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Brook Lampreys of Life: Towards Holistic Monitoring of Boreal Aquatic Habitats Using 'Subtle Signs'

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Abstract

In this article the observation and spread of brook lamprey (*Lampetra planeri*) will be discussed as a bio-indicator and a 'subtle sign' in the boreal. Brook lamprey is a small non-parasitic freshwater lamprey species indicating good ecological health of aquatic habitats. This article presents knowledge

co-produced through a seven-year monitoring programme in the south boreal catchment area of the Jukajoki River, North Karelia, Finland. Over the past one hundred years, this basin has been negatively affected by human land use. Monitoring methods employed as part of this programme have included both rigorous scientific sampling and large-scale traditional and local knowledge (TEK) monitoring. International long-running community monitoring efforts are assessed to position these Finnish traditional knowledge flows. Examples provide for the discussion of new monitoring and restoration methods of boreal aquatic habitats and contribute to the new realisation of these landscapes that were once hidden and now positioned to emerge, providing the suitable social-geographical space is present and accessible to allow for that.

Key words: acidic soils, boreal basins, brook lamprey, ecological restoration, Finland, traditional knowledge

Brook Lampreys of Life: Towards Holistic Monitoring of Boreal Aquatic Habitats Using 'Subtle Signs' and Oral Histories

Introduction

*In December 2015, in boreal Finland, a local landowner (Kissapuro Oral History Tape 100516) detected a group of brook lamprey (*Lampetra planeri*) unexpectedly. He was digging with his shovel on the Kissapuro stream bank, when he detected these specimens in the sediment (Kissapuro Oral History Tape 100516). This unexpected discovery of a 'new' species demanding good ecological conditions for their survival was therefore under way using traditional knowledge.*

We will review the unfolding of the lamprey observation, subsequent events and its relevance for the monitoring of fish and fish habitats by providing narrative descriptions of the events themselves followed by relevant research analysis. We believe this is a good example of using traditional knowledge and science in tandem to achieve new discoveries of ecosystem health. We present the narrative of the events in italics to highlight them from the analytical parts of the paper.

Selected Study Area in the Boreal

Kissapuro local knowledge (Berkes 1999, Olwig 2008) observation kicked off a chain of important events challenging the existing, assumed notions of ecological monitoring in the area. Our study area was a south boreal catchment area of the Jukajoki River, located in North Karelia, Finland. It is a part of the larger Pielisjoki basin. Due to assumed poor ecological health of the sub-catchment area of Lake Jukajärvi, especially the Kissapuro Brook a monitoring process had been under way for a decade in the basin.

The Kissapuro sub-catchment area is 23.9 square kilometres in size (Kiiskinen 2013). The overall length of the Kissapuro Stream itself is seven kilometres (Kiiskinen 2013). Close to 30% of the catchment area of Kissapuro has been channelled and ditched for forestry management purposes. The soils contain large amounts of iron, and the low pH levels of the water are derived from the soil itself and aggravated by the industrial ditching and forestry. In theory, scientific literature supports the possibility of the bottom of Kissapuro Stream to be a natural habitat for brook lampreys, including their ammocoetes larvae (Yrjölä et al. 2015, Aronsuu 2017).

Kissapuro is a part of the Jukajoki river restoration actions. In the first years of the ecological restoration, between 2011-2013, the Kissapuro stream and catchment area was surveyed (Kiiskinen 2013) for erosion, selected acidic sites (resulting from the expected iron sulphates in the soils) and for its contribution to iron loading into Lake Jukajärvi. Goodwin et al. (2008) position the role of pH to be a key indicator for lamprey species. For Finland Myllynen et al. (1997) confirm the impact of acidity and iron as a negative driver of hatchability of lamprey roe and survival of newly hatched larvae (see also Mäenpää et al. 2001). Kiiskinen (2013) reported that the sub-catchment area of Kissapuro is responsible for 51,8 % of the total loading of iron into the lake Jukajärvi (total load of 43673 kg per annum, of which 22638 kg per annum results from Kissapuro). According to Kiiskinen (2013) Kissapuro is also producing 56,31 % of the total acidic discharge into Lake Jukajärvi.

At the time, in the early 2010s it was therefore determined, using these 'macro-indicators' (Degerman et al. 2016), that the Kissapuro sub-catchment area was like other parts of the basin, significantly damaged. Oral histories and traditional knowledge collected at the time (Mustonen 2013) also indicated that the delta of Kissapuro stream was suffering from various chemical processes and

nutrient and organic loading, resulting in sediment accumulation to the entry point of the stream at the lake.

River Lamprey as a Boreal Indicator Species

Schroll (1959) and Freyhof (2011) provide an overview of brook lamprey (*Lampetra planeri*) and in Finnish waters the situation has been investigated by Aronsuu and Virkkala (2014) and Yrjölä et al. (2015). It is listed under Annex II of the European Habitats Directive (Jazdzewski et al. 2016). According to them brook lamprey live in the same stream for their entire lifecycle. They live typically four-to-six years as ammocoetes larvae and as adults only from transformation in the autumn to spawning in the spring (Freyhof 2011).

Li et al. (2014) stress the role of water velocity, hardness and ammocoete abundance. Adults are at maximum 18 centimetres long. Typical habitat for the species is a small, ecologically healthy stream or a river (Aronmaa and Virkkala 2014). In Finland similar species and habitats suffer from river regulation measures, including impoundment, hydro peaking, dredging and embanking (Aronsuu et al. 2015).

Shasteen (2007), Grabarkiewicz and Davis (2008), Civas and Kesminas (2011), Li et al. (2014) and Jazdzewski et al. (2016) confirm brook lampreys to be intolerant of pollution and habitat disturbance, with their presence acting as an indicator (Degerman et al. 2016) of good water and substrate quality. Li et al. (2014) refer additionally to the cultural values various lamprey species have. Goodwin et al. (2008) confirm pH to be a significant factor for the brook lamprey, but also refer to underlying factors such as climate and weather, bedrock types, land uses and watershed capacity. Myllynen et al. (1997)

speculate that acidity combined with iron is a major negative driver for the lampreys, but there is a need for further investigation.

Ammocoetes larvae live in the clay sediment, with only their mouths protruding (Yrjölä et al. 2015). Adult brook lamprey inhabit the same stream beds, but prefer harder river bottoms than the larvae. After transforming from larvae into adults in late summer-autumn the brook lamprey does not eat anymore – rather the spawning is the last stage left prior to death (Freyhof 2011).

Aronsoo et al. (2015) provide a natural sciences link between lunar cycles, winds and lamprey behaviour on the coast of Finland. These signs are quite well known to subsistence and professional fishermen by experience. This is a good example of the multiple-indicator (Degerman et al. 2016) approach to monitoring aquatic ecosystems and provides ground for the lamprey to be a species that can act as a traditional knowledge marker for ecosystem health.

Materials Involved and the Context for Subtle Signs

It was a warm start of the winter. Snow was only just on its way and the soils were still rather warm. None of the brooks had frozen yet. A scientific team was dispatched to the site of the lamprey discovery (Kissapuro Oral History Tape 100516). The two parties, the landowner and the scientific team, proceeded to carefully survey other parts of the riverbank together. They detected dozens of brook lampreys in the sediment. The science leader for the field team sampled one of them in alcoholic preservative and documented the site and the species using digital cameras. The identity of the brook lamprey was subsequently determined in the local laboratory of the scientific team. This observation was made in early-December 2015 which would indicate the presence of adults overwintering in the sediment, preparing for the spawning next spring (Yrjölä et al. 2015).

In the Jukajoki River Basin, past damages have been mapped using science, field trips, interviews and oral history documentation (Mustonen 2013, Mustonen and Mustonen 2013). This has included field sessions using maps. Villagers have been asked to mark central themes of environmental change on these maps, including areas of fish populations, spawning areas, fish deaths, changes to water quality, iron-sulphate soils, bird surveys and severe weather phenomena. The early monitoring and observation materials (Kiiskinen 2013, Mustonen 2014) focused on the main themes of fish deaths, severe damages of aquatic ecosystems and soils suffering from acidic iron sulphates (Goodwin et al. 2008). These observations from the basin help to indicate the significance and relevance of integrated steps for holistic monitoring, management and, ultimately, restoration.

'Learning from the Lamprey' – Positioning Subtle Signs as a Method for Increased Monitoring

Aquatic landscapes in Finland (Lehtinen 2008) contain traditional readings of boreal catchment areas. The concept of “*subtle signs*” and their location inside local-traditional knowledges (Berkes 1999, Johnson et al. 2015) is a means to realising the ‘hidden’ emergence of a place, and temporal scales. We argue that the Northern discourses of traditional knowledge constitute a still emerging scale through which the cultural readings of land and waterscapes can be explored to reach the non-domination of a place in a more ‘just’ method (meaning here one that does not repeat the colonial top-down readings of the past) (Lehtinen 2008).

Subtle signs can only be detected through a combination of long-term residency in an area, in this case the Jukajoki River Basin, combined with a co-production of knowledge (Apgar et al. 2016) building on trust in the local socio-cultural matrix. They form a marker of the “background noise” of

a community that takes a long time to emerge. By nature they are therefore slow to be detected and understood in a given societal context.

Agencies of Subtle Signs in Monitoring

What constitutes and affects the agency of those monitoring agents who observe these subtle signs?

In human systems, the role of authorship and power relations affect the positions from which observations and public statements are and can be made. In the Jukajoki basin this dynamic operates, broadly, according to two factors:

- a. Power position of expert knowledge and discourses as instituted ways of assessing environmental change (Mustonen 2014)
- b. Internal village roles and positions: Fishing frequency, family orientation, land ownership, membership in hunting societies, gender (Mustonen and Mustonen 2013)

Subtle signs are therefore indicators of change that are embedded in discourses, knowledge and processes of the long-term engagements with socio-ecological systems. As a result, they are often placed in a non-power position in assessments of change, yet may contain crucial new data or observations.

In the case of the brook lamprey detection, we can assess this to be a ‘subtle sign’ in Kissapuro. It took place half a decade after the primary observations had been collected in the basin (Kiiskinen 2013). Many villagers felt that their observations and local-traditional knowledge was taken seriously during this on-going process. The landowner who identified the presence of brook lampreys felt confident in sharing his new (Kissapuro Oral History Tape 140716) observations about the lamprey. He had not participated previously in the documentation of oral histories, but was aware of the role of local-traditional knowledge in the restoration work taking place in the Jukajoki Basin.

The case of a discovery of brook lampreys in the Jukajoki basin in the boreal of Finland demonstrates that the scale of human and non-human presences requires a new approach, one that we position and call a “subtle sign”, a slow emergence of the hidden / invisible / traditional / unknown / marginalised in a landscape or in this case, a boreal catchment area, a natural interconnected whole in itself. The hidden may emerge into light, but only if proper cultural-ecological dialogue allows for the space for that to happen.

Results - Lamprey Detection Re-Aligns Monitoring Efforts

The following spring renewed interest in the monitoring of the Kissapuro stream. After the spring ice break-up on the stream, the landowner and the scientific teams proceeded to increase their monitoring of brook lampreys to detect the range and distribution of this species in the sub-catchment area (Kissapuro Oral History Tape 140716). At the same time the main goal of ecological restoration of the stream and its sub-catchment area proceeded. A secondary goal was to plan the restoration of salmon and trout spawning areas along the stream. The actual work proceeded with excavators in July 2016. The landowner was present on a second site when ecological restoration measures were carried out. He detected further presence of brook lampreys on the riverbank sediments approximately one kilometre from the original site of observation (Kissapuro Oral History Tape 140716). This seemed to indicate the presence of the brook lampreys along the whole of the Kissapuro Stream from Lake Jukajärvi towards the headwaters. The scientific team visited the site and confirmed these newer observations. The first site science sample contained a total of 5-7 ammocoetes / square meter. At the second site, in the Kissapuro Delta, a total of 10-12 ammocoetes / square meter were found (Tossavainen 2018).

Aronsoo (2017) says that, overall, very little is known about the expected amounts of ammocoetes / square meter in healthy boreal streams. According to him (2017) the presence of 10 ammocoetes / square meter could be a robust assessment of a healthy stream. Anything below 5 ammocoetes / square meter indicates poor water quality and living conditions (Aronsoo 2017). Using this indicator, the first results indicated a relatively good situation in the delta area of Kissapuro and medium living conditions for the brook lampreys in the middle part of the stream. Referring to the national registries of brook lampreys within a surrounding 50 kilometer radius, for example the comparative Kuusojä Stream, which is approximately 35 kilometers from Kissapuro, there is an observed population of brook lamprey, but status and trends for the species are largely unknown in the region (Luke 2017).

Monitoring Re-visited – Limnological Studies Expanded After the Lamprey

As a result of these findings, the scientific team expanded their fieldwork in the winter to early summer 2016 to assess all of the limnological situation of the Kissapuro Stream. A more thorough picture emerged from this fieldwork. While the ditches flowing into the stream occasionally demonstrated problems which are typical of iron sulphate soils with low pH levels and high concentrations of iron and manganese, the stream itself had quite typical pH levels during spring and early summer for a south Boreal stream, supporting habitats which sustain brook lampreys. More monitoring increased the scale and range observations of the brook lamprey in this stream.

Brook lampreys are hard to detect, prior to transformation (Yrjölä et al. 2015) due to their being present in the deep sediment. The observation made by the landowner thus provided new evidence of the presence of this species (Degerman et al. 2016) in the stream. As the brook lamprey requires ecologically healthy streams (Yrjölä et al. 2015) the previous understanding developed of Kissapuro

as an acidic stream with severe erosion problems was not a complete view (Myllynen et al. 1997, Goodwin et al. 2008, Kiiskinen 2013).

In this case, the local-traditional knowledge observation of brook lamprey proved to be a crucial bio-indicator (Degerman et al. 2016) of a better-than-expected health of the sub-catchment area of Kissapuro. Triggered by the traditional knowledge observation and in order to develop a better understanding of Kissapuro's ecological situation, scientific teams were dispatched along the stream and catchment to document and monitor the situation from early winter 2016 to summer 2016.

According to Myllynen et al. (1997) the presence of heavy iron loading combined with the acidic soils are a major negative driver for the survival of lampreys in the brooks and rivers of Finland. In the Kissapuro case the situation emerged to be far better than expected. It can be speculated that, while the acidity and iron are present in the Kissapuro stream, the large amount of groundwater that bursts into the system (Kiiskinen 2013) may potentially provide a balancing factor that enables the lamprey to survive (Myllynen et al. 1997). Ultimately, the scientific team was able to identify potential explanations for the discrepancy in previous assumptions and new observations and measurements.

Main science measurement data from different parts of Kissapuro Stream is summarized below, using indicators including pH, iron and manganese, characteristic of iron sulphate catchment areas, as well as benthic data to provide a view of the situation:

Acidity of the waters fluctuated according to the stream flow and season with a low of 4.43-4.51. It was 45 times more acidic water than the peak high of pH registered in the river. However, pH 6.17 resulted close to a 'normal' on boreal catchment areas. As expected high amounts of iron were

registered in the basin, at 1010 – 2380 µg/l, as well as manganese, 217 – 389 µg/l, due to the soil composition of the basin. Biodiversity of the brook is rather low on the Shannon-Wiener index for benthos (H' 1.33 – H' 1.92). This is present also in the species distribution that included *Chironomidae*, *Ceratopogonidae*, *Chaoborus spp.*, *Plecoptera*, *Trichoptera*, *Ephemeroptera*.

In this basin, once the ‘main’ or ‘power’ observations of ecosystem degradation had been reported and acted on, and the local-traditional knowledge observation network and process was maintained, combined with a rigorous presence of the scientific teams across the catchment area, the landowner felt confident and positive about sharing his new and relevant observation of the brook lamprey (Kissapuro Oral History Tape 140716).

Discussion

*The land owner is now in direct communications with the scientific team on a regular basis. Post-lamprey detection, he has conveyed the presence of otter (*lutra lutra*) and expansion of a range of ordinary fish species such as roach and northern pike upstream in the Kissapuro area. Meanwhile the scientific team has received a more comprehensive view of the whole sub-catchment area.*

Now in its seventh year, the Jukajoki Restoration Project has provided a platform and a space for local-traditional knowledge observations. Villagers trust that their knowledge will be taken seriously and thus the project provided a *social space* for a ‘subtle sign’ of brook lampreys to be reported and detected, and then confirmed by scientific measures. While the overall area is not large by international standards our research points to the need and benefits of a long-term engagement with aquatic ecosystems using both science and traditional knowledge to arrive at a more clear view of status and trends.

Traditional ecological knowledge, indigenous and local-traditional knowledge have received much attention in the past 25 years as a topic for environmental and climate monitoring (McDonald et al. 1997; Huntington 1998; 1999; 2000; 2011; Smith 2005; Sheridan and Longboat 2006; Krupnik et al. 2010; Danielsen et al. 2010; Alexander et al. 2011; Johnson et al. 2015). Berkes (1999) treats this knowledge as a knowledge-practice-belief complex where there is no separation between nature and culture.

McDonald et al. (1997) documented aquatic environmental observations of the Inuit and Cree in the Hudson Bay eco-region in the 1990s. By investigating oral histories and conducting community-based monitoring over several years, McDonald et al. (1997) were able to discern connections between seal behaviour and changes in sea currents, the impact of hydroelectric development on sturgeon, a local bio-indicator, and so on. We can define these nuanced trails of connections, impacts and interlinkages also as ‘subtle signs’ of interconnectivity that have been missing from assessments of development projects in the Hudson Bay region driven only by natural science approaches.

MacDonald (2000), a long-time scholar of the oral histories of the Inuit of Igloolik, Nunavut, Canada, has remarked: “Inuit traditional knowledge is characteristically personal, its acquisition and application, in varying degrees, specific to communities, families and individuals.” His views are guided by a coordination effort spanning over 30 years to document Inuit knowledge in one community, Igloolik in Nunavut. MacDonald (2000) provides us with a rare window into long-running community monitoring and oral history work.

Discovery of the brook lamprey on Kissapuro seems to be in line with the results obtained by MacDonald (2000) in a long-running community-based oral history project in Arctic Canada, as well as cross-species documentation from Hudson Bay (MacDonald et al. 1997).

The local knowledge holder does not necessarily need to position his or her observation into a matrix of ecological relevance. It is enough that the observation emerges as a relevant contribution in the current endemic knowledge-practice-belief complex (Berkes 1999) on the ground. It has inherent value. The literature surrounding cultural knowledge traditions interprets knowledge as documented. We should appreciate the situated existence and presence of these wisdom traditions in themselves, not only as a 'source' of data. Smith (2005) has successfully pointed to the colonial role of research conducted in relation to Indigenous and local-traditional societies in the past. Special care and context is needed in these partnerships.

How do we then decide which observations are 'relevant' (Smith 2005)? A secondary question connected with this is naturally – who are these observations relevant to? As Mustonen (2014) demonstrates for the Jukajoki Basin, relevant discourses and knowledge production are very much about power and the ways in which this power operates in the governance of natural resources. On the other hand MacDonald (2000) and McDonald et al. (1997) demonstrate that traditional and Indigenous knowledge have their own endemic relevance to the knowledge users and holders, irrespective of the interface with science or 'outside' society.

Data from limnological scientific measurements regarding brook lamprey habitat and the sub-catchment area of Kissapuro produced a more detailed view compared with Kiiskinen's (2013) investigations from 2012-2013 (Tossavainen 2017). As the bio-indicator brook lamprey

demonstrated, the acidity was not as low as expected on the primary measurements taken earlier. This is an important lesson for future monitoring efforts of streams, brooks and small rivers.

Conclusions

The discovery of the lamprey and the subsequent status of the ecological health of Kissapuro was made possible because of the awareness of the local landowner combined with the openness of the researchers to listen and follow-up in a collaborative manner. This process also contributed to self-esteem and community knowledge cohesion as the observations of an unexpected event were taken seriously and contributed to a new dialogue between science and wisdom traditions building on traditions and ways of life in the boreal.

Our example presents important lessons to be learned for future monitoring efforts. Results here indicate that a long-term, multi-year engagement with a site may foster new results. Engagement with traditional knowledge in culturally appropriate, sometimes slow, time-consuming ways (MacDonald 2000, Huntington 2011) sharpens the view of monitoring and provides diversity and scale to the observations. Trust is essential while engaging with local communities (McDonald et al. 1997). Challenging the top-down research agenda by providing mechanisms that are culturally appropriate can benefit from long-term commitments.

Relatively little discussion has developed on the role of traditional knowledge as a source of information for ecological restoration (Mustonen and Mustonen 2013, Mustonen 2013), especially for aquatic ecosystems. It has not either been seen often as a scale issue. We have documented experiences from a seven-year, on-going ecological restoration project of a south Boreal basin in North Karelia, Finland – the Jukajoki catchment area.

Take-Home Messages from the Lamprey Discovery

In the case of the brook lampreys of the Kissapuro Stream, several similar themes emerge in this Finnish-Karelian sub-catchment area, though on a different scale. Villagers felt there was a *social space* to share their (marginalized) observations, which, combined with limnological measurements, demonstrated a more nuanced picture of aquatic ecosystem health through the presence of a bio-indicator species.

This process raises several important questions for the future of ecological monitoring and even traditional knowledge projects. First, MacDonald (2000) seems to be correct in demonstrating that the quality and depth of observations will improve if the monitoring is undertaken continuously over a long period of time (in Igloolik 30 years, in Jukajoki seven years and still running). A take home message from here is then that not all observations and ‘data’ will necessarily emerge during a project cycle, which may last between just one and three years.

Second, the cultural context for sharing observations (a forest setting in this case) provided for a comfortable and culturally appropriate social environment for the local community and village person to interact and share his observations. As the space for including traditional knowledge observations had been established quite well during the preceding six years of the Jukajoki Project, a forum existed for new observations to be exchanged. The presence of brook lampreys in the stream was unexpected (Huntington 2011) but proved to be crucial for improved monitoring of the stream.

Thirdly the presence and participation of the villages of Selkie and Alavi in the Jukajoki Restoration Project seems to be in line with the community experiences described by McDonald et al. (1997)

from the Hudson Bay eco-region. It was not so important to offer comparative scales of change, rather the cultural appropriateness of the work demonstrated similar positive outcomes for community engagement.

Uses of Traditional Knowledge in Ecological Restoration

We investigated the case of an observation regarding brook lampreys and the ways in which this observation, combined with scientific measurements, has co-produced a more holistic view of the Kissapuro Stream and sub-catchment area that is useful for ecological restoration. Natural scientists such as Aronsuu and Virkkala (2014) and Aronsuu et al. (2015) also support ecological restoration in streams, including gravel beds, to support brook lamprey habitat and survival. Goodwin et al. (2008) state that multiple spawning sites in the headwaters of a river system such as Kissapuro may compensate for environmental drivers negatively affecting brook lampreys. Since the discovery of the brook lamprey the ecological restoration work in the larger Jukajoki basin has paid attention to traditional knowledge observations when trout and grayling spawning areas are restored. Additionally, observations of past populations and presence of European crayfish (*Astacus astacus*), since lost, have been recorded for restoration purposes (Tossavainen 2018).

The aim of improved monitoring also with traditional knowledge should be towards more holistic management and monitoring of natural resources and ecosystems. While the role of traditional knowledge has emerged in the past 25 years as a field of relevance, the ‘subtle signs’ embedded in local communities’ knowledge may emerge best through long-term oral history projects and community-based monitoring.

These efforts may need to be maintained for decades to succeed. They are in a position to open up the hidden / invisible / traditional / unknown / marginalised of a landscape, getting us closer to a “just” understanding of places and their characteristics, avoiding the equity problems of the past associated with top-down governance and science (Lehtinen 2008)

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