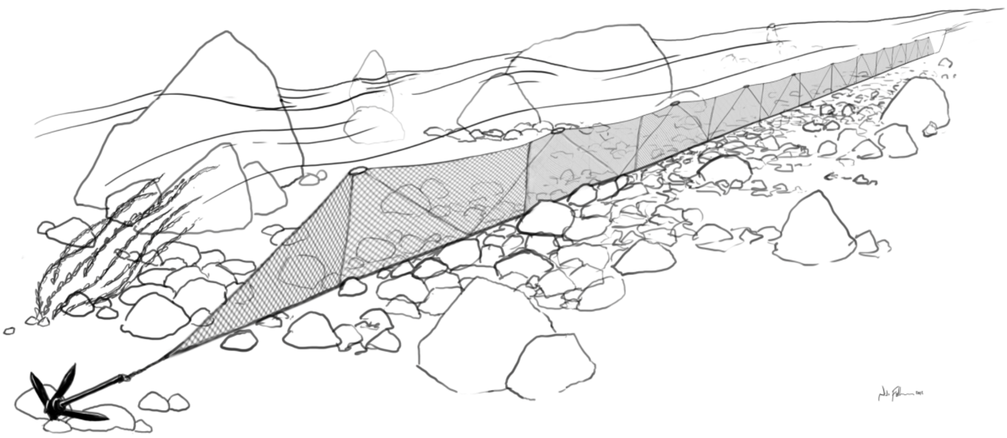
Sveriges lantbruksuniversitet
Swedish University of Agricultural Sciences

Faculty of Natural Resources and
Agricultural Sciences

Fish sampling in lotic water

– A study of the efficiency of the novel Nordic multi-mesh Stream Survey Net.

Anders Eidborn



Department of Aquatic Resources
Master's thesis • 30 hec • A2E
Master Programme in Biology Limnology - Ecology and Environment of Inland Waters, 120 c
Drottningholm 2016

Fish sampling in lotic water – A study of the efficiency of the novel Nordic multi-mesh Stream Survey Net.

Provfiske i strömmande vatten – en studie av effektiviteten hos det nya strömöversiktsnätet.

Anders Eidborn

Supervisor:	Arne Fjällning, Swedish University of Agricultural Sciences, Department of Aquatic Resources
Assistant Supervisor:	Erik Degerman, Swedish University of Agricultural Sciences, Department of Aquatic Resources
Examiner:	Erik Petersson, Swedish University of Agricultural Sciences, Department of Aquatic Resources

Credits: 30 hec
Level: A2E
Course title: Independent Project/Degree Project in Biology - Master's thesis
Course code: EX0565
Programme/education: Master Programme in Biology Limnology - Ecology and Environment of Inland Waters, 120.0 c
Place of publication: Drottningholm
Year of publication: 2017
Cover picture: N. Fällman
Online publication: http://stud.epsilon.slu.se

Keywords: NSSN, gill net, Nordic multi-mesh Stream Survey Net, lotic, fish community

Sveriges lantbruksuniversitet
Swedish University of Agricultural Sciences

Faculty of Natural Resources and Agricultural Sciences
Department of Aquatic Resources
Institute of Freshwater Research

Abstract

A free-flowing stream can offer several ecosystem services. Fish are one of these, and are an important resource for society, both as a food source and as a biological indicator of the water quality, which gives knowledge of the overall health of the stream. The lotic environment in fresh water streams is an important habitat for many fish species.

The standard way to catch fish in lotic environments is electrofishing, which in most cases is performed by two persons wading in shallow, hard-bottom parts of the stream with clear water. If the water is deeper an electrofishing boat may be used, but it may be hard to find launching spots for the rather big boat, making it impossible to reach some parts of the river.

The Nordic multi-mesh Stream Survey Net (NSSN) is a gill net that is designed to catch fish in lotic environments. The net follows the same idea as Norden nets, with varying mesh size in 12 panels. It works in streaming and still standing waters with a depth of 0.5 meters or more and is deployed on the bottom, parallel with the stream.

This study tries to evaluate the efficiency of the NSSN. The survey was performed in Hedströmmen in Sweden during three weeks in July 2015 and was conducted in five sites. The fish community was sampled with the novel Nordic multi-mesh Stream Survey Net. In all, 2,702 fish were caught from 12 different species. To determine the efficiency of the net the CVM-value was calculated for species richness, proportion of individuals and biomass in each location. The data was also compiled to species accumulation curves and compared to data from electrofishing conducted in the same locations.

The result in this study shows that the NSSN works well and can be used as a supplementary sampling method when surveying a lotic environment with electrofishing.

Keywords: NSSN, Nordic multi-mesh Stream Survey Net, lotic, fish community, gill net

Table of contents

1 Introduction

The EU Water Framework Directive from 2000 declares that all European waters should reach good conditions by 2015. To reach these goals, the Swedish government has come up with a number of environmental objectives that should be achieved by 2020. One of these goals, called 'Flourishing Lakes and Streams', strives to reach the objective that lakes and streams must be ecologically sustainable, and their variety of habitats should be preserved. Natural productivity, biodiversity, cultural assets and the landscape ecological and water-conserving function must be preserved, while the conditions for recreational assets are safeguarded (Swedish Agency for Marine and Water Management 2014).

The community in a stream is a good indicator of the water quality and overall health of the stream (McDowell 2009), and there are several ecosystem services that are dependent on free-flowing waterways and streams. Fish are one of these ecosystem services and are an important resource for society, both as a food source and as a biological indicator (Auerbach *et al.* 2014). In addition to this societal contribution, the recreational fishing industry in Sweden had a turnover of 5.8 billion Swedish kronor in 2013 and involved 1.6 million fishermen (Swedish Agency for Marine and Water Management 2013). The lotic environment is important also for many other fish species, both as a permanent habitat where some live their entire lives and as temporary habitats, serving as migration routes, spawning grounds and foraging sites for others. For example, some salmonids (such as salmon, brown trout and whitefish), which are among the most popular fish for recreational fishing, are anadromous, and eels are catadromous, migrating from an ocean or lake into a freshwater stream to spawn (Degerman *et al.* 2001). Clearly, stream dependent fish species are a valuable asset to Swedish livelihood, and as such, their habitat should be protected, hence it is important to examine fish communities in lotic environments.

The standard method to perform test fishing in lotic environments is electrofishing (SS-EN 14011:2006), where an electrical field is produced in the water at the lower end of a handheld pole. This affects the fish and causes immobilization, making them easy to capture with a hand held net. Electrofishing is cost effective, and few fish suffer injuries from the procedure (Beaumont *et al.* 2002), but it also has its disadvantages. Electrofishing works best in shallow, clear waters where wading is possible. If the location has high conductive water or soft bottoms, it may be a hinder to perform electrofishing (Sutherland 2006).

If the water is deeper, an electrofishing boat may be used, but the electrical field that is applied in this instance only reaches a maximum of 2-3 meters deep (Bergquist *et al.* 2007). As the electrofishing boat is quite large and heavy, it requires an appropriate launching point, which could make many parts of the river impossible to reach.

Some countries, such as Sweden, require the operator of electrofishing gear to have a license to use the equipment, which itself is technically advanced, expensive and requires regular maintenance. According to Degerman *et al.* (2012), most contemporary electrofishing techniques focus on catching juvenile and other small fish, meaning the results could underrepresent the fish community in the stream. The success of electrofishing may also vary among operators, as it requires a good technician to handle the gear (Sutherland 2006).

A review of electrofishing data conducted in southern Sweden from the 1980s until 2010 shows that most samplings were made in lotic waters with hard bottoms. While 100% of the programs included data from this type of habitat, soft bottoms were only included in 11% of the programs and calm water only in 4%. A greater variation in sampled habitats is therefore desired, as this may translate to a more varied fish population. (Degerman *et al.* 2010).

While electrofishing is limited to sampling specific habitats, there are other ways to catch fish. The standard way to monitor the fish fauna in lakes is Norden nets (SS-EN 14757). The Norden net, which is a type of gill net, gives a good overall picture of the fish community regarding number of species, individual size and relative density (Kinnerbäck 2001). But when investigating fish fauna in lotic waters, ordinary gill nets, e.g. Norden nets, are not suitable, as the water current may drag down the float line or lift the lead line, making the net less efficient.

When investigating the total fish fauna in a river it is important to catch all sizes of fish. Traps, e.g. fyke nets (i.e. bag-shaped nets, held open by hoops), work well and are often used in streaming water, but the size of mesh and entries determine the selectivity of caught fish. The traps must also be checked often to prevent predation and cannibalism as it may affect the results (Sutherland 2006).

The idea with the Nordic multi-mesh Stream Survey Net (NSSN) is to catch fish in lotic environment where electrofishing is not possible (Fjälling *et al.* 2015). Investigating the fish community with gill nets is a cost effective method, but removing the fish and keeping the nets clean and maintained demand a lot of time. The nets also have a big drawback in that the fish caught usually die (Sutherland 2006). A previous study (Johansson 2011) has shown that the efficiency of the NSSN is in some cases equivalent to fishing with fyke nets. Johansson also reports that he thinks the NSSN is easier to use and deploy than fyke nets, and can therefore be motivated to be used where electrofishing is not feasible, despite their higher risk for fish injury and mortality.

According to Kinnerbäck (2001), test fishing with Norden nets have a considerable advantage when it comes to statistical evaluations, as every net can be seen as a sample of the total fish community. But to get statistically acceptable precision in the survey, the sample size has to be large enough and should be designed to cover the main habitats. As the NSSN works in a similar way to the Norden nets, these considerations should also be valid for NSSN.

The aim of this study is to evaluate the efficiency of the Nordic multi-mesh Stream Survey Net. How many netting effort does it takes to survey a lotic environment? In the discussion I address the question of whether the NSSN can be used as a standard method in lotic waters where electrofishing is impossible.

2 Materials and Methods

2.1 Locations

The sampling was performed over three weeks in July 2015 in river Hedströmmen (Swedish coordinate grid RT90; 6594553, 1515075) in Västmanland, Sweden. The river was sampled at five different locations, from the river mouth at Lake Mälaren upstream to Uttersberg. All locations are shown in Figure 1. A full size map is found in Appendix A. In total 142 nettings were done over 18 consecutive nights, with Table 1 describing the locations and corresponding number of nets deployed.

Hedströmmen empties into the most western part of Mälaren, which is the third largest lake in Sweden. The sampling in the lake was performed close to the river outlet (6594553, 1515075) in two habitats, vegetated zones and deeper water - approximately 4 meters deep. Mälaren is the migration pool from which fish can swim upstream into Hedströmmen.

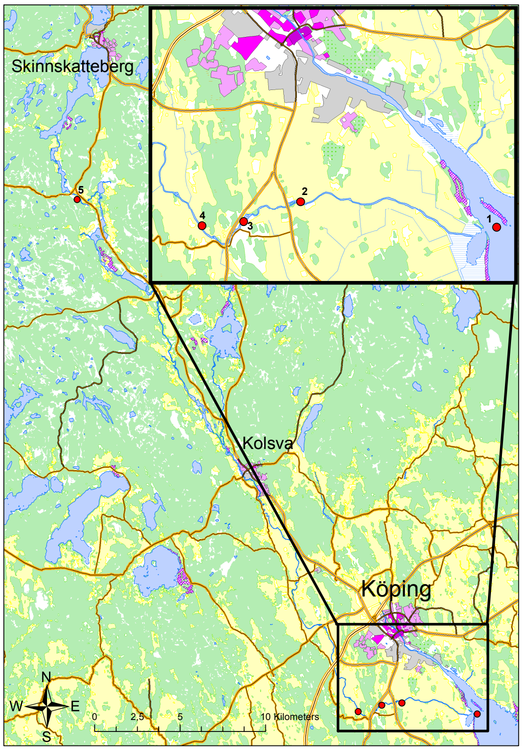


Figure 1. Locations sampled in the study. 1. Mälaren, 2. Kallstena, 3. Östuna, 4. Stora Forsby and 5. Uttersberg.

Going upstream from Mälaren, the first hydropower station is found at Kallstena (6595207, 1510878), almost 5 km from the lake. The sampling was performed downstream from the power station where the three required habitats were found in several locations. At Kallstena a fish ladder was in use since 2012 (Fiskevårdsteknik 2013), and the fish can migrate up to the next sampling location, Östuna (6594760, 1509421). This is a 1.5 km long part of the river where all three habitats are accessible to the fish; the sampling was performed in each one of these.

The location above Östuna hydropower plant is called Stora Forsby (6594285, 1508903) and is approximately 7 km long. No migrating fish from Mälaren can reach this location, as the dam lacks any bypass channel or fish ladder. Only a few nettings were made at this location, as most of the nets were sabotaged or stolen on the third night. No nettings were performed in the 'running water' habitat.

Uttersberg (6624858, 1492489) is situated several kilometers upstream from the other locations, and the river section is about 1.5 km long. Numerous dams along the way hinder upstream migration from the other locations. At Uttersberg a small dam from an old mill hinders upstream migration to the lake Nedre Vättern. Sampling was done below the dam, and since the water from the lake spills over the small dam, downstream migration from the lake into Uttersberg is possible.

All coordinates are written in the Swedish coordinate grid RT90 format.

Table 1. Number of nets used each night and the distribution between the habitats. (1) Two nets were sabotaged during the night and found on land. (2) All nets were sabotaged during the night. Some were found on land, others were stolen.

Date	Location	Number of nets	Stream	Veg.	Deep
06-Jul	Uttersberg	3	1	1	1
07-Jul	Uttersberg	8	3	2	3
08-Jul	Uttersberg	8	2	3	3
09-Jul	Uttersberg	8	3	3	2
10-Jul	Mälaren	8	0	5	3
11-Jul	Mälaren	8	0	4	4
12-Jul	Mälaren	8	0	4	4
13-Jul	Kallstena	9	6	2	1
14-Jul	Kallstena	9	0	3	6
15-Jul	Kallstena	9	4(1)	0	5
16-Jul	Kallstena	8	2	1	5
17-Jul	Östuna	8	3	3	2
18-Jul	Östuna	8	3	1	4
19-Jul	Östuna	8	4	2	2
20-Jul	Östuna	8	3	2	3
21-Jul	Stora Forsby	8	0	4	4
22-Jul	Stora Forsby	8	0	5	3
23-Jul	Stora Forsby	8(2)	5	3	0
	Tot:	142	39	48	55

The net was placed in three different habitats in each location: running water, calmer water close to vegetation and slow running, deep water. The nets were deployed from a small aluminum boat by two persons or in some cases by wading in the water. As the NSSN is a passive method, its success in catching fish depends on the fish activity and behavior. The fishing was therefore performed overnight, deploying the nets at night at 18-19 and retrieving them in the morning at 7-8, to cover both dusk and dawn when the fish are most active

(Vašek *et al.* 2009). All fish were then sorted by species, weighed in grams and measured to the closest millimeter in standard length.

2.2 Habitats

Fish are not randomly distributed in the aquatic environment, as each species occupies its own niche. Ontogenetic preferences dictate where species move throughout their lifecycle, with fish preferring different habitats at different sizes for example. In order to representatively sample all species of fish in the stream, the nets had to be distributed over all existing habitats (Kinnerbäck 2001). The three main habitats were identified as running water, vegetation and deep water. The water depth measured from 0.5 meters down to about 5 meters.

Running water was defined by the presence of some riffles and skims in the water. The depth was between 0.5 – 1.5 meters.

The vegetation habitat primarily existed close to water lilies (*Nymphaeaceae*) or reeds (*Phragmites australis*), and the water was often calm or slow-running. The depth was between 0.5 – 2.3 meters.

Finally, the deep-water habitat existed mainly in the center of wider parts of the stream, where the water velocity was slow and the depth was between 2-4 meters.

Figure 2: In shallow water the netting can be made while wading. Here a NSSN is being retrieved in the habitat "vegetation" in Östuna. Photo: Anders Eidborn

2.3 The Nordic multi-mesh Stream Survey Net

The Nordic multi-mesh Stream Survey Net (NSSN) is constructed in the same way as the Nordic net, using identical ordering of the 12 panels and similar size of the mesh, reaching from 5 mm to 55 mm. The total fishing length of the net is 18 meters, with each section measuring 1.500 mm. The fishing height is 700 mm, and the net stretches to 900 mm, providing a total fishing surface of 12.6 m^2 (Fjälling *et al.* 2015).

The net is deployed at the bottom of the stream, parallel with the water current, fastened with an anchor to the lead line facing upstream, and marked with a buoy fastened to the lead line facing downstream (Figure 3). As with Norden nets, NSSN are left overnight, covering times in the evening and morning when fish are most active (Vašek *et al.* 2009).

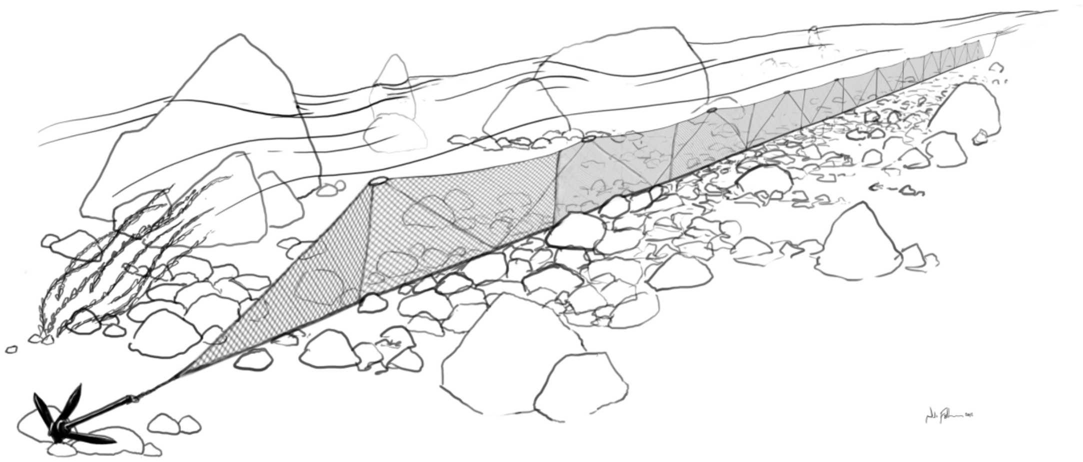


Figure 3 The NSSN shown as it is designed to rest on the bottom of the stream, fastened with an anchor and marked with a buoy. Illustration by N. Fällman

2.4 Statistics

2.4.1 Expected number of fish species

The information about the expected number of fish species in the different locations in Hedströmmen was taken from electrofishing data and reviews of literature (SERS 2015, Fiskevårdsteknik 2013, Degerman *et al.* 2001, Näslund *et al.* 2013). The catchable species differ between the locations due to accessible habitats, season and migration possibilities (Table 2, section 3.1).

2.4.2 Species not expected to be captured in this study

Some species that are present in the migration pool and parts of the river are not catchable with gill nets, e.g. eels (*Anguilliformes*) and lampreys (*Petromyzontiformes*), as the NSSN is not designed to catch fish with an elongated body shape.

Species like ide (*Leuciscus idus*), common whitefish (*Coregonus lavaretus*), asp (*Aspius aspius*) and vimba (*Abramis vimba*) migrate up into rivers to their spawning grounds in the springtime and return to the migration pool as soon as the breeding period is over. Other species, such as burbot (*Lota lota*), vendace (*Coregonus albula*) and fourhorn sculpin (*Myoxocephalus quadricornis*), stay in the lake hypolimnion during the summer, meaning these species will not be caught in Hedströmmen in the summer (Näslund *et al.* 2013, Degerman *et al.* 2012, Nielsen and Svedberg 2006).

In this study, none of the above listed species was expected to be captured in the NSSN, as the sampling was made in July and the maximum fishing depth was approximately 4 meters. The water temperature in Hedströmmen was never below 18 degrees Celsius. When calculating the efficiency of the NSSN, these species were not included.

2.4.3 Accumulation curves

An important consideration in fish sampling seeks to answer the question, how many netting efforts need to be made to catch all catchable species in a single location? To be able to perform a sampling that gives a result with an acceptable precision, while at the same time keeping the expenses and workload low, it is crucial to use the minimum number of nettings required to achieve an adequate precision. In order to evaluate whether fishing with NSSN effectively represents the number of species present, a comparison can be made between the number of species caught and the number of fishing efforts performed.

Species accumulation curves, where the cumulative species number is compared to the number of nets used, is a good way to test the efficiency of a sampling method. However the order in which the test results are reported may affect the accumulation curve. Colwell & Coddington (1994) report that to avoid this, a randomization should be performed at least 50 times, with 20 randomizations already giving more reliable results than data not randomized. In this study the data were randomized by a bootstrapping model, 100 times for each location before the curves were plotted. Bootstrapping is a resampling technique used to obtain estimates of summary statistics. In this case resampling means drawing randomly with replacement from a set of data points, i.e. the original data obtained during our fieldwork. The data were processed in Excel, using a macro called 'AccuCurve' (Drozd & Novotny 2010). The results from the curves were extrapolated and a trend line equation was used for each location to determine how many netting efforts were needed to catch all fish species present. Since the slope of the trend line decreases as more samples are added, a significant amount of nets will theoretically be needed to catch every species, especially in locations with great diversity.

Another way to determine the efficiency of the NSSN with respect to sampling species is to determine how many nettings are needed to reach a point where additional nettings no longer contribute to a significant increase in precision. There is not a certain value of the slope where this is true, as it depends on the cost of each sample and the value of the results.

As a rule of thumb, the most effective sampling number occurs when a doubling of netting efforts failed to catch a new species.

2.4.4 CV- and CVM-value

In order to quantify the relative abundance of different species, number of individuals and biomass of fish in the sampled location and assess if the result is representative, we need to know how much the catches vary. When trying to make an estimate of the fish population, it is important to include information on the average estimates accuracy, which is described using standard deviations and confidence intervals.

By calculating the coefficient of variance (CV) for the entire test fishing area as well as for the test fishing in individual habitats, we can get an idea of how representative the estimate is. The CV-value is a comparison between the standard deviation and the mean value, measured in percentages. By using the CV-value, comparisons of the variation between populations that have different means can be made.

A CV-value that is less than 20% indicates an acceptable estimate of the abundance (Pollock *et al.* 1990), although Degerman *et al.* (2012) says that the required level of the CV-value is not as high when using long-term monitoring.

To calculate the CV, the following formula was used:

$$CV = standard\ deviation/average$$

When this formula was used and graphs were created from the results, it showed no improvement when more samples were added. Perhaps the average value was too low, which is consistent with the assertion from Degerman *et al.* (2012) that the CV-value works best with high mean values.

Additionally the CVM-value (coefficient of variance of the mean value) was calculated with the formula:

$$CVM = sd/(CPUE * \sqrt{n})$$

Where *sd* is the standard deviation, *CPUE* is catch per unit effort (an average of catch per net) and *n* is the number of nets used. This measure of variation takes into account the higher precision normally acquired with increased sample size. Also when CVM is used, a value of 20% or lower indicates a good result.

To calculate the fewest number of nets needed to reach a certain value of CVM, the above formula can be rearranged to:

$$n = (sd/[(CPUE) * CVM])^2$$

Where *CVM* can be changed to the sought value, for example 0.2 (20 %) (Kinnerbäck 2001, Pringle 1984, Nyberg & Degerman 1988).

3 Results

During the fishing in Hedströmmen, eight or nine nets were used each night and a total number of 192 nettings were made during the summer. Of the 2413 fish caught, the most common one was roach (*Rutilus rutilus*) (29%) followed by perch (*Perca fluviatulis)* (25%) and white bream (*Abramis bjoerkna*) (11%). The remaining 35% was a mix of bream (*Abramis brama*), bleak (*Alburnus alburnus*), chub (*Leuciscus cephalus*), rudd (*Rutilus erythrophthalmus*), northern pike (*Esox lucius*), European smelt (*Osmerus eperlanus*), bull-head (*Cottus gobio*), pike-perch (*Stizostedion lucioperca*) and ruffe (*Gymnocephalus cernu-us*).

No eels were caught during the sampling, but signs of them were sometimes visible in the nets as slime rings. No data of these signs were collected.

3.1 Caught fish

There are in total 33 fish species in Mälaren, which theoretically are catchable with the NSSN, but some of these are very rare (Table 1) and are likely to go unsampled. In Hedströmmen 17 different fish species are listed in available literature (Fiskevårdsteknik 2013, SERS 2015). As shown in Table 2, the fish community is slightly different among the different locations in Hedströmmen, and some of the species will not be present or catchable during the sampling period. The total number of catchable species during the sampling peri-od is listed in Table 2.

Table 2. The present fish species at the different locations, according to literature reviews, and comments on the chance to catch them with NSSN. The number in the boxes shows in how big part of the nets the species was caught. a) Lampreys and eels do not get caught in gillnets b) The SERS-data for this location is taken from the location Ekebybro, situated higher up in the river. Only 16 nettings were made in this location, and only the habitats vegetation and deep were sampled. (1) Ide only migrates upstream in the autumn and spends the summer in lakes. (2) Asp migrates in the spring, and after spawning it returns downstream. (3) European smelt migrate in the spring to spawning areas. (4) Vendace do not migrate into streams. (5) Vimba migrates in the spring (Degerman *et al*. 2001, Fiskevårdsteknik 2013, Näslund *et al*. 2013, SERS 2015).

Common name	Scientific name	Mälaren	Kallstena	Östuna	Stora Forsby [b]	Uttersberg
River lamprey	Lampetra fluviatilis	(a)				
Brook lamprey	Lampetra planeri	(a)				
European eel	Anguilla anguilla	(a)	(a)	(a)		
Zope (blue bream)	Abramis ballerus					
White bream	Abramis bjoerkna	95.5%	21.9%			
Bream	Abramis brama	31.8%	6.3%			15.4%*
Zanthe (Vimba)	Abramis vimba		(5)	(5)		
Bleak	Alburnus alburnus	90.9%	21.9%	21.9%		11.5%*
Asp	Aspius aspius		(2)	(2)		
Crucian carp	Carassius carassius					
Carp	Cyprinius carpio	(rare)				
Chub	Leuciscus cephalus		9.4%	6.3%	26.7%	
Ide (Orfe)	Leuciscus idus		(1)	(1)		
Sichel (Chekhon)	Pelecus cultratus	(rare)				
Minnow	Phoxinus phoxinus					
Rudd	Rutilus erythrophthalmus	18.2%				23.1%
Roach	Rutilus rutilus	90.9%	87.5%	87.5%	86.7%	100.0%
Tench	Tinca tinca					
Spined loach	Cobitis taenia					
Sheatfish (wels)	Silurus glanis					
Northern pike	Esox lucius	4.5%	3.1%	6.3%*	6.7%	3.8%*
European smelt	Osmerus eperlanus	22.7%	(3)			
Rainbow trout	Oncorhynchus mykiss	(rare)				
Salmon	Salmo salar					
Brown trout	Salmo trutta					
Vendace (cisco)	Coregonus albula	(4)				
Southern densely-rakered w	Coregonus nilsoni	(rare)				
Common whitefish	Coregonus lavaretus					
Burbot	Lota lota					
Three-spined stickleback	Gasterosteus aculeatus					
Nine-spined stickleback	Pungitius pungitius					
Bullhead (Millers thumb)	Cottus gobio		3.1%	3.1%		
Fourhorn sculpin	Triglopsis quadricornis					
Perch	Perca fluviatilis	95.5%	84.4%	65.6%	66.7%	76.9%
Pike-perch	Stizostedion lucioperca	33.3%	3.1%*			
Ruffe	Gymnocephalus cernuus	81.8%	37.5%	31.3%*	53.3%*	30.7%
Flounder	Platichthys flesus					
Total NSSN-catchable fish in the sampling period		33	12	11	8	10

Caught in at least 25% of the nets

Caught, but at lower frequencies

Present, based on other data

* Caught in NSSN, but not recorded anywhere else

3.2 Accumulation curves of caught species

The number of species caught in each location was compiled into accumulation curves, where the order of the NSSN was randomized 100 times for each data point (Figure 4). Equations for the trend lines and the calculation of how many nettings need to be done to catch all species at each location is presented in Table 3.

An average value for all locations was calculated and added to Figure 4. From this, the point where a doubling of netting efforts fails to catch a new species was calculated, which is reached at approximately 16 nets. A doubling from 16 to 32 nettings only results in 0.5 new species.

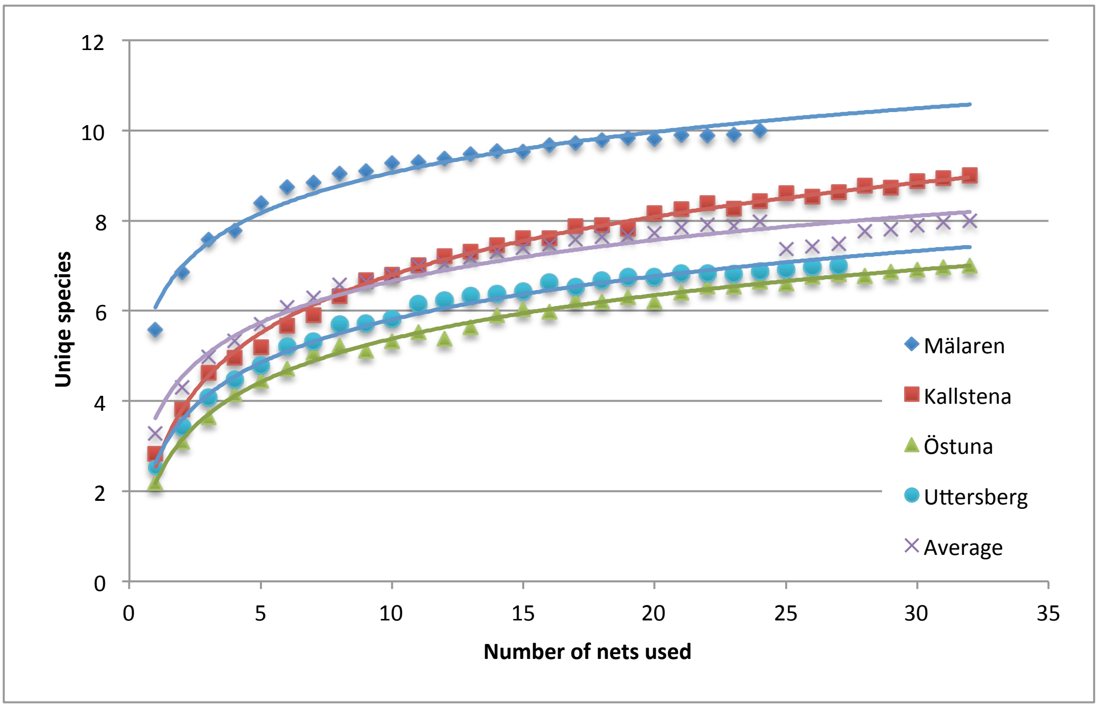


Figure 4. Accumulation curves with trend lines. Shows the number of unique species caught with the NSSN over time (number of netting efforts) at four different locations. The trend line equation is used to calculate how many nettings that needs to be conducted to catch all catchable species. The location Stora Forsby was not included due to too low number of nettings.

Table 3. Trend line equation and the calculated number of nets (x) needed to catch all catchable species (y) at each location (based on table 2).

Location	Trend line equation	No. of species (y)	No. of nettings (x)
Mälaren	y = 1.2992ln(x) + 6.0747	33	1 billion
Kallstena	y = 1.8606ln(x) + 2.5134	12	164
Östuna	y = 1.3935ln(x) + 2.1731	11	564
Uttersberg	y = 1.385ln(x) + 2.6187	10	206
Average	y = 1.3214ln(x) + 3.6135		

3.3 CV-value

The CV-value was calculated for the catch rate of species, number of individuals and biomass on all locations from the mean value and standard deviation. The results were compiled to create graphs. One example is shown in Figure 5.

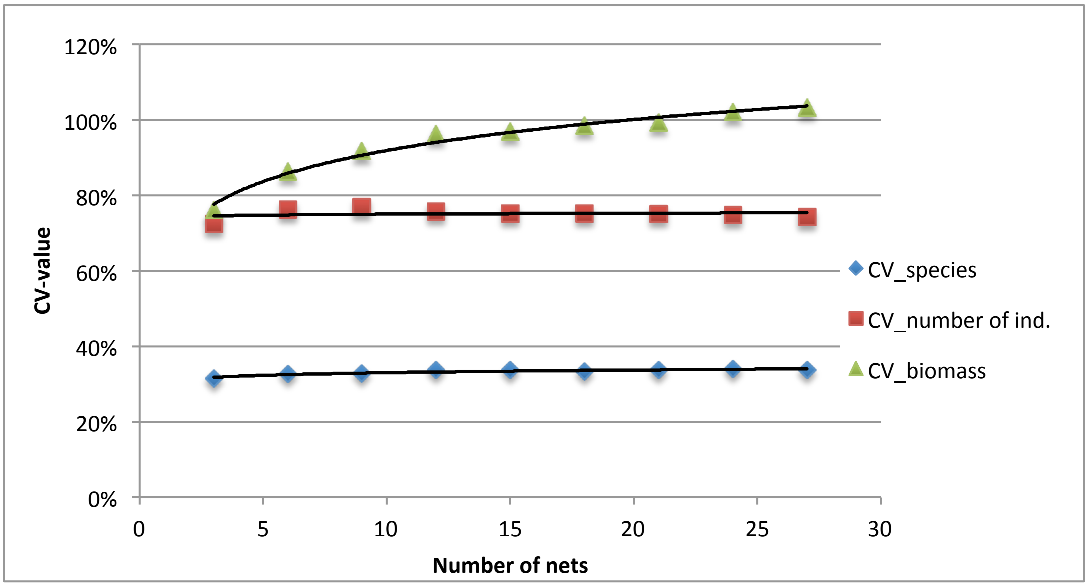


Figure 5. CV-value based on all habitats in the location Östuna. The data points are based on three, six, nine, etc. nets. The nets are randomized 50 times for every data point.

3.4 Number of nettings needed based on CVM-value

The CVM-value is calculated from the standard deviation, mean value of the catch and the number of nets used. The size of the standard deviation decreases when the number of samples goes up; therefore the CVM-value will decrease with an increased number of nettings. An example of this is shown in Figure 6.

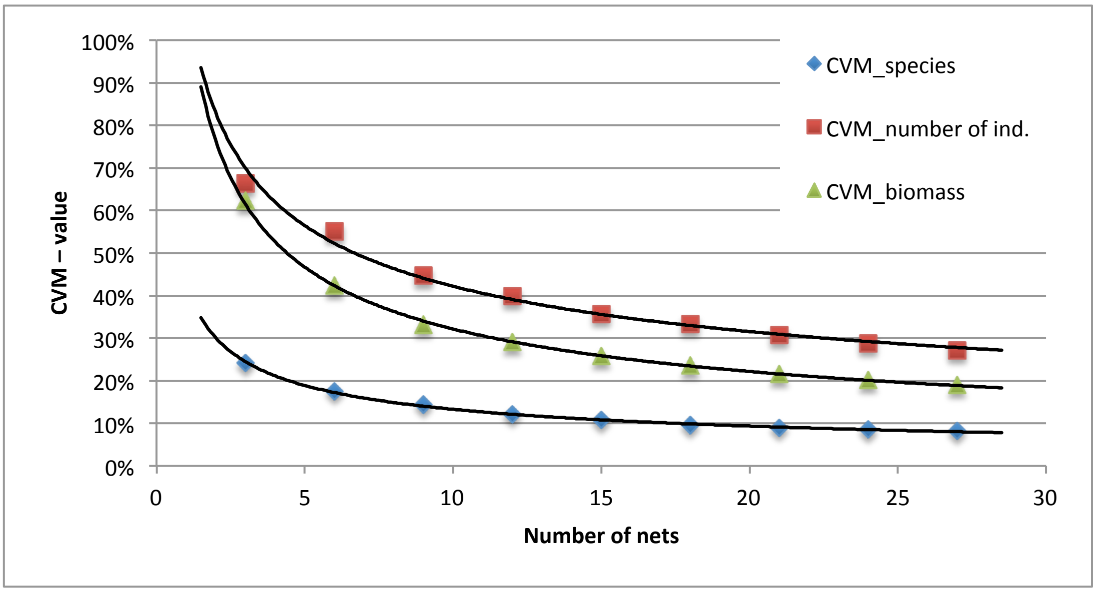


Figure 6: CVM-values with trend lines based on all habitats in Kallstena. The graph shows how the CVM improves when more samples are made. The data points are based on three, six, nine, etc. nets. The nets are randomized 50 times for each data point.

The desired value of CVM is 20%. The exact number of nets needed to reach this limit was calculated and is listed in Table 4.

Table 4. Number of nets needed to reach CVM-value of 20% for a) number of species, b) number of individuals and c) total biomass. The number in the parenthesis shows number of nets used in the calculation. The location Stora Forsby was not included due to too low number of nettings.

a) Number of species

Location	Stream	Vegetation	Deep water	All habitats
Mälaren	-	0.5 (11)	2.4 (11)	1.4 (22)
Kallstena	2.3 (9)	14.0 (6)	3.6 (17)	4.5 (32)
Östuna	8.2 (13)	3.0 (8)	5.1 (11)	5.9 (32)
Uttersberg	0.9 (9)	1.8 (9)	6.3 (9)	2.8 (27)

b) Number of individuals

Location	Stream	Vegetation	Deep water	All habitats
Mälaren	-	3.9 (11)	7.7 (11)	5.7 (22)
Kallstena	35.4 (9)	26.7 (6)	58.1 (17)	49.7 (32)
Östuna	19.7 (13)	5.9 (8)	15.3 (11)	15.2 (32)
Uttersberg	7.4 (9)	7.2 (9)	13.7 (9)	13.8 (27)

c) Total biomass

Location	Stream	Vegetation	Deep water	All habitats
Mälaren	-	5.7 (11)	5.5 (11)	5.5 (22)
Kallstena	8.6 (9)	40.7 (6)	29.8 (17)	24.8 (32)
Östuna	24.1 (13)	13.2 (8)	11.3 (11)	29.5 (32)
Uttersberg	10.0 (9)	23.7 (9)	17.2 (9)	26.6 (27)

4 Discussion

4.1 Results

4.1.1 How many netting efforts is needed to catch all catchable species?

In larger lakes, e.g. Mälaren, where the number of existing habitats and species is much larger than in smaller waters, the relative netting effort per habitat becomes smaller (Lundvall 2010). This is a reason why the difference between the number of species present in literature and the number of species caught is likely to be greatest in Mälaren than in Hedströmmen (Table 2). The NSSN has a heavy lead line to rest on the bottom of streams, and can therefore only be used for benthic fishing. It is not as practical in lakes, where sampling is better conducted with the Norden net, which can be placed both in the pelagic and the benthic zone.

To catch all catchable species in all sections the river with some certainty, up to 160 – 560 nettings is needed. This number of nettings is not realistic to be conducted. When the accumulation curves flattens out, more nettings will not give additional data on species occurrence as compared to the cost of the sampling. There is not a certain value of the slope where additional netting efforts fail to give valuable results. For the purpose of the study, an effective limit was reached when a doubling of netting efforts failed to catch a new species. The accumulation curves from all locations were compiled into an average curve and the number of nettings where the doubling fails to give enough results was estimated to roughly 16 nettings.

Compared to data found in the SERS register, the NSSN does not catch all the present species. On other hand, it managed to catch some species that were not listed in the SERS register in all locations in the river (Table 5).

Table 5. The NSSN does not catch all fish listed in SERS, but catches some species not listed. The table shows number of species. Number in parenthesis shows uncatchable species with nets.

	Species listed in SERS	Listed in SERS, but not captured in NSSN	Cached in NSSN, but not listed in SERS	Total SERS and NSSN
Kallstena	11	3 (5)	1	12
Östuna	9	4 (4)	2	11
Stora Forsby	7	3	1	8
Uttersberg	7	3	3	10

The species, which were listed in SERS but not caught in the NSSN, were burbot, smelt, brown trout and rainbow trout. A reason to why some of these species weren't caught in this study may be the time of year when the study was conducted, as mentioned before (Table 2). The species caught in the net but not in listed in SERS in all locations were northern pike, pike-perch, bream, ruffe and bleak (Table 2).

This confirms that the NSSN is a good complement to electrofishing, as the combination gives a more complete picture of the fish population in the river.

4.1.2 CV-value

The CV-value showed no improvement when more samples were added after an initial three nets. The results were thus stable, i.e. using relatively few nets, a good view of the natural variation of catchable fish in each location was achieved. This may be due to the small and homogenous sites sampled, especially since no thermocline was present.

4.1.3 To reach a good CVM

The number of nettings needed to reach 20% CVM-value depends on what type of habitat and location that is sampled. It is also dependent on what information is required, such as number of species, number of individuals or total biomass.

To determine the number of species in a location and to reach CVM-value of 20%, 1-14 nettings were needed, depending on location and habitat. All except one needed fewer than 10 nettings.

The results needed to reach to reach a CVM-value of 20% for number of individuals were somewhat less favorable. Most habitats needed less than 16 nettings, but some needed more, with up to 58 netting efforts.

Similar results were derived when sampling for biomass in the stream. Most habitats required up to 11 nettings to reach a good CVM, while others needed up to 41 nettings.

The result varied a lot between locations and habitats. The NSSN seemed to give good results regarding species richness, but inferior results when sampling for number of individuals or biomass.

A CVM of 20% can also be achieved by fishing over a number of years on the same sites. But by using just a small number of nets every year, the possibility at detecting changes over time is reduced.

4.1.4 The ratio between the number of samples per fished surface area

When performing sampling in lakes with Norden nets, the size and depth of the lake is considered when planning the number of nettings, as it contains many different habitats and temperature zones (Kinnerbäck 2001).

In a river, on the other hand, the variation between similar habitats along its longitudinal path is relatively small especially compared to big and deep lakes. The habitats along a river are rather consistent, and as the water is mixed in riffles, the temperature and other abiotic factors are more homogeneous compared to lakes. Therefore it is more important to spread the sampling among the different habitats rather than sample the whole length of the river. From this it is recommended that fishing should be planned after an initial habitat survey, and the habitats should then be sampled based on their area.

4.1.5 Limitations

The results from test fishing with NSSN did not give a complete picture of the fish community in the river, but as was evident from the data, neither did electrofishing. The NSSN is a passive fishing method and is therefore dependent on the fish activity and habits, which may depend on factors like stream velocity, temperature, light, visual depth, etc. Sampling in different conditions may therefore have influences on the result. Additionally, some fish, like eels, will not be caught in the NSSN due to their body shape.

Net saturation and net attraction (i.e. small shiny fish caught in the net might attract bigger piscivorous fish) are two other things to have in mind when evaluating sampling with gill nets. Saturation of the nets may happen in waters with high numbers of fish, however, this is a rare problem (Nyberg & Degerman 1988, Kinnerbäck 2001). In the sampling this summer, a few occasions where bigger fish were tangled close to smaller shiny fish were observed (Figure 7).

Figure 7. This tangled pike has tried to catch a bleak that already was caught in the net. The pike was first found with its mouth tight around the bleak. Photo: Anders Eidborn

4.2 Cost of sampling

The cost to do sampling with the NSSN in different countries will vary, as a large part of the cost will be expenses connected to the personnel. Today the NSSN is calculated to cost 4500 Swedish kronor (approx. 460€) each.

The net is expected to last for approximately 30 samplings (Fjälling *et al.* 2015) with daily maintenance, such as fixing small holes damaged by fish and branches. Our experience is that this is fair, but we cannot confirm this, as the nets were sabotaged/stolen in the end of the sampling period. This gives a cost of 150SEK (15€) per netting effort, plus expenses for personnel.

Two persons can handle 8-12 nets each night, and maybe as much as 15 in waters with low fish abundance.

4.3 Personal experiences from the field

After using the net for four weeks during the summer of 2015 in two different streams, I have gathered some personal experience in using the NSSN. The nets worked well and caught many different sizes and species of fish, as has been shown in the results section above. Two persons could easily do the netting, and the most critical part was handling the boat in streaming and often shallow water. The added weight of the nets due to a heavy lead line might be a bit of a challenge for some people, especially if many nets are used at the same time.

All in all the NSSN worked well and did what it is designed for, but there are some potential problems that need to be considered when using the NSSN.

4.3.1 Leafs

One period of sampling with the NSSN was made a couple of weeks after the one in Hedströmmen, this time in river Ätran (The data from the sampling in Ätran is not used in this report). The second fishing period took place during a dry and warm period, and many trees, especially birch trees, had a lot of dry, yellowed leafs. Many of these fell into the stream during a spell of strong winds. Leafs in the water got caught in the net, forming pockets next to the thicker lines (Figure 8). This caused more resistance from the water stream, forcing the net down towards the bottom, which probably made the net less efficient. This might be an even bigger problem when using the NSSN in the autumn.

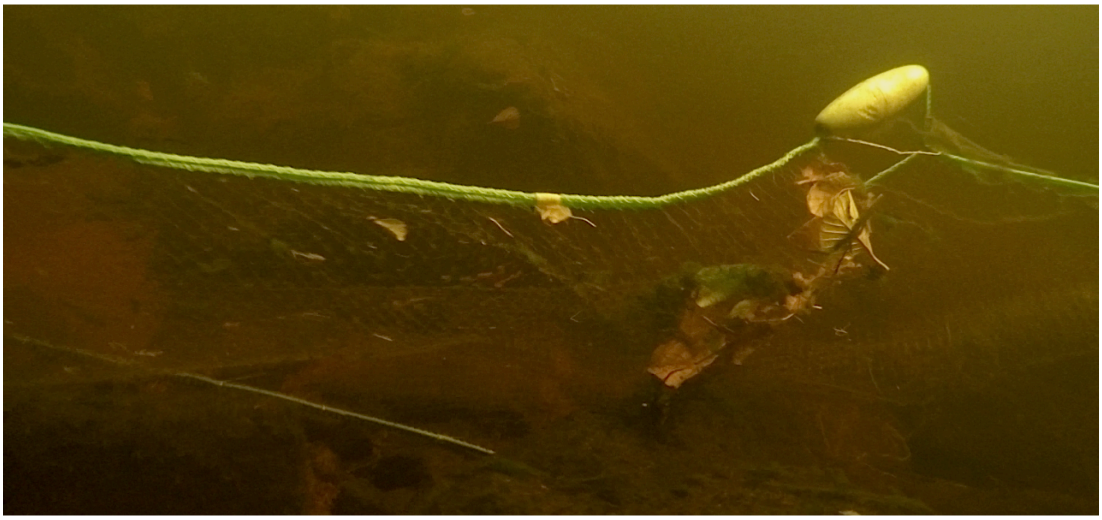


Figure 8. Under water photo show leaf pocket formed at the slanting support lines, forcing the net towards the bottom. (Photo: Anders Eidborn)

4.3.2 Currents

When setting the nets, it can be hard to see the direction of the underwater current, which sometimes differs from the surface of the stream. During the fishing period, some of the nets were filmed with an underwater camera, to see how they worked in the streaming water. When the film was analyzed, it turned out that in some cases the net did not follow the precise direction of the stream at the bottom, even if it followed the direction of the surface water. In those cases the top of the net was forced downstream, making the net lean slightly to the side.

4.3.3 Drifting and dead wood in the water

Drifting wood and branches were sometimes caught in the net as they came floating down the river. Nets sometimes also got stuck in logs on the bottom of the stream. This tended to be a bigger problem when there were beavers in the area. In Hedströmmen one beaver and several beaver dens were spotted during the sampling period.

4.4 Further studies

Although some sampling difficulties were noted, the nets function well and do their job. Relatively few nets are required to get an adequate precision and sample catchable species. Further, the nets are easily handled. I suggest that a manual is developed on how to sample a river (or river section) after a habitat survey. What habitats should be surveyed, on what scale and with what precision are important issues. When such a model is developed it should be possible from the present study to design an appropriate sampling design, with respect to number of nets required.

5 Acknowledgements

First I would like to thank my supervisors Arne Fjälling and Erik Degerman at the Swedish University of Agriculture for their valuable support during the work process.

Further I would like to thank all local residents, fishing rights holders, landowners and others who have given us permission to do sampling, helped us with information, and have given us access to roads and docks. I want to say a special thanks to Ove Nyberg and Lars Bengtsson who offered food and drinks and helped us with transport and more.

I also want to say a big thank you to my fellow students in Uppsala for valuable help, comments and company during the writing of this report.

The sampling was made together with Johan Rudin, whom I want to thank for assistance, company and good food during the sampling period.

This project was funded by Swedish Agency for Marine and Water Management.

References

Auerbach D., Deisenroth D., McShane R., McCluney K. & LeRoy Poff N. (2014). Beyond the concrete: Accounting for ecosystem services from free-flowing rivers. *Ecosystem Services* **10**, 1-5.

Bergquist B., Axenrot T., Carlstein M. & Degerman E., (2007). *Fiskundersökningar i större vattendrag.* Fiskeriverket informerer 2007:10. Fiskeriverket.

Beaumont W.R.C., Taylor, A.A.L., Lee, M.J. & Welton, J.S. (2002). Guidelines for electric fishing best practice, R&D Technical Report W2-054/TR. Environmental Agency, Bristol, UK.

Colwell, R.K. & Coddington, J.A. (1994). Estimating terrestrial biodiversity through extrapolation. *Philosophical Transactions of the Royal Society B: Biological Sciences*, 345:101-118.

Degerman, E., Hammar, J., Nyberg, P. & Svärdson, G. (2001). Human impact on the fish diversity in the four largest lakes of Sweden. *Ambio*, 30, 522–528.

Degerman, E., Nilsson, N., Andersson, HC. & Halldén, A. (2010). Fisk i vattendrag och stora sjöar. Länsstyrelsen Stockholm. Rapport 2010:7.

Degerman, E., Pettersson E. & Sers B. (2012). Analys av elfiskedata. Meddelande nr 2012:12. Länsstyrelsen i Jönköping.

Drozd P. & Novotny V. (2010). AccuCurve. Version 1. Available from: http://prf.osu.cz/kbe/dokumenty/sw/AccuCurve/AccuCurve.xls. Visited 2015-10-15.

European Commission. (2012). *A Blueprint to Safeguard Europe's Water Resources.* WWW-document. 2012-11-14. http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52012DC0673. Visited 2015-10-19.

Fiskevårdsteknik (2013). Mälarenergi ab kallstena krv, Hedströmmen. Fiskvandring 2013, Lund.

Fjälling, A., Degerman, E. & Johansson, U. (2015). Norden multimesh gill net for fish sampling in lotic environments. *Lakes and Reservoirs: Research and Management,* 20**,** 182-186.

Johansson, U. (2011). Migration of spring-spawning fish, and comparison in capture between fyke nets and strömöversiktsnät in the stream Hammerstaån in the Stockholm area. Linköpings universitet, Linköping.

Kinnerbäck, A. (2001). Standardiserad metodik för provfiske i sjöar. *Fiskeriverket informerar* 2001(2): 1-33.

Lundvall, D. (2010). Fiskbestånden i Dalälvens sjöar, faktorer som påverkar och förändringar över tid. Länsstyrelsen Dalarna. Rapport 2010:14.

McDowell, W H. (2009). Ecology and role of Headwater Streams. Encyclopedia of inland waters. P. 357-365.

Nielsen, L. & Svedberg, U. (2006). *Våra fiskar.* Prisma, Stockholm.

Näslund, I., Degerman, E., Calles, O. & Wickström, H. (2013). Fiskvandring – arter, drivkrafter och omfattning i tid och rum. Havs- och vattenmyndighetens rapport 2013:11.

Nyberg, P. & E. Degerman 1988. Standardiserat provfiske med översiktsnät. Information från Sötvattenslaboratoriet, Drottningholm 1988(7), 18 p.

Pollock, K.H., Nichols, J.D., Brownie, C. & J.E. Hines. (1990). Statistical inference for capture-recapture experiments. *Wildlife Monographs 107.*

Pringle, J. D. 1984. Efficiency estimates for various quadrate sizes used in benthic sampling. Can. J. Fish. Aquat. Sci. 41:1485-1489.

SS-EN 14011:2006. Vattenundersökningar – Provtagning av fisk med elektricitet. SIS Swedish Standards Institute.

SS-EN 14757 Vattenundersökningar – Provtagning av fisk med översiktsnät. SIS Swedish Standards Institute.

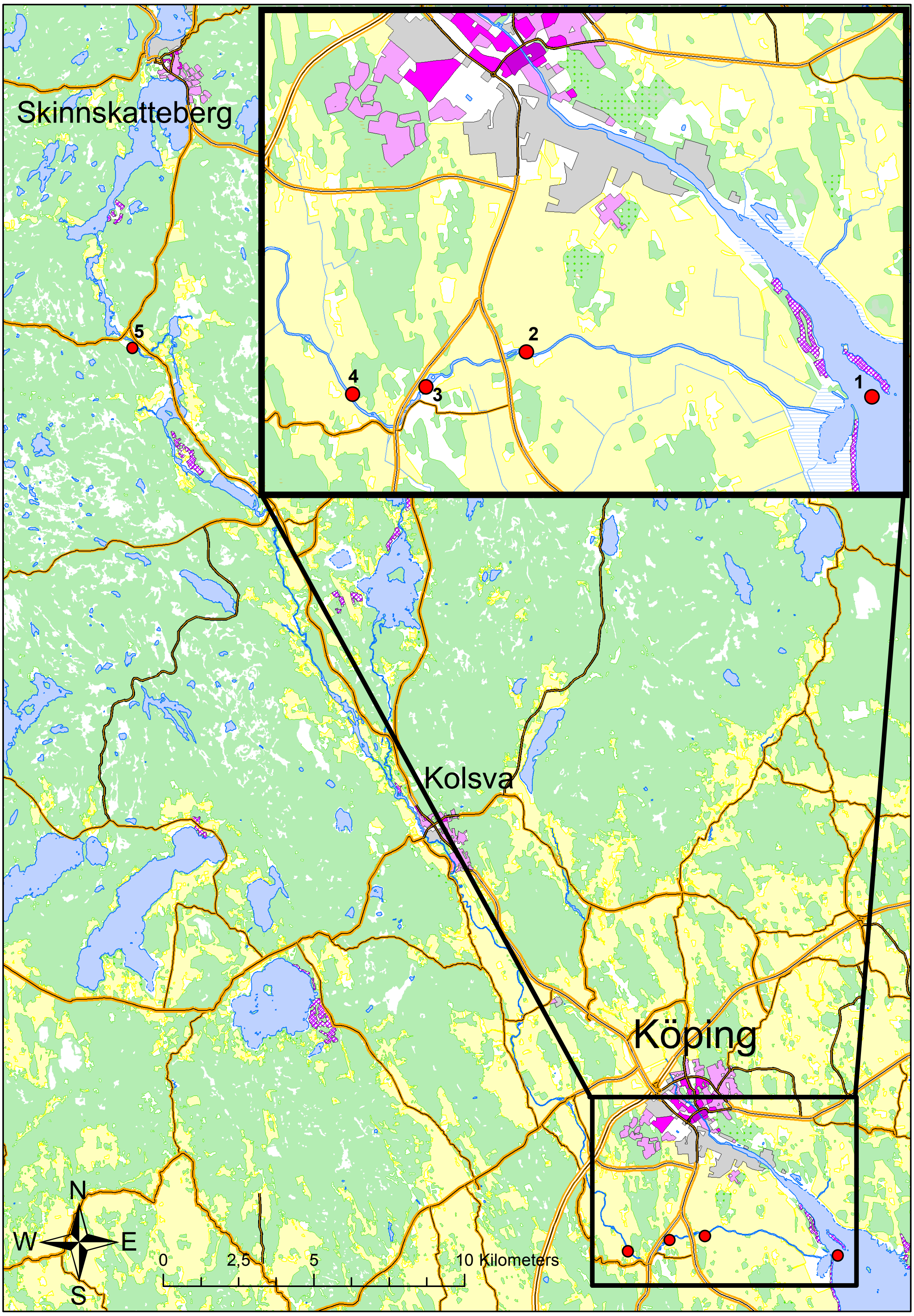
Svenskt ElfiskeRegiSter (SERS). (2015). Sveriges lantbruksuniversitet (SLU), Institutionen för akvatiska resurser. http://www.slu.se/elfiskeregistret Visited 2015-11-04.

Swedish Agency for Marine and Water Management. (2013). Recreational fishing in Sweden 2013. Statistiska meddelanden JO 57 SM 1401.

Swedish Agency for Marine and Water Management. (2014). WWW-document. 2014-01-21. https://www.havochvatten.se/hav/samordning--fakta/miljomal--direktiv/det-svenska-miljomalssystemet/levande-sjoar-och-vattendrag.html Visited: 2015-12-07.

Vašek, M., J. Kubečka, M. Čech, V. Draštík, J. Matěna, T. Mrkvička, J. Peterka & M. Prchalová. (2009). Diel variation in gillnet catches and vertical distribution of pelagic fishes in a stratified European reservoir. Fisheries Research 96:64–69.

Appendix A



Skinnskatteberg
Kolsva
Köping
1
2
3
4
5
N
W
E
S
0
2,5
5
10 Kilometers