Opinion

Considerations needed for analysing data from the Swedish Electrofishing RegiSter (SERS), with special reference to the RivFishTIME database of long-term riverine fish surveys

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The published database RivFishTIME (Comte *et al*. 2021, *Global Ecology and Biogeography*, doi: 10.1111/geb.13210) includes a large section of time-series data on fish abundance in Swedish rivers from the Swedish Electrofishing RegiSter, SERS. Knowledge about the limitations of the source data are important when extracting and analyzing data and with this brief note we provide some details that may be helpful for interpreting the Swedish time-series. The note highlights the importance of linking vital metadata to extracted focal data when constructing new databases, especially concerning time series data from monitoring programs conducted in non-randomly selected sites with human environmental impacts. Many of the SERS data come from rivers that have been affected by human impact, e.g. liming to mitigate environmental acidification and hydropower dams, since before monitoring was initiated. Data in SERS are also biased towards shallow salmonid habitats, due to the configuration of Swedish monitoring programs. Hence, data from many rivers are not representative of their fish biodiversity in general. This information is vital for appropriate interpretation of fish biodiversity trends. For RivFishTIME analyses considerations are important since Swedish data constitutes a large proportion of the database. We also provide background information about SERS and references to other Swedish databases containing complementary information. Finally, we provide contact information of the SERS database curators, who can assist prospective analysts with data extraction from SERS.

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Introduction

The Swedish Electrofishing RegiSter ('SERS'; SERS 2023) is a national database containing data from wading electrofishing surveys in Sweden, made available under an open-data licence (Creative Commons CC0). Within the recently published RivFishTIME global database of long-term riverine fish surveys, approximately 26% of all site IDs (N_{SERS} = 2992, N_{TOT} = 11386) stem from SERS (RivFishTIME SourceID = 42) at the time of the publication of the data descriptor article (Comte *et al.* 2021). The SERS data included in RivFishTIME is a subset of the SERS database, selected based on criteria outlined in Comte *et al.* (2021; section 2.1): i) consistent sampling sites, ii) consistent sampling protocol, ii) sampling survey quantify all species using well-established protocols, iv) species-specific abundances available for each survey; surveys at a site conducted over a ≥ 10 year period, and v) at least two yearly surveys with non-zero fish abundance for a given time series. The RivFishTIME database has the potential to become an important and highly valuable tool in global biodiversity research on riverine fish, and several studies have already reported on their use of RivFishTIME-data (e.g. Kuczynski *et al.* 2023; Carvajal-Quintero *et al.* 2023). However, there are some possible issues concerning the Swedish data that should be addressed, since they may affect interpretation of results from RivFishTIME-derived analyses. The main message we want to convey is that relevant metadata needs to be carefully considered when collating new databases based on materials from other data resources.

Background information about SERS

SERS was initiated in 1989 as a part of the nation-wide programme for liming acidified lakes and streams in Sweden. Prior to this, electrofishing was already an important survey method, e.g. for monitoring of anadromous salmonids, but data were stored in regional archives and data quality control was lacking. While methodological recommendations were available (Bohlin 1984), electrofishing surveys had not yet been fully standardised (Bohlin *et al.* 1989). From 1996 to 2011, the Swedish Board of Fisheries (SBF) was officially hosting SERS for the Swedish Environmental Protection Agency and with a national database established, a national standard for electrofishing with a common field protocol was also developed (Degerman and Sers 1999). With the implementation of the EU Water Framework Directive (European Commission 2000), electrofishing data became the primary national method for estimating the ecological status of wadable streams and rivers. After dissolution and reorganization of SBF in 2011, the database was transferred to the Department of Aquatic Resources at the Swedish University of Agricultural Sciences, on behalf of the newly formed Swedish Agency for Marine and Water Management (both institutions being former parts of SBF). As implemented today, the standardised methodology and reporting follows the current European standard (CEN 2003). However, whether the standardised method is used or not depends on the purpose of the electrofishing and SERS registers all wading electrofishing, standardised or not. SERS contains over 80 000 surveys (ranging from year 1951 to present date) from over 20 000 stream sites in Sweden. Long time series from specific sites generally stem from national and regional environmental monitoring programs.

In addition to the density and location data extracted for RivFishTime, SERS contains extensive metadata about fishing- and environmental variables for each electrofishing site (either collected in the field in association to the electrofishing or estimated from maps by the curators). This additional information is retrievable through the SERS application programming interface (SERS 2023) or by contacting the database curators (details below).

SERS data have been regularly used for scientific analyses of Swedish fish communities (e.g. Appelberg *et al.* 2000; Holmgren *et al.* 2016; Donadi *et al.* 2019) or selected species (e.g. Donadi *et al.* 2021, 2023; Näslund *et al.* 2022), as well as larger-scale European and pan-Arctic analyses (e.g. Beier *et al.* 2007; Degerman *et al.* 2007; Reyjol *et al.* 2007; Laske *et al.* 2022).

Notes on the RivFishTIME time-series derived from SERS

Given the large proportion of RivFishTIME data that originates from SERS, the Swedish data may possibly have influence on the results of analyses. Below, we list the main factors that we think need to be considered when analysing SERS data. More factors than these may, however, be relevant for interpreting the fish abundance at a given site and year. The notes below are relevant for SERS data in general, but since RivFishTIME makes part of SERS accessible to new users within a secondary database, without inclusion of much of the relevant metadata from the primary database, this comment was specifically initiated as a response to the RivFishTIME data descriptor (Comte *et al.* 2021). SERS data are also included in Freshwater Biodiversity Data Portal data sets (e.g. BF15, BF17, BF61; http://data.freshwaterbiodiversity.eu/; data selection accounting for various impacts, and relevant metadata included) and fish occurrence data from SERS is available through GBIF (https://www.gbif.org/; metadata traceable to SERS records).

Acidification/liming

Sweden was severely affected by environmental acidification due to atmospheric deposition of SO_x and NO_x and changing land use in the mid- to late 20th century, which had strong negative effects on freshwater fish biodiversity (Appelberg *et al.* 1992). Liming, i.e. the addition of calcium ions (typically powdered or granulated $CaCO_3$) to the water, is a widely applied countermeasure to mitigate acidification. Large-scale liming programmes have been conducted nationally in Sweden since the 1970's, which in many cases has ameliorated negative acidification effects on biota, including fish (Hasselrot and Hultberg 1984; Appelberg *et al.* 1992; Holmgren *et al.* 2016). Acidification and liming has motivated environmental monitoring and, consequently, many of the long time series in SERS stem from national and regional programmes continuously surveying limed waters (KEU 2023, ISELAW/IKEU 2023, Drakare *et al.* 2023). Since trends in fish biodiversity and abundance often improve over the time-scale covered by the monitoring data (Holmgren *et al.* 2016), the SERS data may in many cases oppose the predicted direction as inferred from changes in other human impacts (e.g. climate change, land use, etc.). Hence, liming is one of the more important factors that needs to be considered when working with Swedish freshwater data, often approached by exclusion of limed sites since liming is performed in several different ways and with a large variety of doses depending on acidification status (e.g. Donadi *et al.* 2023; Drakare *et al.* 2023). All in all, over 1000 time series from limed streams and rivers exist in SERS (Holmgren *et al.* 2016), showing that a substantial part of the available long-term time-series are affected by liming. Furthermore, electrofishing time-series have often been initiated after the start of liming, and reference conditions from before either acidification or liming are not available in these cases (Munthe and Jöborn 2009). Liming activities in Sweden are found in the national online database on liming (Nationella Kalkdatabasen 2023), but data are not always complete with respect to e.g. initiation of liming or dosage.

Migration barriers in river networks

As in many other countries, migration barriers in the form of e.g. dams, weirs and culverts often influence movement and distribution of the fish fauna in Swedish rivers (VISS 2023). Human impact (e.g. acidification, physical alteration, hypoxia related to eutrophication, etc.) has in some cases eradicated species from certain rivers or river sections, and migration barriers hinder recolonization. Barriers also restrict the current distribution of many diadromous species and have, in many cases, done so since before standardised fish surveys started (e.g. Montén 1988; SMHI 2013). While some information is available on the location of dams and other migration barriers (Biotopkarteringsdatabasen 2023; SMHI 2013), these records are incomplete on the national level, both in terms of presence (Belletti *et al.* 2020) and year of construction (SMHI 2013). Some information on barriers with associated fish-ways can be found in the national database on restoration measures in freshwater (Åtgärder i vatten 2023), but again, the data are incomplete. As a consequence of hydropower plant construction, extensive compensatory stocking (mainly salmonids and European eel) occurs in many rivers (Montén 1988; Dekker & Wickström 2015). Hence, even the longest SERS time-series data will not necessarily provide a picture of the historically natural community at a given site.

Spatiotemporal bias

SERS data are strongly biased toward samples from shallow streams with salmonid populations, with larger and deeper rivers, especially alluvial lowland rivers, being highly underrepresented. This is both a consequence of the monitoring programs being focussed largely on salmonid fish and due to difficulties related to electrofishing by wading in the latter rivers. Standardised boat electrofishing data from deeper rivers are scarce for Swedish waters and not yet included in any open database, but collected data from larger and deeper river sections primarily include species such as common roach *Rutilus rutilus*, Eurasian perch *Perca fluviatilis*, and bleak *Alburnus alburnus*; salmonids are less commonly encountered than in wading electrofishing (Näslund *et al.* 2023). Consequently, many species common in slow flowing and deeper riverine waters (often situated adjacent to the shallow areas sampled by wading electrofishing) are severely underrepresented in SERS, as compared to their general abundance in Swedish rivers. This fact inevitably means that fish community assessments based on SERS data will only represent wadable sections of rivers, with a strong bias toward salmonid habitats.

With respect to seasonal bias, the general timing of the standardised electrofishing activity in Sweden is August-September, to make it possible to assess recruitment of salmonid species (Bergquist *et al.* 2014). This means that the density estimates observed at many sites include the often-high density of young-of-the year (YOY) salmonids. These same sites likely have a substantially lower density of fish during October-April, due to the steep decline in the YOY cohort over the early-life survival bottleneck (Mortensen 1977). SERS provides separate estimated densities for YOY and older salmonids, but only the total density is available in RivFishTIME, making it impossible to assess influence of YOY in the catch. Furthermore, when water temperature is low (<5°C, i.e. quarter 1 and the later part of quarter 4, in general) efficient electrofishing is not expected due to general inactivity of fishes (Bergquist *et al.* 2014), but surveys are still registered from such conditions. To make data reasonably comparable, we recommend not including data from quarter 1 and 2 in analyses; data from quarter 4 could possibly be included, if the survey in question was conducted in October (but it should be evaluated in relation to temperature data).

Sampling methodology

While the quantitative electrofishing methodology has been reasonably standardised since the late 1980's in Sweden (Bohlin *et al* 1989), SERS collects all electrofishing data, whether standardised or not. Both qualitative (e.g. single-pass inventories) and quantitative (≥2 passes; often but not necessarily using standardised methodology) electrofishing surveys are included, with ca. 40% being qualitative. One-pass surveys are still reported with fish density estimates, but these have a comparably low precision, as they are based on average species-specific capture efficiency rather than multi-pass removal estimation (Bergquist *et al.* 2014). Single-pass surveys can make it hard to determine whether the obtained fish community data is representative or spurious (Meador *et al.* 2003), risk missing species that are rare or have low catchability (Vehanen *et al.* 2013), and can be systematically biased even for common species (Glover *et al.* 2019). RivFishTIME sometimes includes a mix of quantitative and qualitative surveys from SERS within the same time-series. Hence, some caution in interpreting results is warranted, unless additional data from SERS is included in analyses. Given the bias in SERS, complementary information about the Swedish freshwater fish fauna can be obtained from the National Register of Survey test-fishing (NORS), which covers gillnet surveys in more than 3800 lakes during 1952-2020 (NORS 2023), with circa 2400 lakes sampled since 1993 with Nordic multi-mesh gillnets according to the current European standard (CEN 2015).

Future plans for SERS data

Production of an English-language data descriptor for SERS is planned but not yet initiated, pending a revision of the database structure. Furthermore, we aim to assist the authors of RivFishTIME with a revision of the selection of SERS data for inclusion in RivFishTIME; either by a reduced data set excluding e.g. limed sites, or with a similar-sized data set amended with relevant metadata. However, even with a new selection, issues like human impacts and spatial bias in the data will still need to be recognized by analysts.

Contact information, SERS

For questions about data included in SERS, and requests for data extraction, it is possible to contact database curators through the following e-mail address: sers@slu.se.

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