites by half			

In the second step in CBA, to *determine whose benefits and costs are relevant*, we decided that the population of Finland is the population used for CBA. The adult population of Finland (4.5 million people) was chosen due to high awareness of the Saimaa Seal conservation in entire country. Although, there might be awareness of the Saimaa seal and its conservation also in other European countries, the level of awareness can be assumed to be on very different level than in Finland.

In the third step of CBA, to *identify and categorize impacts and select measurement indicators,* we selected the change in the size of the seal population as the main impact. Although, the conservation measures may also have some other environmental impacts, they are less clear and only discussed as possible side benefits of the conservation efforts. The impacts i.e. the categories for conservation costs and benefits are listed in Table 3.

Table 3. Benefit and cost categories.

Benefits	Costs
• Perceived benefit from the increase in population (existence value) • Recreation benefits • Indirect benefits from the conservation measures: Motor vehicle ban, Restrictions for building sites, Gillnet fishing ban	• Costs of gillnet fishing bans for recreational fishers • Costs of gillnet fishing bans for professional fishers • Costs of land acquisition from building sites • Costs of artificial nests and snowbanks • Compensations to fishing right owners due to fishing restrictions • Costs of enforcing fishing restrictions

In an ideal case, there would be enough information to the fourth step of CBA: *quantitatively predict impacts*. However, in our case this was not possible due to uncertainty in ecological knowledge. To take the uncertainty into account, we applied expert approaches to define the most probable combinations of measures and conservation results. Using expert knowledge is common in conservation science due, e.g., to the complexity of the studied systems and the relative lack of knowledge (e.g., Martin et al. 2012). More precisely, we conducted an expert elicitation exercise, where we asked four Saimaa ringed seal experts to estimate the future development of the seal population, i.e. to estimate the population size in 2040, under different scenarios related to potential management measures and climate change.

The fifth step of analysis is to *monetize all the impacts*. In its core, CBA compares costs and benefits of a given change in a common unit, conventionally in monetary terms, reflecting how much those affected by the project or policy value these changes (OECD 2018). A benefit or increase in an individual's well-being can be measured by the maximum amount of money they would be willing to forego to obtain the change (OECD 2018), here an increase in the Saimaa ringed seal population or in the level of conservation efforts. Costs are realized costs of conservation measures measured with market prices.

It was assumed that the realized *costs* of the conservation measures implemented in previous years would continue with same average annual costs. In case of the opportunity costs of professional fishers, it was assumed that the extended gillnet fishing ban would end the professional fishing entirely regardless of the true coverage of ban region (some areas are not entirely covered by ban). The loss of professional fishing opportunities wouldn't be compensated by changing fishing gear or changing the area where fishing takes place.

The starting point for measuring the *benefits* was the total economic value (TEV) of any change in well-being due to a project or policy. TEV is usually divided to use and non-use values, use-values relating to actual use of the good (e.g. recreational visits to Lake Saimaa to spot a Saimaa ringed seal), planned use (visits planned in the future) or possible use (the option of visiting the Lake to see a Saimaa ringed seal in the future).

Non-use value refer to willingness-to-pay to maintain the environmental attribute, here Saimaa ringed seal population, in existence even though there is no actual, planned or possible use (OECD 2018.) It is usual to classify non-use values to existence value (WTP for keeping a good in existent, without an individual having actual or planned use for it), altruistic value (WTP for preserving the good to be available to others in the current generation) and bequest value (WTP for preserving the good for future generations) (OECD 2018).

In this study, the identified direct benefits included: 1) the existence value of the Saimaa ringed seal, which arises from people's appreciation of the seal population's presence now and in the future, and 2) the recreational value, which comes from the opportunity to see the seals in the wild, both now and in the future.

Based on the conservation scenarios, we also estimated the perceived costs and benefits of the conservation measures. They represent *indirect benefits or indirect costs* of conservation. People may perceive benefits or costs from the conservation measures depending on whether they find them to increase or decrease their well-being. People might value restrictions on shoreline construction and motorized transportation on ice for reasons beyond their conservation benefits. At the same time, some individuals may feel that conservation efforts negatively impact their well-being.

Thus, the following were included as indirect benefits: 1) WTP for extending gillnet fishing ban until end of July, 2) WTP for extending motor vehicle ban on ice, and 3) WTP for reduction of available building sites. Similarly, the following were included as indirect costs: negative WTP for extending net fishing ban year-round.

The sixth step in CBA is to discount benefits and costs, and seventh to calculate the net present value (NPV) of each alternative. However, we chose to compare yearly costs and benefits, assuming both to remain consistent each year. This approach eliminated the need for discounting and calculation of the net present value.

The eighth step of CBA is to conduct a *sensitivity analysis* and assess the feasibility of the chosen scenarios. We explored the sensitivity of the results by conducting CBA with five different set of assumptions concerning costs and benefits, and by studying whether there were any differences in the cost-benefit-ratios calculated with these five versions. In addition, we conducted an expert elicitation exercise to assess the effects of conservation scenarios and climate change on the population size of the Saimaa ringed seal.

The ninth step of analysis is making recommendations. The recommendations based on benefit-cost ratio as well as on sensitivity and feasibility analysis are drawn in Conclusions sections.

2.3 Methods to estimate benefits

We measured non-use values associated with the growth of the Saimaa ringed seal population, as well as use-values linked to the expected increase in future recreational visits to Lake Saimaa resulting from this population growth. These direct benefits were estimated using two environmental valuation methods: choice experiment and travel cost method.

Choice experiment method

The choice experiment (CE) method (e.g. Hanley, Mourato & Wright 2001) is one of stated preference methods. It is a survey-based approach that presents respondents with multiple choice sets, each containing two or more alternatives, described by various attributes and their associated levels. These attribute levels differ between the alternatives, and cost is often included as one of the attributes to facilitate the estimation of welfare measures. Participants are asked to select their preferred alternative in each choice set, and it is assumed that they evaluate the utility of each option, choosing the one that offers the highest utility. Choice sets typically include a "status quo" or "no-choice" option, allowing respondents to opt-out of alternatives with increased costs.

Respondents' choices reveal the trade-offs they make between attributes, allowing the estimation of their willingness to pay (WTP) for different attributes based on these selections. A key advantage of the CE method is that it can provide insights into how individual attributes affect value, as well as the relationships between the values of different attributes.

For the Saimaa ringed seal, the choice experiment (CE) method was applied to estimate the existence value associated with various potential seal population sizes. Since these population increases represent hypothetical future levels, a stated preference approach, like CE, is essential for capturing values that people assign to non-market benefits. In addition, CE was employed to assess the indirect benefits of conservation actions, such as limiting the number of available building sites along the shoreline to better protect the Saimaa ringed seal habitat. By presenting respondents with hypothetical scenarios that included varying levels of conservation measures, CE enables estimating the indirect benefits from these measures.

Travel cost method, contingent behavior method

Use-values of Saimaa ringed seal conservation include recreational visits taken to Lake Saimaa for an opportunity to spot a seal in wild. Because there is no market price for recreational visits to the lake that could be used to assess their monetary value, non-market valuation methods need to be used. The travel cost method (TCM) is a method developed to estimate recreational use values of natural areas.

TCM is based in the idea that the value of a recreational area can be inferred from the costs associated with the visits to that location. To estimate the TCM, two key pieces of information are needed: a) the number of visits an individual makes to a specific recreational area withing a given period time (e.g. a year), and b) the travel costs incurred by that individual, which serve as a proxy for the price of visiting the site (OECD 2018.) The costs of travelling can include both monetary costs of travelling such as petrol costs or ticket fees and the cost of time spent travelling. To provide conservative estimate of the recreational benefits we included monetary costs of travelling only. With these data a demand curve for access to the recreational area can be estimated. The curve explains the number of visits as a function of travel costs and other relevant explanatory variables. Usually, the demand curve is downward sloping as the number of visits usually declines the higher the costs. The demand curve indicates individuals' willingness to pay to visit the site. The non-market value of recreation visits is estimated as the consumer surplus, i.e. the area under the demand curve between individuals' WTP and their travel costs (OECD, 2018). Previously in species conservation context, TCM has been used for example, to assess the benefits of bear viewing in Yellowstone National Park (Richardson & Enriquez, 2024) and white storks in Poland (Czajkowski et al., 2014). In the context of water recreation in Finland, it has been previously employed to assess the economic value of recreational visits to Puruvesi, a sub-part of the Lake Saimaa (Tienhaara et al., 2021), recreational visits to Baltic Sea (Ahtiainen et al., 2022; Czajkowski et al., 2015), visits to leisure homes locating by water systems (Huhtala & Lankia, 2012), and water recreation on the national level (Lankia et al., 2019; Vesterinen et al., 2010).

To evaluate the recreational benefits of an increased number of future visits to Lake Saimaa resulting from the growth of the Saimaa ringed seal population, as well as the potential decrease in the number of visits due to stricter fishing restrictions, we combined TCM with contingent behavior data (Egan et al., 2023; Whitehead et al., 2000). This approach enabled us to measure changes in the Saimaa ringed seal population and fishing restrictions that have not yet happened. Analysis of a combined travel cost – contingent behavior (TC-CB) model involves combining data on number of recreation visits in past with data on planned number of visits in the future in changed conditions and estimating a model that using both types of observations.

2.4 Methods to collect data for the costs of conservation measures

We collected empirical data that described the costs associated with conservation measures that have been either implemented in previous projects (2016-2023) or are currently in progress (compensation period 2021–2025; project period 2021-2027). We used specific excel-worksheet, delivered to persons that had access to relevant costs data. The following steps were taken to ensure comprehensive and clear documentation of these costs: 1) Costs specific to the implementation of each conservation measure were included and recorded separately for each measure. 2) Both incurred (already realized) and expected (projected future) costs were reported. For incurred costs, the exact year in which the expenses occurred were provided. 3) Each cost item was described in sufficient detail, as required by the relevant sections in the database. The specific cost categories included costs of labour, i.e. wages and salaries, including obligatory social security costs/charges. Travel costs included expenses per person, including transport (tickets, car rentals), accommodation, daily allowances etc. We included durable goods equipment and infrastructure costs to calculations, i.e. cost of equipment and infrastructure, such as monitoring equipment, and material costs of artificial nests. We also included land purchase and fishing opportunity losses and compensations as costs in calculations.

2.5 Expert elicitation on the effects of conservation measures

We conducted an expert elicitation exercise to assess the effects of additional conservation measures and climate change on the population size of the Saimaa ringed seal in 2040. We applied a modified Delphi method (see, e.g., Mukherjee et al. 2015) in the elicitation process.

First, we arranged an online meeting with the experts, the purpose of which was to give an introduction to the exercise, to familiarize the experts with the probability-based assessment and to go through the questionnaire they were asked to fill. In this meeting, it was also possible to elaborate and discuss the terminology and the assumptions used in the exercise. After this, each expert was asked to give their numerical estimates using the Excel document created for this purpose. The summary of the results (presented anonymously) was discussed in the second online meeting, where it was also possible to bring out any challenges or vagueness related to the exercise. After this, the experts had an opportunity to revise their answers if needed.

The questionnaire included three parts. In the first part, the experts were asked to give their opinion on the probability of the Saimaa seal population to be in a certain size in 2040 under two different climate-change scenarios if no additional conservation measures were applied. The population had five alternative states, each of which expressed the population size relative to the population size in 2022 (approximately 430 individuals): 0.5-fold (reduction of the population size by half), no change, 1.5-fold increase, 2-fold increase, and 2.5-fold increase. The two climate change scenarios had different frequencies of mild winters that result to poor reproduction success of the Saimaa seal population. The first climate-change scenario assumed the current prevailing climate conditions (approximately 3 poor winters per 10 years, pers. comm. Miina Auttila, Metsähallitus) and the second scenario assumed an “intensified” climate change (5 poor winters per 10 years).

In the second part, the experts were asked to rank the additional conservation measures (Table 2) based on their effectiveness to positively affect the Saimaa seal population development.

In the third part, the experts were asked to evaluate the probability of the Saimaa seal population to be in a certain state in 2040 under the current and intensified climate change scenarios and when the conservation measures were executed either at the moderate level or at the high level (Table 2).

We created a simple Bayesian Network (BN) model (Pearl 1988), a graphical model describing probabilistic relationships between a set of variables, to help the examination of the probability distributions provided by the experts. The BN was implemented with Hugin Researcher 9.5 software (Madsen et al. 2005).

3 DATA

3.1 Data on direct benefits

The benefits of increasing the Saimaa ringed seal population were estimated based on survey data collected in spring 2022 (Lankia et al. 2022). Choice experiment method (CE) and travel cost-contingent behavior (TC-CB) method were employed to assess both the existence and recreational benefits of the seal population increase (Tienhaara, Lankia & Pouta 2024, Lankia et al. 2024). Both the CE and TC-CB models were calculated using a representative sample of the Finnish adult population, ensuring that the benefits reflect a national perspective on the conservation of the Saimaa ringed seal. For recreational benefits, we used the share of visitors in the survey data as a proxy for the share of visitors in Finland as a whole, further aligning the results with a national context (Table 4).

Three scenarios were modeled to illustrate the economic impact of different population levels of the Saimaa ringed seal: 1.5-fold, 2-fols and 2.5-fold, i.e. approximately 600, 800, and 1,000 individuals. In Table 5, the economic values associated with each population level are divided into existence values and recreation values. When population increases by 1.5-fold, the existence value per person is estimated at €50, while the recreation value per person stands at €58. As the seal population increases to 2-fold, the per-person existence value rises to €80, and the recreation value to €115. At the highest level, when the population increases 2.5-fold, these values reach €110 for existence and €175 for recreation per person.

To capture the aggregate economic impact, these per-person values were applied to the population at large. The existence values were multiplied by the total Finnish population over 18 years old in 2022, providing an estimate of the overall existence value benefits for the Finnish adult population. Whereas the recreational value benefits were multiplied by the estimated number of recreational visitors to the Saimaa region, as derived from survey data (Table 4). For the 1.5-fold scenario, the total existence benefit for the Finnish adult population is approximately €230.5 million, with an additional €44.4 million in recreational benefits. For 2-fold population levels, these values increase to €363.5 million and €88.9 million, respectively. At the highest population level considered, 2.5-fold, the total existence benefit is estimated at €501.4 million, while the recreational value reaches €134.7 million.

Table 4. Finnish adult population in 2022 and the share of Lake Saimaa recreational visitors in the survey data.

Finnish population over 18 years in 2022	4 537 778
Share of Lake Saimaa recreational visitors in the survey data	0.17

Table 5. Annual benefits from population increase in existence value and recreation benefits per person and total over Finnish population.

	Conservation result, seal population		
Seal population	1.5-fold	2-fold	2.5-fold
	€/person/year		
Existence value	51	80	111
Recreation value	58	115	175
	Total, million €/year		
Existence value	230.519	363.476	501.424
Recreation value	44.448	88.896	134.690

3.2 Data on indirect benefits

The indirect benefits of conservation measures aimed at increasing the Saimaa ringed seal population were estimated using the same survey data as previously employed for direct benefit estimates. The benefits were estimated using CE method (Tienhaara, Lankia & Pouta 2024).

Two levels of tightened conservation measures for the Saimaa ringed seal were considered: moderate and high. These levels were distinguished by varying degrees of restrictions on human activities, as well as differences in the areas designated for seal conservation. Annual indirect benefits from conservation measures are presented in Table 6.

Table 6. Annual indirect benefits from conservation measures for different levels of conservation.

	Level of conservation measures					
	Moderate			High		
Conservation measure	*Definition*	*€/ person*	*Benefits in total, million €/year*	*Definition*	*€/ person*	*Benefits in total, million €/year*
Motor vehicle ban on ice	Area doubles to 200 km^2	16	71.243	Area quadruples to 400 km^2	0	0
Building sites available for construction along the shoreline	Decreases by a quarter from the current (5600)	35	157.007	Decreases to half of the current (3600)	42	188.317
Duration of the gillnet fishing ban	Extended until the end of July	46	206.469	Extended year-round	-52	-233.696

Under moderate conservation measures, the area in which motor vehicles are banned on the ice would be doubled to 200 km^2. This limitation aims to reduce disturbances to the seals during critical breeding and nesting periods. In contrast, the high conservation scenario significantly increases the area, quadrupling the restricted area to 400 km^2. While the moderate level of restriction is associated with an estimated individual willingness-to-pay of €16, the high level was assigned a zero value, indicating no additional per-person benefit, potentially due to diminishing marginal returns as perceived by survey respondents. On a broader scale, the moderate level is estimated to contribute €71.243 million annually in benefits, while the high restriction does not add additional value in this category.

In addition to motor vehicle restrictions, another conservation measure was reducing building opportunities along the shoreline, with moderate and high conservation levels reducing available construction sites by one-quarter and one-half, respectively. These reductions correspond to individual valuations of €35 per person for reduction by one-quarter and €42 per person for reduction by half. Total annual benefits of these measures are calculated at €157.0 million for the moderate level and €188.3 million for the high level.

The last measure assessed was the ban on gillnet fishing, which aims to reduce accidental seal bycatch. Under the moderate conservation level, this ban is extended to cover the period up until the end of July and carries an estimated per-person value of €46, resulting in a total annual benefit of €206.5 million. However, under the high conservation level, which extends the gillnet ban year-round, the per-person valuation shifts to €-52, indicating a negative perception likely due to the extended ban's impact on fishing activities. Consequently, rather than generating a benefit, the high level for this conservation measure is associated with an annual total cost of €233.7 million.

3.3 Data on costs

When specifically analyzing the opportunity costs of extended gillnet fishing ban, we took advantage of available data from Official Statistics of Finland (OSF), maintained by the Natural Resources Institute Finland. It covered the monthly total catches (kg) of professional fishermen by species in separate segments of the target water area. When calculating the nominal value of the catch in commercial fishery, we used the values in euros per kg by species and gear by month in 2022 (OSF 2024a).

When estimating the total costs of compensating the building sites available for construction we used the average values for realized compensations (33 093 eur per site) in 2017–2022, in calculations of lower and higher scenarios. It was assumed that compensations cost in scenarios are covered within 10 years period and are not affected by the rate that available sites are being constructed. When estimating the annual costs of compensation paid to fishing right owners, we used the annual payments of years 2021–2025 (665 000 euros) in calculations, provided by the Centre for Economic Development, Transport and the Environment.

Table 8. Costs of conservation measures for different levels of conservation.

	Level of conservation measures	
Conservation measures	Moderate	High
	million € per year	
Building sites available for construction along the shoreline (compensations)	5.957	11.914
Gillnet fishing ban		
Professional fishers (loss in catch)	0.011	0.687
Compensations to fishing right owners due to fishing restrictions	0.665	0.665
Enforcement of fishing ban	0.064	0.064
Artificial nests	0.054	0.054

4 RESULTS

4.1 Comparison of costs and benefits

Net benefits (i.e. benefits minus costs) are presented in Table 9 for each combination of conservation result and level of conservation measures. In all the scenarios, benefits exceed costs. Net benefits are the highest in scenario with moderate increase in conservation measures and 2.5-fold increase in the Saimaa ringed seal population.

Table 9. Net benefits of conservation scenarios.

Scenarios		Conservation result, seal population		
		1.5-fold	2-fold	2.5-fold
Level of conservation measures	Conservation measures	Net benefits, million €/year		
Moderate	Gillnet fishing ban until end of July Motor vehicle ban on ice 200 km2 Reduction of building sites by quarter	**M1.5** 703	**M2** 880	**M2.5** 1 064
High	Gillnet fishing ban year-round Motor vehicle ban on ice 400 km2 Reduction of building sites by half	**H1.5** 216	**H2** 394	**H2.5** 577

Table 10 presents cost-benefit –ratios (total benefits/total costs) for each scenario. Benefits are higher than costs in all the scenarios, but in scenarios with moderate increase in conservation measures the benefits exceed the costs considerably.

Table 10. Benefit -cost ratio of conservation scenarios.

Scenarios		Conservation result, seal population		
		1.5-fold	2-fold	2.5-fold
Level of conservation measures	Conservation measures	Benefit-cost ratio		
Moderate level	Gillnet fishing ban until end of July	M1.5 105.12	M2 131.39	M2.5 158.61
	Motor vehicle ban on ice 200 km2			
	Reduction of building sites by quarter			
High level	Gillnet fishing ban year-round	H1.5 1.88	H2 2.59	H2.5 3.34
	Motor vehicle ban on ice 400 km2			
	Reduction of building sites by half			

The difference in the cost-benefit ratios between moderate and high levels of conservation measures arises from higher direct and indirect costs associated with the high level of conservation measures and greater indirect benefits linked to the moderate level of conservation measures (indicating survey respondents preference for moderate measures).

4.2 Sensitivity analysis of assumptions for benefits and costs

To examine whether varying calculation assumptions affect the results, the CBA was conducted five times using different sets of assumptions for calculating costs and benefits.

Using both CE and TC-CB in calculating benefits can theoretically lead to some degree of double-counting. This may occur if respondents, while stating their willingness to pay in the CE, have also considered the recreational benefits associated with an increase in the Saimaa ringed seal population. To account for this, we created versions of the CBA (versions CBA V.2. and CBA V.4. in Table 11) where benefits are calculated only using the CE. This means that the direct benefits account solely for the willingness to pay for the increase in the Saimaa ringed seal population and they do not include any recreation benefits.

In the basic version of the CBA, we calculated the benefits based on data collected from across Finland. Additionally, we created versions of the CBA (versions CBA V.3 and CBA V.4 in Table 11) that analyze fishers and visitors separately. A separate TC-CB model for respondents who reported fishing in Saimaa allowed us to calculate the change in recreational benefits separately for Saimaa fishermen and other respondents. Similarly, a separate CE model for respondents who reported visiting Saimaa for leisure at least once in the past year. This model allowed us to calculate the willingness to pay for the increase in the Saimaa ringed seal population and conservation efforts separately for Saimaa recreational users and other respondents.

By combining these assumptions, we created four different versions of the CBA. Additionally, we created fifth version of the CBA (CBA V.5) in which we included direct costs and benefits only. Comparing the results of these versions shows how they affect the outcomes. The five versions were as follows:

1. Benefits calculated with both CE and TC-CB methods, benefits estimated for representative sample of Finnish population (CBA.) This version of the CBA was presented in the preceding sections of this deliverable.
2. Benefits calculated with CE method only, benefits estimated for the representative sample of Finnish population (CBA V.2.).
3. Benefits calculated with both CE and TC-CB methods, benefits estimated separately for people visiting Lake Saimaa for recreation, and people not visiting Lake Saimaa as well as for people participating in fishing at Lake Saimaa and people not participating in fishing at Lake Saimaa (CBA V.3.)
4. Benefits calculated with CE only, benefits estimated separately for people visiting Lake Saimaa for recreation, and people not visiting Lake Saimaa as well as for people participating in fishing at Lake Saimaa and people not participating in fishing at Lake Saimaa (CBA V.4.)
5. Costs and benefits included direct costs and benefits only, i.e. benefits included willingness to pay for increase in the seal population and the associated recreational benefits and costs includes the actual costs of realization of the conservation measures. Benefits estimated for representative sample of Finnish population.

We calculated cost-benefit -ratios for these five versions to see if there are differences in the results (Table 11). Table 11 shows that benefits are higher than costs in all CBA versions and conservation scenarios except for CBA V.3. In CBA V.3., in the scenario with high level of conservation measures and 1.5 -fold increase in the seal population, the cost-benefit -ratio is less than one indicating that costs exceed benefits.

Table 11. Benefit-cost ratio of conservation scenarios with different calculation assumptions

		CBA version				
Level of conservation measures	Conservation result, seal population	CBA	CBA V.2.	CBA V.3.	CBA V.4.	CBA V.5.
Moderate	1.5-fold	105.12	98.53	4.75	94.22	40.73
	2-fold	131.39	118.23	5.84	110.86	67.00
	2.5-fold	158.61	138.66	7.18	132.61	94.22
High	1.5-fold	1.88	1.70	0.93	1.32	20.55
	2-fold	2.59	2.23	1.26	1.69	33.80
	2.5-fold	3.34	2.79	1.66	2.17	47.53

4.3 Feasibility of scenarios: effects of conservation measures

The BN created based on the expert elicitation exercise has four variables (Table 12, Figure 1). The effect of the conservation scenarios under two different climate scenarios are depicted in the variable “Population size in 2040”. The network includes a variable “Expert”, which enables examination of the results also at the expert-level. However, the following results are presented as averages, i.e., all experts are given the same weight.

Table 12. The variables and the states of the BN model.

Variable	States
Conservation scenarios	Business-as-usual (BAU), moderate, high
Climate change	Current, intensified
Expert	Expert 1, Expert 2, Expert 3, Expert 4
Population size in 2040	0.5x, 1x, 1.5x, 2x, 2.5x

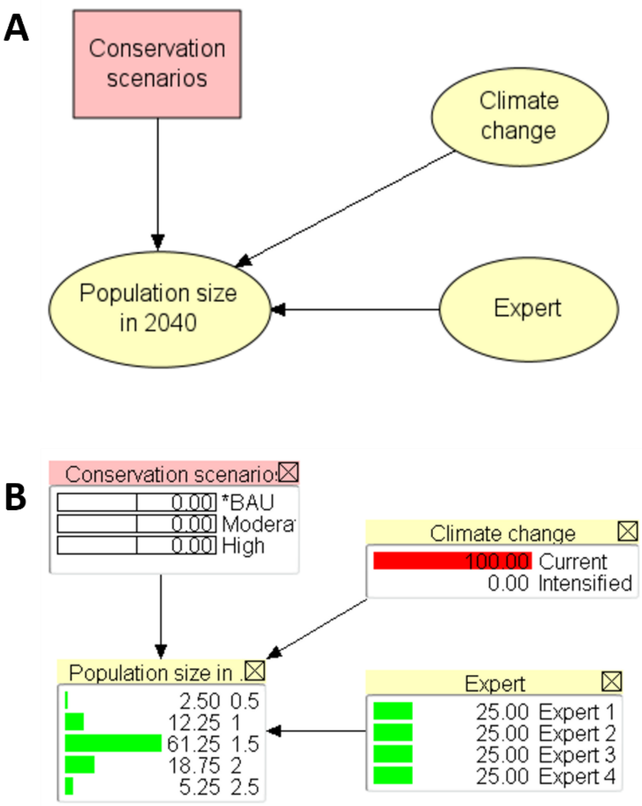

Figure 1. A. The structure of the model. B. An example showing the probability distribution for the population size in 2040 when no (Business-as-usual, BAU) additional conservation measures are applied, the scenario for the climate change is "current" and the resulting probability distribution is an average over the experts' distributions.

It seems that assuming the current climate conditions with no additional measures, the most probable population size in 2040 is 1.5-fold compared to year 2022, but there is relatively high probability to achieve even a 2-fold increase (Table 13). With the highest level of conservation measures, i.e., the ban for fishing with nets are year-round, the motor vehicle ban on ice is 400 km^2, and the potential building sites are reduced by 50%, the probability to witness a 2-fold increase is over 52% and the probability to reach a 2.5-fold increase is almost 17%. With the moderate level of additional conservation measures the probabilities lay between these two cases.

However, when we assume that the climate change will advance and the frequency of winters resulting in poor reproduction will increase, the probability that the population will increase is low (Table 13). With this climate scenario, it is most probable that in 2040 the population is at the same level as in 2022. The probability that the population will decrease is almost 19%, and the probability to achieve a 2.5-fold increase is very low. With the moderate level of additional management measures the probabilities in this climate scenario changes only marginally towards higher population sizes. When we assume a high level of additional management measures, there is almost 46% probability that the population size is 1.5-fold compared to the population size in 2022.

Table 13. The probability distributions (expressed as %) describing the size of the Saimaa seal population in 2040 with different climate and conservation scenarios. Each distribution is the average of the distributions elicited from four Saimaa seal expert.

	Climate scenario	**Current climate**			**Intensified climate change**		
	Conservation scenario	**BAU**	**Moderate**	**High**	**BAU**	**Moderate**	**High**
Population size in 2040	0.5 x	2.5	1.63	0.25	18.75	15	7.50
	1 x	12.25	9.25	2.50	54	50	38.75
	1.5 x	61.25	51.25	28	24.48	29.45	45.68
	2 x	18.75	31.75	52.50	2.50	5.25	7.75
	2.5 x	5.25	6.13	16.75	0.28	0.30	0.33

The experts also ranked the additional management measures and two climate change scenarios according to how much impact they have on the population size using the scale from 1 to 5 (1 = the weakest impact on the population size in 2040, 5 = the strongest impact on the population size in 2040). The motor vehicle ban was judged to be the most ineffective, whereas the year-round net fishing ban for recreational fishers was assessed to be the most effective (Table 14).

It should be noted that these results are conditional on the premises and assumptions of the exercise. The period considered in this study is only approximately 18 years, which means that, e.g., the full effect of the reduced number of available building sites may not be visible in this time, as due to the philopatry of the females, the population is probably not capable of utilizing all the “free” area straight away. In turn, the gillnet fishing ban would decrease the mortality of pups, juveniles, and adults directly, which would be reflected in the population growth substantially already within the studied time period. Further, the climate change (the average scores 4.5 and 5 for “current” and “intensified” climate scenarios, respectively) was deemed to have overall the most significant impact on the population, although this impact is opposite compared to the effects of the management measures.

Table 14. Ranking of the conservation measures by the experts.

Conservation measure	**Level of implementation**	**Average rank of impact**
Gillnet fishing ban for recreational fishers	Year round Until end of July	4.3 3.6
Gillnet fishing ban for professional fishermen	Year round Until end of July	3.7 3.1
Building sites	Reduction by 50% Reduction by 25%	2.4 2.6
Motor vehicle ban on ice	400 km^2 200 km^2	1.1 1

The experts participating in the exercise found the exercise interesting yet demanding, and some of the measures were easier to assess than others. E.g., the experts based their assessment on gillnet fishing bans on the existing fishing mortality data and estimated the effect of bans on the population growth based on these. The effect of the reduction of the building sites was more challenging to evaluate, as, e.g., we were not able to provide the locations of the potential building sites that would be left undeveloped, but we had to provide the experts more coarse descriptions of the conservation scenarios. Further, it should be noted that the experts may have had differing interpretations on the definitions and premises of the exercise, which, despite the joint meetings, may bring some additional uncertainty to the results.

5 DISCUSSION

In this cost-benefit analysis of Saimaa ringed seal conservation, benefits exceed costs in all scenarios, indicating that the willingness to pay for the increase in the seal population among Finns exceed the associated costs. These results demonstrate a strong support for Saimaa ringed seal conservation. The benefit-cost ratio was higher for moderate-increase measures than for high-increase measures. This difference is mainly due to the results of the CE used to estimate the benefits, which showed that citizens preferred moderate increase on conservation measures. The sensitivity analysis indicated that under certain calculation assumptions, in the scenario where the strongest conservation measures achieve only a 1.5-fold increase in the seal population, the benefits slightly fall below the costs.

Several factors influence the estimated benefits and costs. Firstly, not all benefits resulting from the increase in the seal population could be evaluated. For instance, potential increases in tourism revenue and the wellbeing benefits for volunteers (such as those shoveling snow drifts) could not be evaluated. Additionally, potential other biodiversity benefits or impacts on fish populations could not be evaluated. On the other hand, adding up the results from CE and TC-CB can cause double-counting of benefits if the willingness to pay assessed by CE includes recreational benefits experienced by people. However, the sensitivity analysis showed that after excluding recreation benefits from the CBA, benefits remained above costs. The magnitude of benefits also depends on how the benefiting population is defined. In this study, we assumed that the benefits from increased seal population apply to all Finns. This is supported by the CE results, which indicate that even respondents who do not visit Saimaa place value on the existence of the Saimaa ringed seal. Research costs were not included in the cost estimates. All benefits and costs were assumed to be constant over the years.

According to expert assessment, scenarios in this CBA are feasible. Under the current climate and existing conservation practices it is most probable that the Saimaa ringed seal population will exhibit a 1.5-fold increase compared to the year 2022 level by 2040. With the moderate level of additional conservation measures, the most probable result would be a 1.5-fold increase in the population size with an increased likelihood also for a greater population growth. With stricter conservation measures, experts estimated that the seal population will most likely double. Based on the cost-benefit analysis, both scenarios would be beneficial for society since the benefits of these scenarios exceed their costs. If climate change progresses and mild winters become more frequent, the reproductive success of Saimaa ringed seals may weaken in the future. In such case, the conservation measures assessed in this study may not be effective enough to increase the population. However, these measures will still be necessary to maintain the population close to its current level and to prevent a decline.

In the benefit estimation of this study, we did not estimate citizens' willingness to pay to prevent the decline of the seal population. However, the positive willingness to pay for increasing the seal population demonstrates that Finns are also willing to pay to maintain the Saimaa seal population. According to previous literature, willingness to pay for the avoidance of loss in environmental quality is typically higher than willingness to pay for an improvement in environmental quality. This phenomenon is known as asymmetry of preferences and loss aversion (e.g., Ahtiainen et al. 2015). Therefore, providing benefit estimates for avoiding population decrease would require a new valuation study. Additionally, evaluating the benefit-cost ratio of past conservation measures is beyond the scope of this study, although it would have been an interesting issue to address at the beginning of conservation activities.

There are uncertainties related to the conservation scenarios presented in this study. The expert assessment of the impacts of conservation measures on the seal population was not a trivial task. For example, the reduction of the number of available building sites as conservation measure would not directly affect the population. Instead, it would ensure that a certain amount of the shoreline that is not constructed today would remain unconstructed, i.e., is available for Saimaa ringed seals, also in the future. Further, the time frame in this study is relatively short for a long-lived species like Saimaa ringed seal, which has the generation time of 11 years (Palo et al. 2001, 2003). Different measures also affect the seal population over different time frames. For instance, extensions of gillnet fishing ban would have a rapid impact on the population because it would decrease the mortality immediately, while the full effect of reducing the number of available building sites would probably be seen over a longer period. It should be noted that in this study it was not possible to define precisely, e.g., the locations of specific building sites that would stay free from construction. Hence, a more thorough estimation of the effects of building site reductions calls for a spatially explicit analysis.

The experts evaluated that the most effective additional management measures would be to extend the gillnet fishing bans to cover the whole year, followed by the extension of the gillnet fishing bans until end of July. However, the year-round ban was seen negatively by citizens, i.e., it resulted in perceived losses. In turn, extending the ban until the end of July was seen as positive by citizens and resulted in benefits. Hence, this suggests that it would be relevant to evaluate the latter management measure as a potential option to support the growth of the Saimaa ringed seal population.

It is important to note that the conservation measure scenarios in this study did not include all existing conservation measures. In particular, the changing climate highlights the importance of implementing also other management measures, such as human-made snow drifts and artificial nests, which have the potential to reduce pup mortality in mild winters (see, e.g., Auttila et al. 2014). However, they were not included in the conservation measure scenarios of this study.

Further, the Saimaa ringed seal has lost up to 70% of its genetic diversity compared to the Arctic ringed seal due to long-term isolation and a historically small population (Palo et al. 2003). This reduction in genetic diversity makes it harder for the seals to adapt to environmental changes.

One way to maintain and improve genetic diversity is to translocate individuals within Saimaa. In addition to maintaining genetic diversity, the translocations strengthen the spatial distribution of seals. The most recent translocations were conducted in 2023 and 2024, but their potential effects on the population will become visible only in the future generations. Currently, it is not clear whether they will become a common measure to support the population.

Certain measures target to some citizen groups. For example, the impact of restricting building sites depends on the actual usage of possible vacation homes. The impact varies based on their location, whether on the mainland coasts or within the archipelago, where boating is required to access the property. Vacation homeowners can also play a crucial role as volunteers by providing artificial nests and thus positively impacting seal nesting at a low cost. They are important as fishers as well. Although gillnet fishing is a declining activity due to aging of fishers using the method (OSF 2024b), increasing awareness and positive attitudes towards alternative fishing methods among vacation homeowners can reduce the perceived cost of fishing restrictions. Therefore, more detailed information about vacation homeowners is needed in the future.

There are uncertainties that were beyond the scope of this analysis. Some institutional changes could challenge seal conservation. For example, new building act (2025) does not require building permit for small vacation buildings, which may increase the land use pressure also in Saimaa region. Additionally, budgetary changes in project-based conservation funds may lead to sudden change in conservation measures.

To summarize, the Saimaa ringed seal population has a potential to increase substantially compared to the population size in 2022. For example, under the current climate and the high level of additional management measures there is over 95 % that the population increase will be at least 1.5-fold according to the expert opinion. However, the development is highly dependent on the future climate, and under the intensified climate change scenario, when implementing even the strongest management measures, the probability to reach at least a 1.5-fold increase is only approximately 53%. This highlights the need to apply a wide range of conservation options including, e.g. measures that have a potential to mitigate the negative effects of climate change directly (like artificial nests). Further, it is important to notice that the results are conditioned on the assumptions of the study. The relative importance of the conservation measures may be dependent, e.g., on the size of the population and the phase of the recolonization of the population.

6 CONCLUSIONS

These results indicate a strong support for Saimaa ringed seal conservation as in all the scenarios benefits outweighed costs. The higher benefit – cost -ratio for a moderate increase in conservation measures (duration of the springtime net gillnet fishing ban, area of the motor vehicle ban on ice, restrictions on shoreline constructions) than for a high increase suggest a moderate increase in conservation measures. However, the intensification of climate change may, in the future, require stronger conservation measures for the seal to ensure its population to continue growing.

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