Deliverable 3.6

Report on assessed cost-benefits of the proposed innovative governance measures across selected case areas in the Baltic Sea Region, and identification of knowledge gaps

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1 INTRODUCTION

Building on the previously assessed, and continuously updated, cost structures and benefit assumptions of selected nutrient mitigating, biodiversity promoting and flood preventing measures in deliverable 3.3 (Carolus et al., 2017a) and deliverable 3.4 (Carolus et al., 2017b), the aim of the following report is to outline and discuss the results of the Cost-Benefit Analysis (CBA) of the selected innovative measures and pathways in the different case countries in the Baltic Sea Region. The report, which serves as deliverable 3.6, thus summarises all CBA key tasks described in deliverable 3.1 (Carolus et al., 2015), namely

- Step 1: Pathway definitions as suggested by stakeholder in the four case areas
- Step 2: The identification of the physical impacts of the pathways
- Step 3: Valuing the impacts
- Step 4: Discounting of costs and benefits
- Step 5: Applying the net present value test
- Step 6: Sensitivity analysis

Furthermore, as it is evident that a CBA inherently entails some level of uncertainty, and is in any case "not a precise tool that yields firm numerical results" (US EPA, 2000, p. 33), the report gives an overview and investigates the role of both theoretical and practical knowledge gaps in CBA development.

After presenting the updated cost structures, the physical impact and benefit assumptions and, finally, the CBA results in section 3, section 4 covers the experienced knowledge gaps and uncertainties. We thereby separate the gaps into two categories, namely (1) model-specific knowledge gaps based on the CBA application within the MIRACLE project, and (2) general theoretical uncertainties inherent in CBA.

2 The MIRACLE Project

2.1 Project Charter

Mediating integrated actions for sustainable ecosystems services in a changing climate

More than 85 million people live in the Baltic Sea catchment area, and around 60-70 % of the land is farmland. Thus, the agriculture sector and wastewater treatment sector are key actors that have an impact on eutrophication. The problem is, however, that there are insufficient incentives within these sectors to further reduce their contributions to nutrient enrichment of aquatic ecosystems. The hypothesis underpinning the MIRACLE project is that more effective approaches to 'nutrient governance' cannot focus solely on the nutrient issue itself. Real changes will require bringing on board new constellations of stakeholders with issues that are interconnected with nutrient enrichment. We will seek win-win models for governance by emphasising synergies between aligned policy communities, such as the flood control sector, downstream urban communities vulnerable to flooding, biodiversity conservation interests, and the human health and biosecurity sector.

In this interdisciplinary project, social scientists work with economists and hydrologists in a social learning process with stakeholders. The aim is to identify new configurations for governance (conceptual, institutional and practice based) to reduce nutrient enrichment and flood risks in the Baltic Sea region. An example could be how to reform farming practices in a way that measures such as flood control and biodiversity conservation become new 'agricultural products' which also impact emissions of nutrients.

A set of workshops will be organised in four case areas, the Berze (Latvia), Reda (Poland), Helgeån (Sweden), and Selke (Germany). Cross-case and regional workshops will facilitate scaling up the results to the Baltic Sea region level. The workshops will identify innovative actions and plans that offer multiple ecosystem service benefits to diverse stakeholders. The social learning process will be supported by interactive hydrological modelling of what impacts the suggested measures will have on nutrient transport and flooding risks. Here, uncertainty assessments and the need for adaptation to climate change scenarios are key features. Economists will assess the cost and benefits of selected governance features and policy instruments in the environmental mitigation and flood prevention scenarios. The goal is to identify the most socioeconomically efficient measures and governance features to deliver multiple ecosystem service benefits.

In the project, an interactive visualisation platform will be used where stakeholders will guide the use of input data sets and the development of visualised scenarios. The aim is to facilitate their understanding of suggested governance actions' consequences and assist identification of novel actions. Policy analyses will be done to identify how institutional settings have shaped governance structures in the Baltic Sea region. In the next step, opportunities for greater integration of agricultural and environmental policy actions at different scales will be identified. A particular focus will be on identifying prospects for introduction of payments for ecosystem services as a key governance approach. Finally, emerging from the social learning process, to the project aims to support the development of road maps that integrate agricultural, environmental and risk management governance in the Baltic Sea region.

Project partners

Linköping University, Sweden, (coordinating partner)
POMinnO Sp. z o.o., Gdynia, Poland
Institute of Meteorology and Water Management, Warsaw, Poland
Johann Heinrich von Thünen-Institut, Braunschweig, Germany
Helmholtz Centre for Environmental Research, Magdeburg, Germany
University of Latvia, Riga, Latvia
Latvia University of Agriculture, Jelgava, Latvia
University of Copenhagen, Denmark
Swedish Meteorological and Hydrological Institute, Norrkoping, Sweden
Stockholm Environment Institute, Sweden
Swedish International Centre of Education for Sustainable Development, Uppsala University, Sweden.

3 Cost-benefits of selected pathways for change

Based on the previously defined system boundaries (deliverable 3.1), the cost structures (deliverable 3.2) and benefits (deliverable 3.3), this chapter outlines the results on costs and benefits of stakeholder suggested pathways for change in the case catchments. Adding on to the CBAs in deliverable 3.4, this report also includes the cost structures, benefit assumptions and thus the CBA results for the Berze river catchment case area. Due to insufficient information and data delivery, the CBA for the Reda river case area can still not be provided.

3.1 Summary of cost structures

While the detailed cost structures and the benefits are already itemised in the deliverables 3.2, 3.3 and 3.4, the cost structures of the different pathways in the Selke, Helge and Berze case areas are summarised below. Compared to the indications as previously outlined in e.g. deliverable 3.4, the following information displays, based on emerging findings and improvements, refined pathways and cost structures. Table 1-3 show the measures and their scopes as included in the respective pathways, and, furthermore, the total cost of each measure in terms of its present value (for the respective pathway's period of time).

While the required costs for all suggested alternative pathways are much less (Selke catchment) or roughly the same (Berze catchment), compared to the business-as-usual scenarios, pathway 3 in the Helge catchment exceeds the baseline costs by a factor of 2. However, the assumed costs for the measures of the potential pathways for change may be considered more uncertain than the currently implemented measures with known costs. For instance, as restoring alder swamp forests in the Helge catchment is a rather innovative measure which is, so far, not implemented in the catchment. Experience values regarding its cost structures are consequently missing. The cost assumptions are based on the average forest land prices and production values of low-productivity forests, as indicated by the local stakeholders related to forestry. The real costs may therefore differ significantly, for instance when constructed in higher-productivity forest areas.

Table 1 Costs and scopes of the pathways for change, Helge river catchment

Measure		Scope	Unit	Total Costs (Present Values in Million SEK)
Pathway 1 (2017 – 2030)				
Liming	by doser	4262.4	tons/year	103.9
	by boat	673.6	tons/year	7.4
	by air	365.5	tons/year	6.6
Buffer Strips		181	ha	12.7
Wetlands		210	ha	55.1
Individual Sewage Emission	Reduction to normal level	5431	facilities	423.6
	Reduction from normal to high level	1657	facilities	26.2
Non-productive field margins in agricultural landscape		300	ha	22.9
Upgrade or removal of traditional water regulating dams		78	units	196.4
Total				**854.8**
Pathway 2 (2021 – 2030)				
Urban Stormwater Ponds		15.35	ha	35.7
Flood plain		150	ha	31.8
Wetlands		597.4	ha	132.5
Phosphorus Wetlands		58.65	ha	36.5
Riparian Zones		400	ha	19.8
Re-Meandering		82.5	km	71.8
Total				**328.1**
Pathway 3 (2021 – 2030)				
Alder Swamp Forest		35000	ha	1351.3
Riparian Zones in Forest Landscape		600	ha	28.2
Fishway or Removal of Migration Obstacle	Size 1	3.1	m	0.3
	Size 2	184.48	m	83.4
	Size 3	31.3	units	30.0
Culvert Replacement		4	units	0.7
Transition from coniferous to broadleaved forest		500	Ha	375.1
Total				**1,869.0**

Table 2 Costs and scopes of the pathways for change, Selke river catchment

Measure	**Scope**	**Unit**	**Total Costs (Present Values in Million EUR)**
Pathway 1 (2017 – 2030)			
Flower and water protection strips (EFA)	0.70	ha	0.0
Ploughing and cropping techniques	1,000.00	ha	0.8
Extensive permanent grassland	338.80	ha	0.9
Organic Farming	1,243.80	ha	3.5
Ventilation, treatment & retention of mine water	3.00	implementation(s)	81.0
Dismantling of transverse structures (weir)	2.00	implementation(s)	0.9
Creation of ecological bypassing options	2.00	implementation(s)	0.3
Flood Control Basin – Straßberg	1.00	units	18.9
Flood Control Basin – Meisdorf	1.00	units	9.9
Total			**116.2**
Pathway 2a (2021 – 2030)			
Development and management of riparian strips - 10 m	274.45	ha	1.3
Optimisation of fertilizer use - Reduced N fertilizer by 20%	24,228.00	ha	-1.1
Contour ploughing	22,844.00	ha	0.0
Different adjustments to the morphology and characteristics	68.00	km	7.7
Total			**7.8**
Pathway 2b (2021 – 2030)			
Development and management of riparian strips - 20 m	551.27	ha	2.5
Optimisation of fertilizer use - Reduced N fertilizer by 20%	24,228.00	ha	-1.1
Contour ploughing	22,844.00	ha	0.0
Different adjustments to the morphology and characteristics	24,228.00	ha	7.7
Total			**9.1**
Pathway 3a (2021 – 2030)			
Connect 5% of households to sewage plants	1,650.00	PE	5.4
Pathway 3b (2021 – 2030)			
Connect 10% of households to sewage plants	3,300.00	PE	10.7

Table 3 Costs and scopes of the pathways for change, Berze river catchment

Measure	Scope	Unit	Total Costs (Present Values in Million EUR)
Pathway 1 (2017 – 2030)			
Crop Diversification	41,134	ha	24.3
Ecological Focus Areas	2,930	ha	1.7
Perennial Grassland	1,201	ha	0.7
Organic Farming	1,305	ha	1.6
Total			**28.3**
Pathway 2 (2021 – 2030)			
Rural Wastewater Treatment Plants (100 – 300 p.e)	3	plants	0.4
Total			**0.4**
Pathway 3a (2021 – 2030)			
Buffer Strips [2 + 10 m]	741	ha	1.5
Sedimentation Ponds	4	ha	0.5
Optimisation of fertiliser use [20% reduction of mineral N & P fertiliser]	32,320	ha	33.3
Total			**35.3**
Pathway 3b (2021 – 2030)			
Ecological Buffer Strips [2 + 5 m]	540	ha	1.1
Sedimentation Ponds	4	ha	0.5
Optimisation of fertiliser use [20% reduction of mineral fertiliser]	32,320	ha	33.3
Total			**34.9**
Pathway 4 (2021 – 2030)			
Fishways	5	Units	0.4
Total			**0.4**

3.2 Summary of physical impact assumptions and benefits

Generally, the quantification of impacts can be done by drawing on existing information, or by generating new assessments by using instruments such as modelling tools, scenario analyses or expert elicitation (Börger et al., 2017). As outlined in deliverable 3.4, the benefit assessment of the CBA is based on two sets of information. First, the nutrient mitigation rate of each measure or pathway is based on quantitative assessments, either by literature, or by the modelling results of the MIRACLE work package 2 (cf. deliverable 3.5). Table 4-6 summarise the nutrient mitigation rates per pathway for the Helge, Selke and Berze River catchments respectively. Most notably and compared to the respective (business as usual) pathways 1, some pathways resulting in significantly lower costs (e.g. pathway 2 in the Helge catchment, pathways 2a and 2b in the Selke catchment) show much higher nutrient removal rate of N and P, respectively.

Table 4 Total nutrient mitigation at the river outlet, Helge River catchment

	Total N reduction (in kg/year)	Total P reduction (in kg/year)
Pathway 1	18,077	2,083
Pathway 2	88,089	5,563
Pathway 3	4,500	135

Source: MIRACLE project results (based on both HYPE modelling results from WP2, and literature)

Table 5 Total nutrient mitigation at the river outlet, Selke River catchment

	N (kg/year)	P (kg/year)
Pathway 1	19,557	93
Pathway 2a	15,329	1,783
Pathway 2b	15,350	1,821
Pathway 3a	452	173
Pathway 3b	904	346

Source: MIRACLE project results (based on both HYPE modelling results from WP2, and literature)

Table 6 Total nutrient mitigation at the river outlet, Berze River catchment

	N (kg/year)	P (kg/year)
Pathway 1	2,115	79
Pathway 2	687	184
Pathway 3a	86,474	2,654
Pathway 3b	86,474	2,455
Pathway 4	0	0

Source: MIRACLE project results (based on both HYPE modelling results from WP2, and literature)

Second, the different measures and pathways lead to benefits beyond nutrient mitigation, namely the other MIRACLE objectives of flood prevention and biodiversity promotion, or the defined systemic issue. Due to unavailability of quantifications of such case- and measure-specific physical impacts, expert elicitation was used to assess the likely impacts in terms of the additional ecosystem services. The experts chosen for assessing the qualitative impacts on ecosystem services were researchers from the Stockholm Environment Institute (SEI) and Linköping University (LIU) for the Helge River catchment, University of Latvia for the Berze River catchment, and Johann Heinrich von Thünen-Institut and Helmholtz Centre for Environmental

Research for the Selke River catchment. As all of them are involved in the MIRACLE project, the assessment was consequently based on both scientific knowledge and experience with the respective catchment. The impact on the whole catchment was considered, i.e. the scope of the measure was taken into account. The rating describes the experts' overall assessment of the likely impacts caused by the implementation of the strategies, compared to no implementation (Table 7 - Table 9). The qualitative ratings of expected benefits were the underlying assumptions of the cost-benefit results, yet they rather served as a starting point for the analysis. The rating can be altered within the dynamic database anytime (deliverable 3.3), e.g. based on emerging findings, changing stakeholder opinions or to foster dialogue by creating "what-if?"-scenarios.

Table 7 Experts' rating of impacts in Helge River catchment

Ecosystem Service	Pathway 1	Pathway 2	Pathway 3
Biodiversity/Habitat Preservation	Medium	Medium	High
Flood Risk Reduction	Low	Medium	High
Erosion/Sediment Control	Medium	Medium	High
Recreation and Tourism	High	High	Medium
Improved surface and groundwater quality	Medium	Medium	High

Table 8 Experts' rating of impacts in Selke River catchment

Ecosystem Service	Pathway 1	Pathway 2a	Pathway2b	Pathway 3a	Pathway 3b
Biodiversity/Habitat preservation	Low	Medium	Medium	Low	Medium
Flood Risk Reduction	Medium	Medium	Medium	None/Negligible	None/Negligible
Erosion/Sediment Control	Medium	Medium	Medium	None/Negligible	None/Negligible
Recreation and Tourism	None/Negligible	None/Negligible	None/Negligible	None/Negligible	None/Negligible

Table 9 Experts' rating of impacts in Berze River catchment

Ecosystem Service	Pathway 1	Pathway 2	Pathway 3a	Pathway 3b	Pathway 4
Biodiversity/Habitat preservation	Low	Low	High	Medium	High
Flood Risk Reduction	Low	None/Negligible	Medium	Medium	Low
Erosion/Sediment Control	Medium	None/Negligible	High	High	None/Negligible
Recreation and Tourism	None/Negligible	Low	Medium	Medium	High
Improved surface and groundwater quality	Low	Low	Medium	Medium	None

As discussed in previous deliverables, it is beyond the scope of the MIRACLE project to generate new benefit estimates of measures, and the economic benefit analyses are relying on existing and available information. The CBA thus had to make use of transferred benefits (see deliverable 3.4 for the description of the benefit transfer procedures and formula).

Relative to other ecosystem services, a wide range of primary valuation studies related to ecosystem services in aquatic ecosystems is available (Markandya, 2016), which allows for benefit transfer for most of the required impacts. To include the most suitable values, and to reduce the potential transfer errors which may occur due to transferring from too dissimilar sites (Kaul et al., 2013), the following priorities were set to identify and select valuation studies (in that order): similar site in (1) the same country, (2) in one of the other MIRACLE case study countries, and (3) in a country within the Baltic Sea Region. Table 10 outlines the monetary unit values of the respective benefits which emerged due to the change in provision of ecosystem service (both before and after the benefit transfer).

Table 10 Monetary values of benefits (before and after the benefit transfer)

Ecosystem Services	Benefit	Original Unit Value	Transferred Unit Value (to Berze)	Transferred Value (to Helge)	Source
Biodiversity/Habitat Preservation	High number of different species of plants and animals, their population levels, number of different habitats and their size in the river ecosystem in the next 10 years.	4.6 Zloty [2007]/household/month	8.7 EUR [2016]/person/year	246.0SEK [2016]/person/year	Birol et al. (2008)
	Habitat for endangered and protected species (Forest)	8.0 EUR [2004]/person/year	not used	129.5 SEK [2016]/person/year	Meyerhoff et al. (2009)
	Landscape diversity (Forest)	4.6 [2004]/person/year	not used	14.2 SEK [2016]/person/year	
	Species diversity (Forest)	12.5 [2004]/person/year	not used	190.3 SEK [2016]/person/year	
Provision of Food Recreation and Tourism Biodiversity	Improve fish variety from “moderate” to “very high”	42.2 SEK [2014]/person/month	15.8 EUR [2016]/person/year	543.8 SEK [2016]/person/year	Ek and Persson (2016)
	Improve fish variety from “moderate” to “high”	25.5 SEK [2014]/person/month	9.6 EUR [2016]/person/year	329.3 SEK [2016]/person/year	
	Change fish variety from “moderate” to low”	-287.6 SEK [2014]/person/month	-107.6 EUR [2016]/person/year	-3709.8 SEK [2016]/person/year	
	Non-use Value - Salmons passing fish ladders (salmon increase between 1000 – 6000 per year)	51.0 SEK [2004]/person/year	2.2 EUR [2016]/person/year	77.2 SEK [2016]/person/year	Håkansson (2009)
	Access to the riverbank for recreational purpose	6.6 Zloty [2007]/household/month	12.5 EUR [2016]/person/year	352.9 SEK [2016]/person/year	Birol et al. (2008)
Flood Risk	Reduce flood risk from “high” to “low”	14.5 Zloty [2007]/household/month	27.4 EUR [2016]/person/year	775.4 SEK [2016]/person/year	
Surface water quality Erosion/Sediment Control Recreation & Tourism	Erosion Prevention Grassland	49.0 Dollar [2007]/ha/year	15.72 EUR [2016]/ha/year	541.87 SEK [2016]/ha/year	de Groot et al. (2012)
	Erosion Prevention Woodlands	13.00 Dollar [2007]/ha/year	not used	143.8 SEK [2016]/ha/year	
	Improve water clarity from "moderate" to "clear"	106.4 SEK [2014]/person/month	35.1 EUR [2016]/person/year	1347.1 SEK [2016]/person/year	Ek and Persson (2016)
	Change of water clarity from “moderate” to “turbid and colored”	-199.8 SEK [2014]/person/month	-67.2 EUR [2016]/person/year	-2577.9 SEK [2016]/person/year	
Surface and groundwater quality (Ecological Status)	Benefits of Nitrogen (N) and Phosphorous (P) reduction	10.5 EUR (1995)/kg N reduction	21.3 EUR (2016)/kg N reduction	190.0 SEK [2016]/person/year	Interwies et al. (2012) based on Turner et al. (1999)

Given (1) the qualitative impact rating of consequential provisions of ecosystem services, and (2) available unit values related to such ecosystem services, both (1) and (2) have to be set in context. As valuation studies are often binary (for instance a positive or negative change versus the status quo), the rating scales must be adapted if necessary. This was done as follows:

Table 11 Conversion legend

Valuation Study	Expert rating
Positive Change	High Impact
	Medium Impact
Status Quo	Low Impact
	No Impact
Negative Change	Negative Impact

By being split into the different ecosystem services, Table 12 -14 outline the resulting total benefits (in present values), based on the experts' rating (Table 7 - Table 9) and monetary unit values (Table 10). The tables highlight that typically, one pathway alone may not generate all desired benefits. Only pathway 3 in the Helge catchment, and pathways 3a and 3b in the Berze catchment result in a provision of all selected relevant ecosystem services. However, in both examples the benefit in terms of erosion and sediment control is minimal.

Table 12 Monetary benefits summary, Helge River catchment (Present Value in SEK)

Ecosystem Service	**Total Benefits**
Pathway 1	
Biodiversity/Habitat Preservation	0 SEK
Flood Risk Reduction	0 SEK
Erosion/Sediment Control	0 SEK
Recreation and Tourism	0 SEK
Water Purification	264,544,003 SEK
Reduced Brownification	0 SEK
Total	264,544,003 SEK
Pathway 2	
Biodiversity/Habitat Preservation	565,284,995 SEK
Flood Risk Reduction	0 SEK
Erosion/Sediment Control	0 SEK
Recreation and Tourism	346,804,880 SEK
Water Purification	305,183,406 SEK
Reduced Brownification	1,323,727,592 SEK
Total	2,541,000,874 SEK
Pathway 3	
Biodiversity/Habitat Preservation	776,064,153 SEK
Flood Risk Reduction	761,919,813 SEK
Erosion/Sediment Control	2,438,788 SEK
Recreation and Tourism	422,637,443 SEK
Water Purification	10,771,785 SEK
Reduced Brownification	1,323,727,592 SEK
Total	3,297,559,574 SEK

Table 13 Monetary benefits summary, Selke River catchment (Present Value in Euro)

Ecosystem Service	Total Benefits
Pathway 1	
Biodiversity/Habitat preservation	0 €
Flood Risk Reduction	6,508,008 €
Erosion/Sediment Control	50,149,613 €
Recreation and Tourism	0 €
Water Purification	3,792,160 €
Total	60,449,781 €
Pathway 2a	
Biodiversity/Habitat preservation	16,735,699 €
Flood Risk Reduction	0 €
Erosion/Sediment Control	8,767,071 €
Recreation and Tourism	0 €
Water Purification	6,694,206 €
Total	32,196,975 €
Pathway 2b	
Biodiversity/Habitat preservation	16,735,699 €
Flood Risk Reduction	0 €
Erosion/Sediment Control	8,767,071 €
Recreation and Tourism	0 €
Water Purification	6,800,961 €
Total	32,303,731 €
Pathway 3a	
Biodiversity/Habitat preservation	0 €
Flood Risk Reduction	0 €
Erosion/Sediment Control	0 €
Recreation and Tourism	0 €
Water Purification	525,363 €
Total	525,363 €
Pathway 3b	
Biodiversity/Habitat preservation	16,735,699 €
Flood Risk Reduction	0 €
Erosion/Sediment Control	0 €
Recreation and Tourism	0 €
Water Purification	1,050,726 €
Total	17,786,425 €

Table 14 Monetary benefits summary, Berze River catchment (Present Value in Euro)

Ecosystem Service	Total Benefits
Pathway 1	
Biodiversity/Habitat preservation	0 EUR
Flood Risk Reduction	0 EUR
Erosion/Sediment Control	10,339,034 EUR
Recreation and Tourism	0 EUR
Water Purification	879,181 EUR
Total	11,218,215 EUR
Pathway 2	
Biodiversity/Habitat preservation	0 EUR
Flood Risk Reduction	0 EUR
Erosion/Sediment Control	0 EUR
Recreation and Tourism	0 EUR
Water Purification	688,425 EUR
Total	688,425 EUR
Pathway 3a	
Biodiversity/Habitat preservation	4,323,858 EUR
Flood Risk Reduction	4,840,169 EUR
Erosion/Sediment Control	77,702 EUR
Recreation and Tourism	2,203,111 EUR
Water Purification	20,801,893 EUR
Total	32,246,732 EUR
Pathway 3b	
Biodiversity/Habitat preservation	3,223,969 EUR
Flood Risk Reduction	4,243,194 EUR
Erosion/Sediment Control	56,627 EUR
Recreation and Tourism	2,203,111 EUR
Water Purification	20,162,635 EUR
Total	29,889,536 EUR
Pathway 4	
Biodiversity/Habitat preservation	4,323,858 EUR
Flood Risk Reduction	0 EUR
Erosion/Sediment Control	0 EUR
Recreation and Tourism	2,591,513 EUR
Water Purification	0 EUR
Total	6,915,371 EUR

3.3 Cost-Benefit Analysis results

In a CBA, all costs and benefits are monetarised and translated into a single number, the net present value (NPV). The interpretation of this is usually straightforward: a positive NPV means that the social benefits outweigh the social costs of the assessed policy or project. Implementation of the policy or project is thus justified as it represents an efficient reallocation of resources that overall increases welfare in society.

Based on cost structures and the total benefits, the results for the Swedish case are outlined in Table 15. While the costs exceed the benefits in the "business-as-usual" pathway 1, the benefits outweigh the costs in all alternative pathways, i.e. pathway 2 and pathway 3. From a welfare-economic point of view these results state that society is better off if either (or both) alternative pathways are implemented. This interpretation, however, assumes that the expert ratings outlined in Table 7 represent the actual situation.

Furthermore, the CBA results do not only transparently expose the costs and benefits of implementing the pathways, but also the potential weaknesses of the participative social learning process. For instance, the stakeholders were not constrained by a financial budget in the discussions of possible mitigation measures related to their identified issues. Pathway 3, targeting the forestry sector in the Helge River catchment, illustrates the resulting issue clearly: While the total benefits of pathway 3 are the highest, its total costs exceed the costs of pathway 2 by a factor of almost 6.

Table 15 Costs and Benefits Summary, Helge river catchment (Present Value in million SEK, 3.5 % social discount rate)

Costs and Benefits	Pathway 1 (2017 – 2030)	Pathway 2 (2021 – 2030)	Pathway 3 (2021 – 2030)
Total costs	854.8	328.1	1,869.0
Total benefits	264.5	2,541.0	3,297.6
Net Present Value	-519.2	2,212.9	1,428.6
Benefit-Cost ratio	0.3	7.8	1.8

Table 16 shows the CBA result for the Selke catchment in Germany. Again, the NPV of pathway 1 (business as usual) is negative, while the benefits of all but one of the other alternative pathways exceeds the costs. Especially pathway 2 (implementation of buffer strips and N fertilizer application reduction) appeared to have a significant economic impact with both a high NPV and a high "Benefit-Cost ratio" due to relatively high benefits compared with low cost of implementing the pathway. In contrast to the pathways suggested in the Helge catchment, the pathways aiming to improve the provision of aquatic ecosystem services in the Selke catchment demanded a minor share of the total costs of the business-as-usual pathway 1.

Table 16 Cost and Benefits Summary, Selke river catchment (Present value in million Euro, 2.0 % social discount rate)

Costs and Benefits	Pathway 1 (2017 – 2030)	Pathway 2a (2021 – 2030)	Pathway 2b (2021 – 2030)	Pathway 3a (2021 – 2030)	Pathway 3b (2021 – 2030)
Total costs	116.2	7.8	9.1	5.3	10.7
Total benefits	60.4	32.2	32.3	0.5	17.8
Net Present Value	-55.8	24.3	23.2	-4.8	7.1
Benefit-Cost ratio	0.5	4.1	3.5	0.1	1.7

The CBA result for the pathways targeting water quality improvements in the Berze River catchment are presented in Table 17. Once again, the NPV of pathway 1 is negative. Two of the alternative pathways show a positive NPV (pathway 2 and 4), while the costs of the two versions of pathway 3 (mitigation measures in the agricultural sector) slightly outweigh the benefits. One reason for the negative NPVs is that, for instance compared to the negative costs in the Selke catchment, the reduction of fertiliser application in the Berze catchment assumes significant costs, which represents the lion's share of the costs for pathway 3 (cf. cost structures in section 3.1). Most notably, pathway 4 (improving fish migration routes) shows a benefit-cost ratio of 17, which is by far the highest ratio of all pathways in the three case countries. However, once again, this result assumes that installing 5 fishways in the catchment results in a high impact on biodiversity and recreation/tourism.

Table 17 Cost and Benefits Summary, Berze river catchment (Present value in million Euro, 5.0 % social discount rate)

Costs and Benefits	Pathway 1 (2017 – 2030)	Pathway 2 (2021 – 2030)	Pathway 3a (2021 – 2030)	Pathway 3b (2021 – 2030)	Pathway 4 (2021 – 2030)
Total costs	28.3	0.4	35.3	34.9	0.4
Total benefits	11.2	0.7	32.2	29.9	6.9
Net Present Value	-17.1	0.3	-3.1	-5.0	6.5
Benefit-Cost ratio	0.4	1.9	0.9	0.9	17.0

3.4 How sensitive are the results?

In both the Helge and Berze River catchments, the signs of the NPV of all strategies did not change if the time period was extended from year 2030 to year 2050 and 2100, or the social discount rate was changed to any value between 0 and 20 %, *ceteris paribus*. For the Selke catchment, however, the first pathway showed a positive NPV if the period was extended to 2050 or 2100. This can be explained by the relatively high investment costs for two flood control basins and the three implementations of "ventilation and treatment of mine water and mine water retention", which altogether represented 97 % of the total pathway costs, yet certainly target a much longer time period than the 14 years defined for pathway 1 (see figure 1).

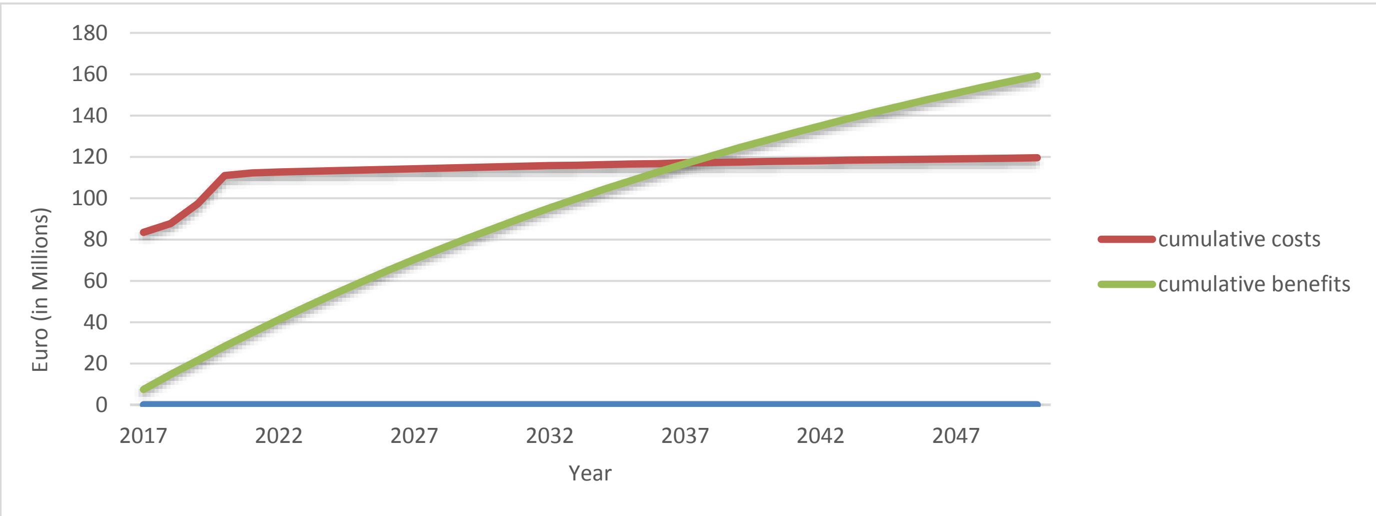

Figure 1 Cost-Benefit timeline, Selke river catchment pathway 1

4 Identification of knowledge gaps and uncertainties

It is evident that a CBA, just like most other decision support tools, inherently entails some level of uncertainty, and is in any case "not a precise tool that yields firm numerical results" (US EPA, 2000, p. 33). CBAs come not only with a high data demand, relying on predictions of future variables and estimations of monetary values of non-market goods or services, but also with the equally challenging quantification of physical effects. In the following we elaborate on such gaps, separated into (1) model-specific knowledge gaps based on the CBA application within the MIRACLE project, and (2) theoretical uncertainties.

4.1 Model-specific knowledge gaps

In terms of the CBAs as presented in section 3, knowledge gaps include (1) different aspects in the process of pathway formulation, (2) uncertainties regarding setting the system boundary and the time frame, as well as (3) the identification, rating and monetary valuation of physical impacts.

4.1.1 Pathway formulation

When it comes to the formulation of the pathways, the applicability of any measure integrated into such pathway and analysed by the CBA might be impaired, for instance due to (a) budget constraints, (b) existing property rights, (c) geo-physical characteristics, or (d) any kind of aversion by another stakeholder or interest group. By working with local stakeholders and therefore drawing on local and case-specific knowledge, the likelihood of selecting measures which are compromised by (b), (c) or (d) may be reduced to some extent, even though the practical feasibility and the availability of matching cost and benefit data of some innovative measures (e.g. in the Helge River case area) might still be considered as highly uncertain. The validity of relying on local knowledge is, however, subject to the assumption that all relevant stakeholder groups are involved in the participative learning process. When it comes to the pathway formulation, the identification of who the stakeholders consist of, i.e. who decides which measures are to be included in each pathway, is thus a key aspect. By allowing that (i) stakeholders could continuously be added, (ii) spatial and demographic differences were considered in the selection process, and (iii) actors from the public sector, civil society and private sector were represented, the likelihood of having overlooked important stakeholders was minimal. Yet, for instance, the high share of public sector participants of centralised institutions in the Berze River case study may have caused the suggestion of rather conventional measures, compared to the strategies in Helge River, where the stakeholder groups appeared to be more balanced and consisted mainly of decentralised institutions (e.g. interest groups and the private sector).

Despite the integration of local knowledge, the budget constraint (a) may still be an issue, as evidenced by pathway 3 of the Helge River case study (cf. section 3.3). Due to assessing possible actions beyond the current implementation period of the Common Agricultural Policy (CAP), available budgets for future actions are, however, unknown.

4.1.2 System boundaries and time frame

Setting the system boundaries and the time frame are further CBA development steps revealing knowledge gaps and uncertainties.

Defining the system boundary of the CBA is essentially a trade-off between general acceptability or completeness (in terms of considering and incorporating all relevant impacts) and easier usability or pragmatic implementation (cf. Sen, 2000). As defined in deliverable 3.1 and following EU recommendations, the geographical and hydrological catchments were set as system boundaries for the CBA in the MIRACLE project, which is seen as ideal to facilitate the cooperation of all relevant actors (European Commission, 2016). This, however, entails that the CBA assesses the well-being of the population within the system boundaries, which implies that only the costs and benefits are considered which occur or are held by people living in the catchment. For instance, if the nutrient load from one catchment is reduced, it contributes to decrease the rate of eutrophication in the Baltic Sea, which may benefit up to 84 million people living in 14 different countries in the Baltic Sea catchment area (Svendsen et al., 2015), as well as tourists or any other people holding a stake related to the Baltic Sea's water quality. Moreover, and due to the complexity of ecosystem services, it is difficult to estimate the relevance of impacts beyond the catchment level. For instance, the wetland area "Kristianstad Vattenrike", which is partly situated in the Helge River catchment, is a preserved UNESCO Biosphere reserve with "landscapes and biological values of regional, national and international importance" (UNESCO, 2011) and various endangered or rare species (UNESCO, 2006). Such values, for instance related to tourism or as breeding ground for migrant bird species, highlight that a high share of benefits is not held only by the society within the catchment. The total benefits are thus likely to be underrepresented in the outcome of the CBAs.

Besides of setting the system boundaries, a CBA requires a defined time period within which all costs and benefits are considered. The length of the period, in MIRACLE 14 and 10 years for the "business-as-usual" and the alternative pathways respectively, may have had an impact on the CBA results, as revealed in section 3.4. This can be due to some measures with high investment costs, yet with the overall aim of generating benefits for a longer time period than considered in the CBA. Furthermore, if the CBA is, as it was done in the MIRACLE project, applied ex-ante, uncertainties regarding possible changes in costs and benefits remain, for instance due to the change of climate and land-use, or due to development of new technologies.

4.1.3 Identification and rating of physical impacts

While the effects of the pathways on the nutrient loads of the respective rivers was based on the HYPE[1] modelling results of MIRACLE WP2, as well as literature, expert elicitation was used to assess the likely impacts in terms of the additional ecosystem services. While the experts can draw on both scientific and case-specific knowledge, a high uncertainty regarding the provision of ecosystem services and their quantification remains in any case (TEEB, 2010). For instance, the links between e.g. "biodiversity and biological systems and the economic and social values that they support are extremely complex" (Markandya, 2016). Consequently, the assessment may be considered a qualified guess that is inherently uncertain. The resulting issue can be exemplified by pathway 3a in the Selke River case area: When changing

[1] The HYPE-model also struggles with a wide range of uncertainties the CBA consequently takes over.

the assumed impact on biodiversity from "low" to "medium", the NPV changed from a negative 4.8 to a positive 11.9 million Euro, which changed the welfare-economical message of the outcome tremendously.

Furthermore, if the assumed completeness in terms of stakeholder interests and inputs cannot be guaranteed (as discussed in section 4.1.1), the selection of considered impacts may be affected, for instance by neglecting important impacts (or including irrelevant ones). Just like the selection of the different measures and pathways, the variety of considered impacts is based on stakeholders identifying such impacts as relevant. Hence, if the included stakeholders do not represent the interests of the entire society within the catchment, neither will the outcome of the CBA.

4.2 Theoretical uncertainties

Applying CBA involves various methodological and theoretical approaches, such as economic valuation (of both market and non-market costs and benefits), benefit transfer or the social discount rate. While all the methods have a theoretical foundation and justification, the application entails some degree of uncertainty. As lowering such uncertainties is difficult or costly, if at all possible, and was beyond the scope of the MIRACLE project, the following section is meant as a short introduction only. Interested readers may for instance refer to Hanley and Barbier (2009) or, specifically targeting ecosystem services, Hockley (2014).

4.2.1 Economic valuation

Economic valuation of environmental goods is often done by willingness-to-pay studies. With an underlying foundation in the theory of rational behaviour, such approaches are likely to be adversely affected by preference anomalies (Hanley & Barbier, 2009), uncertainties regarding the respondents' preferences about ecosystem services (TEEB, 2010), non-linearities in ecosystem service provision, varying perception towards risk, preference reversals[2] (Hanley & Barbier, 2009), or double-counting (Markandya, 2016). Most of the uncertainties are generated in the primary valuation study and it was therefore, due to making use of benefit transfer, beyond the scope of the MIRACLE project to solve or reduce those. However, the issue of double-counting, i.e. adding the unit values of, for instance, recreation and biodiversity was certainly present in the CBA approach in this deliverable.

4.2.2 Benefit transfer

However, while the methodological uncertainties related to economic valuation methods were beyond the scope of the CBAs in this report, additional uncertainties occur due to benefit transfers of ecosystem services. Potential uncertainties are summarised by TEEB (2010) as transfer errors, aggregation of

2 "preference reversal occurs when rankings of two bundles differ according to whether people rank on the basis of their preferences or on the basis of value – their willingness to pay" (Hanley & Barbier, 2009)

transferred values, challenges related to spatial scale, variation in values with ecosystem characteristics and context, non-constant marginal values, distance decay and spatial discounting or equity weighting.

For the assessments of costs and benefits in this report, an income adjusted value transfer with a constant income elasticity was used, which, in the context of water quality in the Baltic Sea Region, was found to perform the best compared to alternative approaches (see Czajkowski et al. (2017) and the previous deliverables). However, uncertainties remained: Significant transfer errors were still likely to occur, and income elasticities in terms of the willingness-to-pay indications are likely to be non-constant (Barbier et al., 2017).

Furthermore, primary valuation studies usually need to be adapted to fit the purpose of the underlying CBA (see section 3.2). In doing so, emerging knowledge gaps are twofold: First, it is questionable if the unit values, which are based on a, typically, binary ranking of a primary valuation study, can be transferred to a different ranking, such as the expert rating with five weighting levels in this study, without further adjustments. Second, due to the complexity of ecosystem services, it is likely that the original unit value describes a different situation than that found in the respective case catchment areas. In other words, the “high number of different species of plants and animals, their population levels, number of different habitats and their size in the river ecosystem in the next 10 years”, which was used as one indicator describing the value of biodiversity, may describe something different in Poland than in Sweden. This can for instance be in terms of different occurring species, or the understanding of how “high numbers” or “population levels” are defined.

4.2.3 The social discount rate

The social discount rate is an instrument to account for time preferences of individuals (cf. D3.3). By assigning present values to future costs and benefits, the rate makes “outputs at different points in time commensurable with each other” (Feldstein, 1964, p. 361). Typically based on the Ramsey equation, the social discount rate is, however, essentially “as much a political decision as an economic one (Hanley & Barbier, 2009). Consequently, the rate is a common subject of discussion (e.g. Arrow et al., 2014), and Moore et al. (2004) even see in it a major reason for varying qualities of CBA results. However, the CBA results presented in this report showed that the discount rate had no impact in terms of influencing the overall results, such as changing the sign of the NPV.

5 Concluding remarks

In this report we have presented the assessed costs and benefits of the pathways as suggested in the social learning process in three of the four MIRACLE case study areas, and outlined the underlying knowledge gaps and uncertainties. The results from the assessments showed that the majority of the alternative pathways appeared to be economically viable with positive NPVs and relatively high benefit-cost ratios. However, the outcome of the assessment should be treated with caution, due to the following reasons. First, the CBA relies on predictions of future variables, estimations of monetary values of non-market goods, and benefit transfer. Second, relying on the expert assessment in terms of the quantification of the physical effects of the respective pathways is the second-best solution, yet entails a high degree of uncertainties. Third, as the system boundaries for the CBA were set on catchment levels, the total benefits are likely to be underrepresented in the outcome of the CBAs. It can thus be concluded that the outcome of the analysis was determined by many underlying assumptions. Therefore, the results need to be interpreted with caution in the context of the specifically designed setting. Generalised conclusions, e.g. for the whole Baltic Sea region, are not appropriate, for instance due to large culturally, geographically or socio-demographically differences .

However, while some knowledge gaps and uncertainties cannot be avoided in any setting, and others may only be reduced with high costs and efforts (e.g. by conducting primary valuation studies to generate pathway-specific unit values and avoid benefit transfer), some knowledge gaps may be reduced. Besides of carefully conducting sensitivity analyses to assess the impact of rather uncertain assumptions on the outcome, it may be recommended to include some kind of budget orientation (e.g. based on current expenditures) for similar projects or approaches, as the possibility of utilising the outcome, e.g. as one input into policy-making, might otherwise be not feasible

Nevertheless, as the CBA in the MIRACLE project was rather intended as a way of engaging and communicating with stakeholders, and to bring attention to the importance of considering multiple benefits, the final results have a twofold aim which is (1) to provide a tool to involve stakeholders in a participative CBA development and discuss their pathway suggestions from a welfare economical point of view, and (2) to deliver a cross-regional CBA analysis of alternative pathways, which aimed at improving the provision of aquatic ecosystem services in the Baltic Sea Region.

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