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Ecosystem services provided by Baltic salmon – a regional perspective to the socio-economic benefits associated with a keystone migratory species

Authors: Kulmala S.[1,2,3], Haapasaari P.[4], Karjalainen T.P.[5], Kuikka S.[4], Pakarinen T.[2], Parkkila K.[6], Romakkaniemi A.[2] and Vuorinen P.J.[2]

Short title: Ecosystem services provided by Baltic salmon

Key Message: Baltic salmon (*Salmo salar L.*) is one of the keystone migratory species in the Baltic Sea. In the past salmon played a central role in the economy and culture of the region. However, salmon population collapsed because of logging, dams for hydropower production, pollution and overfishing. Today salmon is still of great cultural importance as shown for example by estimates of public spending for habitat restoration and WTP by angler. Estimates suggest that the cultural services of salmon are greater than the economic value of commercial salmon landings with a net present value ranging from 6 million EUR to 25 million EUR (ie 0.9-3.6 million EUR / year) in Denmark, Finland, Poland and Sweden for 2009-2015. Baltic salmon plays also an important role in reducing sedimentation, regulating food webs and maintaining the general ecological balance of ecosystems Maintaining and restoring the salmon population requires concerted efforts for habitat restoration and conservation in rivers and the sea.

Reviewers / comments: M. Kettunen (IEEP), M-L. Koljonen and Irma Kallio-Nyberg (Finnish Game and Fisheries Research Institute - RKTL), Johannes Förster (UFZ)

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What is the problem?

Fish provides one of the major protein sources for humans around the world. They also play an integral role in regulating the structure of marine food webs, maintaining nutrient cycling and contributing to recreation opportunities associated with marine areas. Salmon is also important for cultural heritage and identity. All these services and values have become increasingly threatened due to the collapse of wild salmon stocks.

[1] Marine Research Centre, Finnish Environment Institute (SYKE)
[2] Finnish Game and Fisheries Research Institute
[3] MTT Agrifood Research, Finland
[4] Fisheries and Environmental Management Group (FEM), Department of Environmental Sciences, University of Helsinki, Finland
[5] University of Oulu, Thule Institute
[6] Department of Economics and Management, University of Helsinki

Baltic salmon (*Salmo salar L.*) is the keystone migratory species in the Baltic Sea. It is an anadromous species, ie the fish are born in fresh water, spend most of their life in the sea and then return to fresh water to spawn. The species is geographically and genetically isolated form Atlantic salmon stocks. Nowadays, Baltic salmon reproduce naturally in nearly 30 rivers, however in the past the number of rivers with wild Baltic salmon stocks is known to have been considerably higher, ie around one hundred rivers. Damming, habitat destruction, pollution and intensive fishing have been identified as the main causes of the decline. Presently, the majority of the wild salmon originates from rivers located in Sweden and Finland.

Which ecosystem services were examined and how?

This case study provides an overview on the ecosystem services and associated socio-economic benefits provided by Baltic salmon to Nordic countries over the past decades (Figure 1). In general, the management of Baltic salmon in the Baltic Sea area illustrates the challenges for sustainable management of the multiple benefits provided to a keystone species with regional importance (eg valuation of these benefits). The ecosystems important for Baltic salmon exist at varying spatial scales. Furthermore, the suitability of these ecosystems to salmon depends on habitat diversity and connectivity between the sea and rivers. Also, the benefits associated with salmon – direct and indirect - benefit different stakeholders in different geographical areas.

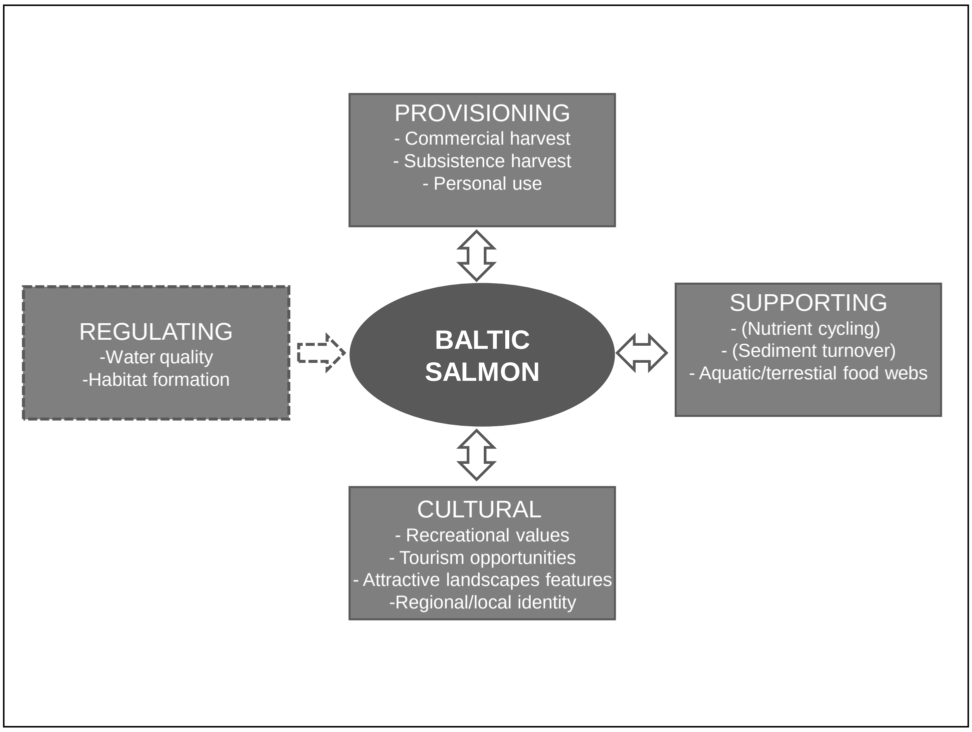

Figure 1. Ecosystem services of Baltic salmon. Salmon population in the Baltic Sea provide provisioning, cultural and supporting ecosystem services that benefit people. These services involve two-way interactions with feedback to salmon (adapted from Bottom et al. 2009). Nutrient cycling and sediment turnover are not as significant as it is for some Pacific salmon species.

Habitat and supporting services

Salmon is the fish species with the widest migration routes over the Baltic Sea catchment area. As an example, salmon juveniles occupy the headwaters of the River Tornionjoki 400-500 km upstream from the sea, which is the northernmost point of the Baltic Sea drainage area. After 3-5 years' growth in freshwater, juveniles migrate to the sea and half a year later they are feeding herring and sprat in the south-west part of the Baltic Sea proper. These salmon mature after 1-4 years' growth on the feeding grounds, after which they migrate the 2000 km distance back to their natal headwater rivers for spawning.

At each stage of migration and life cycle, salmon occupies a specific niche which cannot be occupied by any other species of the ecosystem. For instance, salmon juveniles are one the few species that can utilise fast-flowing freshwater habitats in the large northern rivers. No other fish species was able to replace salmon juveniles in fish production during the deep depression in salmon abundance in the latter half of the 20th century. Salmon is adopted to uniquely utilise and link the low-productive, fast-flowing river habitat, which is a good environment for reproduction, with the pelagic sea habitat, which offers good conditions for fast growth due to the high abundance of prey species.

Maintaining food web: Building on the above, salmon juveniles are key consumers of the invertebrate production in fast-flowing sections of spawning rivers. In the fish community of sea some other predatory species are by far more abundant than salmon and therefore quantitatively salmon is not playing a key role in the marine food web. Predatory fishes (pikes, burbots etc.) and several birds (mergansers, seagulls etc.) are eating salmon juveniles both on their freshwater feeding habitat and during their migration. Some river fish species are eating salmon eggs. Seals are eating maturing salmon on their spawning migration, but also salmon in their early marine life belong to their diet. To conclude, salmon plays an important role in maintaining the balance in riverine food webs, both by harvesting invertebrate populations and also providing an important food source for other predatory species (eg a number of species valuable to humans).

Nutrient cycling: Nutrient transportation by salmon between freshwater and sea was important Baltic-wide before the industrial period when salmon spawned in almost all middle-sized and large rivers. Nutrient transportation is nowadays more limited than in the past due to damming and other human activities which have destroyed natural migration and life cycle of salmon in many spawning rivers. Relatively few Baltic salmon have been observed to die in freshwater after spawning and therefore the nutrient transportation from sea to freshwater is not as significant as it is for some Pacific salmon species. However, Baltic salmon do encounter a post-spawning mortality which results in accumulation of carcasses away from the feeding areas. Typically, only 1-2% of salmon eggs survive over hatching, fry and parr stages and contribute to the juvenile salmon (ie smolt) population. Dying eggs, fry and parr are releasing nutrients to the freshwater ecosystem. Currently nutrients are mainly transported between south and north and within the sea, but salmon has a minuscule role in overall within-sea transportation of nutrients.

Reducing sedimentation: Salmon is clearly the largest of the Baltic species which scours river bed while spawning. This bioturbation cleans river bed from, for example, organic particles the sedimentation of which is high in the Baltic rivers. Spawning removes also macrophytes and invertebrates from the sediment, which may more easily be fed by river fish.

Indicator of food web change: Salmon is a top fish predator that eats nearly exclusively sprat and herring, in the south mainly sprat and towards the north increasingly herring, in the Baltic Sea. Thus salmon in a way refines various micronutrients for use of other top predators like mammals, including humans. Salmon muscle indeed contains plenty of polyunsaturated fatty acids, which are beneficial for human circulatory system. However, being at the top of the food chain salmon unfortunately also accumulates harmful substances, ie various environmental toxicants. This feature, on the other hand, also makes salmon as a good indicator species of those toxicants. In the southern

Baltic Sea salmon grow fast and thus the concentrations of toxicants in muscle are lower than in the northern sea areas. There are also differences between the feeding grounds. Some toxicants are more common in certain than other areas, and the toxicant patterns may also differ. During the spawning run, when salmon reduces food intake and finally cease it, the concentrations of toxicants in muscle increase. The toxicants of most concern are polychlorinated biphenyls (PCB compounds) and dioxins. In salmon muscle the concentrations of dioxins and dioxins plus PCBs are higher than the maximum allowable concentrations in fish muscle set by EU legislation. On the other hand, analysis results of those dioxin-like toxicants from salmon muscle have been used to adjust EU legislation, and national food administrative authorities are obliged to inform consumers of those concentrations.

Provisioning service

Provisioning of food (fish catch) is the most obvious ecosystem service of salmon. However, in the Baltic Sea region, wild-caught salmon is nowadays a source of living for a relatively small number of fishermen catching salmon for commercial or household subsistence use. The **commercial salmon landings** have been declining from 5600 tonnes in 1990 to 900 tonnes in 2010, which was the lowest registered landing since 1970. The decline in the landings is mainly caused by a decline in natural survival during the early marine life of salmon (salmon at this stage are called post-smolts), resulting in a decline in the total stock size. Underlying reasons for the declined post-smolt survival are probably in the changes in the biota of the Baltic Sea during the last decades.

Declining stocks, fishing regulations in the coastal areas and the recent landing restrictions due to the dioxin contents of salmon have caused a decline in the commercial fishing effort. The decline in fishing efforts has also been supported by the influx of farmed Atlantic salmon into the European fishing markets. Consequently, there as has been a drop in salmon prices in Europe from 10 EUR / kg in the early 1980s to 3 EUR / kg in 2000.

From an economic point of view the value of the provisioning service is the net present value of the future benefits of the service. When defining this service as the commercial salmon catch then the total net present value of the salmon catch in Denmark, Finland, Poland and Sweden in 2009-2015 is estimated to range from 6 million EUR to 25 million EUR depending on the fisheries policies and the abundance of salmon (which is mostly dependent on survival of post-juveniles) (Finnish Game and Fisheries Research Institute 2009). Based on this, the annual value of the total landings is 0.9-3.6 million EUR. This estimate is based on a bioeconomic model that accounts for 15 wild salmon stocks and the stocking of salmon (Finnish Game and Fisheries Research Institute 2009).

Kulmala et al. (2008) studied the optimal management of the river Simojoki salmon stock and found that the annual net benefits from the commercial fishery of the single salmon stock in Finland is 0.06 million EUR. However, the investments in stocking of hatchery reared salmon to supplement fishing possibilities and in river restoration indicate that the social value of salmon in the region is considerably higher than the value of the commercial catch. For instance, the Finnish state budget allocated nearly 1.4 million EUR for annual stockings during the years 2000-2004, and over 9 million EUR were spent for habitat restoration during 1997-2005.This reflects the political will to invest in the maintenance of fisheries - for both commercial and non-commercial values - in the region (see below).

Cultural services

Cultural heritage and identity: From time immemorial, Baltic salmon has been an important factor behind the well-being of especially the Northern parts of the Baltic Sea areas. It has provided a source for a healthy diet for the local people and in the old times salted exported salmon brought significant wealth to communities with signs of this still visible in the Nordic landscape. For example, several grand houses built with the money earned from salmon in the 19th and the 20th centuries are still an integral part of the cultural heritage. The annual rhythm of whole villages was adapted to salmon migration, specific professions and skills were developed and buildings constructed to serve salmon fishing. Salmon shaped people's way of living and their thinking. Thus, in several areas people owe salmon their pride, identity and cultural heritage.

Several of today's fishers are descendants of the bygone salmon fishers that markedly contributed in the regional development of the coastal areas still inhabited by the few remaining salmon fishers. The future of salmon fishing, as it is seen today, will probably be more pronounced to sport fishing in the rivers than at present. Salmon is increasingly a cultural service produced by the ecosystem for people representing different professions, living nearby and far away, and it can be a connecting element for very different kinds of people that want to relax in the nature. Yet, salmon is still expected to produce wealth to the today sparsely populated salmon river areas; this is why the inhabitants of those areas struggle for promoting the improvement of the salmon stocks and for developing infrastructure around fishing tourism. Especially in the northern parts of the Nordic countries salmon fishing and overall fishing tourism is considered to have significant potential for the local and regional tourism business (Haapasaari and Karjalainen 2010, Kauppila and Karjalainen, accepted).

Recreational activities, such as recreational salmon fishery, and supply of aesthetic values derived from free flowing salmon rivers, for instance, are typically not fully priced by the market and information about monetary value for these non-marketed goods is not directly available. When required, monetary estimates can be derived from estimating people's willingness to pay (WTP) for a change, such as for improvement in status of particular salmon stock due to the new policy action.

The question about the value of recreational fishing cannot be answered completely based on the current knowledge. <u>However, studies show that salmon anglers are willing to pay for improved quality of recreational fishing and more importantly for preserving wild salmon stock</u>. For example, mean WTP estimates per angler vary from 8 EUR to 19 EUR per fishing day (Parkkila 2005, Håkansson 2008, Finnish Game and Fisheries Research Institute 2009, Parkkila et al. 2011). Moreover, results indicate high support (in most cases over 80 % of the respondents) for the implementation of the new management programmes aiming to recover the salmon stocks. The fair allocation of the fishing restrictions among different fisher groups seems to be important for the anglers. Interestingly anglers support the restriction of the sea fishery, but they are not willing to pay for the programme that would ban the commercial sea fishery completely.

The purpose of valuation studies is to make the non-market benefits explicit and comparable with other monetary measures. Thus, these mean WTP values per angler are typically aggregated by the number of people who will gain from the change, ie in case of recreational fishing by the size of the angler population in the river area that typically consist of both local anglers and visitors. The motives for recreational fishing seem to be various, such as importance of catching a salmon during the fishing trip, relaxing, good state of salmon stocks, which all are examples of factors affecting fishing experience and value of recreational fishing. This diversity of motives indicates that different ecosystem services are not completely exclusive but interlinked, which complicates estimation of value for recreational fishing. <u>Successful assessment of the economic value of recreational fisheries</u>

of Baltic Salmon necessitate more empirical valuation studies to be conducted in different countries and rivers with their own environmental and user characteristics. Particularly, the non-use value of preserving the wild salmon stocks should be estimated, which presumes survey data regarding public.

Sustainable future management of Baltic salmon

When applying the concept of ecosystem services in the context of Baltic salmon fisheries management, tackling trade-offs is unavoidable. This involves identifying the beneficiaries whose values and benefits need to be taken into account. Salmon is a part of marine and freshwater ecosystems and thus linked to the social systems at the catchment area. Free flowing rivers can provide a range of ecosystem services but if they are used to produce hydropower then their potential to maintain healthy fish stocks diminishes considerably (eg Karjalainen and Järvikoski 2010). Thus, the management of Baltic salmon and related ecosystem services requires consideration of trade-offs between benefits provided by salmon and benefits arising from the use of river to generate hydropower. In addition, trade-offs also exists between the provisioning and cultural services provided by salmon affected by the regulation of salmon catch and considering the allocation of catch between the commercial and recreational fishers (see below). Finally, the 'owners' of fishing right (ie the beneficiaries) change along the long migratory routes, impacting the availability and value of salmon to individual beneficiaries.

To compensate for the current loss of natural spawning areas hatchery-reared salmon has been stocked. However, this reared salmon may mix with the wild salmon in some rivers and cause a genetic risk particularly for small wild salmon populations. Due to this potential risk, it has been recommended that the releases would be gradually stopped: '...in the long-term, the practice of compensatory releases should cease. In order to preserve the genetic make-up of stocks used in compensatory releases, there is a need to establish a natural life cycle for such stocks in the wild.' (STECF 2009). However, the genetic risk is difficult to estimate. There is a need to use models to estimate how big proportion of the spawning migrating fish could potentially ascend other rivers than their home river or release area. The cost of stocking has also been found to exceed the benefits. However, the estimate of benefits does not account for economic value components like the existence or option values of the gene pool. Therefore, in some cases stocking can still be justified and/or worthwhile in socio-economic terms.

The advice to cease stocking has created a considerable discussion in the Baltic Sea states (eg Finland) as reared salmon component is still considered to be important for professional fishermen. Stocking can be replaced by increasing the natural reproduction potential by improving wild salmon passage in regulated rivers. On an average the total number of juveniles can be up to a couple of hundred per spawning adult female, and after the natural mortality in juvenile phase (post-smolt mortality) taking place in the sea the provided number of adult salmon by one spawner can be up to 10-15. However, those rivers with the high enough water quality that would enable salmon reproduction are mostly dammed. Thus, the increase in reproduction possibilities comes with a cost in terms of lost electricity or construction costs of fish ladders.

No estimates are available that would provide an indication of the overall costs and benefits of increasing wild Baltic salmon stocks by addressing its ecological requirements. In general, whether or not the increase in natural reproduction outweighs its costs depends on the number of adult salmon that return to spawn in their home rivers, which in turn is dependent on natural mortality and fishing pressure (ie fishing mortality). Fishing mortality can be controlled via international and national management measures. Highly productive species like salmon has a strong response to management actions particularly at the low stock status. Increase of spawners as a result of fishing regulations may increase quickly the recruitment. On high stock sizes, however, salmon has strong density dependent mechanisms during the early freshwater stage which effectively suppresses the recruitment.

At present the major wild salmon production occurs in rivers that have good quality of spawning and rearing habitats. However, there are also a number of salmon rivers where habitat improvements would be welcomed. Removing the migration obstacles and reducing the eutrophication would benefit the wild salmon production and particularly safeguard the biodiversity of Baltic salmon ecosystem. Salmon in the southern Baltic Sea rivers may have genetic features that are the result from an adaptation to warm summers and higher nutrient levels. These features may become increasingly important for the survival of Baltic salmon as the climate change continues.

Conclusions and lessons learned

Baltic salmon is a keystone migratory species in the Baltic Sea that plays a crucial role in maintaining the functioning of ecosystems and provides a range of socio-economic benefits, eg provisioning and cultural ecosystem services. However, at present estimates for economic value exist only for a fraction of these benefits. Protecting the long migration routes of salmon is a key factor for maintaining the range of important ecosystem services provided by Baltic salmon. This, however, involves a consideration of a range of trade-offs, both between different uses of the migratory rivers and between different beneficiaries of salmon. This leads to a complex framework of cultural, scientific, socio-economic and political aspects required to be taken into account when considering the future management of Baltic Sea salmon fisheries.

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