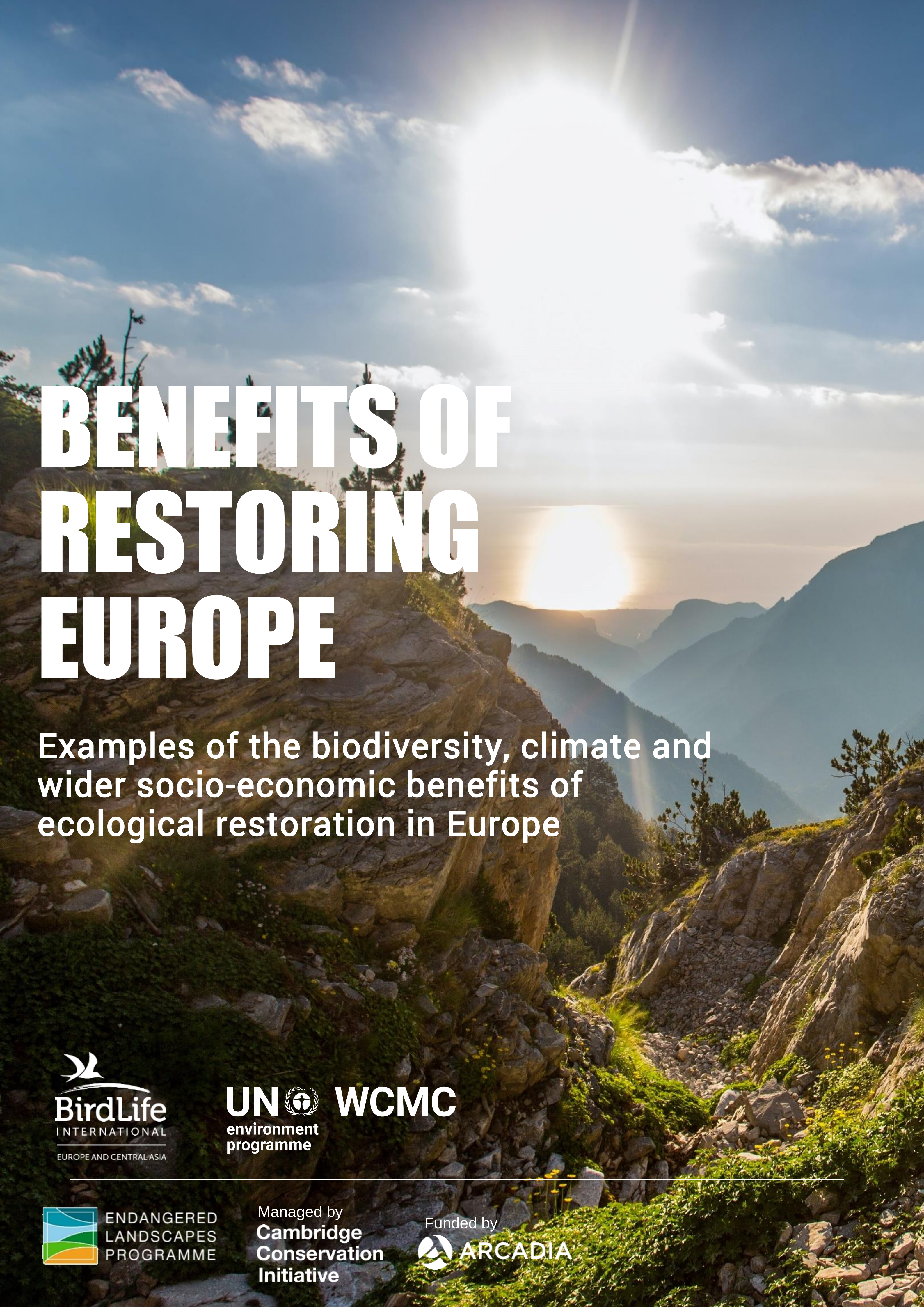

BENEFITS OF RESTORING EUROPE

Examples of the biodiversity, climate and wider socio-economic benefits of ecological restoration in Europe

BirdLife
INTERNATIONAL
EUROPE AND CENTRAL ASIA

UN environment programme WCMC

ENDANGERED
LANDSCAPES
PROGRAMME

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Contents

1 Introduction

This technical report was produced for the Endangered Landscapes Programme (ELP) by UN Environment Programme World Conservation Monitoring Centre (UNEP-WCMC), together with BirdLife Europe and Central Asia, in order to assess the benefits of ecosystem restoration in Europe. The report is the result of a literature review conducted in 2020.

1.1 Context

The European Union (EU) adopted in 2020 a new Biodiversity Strategy for 2030. Nature restoration is a key element of the strategy. The European Commission has stated that, subject to the results of an impact assessment, it will put forward "*legally binding EU nature restoration targets… to restore degraded ecosystems, in particular those with the most potential to capture and store carbon and to prevent and reduce the impact of natural disasters*", to be proposed within new restoration legislation (European Commission, 2020). The main focus of the impact assessment is likely to be the potential for reversing biodiversity losses and addressing climate change, including an economic cost-benefit analysis, but other benefits may also be considered if feasible (European Commission, 2020). This provides an opportunity to inform the EU with evidence on the further benefits of ecosystem restoration.

The aim of this review therefore was to produce an authoritative, evidence-based assessment of the multiple benefits that can be achieved by the restoration of ecosystems, to be used in informing development of the EU Biodiversity Strategy for 2030. This was to be achieved by reviewing the evidence for the benefits of restoration across marine, freshwater and terrestrial ecosystems in Europe and providing quantitative summaries of these benefits. Through this process, the review also aimed to identify the extent to which published research has focused on measuring different kinds of benefits and in doing so, highlight where there are evidence gaps.

1.2 Scope

This review aimed to gather evidence on the following types of 'key' benefits of European ecosystem restoration, as identified by the project team (ELP core team, BirdLife Europe and Central Asia and UNEP-WCMC). These included:

- Biodiversity benefits
- Climate change mitigation benefits
- Climate adaptation benefits
- Socio-economic benefits

Other additional benefits were also recorded when documented.

Initially, the review was to give a particular focus to the additional benefits that might arise from restoring ecosystems at large scales, which would identify how the benefits in such cases go above and beyond what would be expected from the cumulative benefits of small projects. However, as detailed in section 2.3, this aspect of the review was challenging to complete due to the limitations that were encountered.

The following technical report is a synthesis of the evidence that was found through the review.

2 Methodology

2.1 Selection criteria

For the purposes of this review, the Society for Ecological Restoration's definition of **ecological restoration** was used, defined as the "*process of assisting the recovery of an ecosystem that has been degraded, damaged or destroyed*" (SER Primer, 2004). A very similar definition is used for **ecosystem restoration** by the UN Decade on Ecosystem Restoration (UNEP and FAO, 2021), which also references "*conserving the ecosystems that are still intact*". Conservation of intact ecosystems was felt to be beyond the scope of the current review. The geographic region of Europe was defined using the UN Statistics Division list of European countries (UN Statistics Division, 2020).

The literature review took place between October and November 2020. Published and grey literature was initially searched for in a systematic way using a specific set of key words and using the academic literature search engine Web of Science (2020). We included only English-language publications published between 2000 – 2020. Pre-determined search strings were used, compiled as follows: 'Restoration phrase' + 'Type of ecosystem' + 'Type of benefit' + 'Europe' (e.g. Restoration grassland biodiversity Europe). 'Restoration phrase' included 'restore', 'restoration' and 'restoring'. The MAES classification system (Biodiversity Information System for Europe, 2020), which lists the main ecosystems found in Europe, was used to create the word list for 'Type of ecosystem'. The agreed key benefits were used to create the word list for 'Type of benefit' (see Annex 1 for word lists). This resulted in 75 different search term combinations. Additionally, an asterisk was used for some search terms to ensure a return of as many relevant results as possible (e.g. restor*). For each search term combination, the first 20 results were considered, or all of the results if fewer than 20 results were returned.

2.2 Selection of relevant studies

For each study, the abstract was read to determine if it was relevant and could be entered into a spreadsheet created in Microsoft Excel, which was used to store information found during the literature review. If the study was relevant, the full publication was read to extract the information and enter it into the spreadsheet, adding to the dataset. Initially, only large-scale restoration projects were considered, excluding smaller-scale projects, even if they met the other criteria below. A definition of 'large scale' was to be developed by the team once a general picture of the scales involved had been established. However, due to a lack of results on large-scale restoration (described further below), developing a definition became unnecessary.

The main variable determining if a study was relevant was then whether one or more benefits directly resulting from ecosystem restoration was being measured or projected through modelling of future outcomes. Other studies on ecosystem restoration were excluded. A number of studies covered more than one benefit and, in these cases, if each benefit was addressed independently it was added to the dataset separately[1]. This meant a study could be added more than once to the dataset. However,

[1] For example, if a single study, after restoration had taken place, recorded an increase in invertebrate biodiversity by five species, a twofold increase in carbon storage and a €10,000 increase in tourism revenue, each of these benefits were added separately to the dataset.

studies that included multiple benefits without providing a separate result for each were only added once[2].

Studies that measured benefits before and after restoration at the same site were included, as well as studies that compared a restored site with a different, degraded site. Studies which projected benefits through modelling were also included if they met the other criteria. Although different from restoration studies which have recorded existing benefits, they provide another type of evidence for restoration and have potential to guide future restoration activities.

The minimum criteria for all studies were:

- A defined benefit being measured resulting directly from restoration;
- Results or a conclusion as to whether the measured benefit increased, decreased, or if there was no change; and,
- A defined ecosystem being measured.

A full list of criteria is provided in Annex 1.

2.3 Methodological limitations and solutions

As described, once the literature review began it became apparent that the evidence base for the benefits of large-scale restoration was smaller than expected. Further still, even when considering smaller-scale restoration efforts, measured and quantified benefits of restoration were challenging to find. As a result, we widened our scope to include smaller restoration projects. In addition, we sought further relevant literature by (a) seeking recommendations of studies and projects from experts within UNEP-WCMC, ELP and BirdLife Europe and Central Asia, (b) looking into existing databases (e.g. Conservation Evidence (2020), Nature-based Solutions Initiative (2020)) and (c) consulting the reference lists of appropriate papers.

Due to only English-language published and grey literature being included in the search, it is likely that some relevant literature in other languages was excluded.

[2] For example, if a single monetary value was given which captured the combined value of increased biodiversity, carbon storage and tourism revenue.

3 Results

A total of 37 relevant studies matched our criteria (Annex 2), just five from the systematic literature review and the remainder from our additional efforts to find relevant literature. Four studies were grey literature and the rest were published literature.

Due to some studies addressing more than one benefit, in total there were 47 examples in the dataset. Table 1 shows the number of examples recorded in the dataset for each key benefit. Throughout the results section, the term 'examples' is used in reference to the data rather than 'studies'. This is because each example to the dataset was considered independently in the analysis, including cases of multiple entries, or examples, which came from a single study.

Table 1: The number of examples identified for each key benefit.

Benefit	No. of examples
Biodiversity	18
Climate change mitigation	13
Climate change adaptation	2
Socio-economic	9
Other (benefit other than the identified key benefits)[3]	4
Multiple key benefits (if each benefit wasn't measured separately)	1

3.1 Ecosystems restored

The type of ecosystem being restored was recorded as part of each example and can be seen in Table 2 alongside which benefits were being measured for each ecosystem. Some examples detail restoration of more than one ecosystem, so the numbers do not match the number of examples to the dataset.

Of the 25 examples recording the actual or potential benefits of restoration of terrestrial ecosystems, 46% focused on biodiversity, 37% on climate change mitigation, 14% on socio-economic benefits and 3% on climate change adaptation benefits.

Out of 14 examples covering restoration of freshwater ecosystems, 57% focused on biodiversity benefits, 21% on 'other' benefits, 7% on climate change mitigation benefits, 7% on climate change adaptation benefits and 7% on multiple benefits.

Of the 8 examples covering restoration of marine ecosystems, 50% focused on socio-economic benefits, 25% on climate change mitigation benefits, 12.5% on climate change adaptation benefits and 12.5% on 'other' benefits. No studies detailing benefits of marine ecosystem restoration for biodiversity were identified.

[3] The 'Other' benefits included: Reduced siltation in reservoirs; Reduced eutrophication; Enhanced ecological functioning via detritus retentiveness and decomposition; and, Enhanced ecological functioning by reduction in phytoplankton.

Table 2: Summary of the 47 examples in terms of the ecosystem being restored and the associated benefits measured or projected to materialise in future. N.B. Nine studies focused on the restoration of more than one ecosystem, so the numbers do not match the number of examples in the dataset.

Ecosystem		Benefit					
		Biodiversity	Climate change mitigation	Climate change adaptation	Socio-economic	Other	Multiple (if not measuring each benefit separately)
Terrestrial	Grassland	6	2	-	1	-	-
	Heathland and shrub	1	-	-	-	-	-
	Cropland	2	3	-	2	-	-
	Woodland and forest	3	1	-	-	-	-
	Sparsely vegetated land	-	-	-	-	-	-
	Wetlands	4	7	1	2	-	-
	Urban	-	-	-	-	-	-
Freshwater	Rivers and lakes	8	1	-	1	3	1
Marine	Marine inlets and transitional waters	-	-	-	1	-	-
	Coastal	-	2	1	3	1	-
	Shelf	-	-	-	-	-	-
	Open ocean	-	-	-	-	-	-

3.2 The key benefits from restoration

Section 3.2 summarises the findings of the 47 examples, split by the key benefits explored. For each key benefit, case studies are presented.

3.2.1 Biodiversity benefits

There were 18 examples to the dataset measuring biodiversity benefits. Two thirds of examples involved restoration of terrestrial ecosystems, with the remaining third including restoration of rivers and lakes. No studies measuring biodiversity benefits of restoring marine ecosystems were found (Table 2).

The examples measuring biodiversity benefits varied in terms of which indicator of biodiversity was being measured. Some looked at ecosystem structure, such as tree height and vegetation cover, whereas others looked at species diversity, including plant diversity, plant species richness (case study 3), invertebrate diversity (case study 2) and fish diversity. Other examples focused on focal species, measuring numbers of breeding pairs of birds and overall numbers of birds (case study 1).

Biodiversity benefits

Case study 1: Bregnballe et al. (2014). Skjern River Valley, Northern Europe's most expensive wetland restoration project: benefits to breeding waterbirds.

Benefit: Biodiversity

Ecosystem: Freshwater, Rivers and lakes; Terrestrial, wetlands

Location: Skjern River, Denmark

Area: 2200 ha

Restoration: Active; Removal of dykes, pipes, weirs and pumping stations

Cost: €38 million

Type of study: On-the-ground restoration

Study approach: Benefits measured at the same site, before and after restoration

Context: After 35 years of drainage and intensive arable tillage, the lower Skjern River was re-engineered to its original meanders and flooding regime, creating 22km² of lakes, shallow wetlands and seasonally flooded grazed wet grassland. The primary motivation was to reduce eutrophication at the Ringkobing Fjord, with secondary objectives to restore bird breeding habitats, increase the salmon population and improve recreational and tourist activities. This study looked into the bird populations before and after the restoration activities.

Results:

- 29 breeding waterbird species returned to the restored area having been absent for the previous 30-35 years
- 10 of those species are of national or international significance
- Waterbird numbers *before* restoration 134 ± 22.9, *after* restoration 1,744 ± 153
- Waterbird species richness and diversity increased

Although outside the scope of the study, whether the water quality improved as a result of the restoration (the primary aim) is not disclosed.

Case study 2: Lorenz et al. (2009). Re-Meandering German Lowland Streams: Qualitative and Quantitative Effects of Restoration Measures on Hydromorphology and Macroinvertebrates.

Benefit: Biodiversity

Ecosystem: Freshwater, Rivers and lakes

Location: The Schwalm and the Gartroper Muhlenback, Germany

Area: 55 ha

Restoration: Active; Meandering river and re-creating habitats

Cost: No information

Type of study: On-the-ground restoration

Study approach: Benefits of the restored site compared to a separate, degraded site

Context: Two lowland rivers were restored in Germany by meandering the stream channels and lowering the floodplain levels to better connect the streams to their floodplains.

Macroinvertebrate diversity was compared between these restored sites and nearby anthropogenically straightened reaches.

Results:

- Total numbers of macroinvertebrate families, genera and taxa were higher in the restored reaches of river compared to the straightened reaches
- 28 species were found in the restored reaches that were not found in the straightened reaches
- Across two sites in each condition, 25 species occurred in the straightened reaches and 56 occurred in the restored reaches.

Case study 3: Pykälä (2004). Cattle grazing increases plant species richness of most species trait groups in mesic semi-natural grasslands.

Benefit: Biodiversity

Ecosystem: Terrestrial, Grassland

Location: Southwest Finland

Area: Sites varied from 0.25 to 0.8 ha, 31 sites in total

Restoration: Active; Grazing

Cost: No information

Type of study: On-the-ground restoration

Study approach: Benefits of the restored site compared to a separate, degraded site

Context: The effects of cattle grazing on plant species richness was studied at three types of mesic semi-natural grasslands: old (continuously cattle grazed/intact ecosystem), new (cattle grazing restarted 3-8 years ago/restored ecosystem) and abandoned pastures (grazing stopped over 10 years ago/degraded ecosystem).

Results:

Plant species richness per type of grassland,

- Old – 209 species
- New – 173 species
- Abandoned – 156 species

This study is restoring what could be described as a 'cultural' system, due to the fact grazing meadows are the 'restored' ecosystem rather than the natural or unmanaged system being the restored ecosystem. There are likely to be differences in opinion as to which one is preferable, yet for the purposes of increasing plant biodiversity, the grazing system has 'better' results.

3.2.2 Climate change mitigation benefits

Climate change mitigation was the second most common key benefit being measured or projected from restoration efforts, accounting for 13 examples in the dataset. 81% of examples included restoration of terrestrial ecosystems, 12.5% included marine ecosystems and 6.5% included freshwater ecosystems (Table 2).

The most common indicator for climate change mitigation benefits was carbon storage, accounting for seven examples (including case studies 4 and 5). However, other examples measured the value of mitigating carbon emissions or the cost of carbon emissions. Seven examples measuring climate change mitigation benefits were restoring wetlands. Five of these examples were specifically looking at the restoration of peatlands.

Climate change mitigation benefits

Case study 4: Calvo Robledo et al. (2020). Restoration scenario planning at a Spanish quarry can be informed by assessing ecosystem services.

Benefit: Climate change mitigation

Ecosystem: Terrestrial, Wetlands & Cropland

Location: Spain

Area: 440 ha

Restoration: Active; Restoring mixtures of habitat e.g. mosaics of wetlands

Cost: No information

Type of study: Computer model creating future scenarios

Study approach: Benefits measured at the same site, using different modelled future scenarios

Context: An active gravel quarry site with plans to be restored to agricultural land was assessed using the TESSA toolkit to compare the plans with other restoration strategies in terms of their potential to store carbon. The current agriculture-focused plan was compared with a nature-focused restoration scenario and a compromise scenario which had a mixture of agricultural land and restored habitats.

Results:

Annual carbon emissions per scenario for the entire site,

- Agricultural land scenario – 80 tonnes CO_2 *emitted*
- Nature scenario – 2,358 tonnes CO_2 *stored*
- Compromise scenario - 2,874 tonnes CO_2 *stored*

The compromise scenario stored more carbon than the conservation scenario. This is due to the types of habitat included in each scenario and their associated carbon storage potential. Three types of habitat included were riparian forest, reedbed and open water, with the former estimated to store carbon and the latter two estimated to emit carbon. The compromise scenario had a higher cover of riparian forest compared to the conservation scenario and a lower cover of reedbed and open water, meaning overall this scenario stored more carbon.

Case study 5: Graves and Morris (2013). Restoration of Fenland Peatland under Climate Change. Report to the Adaptation Sub-Committee of the Committee on Climate Change.

Benefit: Climate change mitigation

Ecosystem: Terrestrial, Wetland (Peatland)

Location: United Kingdom

Area: 20,500 ha

Restoration: Active and passive; Stopping agriculture and flooding (modelled study)

Cost: No information

Type of study: Computer model creating future scenarios

Study approach: Benefits measured at the same site, using different modelled future scenarios

Context: Much peatland in the Anglian Fens has been converted to agricultural land. This study compared the carbon emissions of the landscape in several future scenarios, including where agriculture is dominant and where there is large-scale restoration of peatland.

Results:

	Tonnes CO_2 emissions per ha per year	Tonnes CO_2 emissions over study area (20,500 ha) per year
Agricultural scenario	22.5	461,250
Peatland restoration scenario	-5.56 to -5.34	-113,980 to -109,470

- Agricultural scenario is a net emitter of carbon
- Peatland restoration scenario stores carbon

3.2.3 Climate change adaptation benefits

Two examples measured the climate change adaptation benefits as a result of restoration, one marine and one terrestrial example (Table 2).

The example focused on terrestrial ecosystems looked into the benefit of flood prevention provided by restoration of a wetlands situated in the United Kingdom and is described in section 3.2.5 'Multiple benefits' (case study 8). The example focused on a marine ecosystem considered the value of avoided climate change impacts from the presence of eelgrass and is described in section 3.3.3 'Cost of inaction' (case study 11). There are no further case study examples for this section.

3.2.4 Socio-economic benefits

Nine examples measured or projected the socio-economic benefits of restoration. 44% of these included restoration of terrestrial ecosystems, 44% included marine ecosystems and 12% included freshwater benefits (Table 2). The examples measuring socio-economic benefits included a higher proportion of marine ecosystems than any other key benefit.

All studies measured socio-economic benefits in terms of economic value. Other measurements of socio-economic benefits, such as job creation and wellbeing, were included in our classification of socio-economic benefits, yet only studies that measured economic value were found.

Examples of socio-economic benefits included the value of recreation, income for farmers, income for farmers specifically related to hay yield, fisheries landings value and seagrass value. Recreational revenue was the most common, accounting for four of the examples.

Socio-economic benefits

Case study 6: MacDonald et al. (2017). Benefits of coastal managed realignment for society: Evidence from ecosystem service assessments in two UK regions.

Benefit: Socio-economic

Ecosystem: Marine, Coastal

Location: United Kingdom

Area: 180 ha

Restoration: Active; Sea wall removed

Cost: No information

Type of study: On-the-ground restoration

Study approach: Benefits measured at the same site, before and after restoration

Context: At a coastal site in north-west England, a sea wall was created in the 1980s and the marshland converted to agricultural land. In 2006 the land was purchased by the Royal Society for the Protection of Birds and by 2009 the sea wall had been removed and the Hesketh Outmarsh West Nature Reserve created, re-establishing salt marsh habitat. Data before the restoration on recreational visitors was collected in 2008 and again after the restoration in 2011-2012.

Results:

Annual recreational revenue,

- Before restoration - €53,562
- After restoration - €122,837

Case study 7: Blaen et al. (2015). Rapid assessment of ecosystem services provided by two mineral extraction sites restored for nature conservation in an agricultural landscape in Eastern England.

Benefit: Socio-economic

Ecosystem: Terrestrial, Wetlands

Location: United Kingdom

Area: 153 ha

Restoration: Active; Reed planting, creating shallow wetland areas, cattle grazing

Costs:

	Agriculture scenario	Conservation scenario
One-off cost during restoration	€919,234* €5,745 per ha*	€919,234* €5,745 per ha*
Ongoing management costs per year	€1,315 per ha**	€746 per ha**

*Exact figures are not provided for each scenario, the paper states the two scenarios are 'similar' to one another and are 'approximately' these figures.

** Ongoing management cost for entire site per year not provided

Type of study: Computer model creating future scenarios

Study approach: Benefits projected at the same site, using different modelled future scenarios

Context: Recognising that impacts on biodiversity are often measured at sites restored for conservation, this study aimed to measure the broader ecosystem services that are provided alongside biodiversity. Annual recreation revenue was compared at a gravel extraction site between two future scenarios: a conservation scenario where post-extraction the site is restored to wetlands, and an agricultural scenario where post-extraction the land is converted to agricultural land. The recreational revenue was calculated using estimates of annual visits and the amount spent per visit on travel and in the local area. The agricultural scenario still allows some recreational revenue as some areas would still be open to the public, such as to walk through, for example.

Results:

	Agriculture scenario	Conservation scenario
Annual recreational revenue	€14,348	€20,625
Annual crop production	€291,344	€0

The authors note that although the value of crop production under the agriculture scenario was higher than other ecosystem services in the study with a monetary value, the annual management costs associated with this scenario were also the highest, meaning the actual revenue from crop production was €70,893. They also note the difference in beneficiaries, where under the agricultural scenario the financial benefits are more concentrated (although they acknowledge this doesn't take into account the provision of food to the wider public), whereas under the conservations scenario the recreational benefits are felt more widely in the local area. The study did also consider climate change mitigation, estimated for the conservation scenario to be twice that of the agricultural scenario.

3.2.5 Multiple benefits

Nine studies measured or projected multiple benefits resulting from restoration.

In the examples below, case study 8 measures each benefit separately and case study 9 has combined the measured benefits into one overall benefit value.

Multiple benefits

Case study 8: Peh et al. (2014). Benefits and costs of ecological restoration: Rapid assessment of changing ecosystem service values at a U.K. wetland.

Benefits: Climate change mitigation, climate change adaptation and socio-economic

Ecosystem: Terrestrial, Wetlands

Area: 479 ha

Location: United Kingdom

Restoration: Active; Reflooding wetlands, grazing

Cost:

One off cost during restoration:	Ongoing management costs per year:
€808,349	€64,792
(€1,687 per ha)	(€135 per ha)

Type of study: Computer model creating future scenarios

Study approach: Benefits projected at the same site, using different modelled future scenarios

Context: The TESSA toolkit was used to compare ecosystem services of restored wetland and adjacent arable land, and calculate the monetary value of those services. Climate change mitigation benefits were measured by the cost of greenhouse gas emissions, climate change adaptation was measured by flood damage savings and socio-economic benefits were measured by revenue generated from recreation.

Results:

	GHG emission costs per year	Flood damage savings per year	Recreation revenue per year
Restored wetland	- €13,409 - €28 per ha	€16,790 €35 per ha	€282,269 €589 per ha
Arable land	- €38,505 - €80 per ha	€0 €0 per ha	€48,285 €101 per ha

- The restored wetland scenario, in comparison to the arable land scenario, had lower costs from greenhouse gas emissions, higher flood damage savings and higher revenue from recreation.

Case study 9: Vermaat et al. (2016). Assessing the societal benefits of river restoration using the ecosystem services approach.

Benefit: Climate change adaptation, climate change mitigation and socio-economic

Ecosystem: Freshwater, Rivers and lakes

Location: Netherlands, Denmark, Sweden, Finland, Poland, Czechia and Austria

Area: 37km of river

Restoration: Active and passive (many different types of restoration activities due to number of sites in study)

Cost: No information

Type of study: On-the-ground restoration

Study approach: Benefits of the restored site compared to a separate, degraded site

Context: The benefits of river restoration were measured at eight locations across Europe, comparing a restored and unrestored reach of river at each location. A wide range of benefits were measured, including the key benefits of climate change adaptation, climate change mitigation and socio-economic. These benefits were given monetary values and compared to determine whether the restored or unrestored reaches of river provided more benefits.

Results:

- Total benefits value of the restored reaches of river was €1,400 ± 600 per ha per year

The study did not provide the estimated value of each different benefit, but only gave the overall value of all benefits.

3.3 Location

Table 3 shows which countries the restoration activities described in the studies took place in. In this case they are counted per study, rather than by each example.

Table 3: The number of studies per country.

Country	No. of studies
Austria	1
Czechia	1
Denmark	1
Finland	5
France	2
Germany	1
Greece	1
Hungary	1
Slovakia	1
Spain	4
Sweden	5
United Kingdom	8

Europe	2
Mediterranean	2
Multiple countries	2

Studies in the United Kingdom accounted for 21% of all studies, more than any other country. This was followed by Finland and Sweden, each accounting for 13% of all studies.

3.4 Area of restoration

The area restored or used to project models ranged from <0.1 ha to 59,300 ha. The mean area was 4,724 ha, however, this is skewed by the studies with the two largest areas, of 59,300 and 20,500 ha. All other studies were 9,000 ha or less. Excluding the two largest areas resulted in a mean of 1,206 ha.

Studies that looked into the restoration of rivers sometimes measured the length of the river, rather than measuring it by area. Of these studies, the length of river being restored ranged from 0.25 km to 210 km, and the mean length was 59 km.

3.5 Other factors affecting measures of benefits

Approaches to monitoring or calculating benefits differed across studies and key variables are described below.

3.5.1 Study approach

Some studies collected data on benefits before and after restoration of the same site, whereas others collected data on benefits at the restored site and compared it to the benefits of a different degraded control site. A third study approach, namely modelling studies, compared the benefits at a degraded site with a future scenario of that same site if it was restored. Often, these studies considered more than one scenario. These three different categories are labelled within each case study under 'Study approach' and the number of studies of each type is displayed in Table 4.

Table 4: The number of studies per 'study approach', as described in section 3.5.1. N.B. 'Cost of inaction' studies are not included as they are not restoration studies in the strictest sense so the three categories do not apply (see section 3.5.3 for more details on these studies).

Study approach	No. of studies
Benefits measured at the same site, before and after restoration	10
Benefits of the restored site compared to a separate, degraded site	18
Benefits projected at the same site, using different modelled future scenarios	6

3.5.2 Modelling

Some studies measured benefits that resulted from restoration that had already been carried out. Other studies were based on computer models, estimating the restoration benefits that could be achieved in the future. While only the former constitutes evidence in the pure sense, both types of study are important as modelling studies can be used to identify and quantify restoration opportunities, which can be followed up with studies looking at the reality of such studies. These two different categories are labelled within each case study under 'Type of study' and the number of studies of each type is displayed in Table 5.

Table 5: The number of studies measuring benefits from restoration that had already been carried out or from projected computer models. N.B. 'Cost of inaction' studies are not included as they are not restoration studies in the strictest sense and so the three categories do not apply (see section 3.5.3 for more details on these studies).

Type of study	No. of studies
On-the-ground restoration that has already been carried out	28
Computer model projecting future scenarios	7
Both	1

3.5.3 Cost of inaction

Five papers were identified that didn't measure the benefits as a consequence of restoration, but rather highlighted the contribution of existing ecosystems and their current value to society, as well as what stands to be lost as a consequence of inaction (i.e. the cost of ecosystem degradation). Studies focusing on the cost of inaction were not actively sought during the literature review but were found whilst searching for restoration papers.

As these studies are not measuring benefits of a consequence of restoration and have an implicit assumption that restoration can restore 100% of benefits, caution should be exercised when comparing them to restoration studies. However, these types of analyses do have value as part of the restoration dialogue as they quantify what stands to be gained from fully functioning ecosystems, the existence of which is necessary to complement restoration actions on degraded ecosystems. It's important to note that these studies do sometimes identify how restored ecosystems do not deliver as high a level of benefits as original, protected ecosystems, at least within the timeframes under consideration.

The five 'cost of inaction' studies were added to the dataset and all were focused on coastal ecosystems. However, this is likely to be due to the method in which they are found, rather than necessarily reflecting a bias in the literature. Further research into these types of studies would likely find similar studies focusing on other ecosystems too. Below are some examples of 'cost of inaction' papers.

Cost of inaction
Case study 10: Jackson et al. (2015). Use of a seagrass residency index to apportion commercial fishery landing values and recreation fisheries expenditure to seagrass habitat service. **Benefit:** Socio-economic **Ecosystem:** Marine, Coastal **Location:** Mediterranean Sea **Area:** Entire Mediterranean **Context:** The seagrass in the Mediterranean is well-documented, but their value to fisheries is not. The proportion of commercial fishery landings that could be attributed to seagrasses was calculated for the Mediterranean Sea, with the aim of highlighting what stands to be lost as seagrass ecosystems decline. **Results:**

- €77 million of fish landings per year directly attributable to presence of seagrass
- This equates to 4% of Mediterranean commercial fisheries landing value.

Case study 11: Cole and Moksnes (2016). Valuing Multiple Eelgrass Ecosystem Services in Sweden: Fish Production and Uptake of Carbon and Nitrogen.

Benefit: Climate change adaptation, Other

Ecosystem: Marine, Coastal

Location: Sweden

Context: Linkages were quantified between the presence of eelgrass and particular economic goods in Sweden. The results on those goods as a result of eelgrass decline were then calculated.

Results:

Over a 20-50 year period, it was estimated…

- The value of avoided climate change and eutrophication impacts was €1,074 per hectare of eelgrass compared with unvegetated habitats.
- One hectare of eelgrass produces an additional 626kg cod fishes, 7535 wrasse individuals and sequesters 99 tonnes of carbon and 466kg of nitrogen.

4 Conclusions

The amount of published and grey literature available that quantified the benefits of ecosystem restoration in Europe was lower than expected, particularly when considering large-scale restoration. The amount of literature available on restoration broadly was high, but was mostly focused on guidance for maximising success of restoration or simply documenting the results of attempted restoration efforts (for example, by studying the most favourable conditions for restoration of a particular plant species). The subsequent link to the additional benefits of such restoration and, a step further still, measuring those benefits, was rare. Given the important role of restoration in meeting global and regional environmental policy goals in the forthcoming decade and beyond, this lack of evidence highlights the need for an increase in research which measures the benefits of restoration. Such an evidence base can help to inform target setting and guide action.

However, there may be other contributing factors towards a lack of evidence. One factor could be a language bias as a result of the literature review being carried out in English, meaning published or grey literature in other languages may have been excluded (Amano et al. 2016). If a similar European-focused restoration benefits review were to take place in the future, widening the scope to include other languages could be a consideration. Another factor which likely influenced the small number of results was limiting the scope of the review to Europe. Removing "Europe" from the search resulted in higher instances of studies which would have met the criteria if not for their geographic location. If there truly is limited evidence of benefits that can be gained from restoration within a European context, using evidence from outside Europe may be necessary to guide future restoration efforts. The small number of studies found could also be due to the timeframes involved, as many known large scale restoration projects taking place in Europe were found to not have any reported results at the time of the literature review, but often listed 'expected' results to come in the years ahead. However, there was an increase in the number of studies published over time between 2000 and 2020 (see Annex 1, Figure 1), meaning in the forthcoming years the evidence base might increase if this trend continues.

The studies that did meet the criteria tended to be focused on one or a small number of sites, and often each site was small in size. Results can be extrapolated to estimate benefits from restoration at larger scales, but these estimations may not be entirely accurate. The timescales involved are also important in restoration, which is typically an ongoing process with benefits continuing to develop over decades, a timespan outside of the scope of a lot of studies. Many studies measured benefits at a fixed point in time post-restoration, as opposed to continually monitoring the benefits over many years, which would likely give a fuller picture of the benefits to be gained and indeed, how they may change over time. Although some of the studies found did consider multiple benefits, most were not full ecosystem audits, however, these were not actively searched for so may be a result of the search methodology. In addition, the benefits were the focus of this review, rather than full ecosystem audits.

No studies that focused on marine ecosystems measured biodiversity benefits, whereas terrestrial and freshwater ecosystems did. This may be because marine restoration is a newer science compared to terrestrial or freshwater restoration, so the available data and publications are smaller. Compounding this, marine ecosystems found in Europe, such as seagrass, can take many decades to restore due their slow growth rates, meaning the results of marine restoration efforts may still be several decades away, including any associated increases in biodiversity. Marine restoration also takes place on a smaller scale globally compared to terrestrial or freshwater, in part due to the higher expenses associated with monitoring, such as boat time and diving, and the marine restoration that does take place has tended to focus on tropical ecosystems.

However, despite these limitations, virtually all studies found or projected measurable benefits as a result of ecosystem restoration. The sample size is too small to support the analysis of the magnitude of benefits, but initial results suggest they could be substantial. This promising finding simply highlights how more studies of this kind are needed, but on larger scales in terms of space and time. Such evidence will be invaluable in informing restoration efforts in Europe in the years to come.

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6 Annex 1

Word list for 'Types of ecosystem' (using the MAES classification system, Biodiversity Information System for Europe, 2020):

- Terrestrial
  - Urban
  - Cropland
  - Grassland
  - Woodland and forest
  - Heathland and shrub
  - Sparsely vegetated land
  - Wetlands
- Fresh water
  - Rivers and lakes
- Marine
  - Marine inlets and transitional waters
  - Coastal
  - Shelf
  - Open ocean

Word list for 'Types of benefit':

- Biodiversity
- Climate change mitigation
- Climate change adaptation
- Socio-economic

Full criteria for studies to meet in order to be added to the dataset:

- The publishing date had to be between 2000 – 2020
- The study had to be in EnglishThe restoration must have been carried out in Europe, in one of the countries listed on the UN Statistics Division list of European countries (UN Statistics Division, 2020)
- The ecosystem being restored had to be defined or described e.g. forest/wetland/coastal. The ecosystem was then considered against the MAES Classification System to standardise types of ecosystem.
- Restoration of any scale was allowed
- The study had to be measuring a defined benefit resulting directly from restoration e.g. carbon storage or biodiversity measured before/after restoration, or compared between a degraded and restored site
- The study had to include the results or a conclusion as to whether the measured benefit increased, decreased, or if there was no change e.g. carbon storage increased by XX% after restoration, or, biodiversity remained the same after restoration
- The key benefits (biodiversity, climate change mitigation, climate change adaptation and socio-economic) were used in the search which gave a bias to these types of benefits, but

other benefits could included if they met the other criteria e.g. reducing siltation in reservoirs. Food production was not included in the criteria as a benefit.

The number of studies published per year from 2000 – 2020:

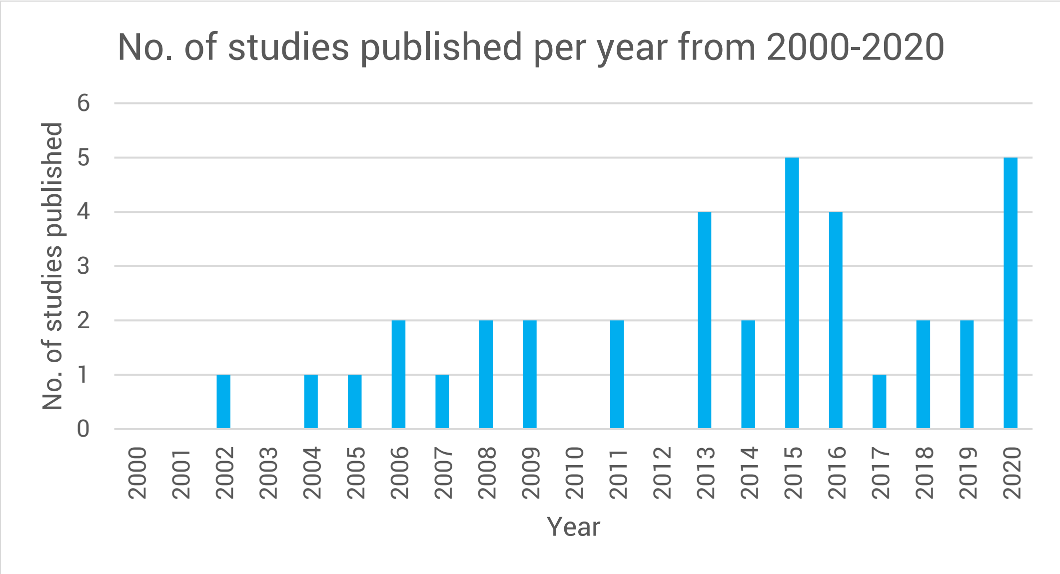

Figure 1: The number of studies published per year from 2000 – 2020

7 Annex 2

The Microsoft Excel spreadsheet containing the dataset of studies used in this review is saved on a Microsoft SharePoint site mutually accessible to UNEP-WCMC and BirdLife Europe and Central Asia. It has also been provided to ELP