



# Economic evaluation of the removal of hydropower dams

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## ABSTRACT

Stricter environmental regulations (e.g. the EU's Water Framework Directive) will entail many environmental improvement measures in waters that have been affected by hydropower, and dam removals are becoming a more common measure. This paper reviews economic evaluations of dam removals, primarily drawing on studies in the USA, and identifies key, frequently recurring, issues that future evaluations will likely need to consider. The paper also reports on an ex-ante evaluation of the recent removal of the Marieberg Hydropower Plant in the Mörrum River in Sweden. An environmental valuation survey carried out as a key part of this evaluation was conducted as a replication of a previous study, where the policy context was different but the expected ecological outcome similar. The replication study produced comparable results to those of the previous study.

## 1. Introduction

Stricter environmental regulations (e.g. the EU's Water Framework Directive) will entail many environmental improvement measures in waters that have been affected by hydropower. Dam removals, as well as other environmental improvement measures, are becoming increasingly common in waters affected by hydropower due to these stricter environmental regulations (see e.g. (Feuillette et al., 2016) for examples from France; (Oladosu et al., 2021) for examples from the US). As the number of these measures – and their associated budgets – are likely to continue to grow, it will also continue to be important to prioritise where such measures are carried out and what they comprise. In many countries, legislation or other regulation stipulates that this prioritisation work should include an economic cost–benefit analysis (CBA). CBA can help identify the most impactful measures and assist in determining which to carry out first; prioritising measures that entail economic gains would help ensure cost-effective use of the funds allocated for implementing such improvements. A thorough CBA also requires reliable estimates of the physical and biological effects of the measure to be implemented; thus, the rigorous use of economic evaluations can identify gaps in these physical and biological assessments, which will in turn contribute to more systematic and consistent environmental improvement strategies.

This paper offers a review of economic evaluations of the removal of hydropower dams. We then identify key recurring issues that frequently

need to be considered in ex-ante and ex-post evaluations of dam removals. Finally, we present an ex-ante analysis of the recent removal of the Marieberg Hydropower Plant in the Mörrum River in southern Sweden.

## 2. Economic evaluations, ex-ante and ex-post

A useful summary of the scientific state of the art within CBA is provided in (Johansson and Kriström, 2016). Generally, CBAs of dam removals and other environmental improvement measures aim to compare the economic benefits of such measures with their economic costs. In economic analysis, *benefits* and *costs* are respectively defined as anything that increases or reduces human well-being; hence, an environmental improvement measure is considered economically beneficial if it entails a net increase in human well-being. These benefits and costs are usually valued in monetary terms; however, unlike financial analysis, no actual monetary payments need to take place for an economic benefit or cost to arise. The established best practice in CBA is to include the effects on all inhabitants of the country where the analysis is carried out, and sometimes effects on all people in the world. Thus, while local policymakers may be interested in a measure because it increases local employment, that particular effect would normally be excluded from a CBA of the measure. A case in point is where an environmental improvement measure may draw tourists to a new location, resulting in positive impacts on employment there; this implies concomitantly lower

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visitor numbers could be expected at locations where those tourists would otherwise have gone, resulting in negative impacts on employment in the latter locations. The fact that tourists who previously visited other destinations now have a more attractive destination has an economic value, which corresponds to the difference between their valuation of the new destination and their valuation of the destination they would otherwise have visited. However, the employment effects themselves normally do not have any economic value because they will mainly involve a redistribution of employment among different tourist destinations in the same country, with little net impact on employment in the country as a whole. An analysis that considers the impacts of a measure on the whole country can, therefore, normally disregard employment effects.

The economic evaluation of a measure entails comparing its benefits and costs with what would have happened without it. There will often be a variety of mutually exclusive or complementary measures to consider, and these should all be evaluated and compared with each other. For example, while removing a dam may restore a more natural flow of water in parts of a watercourse, thereby improving its biological diversity and ecological status, other measures could achieve some of the same effects; thus, individual measures and combinations of them should all be evaluated. All these options should also be compared with what is termed a *reference alternative*, which usually constitutes the option of implementing no measures at all. However, the reference alternative may in some cases rather become a scenario where other – rather than no – environmental improvement measures are implemented, since amended legislation now requires many power plants to be reviewed to live up to modern environmental dictates.

A CBA conducted on a dam removal also needs to determine a time horizon, i.e. the number of years for which including the benefits and costs of an impending measure are relevant. The ecosystems in the affected river may take many years to adapt fully to the new conditions in the river (Akpala and Stage, 2021), so removing a dam is a relatively long-term measure. A time horizon of lengthier duration would therefore in many cases be reasonable for the CBA. Furthermore, at least some of the removals that need to be considered will affect old dams with relatively high maintenance costs. Even if an old dam were not removed now, it would still be likely to require removal or refurbishment in the future. In such cases, the reference alternative would be a scenario that included this future removal or refurbishment. Most of the costs and benefits associated with the reference alternative would then probably be the same, albeit somewhat delayed, as those that would obtain if the dam were to be removed today.

It is important to note here that environmental improvement measures can affect the well-being of agents who are not themselves living in, or visiting, the area in question. For example, if a measure led to an endangered species having better opportunities to remain in its natural habitat, this would enhance the well-being of everyone in society who cared about the species' survival. In environmental economics, the economic value of the benefit that people can experience from the knowledge that a species survives, even if they do not use and do not intend to use the species for anything, is known as an *existence value*. The fact that people also care about protecting environmental factors that they do not actually use for anything plays a major role in environmental policy; this role is operationalised in a CBA by taking the effects on existence values into account when evaluating the impact of measures that affect the environment.

Table 1 (based on (Pascual et al., 2010), but adapted to water issues specifically) offers a schematic view of the different types of environmental values derived from a body of water. The introduction of an environmental improvement measure can change several of these values simultaneously. The CBA is therefore required to account for changes in any of these values.

CBAs can be used to assess the economic viability of a measure both before and after its implementation. The theoretical literature (see e.g. (Johansson and Kriström, 2016)) discusses *ex-ante* calculations that are

**Table 1**  
Environmental economic values from a water body.

Total economic value				
Use values			Non-use values	
Direct use values	Indirect use values	Option values	Altruism values and bequest values	Existence values
Goods and services consumed by a specific user (e.g. fishing for food or recreation; other recreation linked to the water body)	Water functions from which one or several users benefit (e.g. ecosystem services, flood control)	The value of having the option of using direct or indirect use values from the water body in future (e.g. biodiversity)	The value to people of knowing that use and non-use values remain available to other people alive now and to future generations (e.g. maintaining habitats, avoiding irreversible changes)	The value of knowing that something continues to exist (e.g. maintaining habitats, protecting endangered species)
Each value normally valued separately. Can often be assigned a monetary value by observing market prices (which may need to be adjusted) and market behaviour	Each value normally valued separately. Can sometimes be valued monetarily by observing market behaviour	Often valued jointly; <i>existence value</i> is also often used as a catch-all phrase for all these values. This is the approach followed in the current paper as well. The willingness-to-pay for these values usually has to be valued monetarily using different stated preference methods where respondents are asked to value hypothetical changes in the environment.		

Source: Authors' adaptation of the typology found in, e.g., (Pascual et al., 2010)

made before an action has been implemented, *in medias res* calculations that are made after the action has been implemented but before all effects have occurred (given the time lags before the ecosystem in a river has recovered fully, these will often be the only analyses that can be carried out after a dam removal), and *ex-post* calculations made after all effects have occurred. The latter two types of analyses are often merged into a common category of *ex-post* analyses, and the term *ex-post* is often used to refer collectively to all analyses made after an action has been carried out.

In principle, the most important difference between an economic *ex-ante* evaluation and its *ex-post* equivalent is that the *ex-post* evaluation has access to better information. This is because at least part of the period to which the *ex-post* evaluation relates has already occurred by the time the evaluation is made. Therefore, the uncertainty in both physical and economic estimates would presumably be less than in the preliminary evaluation.

In practice, however, the academic literature has identified several problems with how *ex-post* evaluations are made. These evaluations are often poorly prepared, e.g. when no study is carried out beforehand, the analyst does not know what the situation was like before a certain measure was implemented, and it is then not possible to say what the effects of that measure were. These problems do not only apply to *ex-post* evaluations, however. Even *ex-ante* evaluations can sometimes not be carried out based on the information available at the time a measure is to be implemented, because it is not always clear in advance what one hopes to achieve with the measure concerned.

Given that many environmental improvement measures, including

dam removals, will probably be implemented in the years ahead, the experience from previous measures should be utilised when new measures are being designed. It is important that ex-post evaluations are carried out as well, at least for a representative sample of measures, and that the groundwork for future ex-post evaluations is properly prepared before the measures in question are implemented.

### 3. Earlier economic evaluations of dam removals

There have been relatively few economic evaluations of dam removals to date. Those that exist have mostly been conducted in the US, where changes in regulations from the 1980s onwards have led to an increased emphasis on environmental aspects when old hydropower licences are reviewed or reconsidered. Thus, many dams in the US are being demolished when their licences expire, partly because environmental considerations are now given greater weight, and partly because the conditions that originally motivated the dam's existence have since changed (Lovett, 2014).

Interest in using economic analysis in environmental work has traditionally been greater in the US than in Europe; therefore, more economic analyses of dam removals have been conducted in the US than in Europe. At the same time, there is also an empirical tradition in the US of mixing CBA and regional impact analysis; however, while this can provide interesting information for local decision-makers, this mix is not correct in principle, and it risks leading to inconsistent decision-making if applied at a national level. Of particular concern is that the US analyses frequently include local employment effects, which, as noted earlier, should not be included in CBAs.

Furthermore, the electricity market in the US is less integrated than many in Europe. Older US power plants (including hydropower plants) were often built to provide electricity to a local area. Since they were built to serve local markets, transmission capacity to other areas is usually limited. This complicates the valuation of the costs of reduced electricity production. In some cases, reduced hydropower production will make it necessary to build new power plants. Determining the cost of reduced hydropower production will then entail calculating the costs and environmental effects of the electricity production used to replace the lost hydropower. In other cases, where an area has been depopulated since the power plant serving it was built, the economic need for the plant may have decreased; there may then be no need to replace the lost electricity, and the value of that loss would then be relatively low. In countries with more integrated electricity markets, where replacement electricity can generally be purchased at marginal cost prices in the spot market, the cost of reduced electricity production is significantly easier to assess.

One of the largest hydropower dam removal projects in the US to date involved the Elwha and Glines Canyon Dams along the Elwha River in the north-western part of the country. The decision to demolish the dams was made in the 1990s, but their removal was not completed until 2014. A feasibility study on the project was reported in (Meyer et al., 1995) and (Loomis, 1996). In (Meyer et al., 1995), a reference alternative was compared with four different packages of measures: one package entailed both dams remaining but being supplemented by fishing improvement measures; the second entailed the Elwha Dam being demolished; the third involved the demolition of the Glines Canyon Dam; and the fourth package involved demolishing both dams. Because the dams were close to the Elwha's estuary, and since most of the river upstream of the dams ran through a national park, the removal of both dams meant opening up a long stretch of river for migrating salmon and other fish species. The costs in the analysis included the cost of acquiring the power plants, the demolition costs, and the cost of building new power plants to produce replacement electricity. The benefits in the analysis included effects on fishing tourism (whose economic value was probably overestimated; see the discussion in Section 2 above), but over 99% of the benefits for the package where both dams were demolished consisted of existence values experienced by the US

population as a whole, estimated in a willingness-to-pay study reported in (Loomis, 1996). These existence values were mainly related to improved migration for wild salmon (which was seen as something valuable in itself) and to the local Native American community gaining access to fishing waters and other culturally important areas that had been inundated when the dams were built. The package where both dams were demolished meant a very large net economic gain, while the other three packages were all estimated to entail net losses. It is debatable how important this CBA actually was for the decision to demolish these dams. The authors in (Gowan et al., 2006), for example, argue that the decision had been made in practice even before the economic evaluation was completed. Moreover, given that the removal did not begin until 2010, parts of the analysis were probably already obsolete when the removal began. A recent ex-post evaluation (Bellás and Kosnik, 2020) questioned whether it was legitimate to include the acquisition costs, and whether it was appropriate to include tourism benefits. However, although these authors also found that several of the other cost and benefit estimates in the ex-ante evaluation had been somewhat off the mark, the overall conclusion – that removing the dams entailed a large net economic gain for US society as a whole – held up.

In (Loomis, 2002) the economic profitability of demolishing four dams along the Lower Snake River, also located in the north-western US, is studied. Here, too, an important environmental benefit entailed improved migration opportunities for wild salmon. Unlike (Loomis, 1996), however, this 2002 study only estimated the use values related to environmental improvements that would result from the dams' removal. The use values were estimated via a survey asking respondents how often and for how long they would visit the area if the dams were removed. The responses were compared with statistics on tourism to the existing water reservoirs. However, there is a risk that this study overestimated the economic benefit from the improved tourism opportunities, since (as explained above) the new tourism would probably mainly entail a redistribution from other parts of the country. On the other hand, the overall economic benefits were probably underestimated, as non-use values were not considered at all. The study concluded that the tourism value would increase six-to tenfold compared with the original situation, but that the economic benefits from improved use values, even with relatively optimistic estimates of how large such values would be, would not outweigh the costs of demolishing the dams.

In (Lewis et al., 2008), an ex-post evaluation was made of how property prices along the Kennebec River in the north-eastern US were affected by the removal of nearby dams. Of course, property prices also depend on many other factors; to evaluate the effect on property prices of the dam removals alone, the authors used a hedonic pricing model. Properties at varying distances from demolished dams were compared with properties close to remaining dams, to see how dam removals affected real estate prices when controlling for other factors. Before the dam removals, there had been concerns that property prices would be affected negatively. For instance, changes in the aquatic environment would make boat docks less useful than before, and property owners who believed they had bought a lakeside plot would experience reduced benefits when their properties instead came to lie along a flowing stream. In practice, however, once other things that also affected property prices were controlled for, it turned out that proximity to a dam made a property less valuable, and the dam's removal increased property values.

Similarly, (Provencher et al., 2008) studied how property values in the US state of Wisconsin were affected by proximity to dams, which in some cases were removed during the period studied. In (Born et al., 1998), where these removals were also studied, the authors stated that, in many cases, the dams in question had deteriorated to such an extent that it would have cost significantly more to repair them than to remove them. Like (Lewis et al., 2008), (Provencher et al., 2008) used hedonic pricing, but with a comparison area that also included properties located at watercourses that were flowing throughout the period studied. Here,

concern was also expressed beforehand that removing the dams would lead to a decline in property values, but in practice the opposite was found: proximity to a dam reduced a property's price, whereas the dam's demolition drove prices higher.

In the ex-ante study (Bohlen and Lewis, 2009), the same methodology was used to examine how prices of properties along the Penobscot River in the north-eastern US were affected by dams in their proximity. They found that beach plots conditioned a higher price than other properties, but that those near (but not at) dam reservoirs cost less than properties further away.

Property prices only capture use values for people located in the immediate area, so hedonic pricing studies provide an incomplete picture of the economic benefits derived from dam removal. Nonetheless, as noted by (Provencher et al., 2008), these local use values will account for a large part of the economic benefit from removing a small dam unless its removal has effects (e.g. for endangered species) that generate benefits outside its immediate vicinity. Thus, hedonic pricing analysis can be enough to capture most of the economic benefit of removing small dams.

The authors of (Johansson and Kriström, 2012a, 2013) studied the effects of hypothetically replacing two power plants in Sweden's Ljusnan River with one new power plant further upstream. In the reference alternative, the existing power plants would remain but would be upgraded to meet modern environmental requirements. In the new-for-old package of measures, the producer would make a net profit compared with the reference scenario. Moreover, even if no monetary valuation study was made of the benefit to the local population of removing the two downstream plants, a survey indicated that most respondents were positive about the change. In addition, there would be improved migration opportunities for wild salmon; although these were not explicitly valued in monetary terms either, they would probably also provide an economic benefit. Overall, therefore, the package of measures would be economically profitable.

The economic effects of demolishing the Marieberg Hydropower Plant in the Mörrum River in Sweden were estimated as part of the study reported in (Bergsten et al., 2014; Stage, 2018). This study is discussed in more detail in Section 5.

#### 4. Key issues to consider in economic evaluations of dam removals

From the studies described in Section 3, we can identify several factors that should also be relevant for many future dam removals. For example, one of the most important items on the cost side will in many cases be the **demolition cost** itself. The agent who pays for the removal will presumably usually estimate this cost before deciding whether to remove the dam, and this estimate can then be used in the economic ex-ante analysis. In the ex-post analysis, the actual removal cost can be used.

The **costs associated with lost electricity production** will be easier to assess in countries with integrated electricity markets. In most cases, a reasonable starting point for such an assessment would be to study the production levels of the power plant in recent years and use this information to forecast the plant's future production if the dam were not demolished. The economic cost of losing this production can be assessed in the ex-ante analysis based on estimated future electricity prices; in the ex-post analysis, the same procedure can be used, but using the actual electricity prices during the evaluated period (and with the benefit of hindsight, this means that the 2022–2024 energy crisis will make many ex-post analyses of measures already carried out less economically beneficial than the ex-ante analyses indicated). In countries with less well-integrated electricity markets, where there is no spot market price that can be used to evaluate the lost production, case-by-case assessments along the lines of the cited US studies will become necessary.

At the same time, the analysis needs to consider that the **operating**

**costs** for the plant will also disappear. Here, it will probably be a question of using the same estimated operating costs in both the ex-ante and ex-post analyses, as in most cases there will be no significant additional information afterwards on what the operating costs would have been if the plant had not been demolished.

When dams have begun to deteriorate to such an extent that **maintenance costs** become important, removal means that these costs disappear. Removal can become even more attractive if the usefulness of the dam has decreased since it was built. Here, too, the ex-ante and ex-post analyses will probably need to use approximately the same estimated costs.

Removing a dam could also entail avoiding **costs for other environmental measures** (such as building fish ladders or changing the water flow in a plant) that would otherwise be necessary to implement in order to live up to modern environmental requirements. If these environmental requirements change during the evaluated period, the ex-post calculation may need to incorporate these new regulations; if they do not change during that period, the ex-ante and ex-post calculations can use approximately the same estimated costs. At the same time, the dam removal may also need to be combined with various additional environmental restoration measures, in order for the removal to achieve its full impact on the river ecosystem; there may be a need to e.g. restore vegetation on the riverbanks, or to restock the river with species that lived there before the dam was established (Cornwall, 2023). The costs for these environmental measures should then be included as part of the dam removal scenario.

The **ecological effects** of removing a dam can contribute to both use and non-use values not only for local residents, but also for residents in the rest of the country. Such values include improved fishing for local residents and angling tourists (see further discussion later in this section) and existence values linked to improved species stocks. Attitude surveys (see e.g. (Christie et al., 2004; Christie et al., 2006) indicate that, in practice, when most of us assess the existence values of species populations outside our own immediate neighbourhood, we divide those species into the following three categories.

- Well-known species that already have large populations, where the willingness-to-pay for further improvements is low (in their immediate area people can of course also value such species);
- Rare but well-known species, where the willingness-to-pay even for 'only' improving a species' population size may be high; and
- Endangered species, whether well-known or not, where the willingness-to-pay is often high.

Thus, if a dam removal or other measure is expected to affect species in categories (b) or (c), that measure would impact economic values that people in the entire country care about, and that impact would often be decisive for the benefit side of the CBA. Including at least a rough estimate of such values in situations where these may be relevant will, therefore, be crucial for obtaining a correct economic evaluation.

The exact ecological effects of a specific dam, and hence of its removal, can vary considerably depending on the type of dam and on local environmental conditions (see e.g. (Pompeu et al., 2022; Haase et al., 2023)) and the ex-ante analysis will often require a location-specific estimate. An ex-post analysis will reveal what ecological effects an implemented measure has had and how quickly they arose; as already noted, the full extent of the ecological impacts may take a long time to materialise. Conducting a new valuation study may be relevant to investigate whether any existence values have changed in the meantime.

If a dam's removal is expected to lead to **improved ecosystem services**, for example, in the form of cleaner water in the immediate area, this can be assessed by estimating by how much the purification costs for water will decrease. Other improvements in ecosystem services that reduce costs (or increase revenues) for local actors can be valued in the same way.



The **fishing effects** of a dam's removal can include improved fishing for locals (which are legitimate economic benefits) as well as effects of fishing tourism (where there is a risk of overestimation, as pointed out in Section 2). Fishing effects must be estimated in an ex-ante evaluation, while an ex-post calculation can use actual fishing figures. Simpler analyses can use fishing licence data and the like, while more sophisticated analyses can make use of willingness-to-pay studies. For the best possible analysis, willingness-to-pay studies should be carried out both for the ex-ante and the ex-post analyses; this would capture any changes in the fisheries valuation during the applicable period.

As for effects on **other tourism**, the same reasoning applies as for fishing tourism. Removing a dam often entails an economic benefit because visitors will then have a better destination to include in their itinerary. However, this benefit consists only of the difference between the value of the new destination compared with that of the destinations these visitors would otherwise have headed for; in other words, the benefit is not the whole value of the new destination. The ex-ante projections of future tourism can be evaluated in an ex-post calculation to show exactly how large the tourism effects ended up being.

**Changes in the local environment** may include effects such as the water line receding and the dam lake being replaced by flowing water. Such effects may also entail the cost of losing possible historical or cultural values associated with previously inundated areas may be restored. This has played a major role in some US studies, for example, where indigenous peoples' traditional uses of a river were prevented by the dam but become possible again once the dam was removed. If the effects on the local environment end up being different from what was anticipated before the dam's removal or are valued differently by people in the vicinity compared with what was anticipated before the removal, the ex-ante and ex-post calculations will be different.

**Changed flood risks** can include reduced risks of dam breaches (for deteriorated dams), but since the river flow during the year will also change once a dam is removed, the risk of minor floods may either increase or decrease. An ex-ante calculation will need to base the estimates of these risks on recent rainfall patterns and (possibly) historical data on what the river flows were like before the river was dammed. An ex-post calculation will be able to use actual flow figures and compare these with estimates of what such flows would have looked like if the plant in question had remained.

**Property values** can be used to capture the value of most of the environmental benefits for people in a dam's vicinity. However, to avoid double counting, caution should be exercised if this is combined with valuing other local benefits separately. In such situations, it may be preferable to measure only property values. For small dams that do not affect species with national existence values, changes in property values will in many cases capture a large part of the economic benefit derived from dam removal. For such dams, therefore, this is an important item to estimate. It also means that the removal of small dams can, in practice, be evaluated quite easily ex-post, even if the ex-ante evaluation was poor.

**Local employment effects** are often included in US analyses but should, as noted, normally not be considered in a proper CBA.

**Court costs** in connection with removal decisions entail a clear risk of double counting, i.e. not only in terms of the costs of the court deliberations themselves, but also in terms of the damages awarded by the court to the affected parties. As many hydropower concessions will in any event need to be renegotiated to comply with new environmental regulations, legal costs associated with these deliberations should not be seen as part of the removal costs per se; only additional legal costs that arise from the actual removal of the dam should be considered as costs linked to its removal. Moreover, decisions on damages and compensation that arise in connection with the removal decision will usually aim to compensate for deteriorations in one or more of the values discussed above and should, therefore, not be counted as additional costs when court costs are considered. Instead, a court decision on what damages to

award should be seen as the court's estimate of the magnitude of the effects on these values.

The following section provides a case study of the removal of the Marieberg Hydropower Plant on the Mörrum River as well as an ex-ante CBA of the main economic effects.

## 5. Removal of the Marieberg Hydropower Plant

### 5.1. Consequences of the removal

The Mörrum River in southern Sweden is one of Sweden's most famous fishing waters, with large stocks of salmon (which is what the river is best known for) and sea trout. Of all the hydropower plants on this river, the Marieberg plant was closest to the sea, about 10 km from the estuary. Although the plant had fish bypasses, facilitating the passage of migratory salmon and sea trout on their way upstream, it remained a partial obstacle to upstream migration. The only way the plant facilitated the fishes' downstream migration was by shutting down for a few weeks each year. The power plant dam also inundated a large spawning and nursery area that had previously been used by both salmon and sea trout. Despite this, both salmon and sea trout migrated all the way to the Fridafors plants, another 20 km upstream, with a few migrating even further. However, their populations upstream of Marieberg were significantly smaller than they would have been without the plant. In (Bergsten et al., 2014; Stage, 2018), the effects of different scenarios for environmental improvement measures in the Mörrum were investigated. The authors in (Bergsten et al., 2014) generated detailed biological population modelling of these scenarios as well as a CBA. Their research included an investigation of the effects of removing the entire Marieberg Hydropower Plant. This single measure was judged to have by far the greatest effect on the fish populations in the river; it was also the only measure deemed economically profitable.

A 2015 ruling by the regional environmental court meant that environmental improvement measures had to be undertaken in some of the power plants further upstream. Relatively similar measures had in fact been included in one of the scenarios studied by (Bergsten et al., 2014; Stage, 2018). Therefore, for the sake of simplicity, that scenario is used as the reference alternative in the CBA presented here. The Marieberg removal is then compared with that reference scenario.

In (Fiskevårdsteknik i Sverige, 2014), the effects of two different scenarios for environmental improvement measures at Marieberg were investigated. One scenario involved improving the bypass around the power plant, while the other constituted the plant's removal. Like (Bergsten et al., 2014; Stage, 2018), these consultants concluded that the plant's removal would be significantly more effective from an environmental point of view.

In 2015, the owner of the plant decided to remove it and applied for permission to do so. Although actual flooding risks were expected to remain negligible, the variation in water levels was projected to increase along the entire stretch of river where the plant was located, and the character of the landscape was projected to change owing to more rapid river flow. In discussions with nearby residents before the removal, some of them expressed concern that fishing tourism would be affected, as the water line would recede when the dam lake disappeared, and jetties used for sport fishing would be stranded. Thus, the local population was not unequivocally positive about the removal. Nonetheless, in March 2019 the regional environmental court granted its permission for the plant to be removed; the plant was demolished the following year.

The plant's removal meant not only that the partial barrier for upstream migration had disappeared, but also that downstream migration could take place all year round, and that the new flowing watercourse restored spawning and nursery areas for salmon and sea trout. The populations of both species were therefore expected to increase significantly because of the removal. Several endangered species (European eel, kingfishers, several mussel species, and probably several bat species) also live on or along the river, but they were not expected to be

affected other than very marginally. As is often the case, the full recovery of the ecosystem could be expected to take a long time to materialise.

The demolition costs were estimated by (Fiskevårdsteknik i Sverige, 2014). Production of electricity at Marieberg ceased with its removal, but the plant had been built in 1918 and relatively high operating and maintenance costs disappeared with its removal as well. In the reference alternative, therefore, it was assumed that the power plant would have been demolished in about 40 years anyway, since the operating and maintenance costs would by then have exceeded the value of production.

## 5.2. The value of improved fish migration and increased fish stocks in the Mörrum River: a replication study

An important effect of the removal of Marieberg was that it was expected to lead to improved conditions for salmon and sea trout. How these improvements affect the use value of the fishery can be estimated using results from (Paulrud and Laitila, 2013), who studied fishing in the Mörrum River (this study was part of a series of economic studies of Swedish recreational fishing reported in, e.g., (Paulrud and Laitila, 2013; Laitila and Paulrud, 2006; Paulrud, 2006; Laitila and Paulrud, 2008; Thangavelu et al., 2017); the fishing values in (Paulrud and Laitila, 2013) were the highest in this series of studies, which was to be expected since the Mörrum and Em Rivers studied in (Paulrud and Laitila, 2013) are famous for their exclusive sportsfishing). Also probably significant is the premium that the country's population puts on the existence value of the river's improved species stocks; however, there are few existing studies that can be drawn on to estimate this value. The closest study is that of (Håkansson, 2008, 2009), who estimated the existence value of improving fish ladders so as to increase the wild salmon populations migrating upstream in the Vindel River in northern Sweden from the current 3000 per annum to (in different scenarios) 4, 000, 6,000, or 9000 annually. The author found little difference between the values attached to the different scenarios, which were all estimated to be valued at a lump sum of between SEK 96 million and SEK 517 million. There are no other studies in Sweden that can be used as a basis for estimating the existence values of improved salmon or trout populations.

For the purposes of this paper, therefore, a replication study was carried out which used a very mildly revised version of the (Håkansson, 2008, 2009) survey on wild salmon.<sup>1</sup> The policy contexts differed considerably, with a hydropower dam being removed in our case while the Vindel case entailed improving migration opportunities past a hydropower plant that would remain in operation. However, the ecological outcomes were comparable, and carrying out the study as a replication study has the added benefit of giving an idea of whether it is possible to use environmental valuation estimates from earlier studies to value comparable environmental outcomes even when the policy contexts differ.

A pilot study was used to investigate whether respondents differentiated between paying for environmental improvements through increased taxes (as in the original Vindel River survey) or through increased electricity prices (which in practice will be the case for the Mörrum River and other future environmental improvements financed by Sweden's Hydropower Environmental Fund). Since the pilot study results indicated that respondents did not differentiate between these two payment alternatives in practice, we proceeded to use only the more realistic alternative, namely the increased price of electricity, in our

subsequent main survey.<sup>2</sup> Both with the original tax alternative as well as the electricity price alternative, respondents were asked to decide on a one-off cost for a year. This is admittedly an unrealistic portrayal of how the financing is likely to happen in practice, but it is often easier for respondents to decide on a once-off cost rather than one that recurs annually.

Instead of the Vindel survey's increase from a baseline level of 3000 migrating wild salmon each year, our survey mentioned the approximately 1000 salmon estimated to migrate past Marieberg each year before the plant was removed, and asked respondents about their willingness-to-pay for an increase from this 1000 salmon baseline. In respect of this increase, our survey had two scenarios: the first entailed that the number of salmon migrating past Marieberg would increase by 1000 to about 2000 each year during a five year-period and then stabilise at the new, higher level, while the second entailed an increase by 2000 to about 3000 each year under the same conditions. The described five-year delay until the full effects materialised was intended to indicate to respondents that the full impact would take time, while also providing a sufficiently short time frame that the scenarios would seem meaningful to respond to.

As mentioned, (Håkansson, 2009) found no major difference in respondents' willingness-to-pay for the different scenarios; most respondents probably took a position on their assessment of a significant improvement, rather than on their assessment of the exact size of that improvement. Therefore, we expected two scenarios to be enough. The only other adaptations we made to the Vindel River survey involved (a) adding a sub-question about whether improvements were also considered for other species when the respondent took a position on the improvements for salmon, and (b) updating the intervals in the income question. As in the Vindel River survey, respondents were given the opportunity to state their willingness-to-pay for the described improvement either as an exact amount or as an interval. Table 2 shows that most respondents who stated a nonzero willingness-to-pay at all chose to state their willingness-to-pay as an interval. Also as in the Vindel study, we excluded a few (three) respondents who had stated an extremely high willingness-to-pay. In our case, this involved amounts of SEK<sup>3</sup> 10,000 or more (no other respondents stated amounts higher than SEK 5000 – even as the upper limit for their willingness-to-pay – and only a few stated more than SEK 1000). Unlike the original survey, we

**Table 2**  
Descriptive statistics for the two scenarios separately and jointly.

Scenario	Number of respondents	Proportion of zero responses	Proportion of exact, nonzero, responses	Proportion of interval nonzero responses
An increase of 1000 salmon migrating upstream annually	503	0.39	0.19	0.42
2000 salmon migrating upstream annually	504	0.45	0.13	0.41
Both scenarios	1007	0.42	0.16	0.42

Source: Authors' calculations

<sup>1</sup> The Mörrum River also has sea trout, but this species was not included in the survey. The sea trout is very similar to salmon in terms of its characteristics and environmental threats to it, and respondents were likely to assess the two species jointly in practice. We therefore assume that respondents' valuation of effects on salmon can also be used for sea trout.

<sup>2</sup> With the dramatic price increases in electricity that Sweden experienced during 2022–2024 as part of the European energy crisis, this equivalence between financing through taxes and through the electricity bill might not have worked as well if the survey had been carried out more recently.

<sup>3</sup> A Swedish Krona or SEK is approximately 0.1 USD or Euro.

used a web panel of respondents selected to be representative of Sweden's population as a whole; thus, unlike the Vindel study, we had no non-responses or incomplete answers. The proportions that responded with SEK 0 in respect of their willingness-to-pay were similar to those reported in (Håkansson, 2008), while the proportions that responded with intervals (among respondents who did not give SEK 0 as an answer) were slightly higher than (Håkansson, 2008) found (see Table 2).

As in (Håkansson, 2009), and in line with our expectations, the results show no clear difference between the two different scenarios studied in respect of respondents' willingness-to-pay. In fact, the average willingness-to-pay was even about SEK 10 higher for the 'worse' scenario (see Table 3). This result, that respondents were willing to pay for a large environmental improvement but did not differentiate clearly between the two levels of improvement proposed, is common in this type of study; (Håkansson, 2008, 2009), for example, had similar results, as did (Johansson et al., 2011; Johansson and Kriström, 2012b). In the subsequent analysis, we therefore merged the two scenarios, and in Table 4 the results from this combined scenario were used to estimate how Sweden's population as a whole would value the annual wild salmon migration past Marieberg improving by either 1000 or 2000 individuals each year. In (Håkansson, 2009) not only the results for the individual's willingness-to-pay were reported (i.e. the question that the respondents were asked to answer), but also what the results would be if those answers were assumed to reflect the household's willingness-to-pay (as some respondents may have thought about the entire household's finances in practice). We follow the same procedure here.

The results reported in Tables 3 and 4 are slightly higher than the results reported by (Håkansson, 2009) for a similarly sized improvement of the wild salmon stock in the Vindel River. However, the (Håkansson, 2008, 2009) survey was conducted in 2004, and both price and income levels as well as population numbers have risen in Sweden since then. When new survey results are not available, it is usually assumed that nominal willingness-to-pay rises at the same rate as the price level if the real income level is constant, and that real willingness-to-pay rises at about the same rate as income if the real income level rises. Adjusting the Vindel River results to reflect changes in price levels, income levels, and population size in Sweden since 2004 generates results that are very similar to our results. That the results are similar for the Vindel and Mörrum Rivers may mean not only that most respondents mainly considered the non-use values of improved wild salmon stocks, but also that geographical proximity did not play a decisive role in the survey participants' willingness-to-pay for the improvement.

In (Bergsten et al., 2014), it was estimated that Marieberg's removal would lead to an increase in the number of migrating salmon females in the Mörrum by between 734 and 764 annually, depending on how well the fish passages worked further upstream, while the number of migrating sea trout females would increase under those conditions by between 127 and 134 annually. Including the males of both species, (Bergsten et al., 2014) estimate the increase in total populations to between 1565 and 1633 migrating fish annually, which – with the

**Table 3**

Average willingness-to-pay per respondent for the two scenarios separately and jointly.

Scenario	Average lower interval boundary (SEK)	Average answer (SEK)	Average upper interval boundary (SEK)
An increase of 1000 salmon migrating upstream annually	50	106	139
An increase of 2000 salmon migrating upstream annually	51	96	130
Both scenarios	51	101	134

Source: Authors' calculations

**Table 4**

Total benefit in million SEK for Sweden's population from having the number of wild salmon migrating upstream past Marieberg increase by at least 1000 annually.

Willingness-to-pay measure	Lower boundary (SEK million)	Point estimate (SEK million)	Upper boundary (SEK million)
Willingness-to-pay, individual	518	1033	1374
Willingness-to-pay, household	235	470	625

Source: Authors' calculations

willingness-to-pay estimated from our survey results – would result in concomitant economic benefits with a present value of between SEK 235 and 1374 million. If the increased fish stocks can withstand catches of about 10% for fishing, then 157–163 additional fish can be caught annually. The highest fishing value was estimated by (Paulrud and Laitila, 2013) to be about SEK 800 for the largest fish; with today's price and income levels, this value becomes approximately SEK 950. Let us assume, somewhat unrealistically, that all the new fish belong to the largest size class and are thus valued by anglers at about SEK 950 per fish. The new catch would then correspond to an additional economic benefit of approximately SEK 149,000–155,000 each year.

### 5.3. Cost–benefit analysis

Since we assume that Marieberg would have been demolished 40 years from now in any case, all projected costs and benefits are compared with a reference scenario where the same costs and benefits are assumed to begin occurring 40 years from now instead. Starting with the demolition costs, (Fiskevårdsteknik i Sverige, 2014) estimated the cost of removing the plant at approximately SEK 4.1 million. More current figures will soon be available, but in the absence of better data, that estimate is employed in the current analysis. Furthermore, (Bergsten et al., 2014) estimated that Marieberg produced an average of approximately 3200 MWh annually. To estimate the cost of replacement electricity, we follow (Johansson et al., 2011; Johansson and Kriström, 2012b), who value production losses using prices in the Nordic electricity market. To estimate the additional environmental costs of replacement electricity – which, in the Nordic market, is produced using Danish coal power – we again follow (Johansson et al., 2011; Johansson and Kriström, 2012b) in assuming non-priced environmental costs of approximately SEK 30/MWh. On the other hand, production costs of about SEK 30/MWh are eliminated once the plant is demolished (Bergsten et al., 2014; Stage, 2018).

The changed water environment has not only meant lower water levels, but also that many jetties and similar structures can no longer be used. The regional environmental court valued the costs of these impacts for the surrounding residents at a total of SEK 689,000. As the court process regarding the demolition was not part of any scheduled renegotiation process, all court costs should be seen as economic costs associated with the removal as such. Of course, the judgment only shows court costs for the residents (a total of approximately SEK 632,000, of which the plant owner was ordered to pay approximately SEK 503,000) and not those for the owner or the court. However, even with generous estimates of these costs, they would only be a minuscule fraction of the total costs of removal.

A CBA suggests that removing the Marieberg power plant today, rather than in 40 years, was profitable (Table 5). The high existence value from improved salmon and sea trout stocks dominates the benefit side completely. This is similar to the findings in the reviewed US studies and is in line with the earlier estimates in (Bergsten et al., 2014; Stage, 2018).



**Table 5**

Cost–benefit analysis of the removal of the Marieberg Hydropower Plant. Present values in million SEK, calculated using a 3% discount rate and an evaluation period of 40 years.

Individual costs or benefits	Present value (SEK million)
Existence values of improved salmon and sea trout stocks	161 to 942
Improved sports fishing	3.54 to 3.69
Increased air pollution	–2.29
Lost electricity production	–45.6 to –32
Property values	–0.47
Demolition cost	–2.81
Court costs	–0.43
<b>Net present value</b>	<b>112 to 908</b>

Source: Authors' calculations

## 6. Concluding comments

From an economic viewpoint, there is nothing unique about evaluating the removal of hydropower dams, so there is no need for completely new ways of reasoning. Many of the issues that become relevant when assessing dam removals resemble those that arise as soon as any major environmental improvement measures are considered. In view of the extensive intervention involved in a removal, however, it is even more important than for less extensive measures that the intervention is preceded by a thorough analysis and that at least some of these removals are also evaluated afterwards so that society can take advantage of previous removal experiences when planning for new removals.

Environmental valuation of the ecological impacts is likely to be an important part of evaluating the overall economic benefit of dam removals. Our environmental valuation of the ecological impacts of a dam removal in Sweden provided results that were comparable to those from a previous study where the policy context was quite different but where the ecological impacts were similar. This suggests that reusing results from earlier environmental valuation studies – even studies that do not entail dam removals per se – can provide acceptable estimates of environmental benefits, as long as the ecological impacts are comparable. Our results also indicate that improved non-use values to the population as a whole – for people in the general population who care about improving conditions for rare or endangered species – were crucial for making the dam removal economically beneficial for society as a whole. In rivers where such species are unlikely to be affected, the economic analysis would be likely to come out differently.

Many countries are generally poor at evaluating implemented measures after the fact, whether in the field of water environmental policy or in other environmental policy areas. Therefore, there is a risk that the ongoing work on reducing hydropower's environmental impacts will lead to unnecessarily high economic costs. At the same time, the problem is notably not limited to the economic evaluation per se. When measures are implemented without a clear baseline, and without clearly specifying what one hopes the measure will achieve, it is difficult to say in retrospect whether the measure has been successful or not by any evaluation criterion, economic or otherwise.

As we have seen, it will be relatively easy to make rough ex-post evaluations after removing small dams; however, these removals are not the ones that risk becoming economically costly. For removing larger dams, it is vital that we make thorough baseline measurements; that we estimate what the physical, biological and economic effects will be; and that we follow up after the fact in order to assess how reliable our forecasts of those effects actually were.

However, precisely because of the large costs involved, when the removal of larger dams is being considered, it is likely to be preceded by attempts to estimate what the physical and biological effects will be. In practice, this also presupposes a precise measurement of the baseline

position. Economic evaluations of dam removals can help identify knowledge gaps in the forecasting of the physical and biological effects of those removals. Work on the economic evaluation of dam removals thus has the potential to contribute to more careful estimates of the effects of environmental improvement measures in general.

## CRedit authorship contribution statement

**Kristina Ek:** Writing – review & editing, Writing – original draft, Methodology, Investigation, Formal analysis. **Elin Spegel:** Writing – review & editing, Writing – original draft, Methodology, Investigation, Formal analysis. **Jesper Stage:** Writing – review & editing, Writing – original draft, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Conceptualization.

## Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests:

Jesper Stage reports financial support was provided by Energiforsk AB and the Swedish Environmental Protection Agency. Kristina Ek reports financial support was provided by the Swedish Environmental Protection Agency. All three authors also do other work on water management and on hydropower issues in Sweden.

## Data availability

Data will be made available on request.

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