Title:

A 50-year series of mark-recapture data of large-sized brown trout (*Salmo trutta*) from Lake Mjøsa, Norway

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Abstract

Individual-based mark-recapture data from animal population provide a wealth of opportunities for studies, such as individual variation in vital rates (*e.g.* survival and reproduction) the links between vital rates and population dynamics. However, maintaining the collection of individual-based data over long time periods comes with large logistic efforts and costs, and studies spanning over decades are therefore rare. Salmonid fishes are of high ecological, cultural, and economical value, but many native wild populations remain in decline. Conservation concerns are particularly great for migratory salmonids as local adaptations and long life spans make them very vulnerable to environmental changes and habitat modifications, e.g., due to hydroelectric power production. This paper describes a unique long-term mark-recapture data set from a land-locked population of large-sized, piscivorous brown trout (*Salmo trutta*) in Norway: the Hunder trout, named after the main water fall (Hunderfossen) in its spawning river. During the period 1966 to 2017, nearly 15,000 Hunder trout have been captured and individually marked during their spawning migration from Lake Mjøsa to the river Gubrandsdalslågen. Fish were first captured and marked while passing a fish ladder within the hydroelectric dam at the Hunderfossen waterfall, and more than 4,000 were later recaptured there alive and/or reported as dead elsewhere. In combination with related life-history and environmental data, these data can be used to gain insights into a variety of questions regarding management and conservation of migratory salmonid populations. In this data paper, we describe (1) a database containing observations on captures and related life-history data obtained from scales (the SUSTAIN trout database), and (2) a publicly available dataset extracted from this database for analysis of survival (the SUSTAIN trout survival dataset).

Introduction

Important processes in ecology and evolution of vertebrates happen over multiple years and decades. Many areas of ecological and evolutionary research – including most of studies with the goals of improving species management and conservation – rely on the availability of data spanning long time periods. Long-term ecological data on animal populations may be collected either at the population level (*e.g.* count or occupancy surveys) or by following individuals with uniquely identifiable marks throughout their lives. Individual-based mark-recapture data resulting from the latter provide a wealth of opportunities for studies that are impossible with only population-level data, as they not only allow linking population dynamics to vital rates (*e.g.* survival, reproduction) but also enable to study individual differences in those vital rates (Clutton-Brock and Sheldon 2010). When mark-recapture studies are run over long time periods and include large numbers of individuals, as well as multiple cohorts and generations, study opportunities and investigable research questions multiply (Clutton-Brock and Sheldon 2010). However, maintaining the collection of individual-based data over long time periods comes with large logistic efforts and costs, and studies spanning many years are thus rare.

Recent decline of freshwater species abundance is more severe than species declines on land or in the ocean, according to the latest Living Planet report (WWF 2018): populations of freshwater species have declined by more than 80% on average during 50 years , while populations of land-dwelling- and oceanic species have fallen by less than 40%. Salmonid fishes, which are top predators and keystone species in many large freshwater ecosystems, are of high ecological, cultural, and economical value (Lobón-Cerviá and Sanz 2018). In spite of extensive study, however, many native wild populations remain in decline (Muhlfeld et al. 2018). Conservation concerns are particularly great for migratory salmonids as local adaptations and long life spans make them very vulnerable to environmental changes and habitat modifications, e.g., due to hydroelectric power production (Piccolo et al. 2012; Van Leeuwen et al. 2018). Overexploitation from fishing, but also stocking with hatchery-reared fish are important anthropogenic pressures threatening the (genetic) integrity of populations (Laikre et al. ; Post 2013). More recently, climate change has emerged as an additional threat to salmonid populations globally (Kovach et al. 2016). Unfortunately, lack of knowledge and data on populations of migratory salmonids severely hamper the effectiveness of management and conservation efforts.

This paper describes a unique long-term mark-recapture data set from a land-locked population of large-sized, piscivorous brown trout (*Salmo trutta*) in Norway: the Hunder trout, named after the main water fall (Hunderfossen) in its spawning river (Figure 1). During the period 1966 to 2016, nearly 15,000 Hunder trout have been captured and individually marked during their spawning migration from Lake Mjøsa to the river Gubrandsdalslågen (Figure 2). Fish were first captured and marked while passing a fish ladder within the hydroelectric dam at the Hunderfossen waterfall, and some were later recaptured there alive and/or reported as dead elsewhere. The resulting mark-recapture-recovery data offer opportunities for studies on, for example, adult survival (a key vital rate generally understudied in salmonid research, (Drenner et al. 2012), fishing and natural mortality, spawning biology, and the usage and effectivity of the fish ladder (Haugen et al. 2008; Nater et al. (in prep.)). In combination with related life history and environmental data (also described in this paper), these data can be used to gain insights into a variety of questions regarding management and conservation of migratory salmonid populations. These include – but are not limited to – consequences of recreational fishing, hydroelectric power production, stocking programmes, and environmental disturbance (including habitat alteration and climate change).

The Hunder trout population constituted a case study of the research project SUSTAIN (harvested ecosystems in changing environments, see "Project details" below). The main goals within this case study were to develop models of growth and survival, to quantify effects of intrinsic and extrinsic factors on these demographic rates, and to project population dynamics under varying environmental conditions and harvesting strategies. To this end, data from several sources were compiled and processed in a project database (referred to as the **SUSTAIN trout database** below). The complete SUSTAIN trout database contains altogether 30,139 capture records from 14,703 individuals (1966-2016), as well as individual growth and spawning information based on scales for more than 8000 of these individuals (1966 – 2005, Aass et al. 2017).

A subset of this database was extracted for analysis of survival and cause-specific mortality (Nater et al. (in prep.)). This subset, referred to as the **SUSTAIN trout survival dataset** below, is focussed on fish captured in the trap during one or more spawning runs; the specific criteria are described in more detail in the following. Within this paper, we describe this static dataset, as well as the more comprehensive SUSTAIN trout database from which it is extracted, following the recommendation of (Penev et al. 2017)). The SUSTAIN trout survival dataset is published as a data package in Dryad [reference when available]. The SUSTAIN trout database is currently not publicly available but holds many opportunities for future research projects and collaborations.

Study system

Lake Mjøsa and River Gudbrandsdalslågen

Lake Mjøsa is a deep fjord lake (max. depth 453 m) situated in Southeast Norway (Figure 2). The surface area is 365 km^2, mean depth is 153 m, and the residence time is 5.6 years. It has a large catchment of 16,5 km^2 with approximately 200,000 inhabitants living close to the lake. The southern parts of the catchment are dominated by pine forests, while the northern parts lie within mountainous regions, and several glaciers in this region feed the main tributary rivers with heavy silt load resulting from snow-melt during June-August. The water flow from the main river, Gudbrandsdalslågen, as well as several smaller inlets, causes reductions in transparency, temperature and algal growth in Lake Mjøsa during early summer, especially in the northern parts of the lake (Holtan 1979).

In the past, eutrophication due to excessive nutrient loads from agriculture, industry and households resulted in poor water quality and harmful algal blooms in Mjøsa in the 1970s-1980s. This triggered the Lake Mjøsa Campaign, a large restoration effort which resulted in a period of re-oligotrophication and the current good ecological status of the lake (Løvik et al. 2017). The campaign also marked the start of extensive monitoring of water quality and plankton communities in Lake Mjøsa, the outcome of which are more than 40 years of physico-chemical and biological time-series data (Løvik and Moe 2016). In addition to the information on changes in water quality, these data have also revealed a trend of increasing water temperature (Hobæk et al. 2012), as well as shorter ice coverage periods and more frequent floods in recent years.

The Hunder trout population

A significant proportion of trout biomass caught in lake Mjøsa belongs to the Hunder trout population (Kraabøl et al. 2009). The Hunder trout is known for its large body size, and its life history and spawning biology have been thoroughly studied (Aass et al. 1989; Kraabøl 2006). Although the population is land-locked, it is very similar to Atlantic salmon and sea trout in terms of life cycle and appearance. After hatching, the young Hunder trout typically spend their first three to five years as parr in the river before smolting and migrating downstream to Lake Mjøsa (corresponding to the seaward migration of anadromous salmon and trout). In the lake they typically prey on fish for two to four years before maturating and migrating back to the river to spawn. At the time of their first spawning run, individuals are on average 7 years old, weigh 3.5 kg and measure 63 cm. Subsequently, the fish perform spawning runs approximately every two years. The Hunder trout have a maximum life span of 15-20 years and a potential maximum size of 15-20 kg and >100 cm. However, less than 10 % reach ages above 10 years, and less than 1 % of the spawners reach weight above 10 kg. Historically, most of the population is believed to have spawned upstream the waterfall Hunderfossen, while some either chose or were forced to spawn downstream. The considerable strength required for the migration and particularly for ascending the large waterfall have been proposed as selection drivers for the large body sizes of this population, relative to that of trout populations spawning in other rivers draining into Lake Mjøsa (Haugen et al. 2008).

The hydropower dam and mitigation measures

A hydropower dam was established at Hunderfossen between 1961 and 1964, and essentially became a barrier for the migrating Hunder trout. To restore the connectivity of the river, a fish ladder was established in 1966 (Aass 1990). The functionality of this fish ladder and its success in allowing trout to pass the dam varies among seasons and depends heavily on water temperature and -discharge, and on individual body size (Haugen et al. 2008; Jensen and Aass 1995).

The fish ladder only functions as an upriver passage, and the dam thus reduced survival during the downriver migration for both smolt and post-spawners. The main factors responsible are likely increased predation in the dammed area and mortality associated with turbine passage and migration delays (Fjeldstad et al. 2018). The damming also led to a decrease in the availability of productive fish habitats in the river both upstream and downstream of the dam (Aass et al. 1989). Potential consequences of the hydropower station have been evaluated by various studies, including recent telemetry studies (Kraabøl 2015; Kraabøl et al. 2013).

To abate the reduced natural production of trout in the regulated river, a compensatory stocking programme was initiated in the mid-1960s (Aass et al. 1990). The programme entails the release of between 10,000 and 30,000 smolts into the river and lake each year and is still being continued today. Each year, eggs and sperm are collected from a fraction of the wild-born spawners that ascended the fish ladder. These are incubated in a hatchery next to the Hunderfossen dam, and the hatchling trout are reared until smolting (usually for 2 years) before being stocked into the population (with their adipose fins clipped to allow recognition later). The fraction of stocked trout in the annual spawning stock (as recorded in the Hunderfossen fish ladder) has varied over time, but exceeded 50% in some more recent years (Kraabøl et al. 2009).

The establishment of the fish ladder within the Hunderfossen dam also brought new opportunities for monitoring the spawning population. Concurrent with the opening of the fish ladder in 1966, a mark-recapture program was initiated and was run continuously until it was terminated in 2016. This monitoring program has resulted in several unique long-term data series including the 50-year time-series of mark-recapture data presented in this paper.

Data collection

In the following, we describe the generation of mark-recapture data from several activities: captures and marking of adult fish in the fish ladder, recaptures in the fish ladder, recaptures by fishers, release of smolt from the stocking programme (years 1966 – 2017, Figures 4 & 5). We also give an overview of additional data on body growth and spawning schedules obtained from the scales of marked individuals. All data were originally collected, recorded, and maintained by several individuals and institutions, as listed in the Acknowledgements section.

Marking: All ascending trout were trapped in the fish ladder at the Hunderfossen hydropower dam on their spawning run. Trapped fish were sexed based on secondary sex characteristics and their origin (wild or stocked) determined based on whether the adipose fin was intact (removed = stocked). After registration and sampling, the fish were individually tagged with Carlin tags, consisting of a disc with information and a stainless steel thread to attach to the fish (Figure 6). After tagging, the fish were released into the fish ladder above the trap, allowing them to pass the dam and continue their migration to the upriver spawning areas.

Recaptures:

Marked fish could be recaptured either in the fish ladder during later spawning runs, or by fishers in the river or the lake. Alternatively, fish could also be found dead in other locations. Fish that were recaptured in the ladder were measured and sampled in the same way as during initial marking (except that they did not receive a new mark, but were instead registered with their previously assigned identity number). When fish were caught by fishers and reported, the amount of data collected varied. As a minimum, fishers would report the tag number of the caught fish, the date of capture, and whether the fish was killed or released. Additional information could include capture location, fishing gear, sex, origin, length, and weight. Reporting the capture/harvest of a marked trout was voluntary, and no monetary reward was given in exchange. As a likely consequence, fisher's rate of reporting caught trout has declined over time from an initial 80% in 1967 to only 10% in 2016 (Nater et al. 2019).

Smolt releases: All hatchery-reared trout stocked into the population were marked as such by removal of the adipose fin prior to release into the river or lake. In some years during the 19080s and 1990s, a subset of the released smolt additionally received individual Carlin tags at release (amounting to close to 50,000 tagged over time). The purpose of this smolt tagging was to evaluate and optimize the stocking strategy, and some (but not all) of the individual-level data on releases and recaptures of stocked smolt have been integrated into the mark-recapture data set.

Analysis of scales: During the whole period 1965-2016, 4-6 scales were sampled from all fish captured in the ladder. For a subset of approximately 8,000 individuals who climbed the fish ladder between 1966 and 2005, the sampled scales have been analysed using schlerochronological methods (Figure 7). These analyses have provided information on development, somatic growth, migration, and spawning (Aass et al. 2017; Jensen and Aass 1995). Specifically, measurements of the year rings on the scales have been used to back-calculate yearly growth, and to identify and analyse important life-history information such as hatching year, age and size at smolting, growth in lake, age and size at sexual maturation, and the number of spawning events (Aass et al. 2017; Haugen et al. 2008; Nater et al. 2018).

The SUSTAIN trout database

The **SUSTAIN trout database** is a compilation of all available data on individuals, captures and scale-based information (growth and life history schedules) available for the Hunder trout. The main purpose of this database was to organise data for analyses in the SUSTAIN project, and the database has not been made publicly available. We nevertheless provide a description of this database and its structure both to explain the context for the published **SUSTAIN trout survival dataset**, and to give a perspective on its potential future uses in combination with related data.

Methods: Data compilation and processing

Data sources

The database was compiled from four main data sources (Table 1).

(1) Individual mark list: table containing individual-level information on marking, sex, origin, length, weight, release site etc. Obtained from the County Governors of Hedmark and Oppland (2016).

(2) Mark series list: table containing ranges of mark numbers with common information on release date, release site, origin (wild or stocked) and stage (smolt or spawner). Obtained from the County Governors of Hedmark and Oppland (2016).

(3) Recaptures dataset: table containing all information related to recapture events including date/year, location, equipment, length, weight, and other information.

Obtained from "Merkesentralen" at NINA (Norwegian Institute for Nature Research), directly and via the County Governor of Oppland (2016).

(4) Growth dataset: table containing all information derived from scales (estimated growth, smolting and spawning). Owned and provided by Per Aass and Atle Rustadbakken, mainly digitized by the County Governor of Hedmark; described in Aass et al. 2017.

Data structure

The database is organised as 5 main tables (Figure 8) containing information on individual fish (**t_Individual**), captures (**t_Capture**), growth in the river (**t_GrowthRiver**), growth in the lake (**t_GrowthLake**), and spawning events in the river (**t_Spawning**). A description of the main fields is given in Table 1, while more explanation to the table structure is given below.

t_Individual is a table summarising all individual-level information that does not change over time. Within this table, each individual is defined by its mark number (**MarkNo**, see Figure 6), and this is associated with sex, origin (wild or stocked), and various information from the initial marking event including date (only year in some cases), length, weight, whether the individual was marked as a spawner or as smolt (**ReleaseStage**), *etc*. The total number of captures per individual (**CaptureNoMax**) is derived from the table t_Capture.

The table **t_Capture** contains one or more captures for each individual, and each entry is defined by a unique combination of **MarkNo** and **CaptureNo**. The marking event represents the first capture of an individual and is given the value CaptureNo = 1, regardless of whether the fish were marked as spawners or smolts. **t_Capture** contains all information related to the specific captures, such as capture date, location, type, and equipment, as well as the individual's measured length and weight, and status before and after capture (dead or alive). This table also contains life-history information derived from scales such as age and length at smolting and maturation, the number of spawning migrations (stored in **t_GrowthRiver**, **t_GrowthLake** and **t_Spawning**). Such information does, in principle, belong to the individual level as it should not change throughout life. However, this information is derived from scales, and the estimates from scales taken at different captures of the same individual may. Therefore, this information has been stored at the capture level.

The complete information on growth derived from the scale analysis (Figure 7) is stored in two tables representing the river phase of life (i.e. from birth to smolting; **t_GrowthRiver**) and the lake phase of life (post-smolting and including later spawning runs; **t_GrowthLake**). The reason for estimating lake growth separately is that scales are sometimes lost and replaced by new scales, e.g. after the fish has migrated to the lake. The replacement scales cannot always represent the complete river phase but can still be used to estimate the growth in the lake phase. **t_GrowthRiver** contains estimated individual records of age and length in each year from the year of smolting (clearly visible on the scale, Figure 7) back to the first year (**AgeRiver** = 1). Likewise, **t_GrowthLake** contains individual records of age and length in each year from the sampling (= capture) year back to the first year in the lake (**AgeLake**= 1). The estimated lake age and river age at capture is stored in t_Capture as **AgeLakeMax** and **AgeRiverMax**, respectively. The estimated **AgeAtSmolting** corresponds to **AgeRiverMax** when this is available. (For fish marked as smolt rather than as spawners, the **AgeAtSmolting** is known). In cases where information from the river phase is intact, the **AgeAtCapture** is the sum of **AgeRiverMax** and **AgeLakeMax**.

All information on individual spawning schedules derived from scale analysis (Figure 7) are stored in **t_Spawning.** This table contains the estimated year, age (or **AgeLake**) and length for all spawning events of each individual. The **AgeAtMaturation** and **LengthAtMaturation** field in **t_Capture** correspond to the estimated age and length at the first spawning event here.

Metadata information

All data fields in the **SUSTAIN trout database** are described briefly in Table 1. In the next section, we describe the subset of fields that are present in the published **SUSTAIN trout survival dataset** in more detail.

Summary of contents

The complete **SUSTAIN trout database** contains and links mark-recapture data and individual-level data on growth trajectories and spawning schedules of the Hunder trout over 50 years.

The mark-recapture data contains altogether 43,249 capture records from all years 1966-2017 (Table 3). 27,773 of these are individual marking events from the years 1966-2015, representing either the first capture of mature trout in the ladder (14,624 individuals) or the release of tagged smolt (13,149 individuals). The remaining capture records are recaptures by different means (as defined by **CaptureType**): 2,190 recaptures in the trap (378 of which resulted in death); 12,905 harvest reports (8,976 in the lake,3796 in the river and 133 in other or unknown locations); 105 reports of fish found dead; and 20 reports of catch-and-release fishing. The individual-level data on growth trajectories contains 29,940 size-at-age records for 5,115 individuals. The individual-level data on spawning schedules contains 7,189 spawning records of 5,007 individuals. All these individuals been captured in the Hunderfossen fish ladder during the period 1966-2005 (Aass et al., 2017) and are also contained in the mark-recapture data.

Technical description

Object name: SUSTAIN trout database

Character encoding: UTF-16

Format name: Microsoft Access Database

Format version: Microsoft® Access® 2016 MSO (16.0.9226.2114) 32-bit as part of Microsoft Office 365 ProPlus

Distribution: The database is not published. Information on access to the data can be obtained from the corresponding author.

Coverage

Temporal coverage: Capture records from all years 1966-2017.

Spatial coverage: The spatial extent of river and lake used by Hunder trout spans the latitudes 60.40° - 61.22°N and 10.43° - 11.29°E (Fig. 1). The altitude ranges from 175 m (upper end of river spawning areas) to 123 m (lake surface).

Taxonomic coverage: The data are from a single population of large-sized brown trout (*Salmo trutta*) (Figure 1) inhabiting Lake Mjøsa and spawning in River Gudbrandsdalslågen.

Taxonomic ranks: Kingdom: Animalia; Phylum: Chordata; Class: Osteichthyes; Order: Salmoniformes; Family: Salmonidae; Species: *Salmo trutta* (L., 1758).

Common name: brown trout, Hunder trout

The SUSTAIN trout survival dataset

Methods: Extraction of dataset for publication of survival analysis

The majority of the mark-recapture data from the **SUSTAIN trout database** has been extracted and organised into a single flat table for analysing survival of mature adult trout (Nater et al. in prep). This dataset conditions on the adult trout having passed the Hunderfossen fish ladder on a spawning migration at least once and was extracted from the database using the following criteria:

- Removal of 13,146 records with CaptureType = "smolt release" (See Table 3). Subsequent recaptures in the fish ladder of fish marked as smolts (CaptureType = trap alive", 222 records) were kept in the dataset, and the fields CaptureNo and CaptureNoMax were adjusted accordingly (minus 1).
- Exclusion of all records with Exclude = "yes" (due to different quality issues described in Comment fields)

Data structure and metadata information

The SUSTAIN trout survival dataset is a flat table containing the columns described below (cf. Table 1).

MarkNo: The alphanumeric code of an individual's tag (Figure 6). All information on individual fish is linked to the MarkNo.

CaptureNo: The running number of the captures of an individual ordered by capture date, including the marking event as CaptureNo = 1.

CaptureNoMax: The total number of captures of an individual.

MarkDate: The exact date of the marking event, if this information is available.

MarkYear: The year of the marking event (a mandatory field).

CaptureDate: The exact date of the capture, if this information is available. For records with missing CaptureDate, the database contains a dummy date (1. January) with the correct year. The dummy data was necessary for the ordering of captures and assignment of CaptureNo also for repeated captures of an individual within one year.

CaptureYear: The year of the capture.

CaptureArea: Area of the capture. All captures in the trap at the Hunderfossen dam (including marking) are denoted as “river trap”. The reported locations of harvests (captures by fishers) are aggregated into five areas (see Fig. 1): "lake" (between Minnesund and Lillehammer), "river below" (between Lillehammer and Hunderfossen), "river above" (between Hunderfossen and Harpefossen), “river” (north of Lillehammer, but unclear if above or below Hunderfossen), and "far away" (elsewhere).

CaptureType: Classification of the type of capture events based on a combination of the fields CaptureArea, StatusBeforeCapture and StatusAfterCapture (Table 2, Figures 4 and 5). The distinguished capture types are defined as follows: “trap alive” = captured in the fish ladder during a spawning run and released alive, “trap dead” = captured in the fish ladder during a spawning run but died prior to/shortly after release (or found dead in the immediate vicinity of the fish ladder), “harvest” = captured by a fisher and killed, “catch release” = captured by a fisher and released alive (only started becoming more common towards the end of the study period), “found dead” = found dead in any location other than the fish ladder, and “smolt release” = release of hatchery fish marked as smolt. The capture type “smolt release” is not technically a capture, but it was most convenient to store the information related to these events as a capture.

CaptureEquipment: The gear involved in the capture summarised into five standardised categories (based on more detailed reported information of equipment). For harvest captures, the fishing gear has been categorised as either "net" or "rod"; for other capture types, the possible values are "trap", "dead in trap", or "found dead".

LengthAtCapture: The measured length of the fish at the capture (unit mm; Figure 1). The distribution of body sizes measured in the data over time are presented in Figure 9.

WeightAtCapture: The measured weight of the fish at the capture (unit g).

Sex: Individuals are categorised as female, male or NA. The representation of female vs. male individuals in the dataset is visualized in Figure 10.

Origin: Individuals are categorised as wild, stocked or NA. Stocked individuals have been reared in the hatchery near Hunderfossen, and are recognizable by their clipped adipose fin. The representation of wild vs. stocked individuals in the dataset is visualized in Figure 3.

Scale_Growth: Information on whether data on somatic growth (inferred from scale analysis) for this individual is available in the **SUSTAIN trout database** (“yes”/”no”).

Scale_Spawning: Information on whether data on spawning schedules (inferred from scale analysis) for this individual is available in the **SUSTAIN trout database** ("yes"/"no").

SurvivalAnalysis: Information on whether this capture event was included in the survival analysis of Nater et al. (2019).

Summary of contents

The contains 19,489 capture records of 14,890 individuals from all years 1966-2016. Captures of all types except "smolt release" are present: "trap alive" (16,726 records), 14,890 marking events (until 2015), 4,599 recaptures in the trap, and 2,306 harvests (Table 3).

The **SUSTAIN trout survival dataset** contains altogether 19,505 capture records from all years 1966-2017 (Table 3). Of these, 14,890 are individual marking events of mature trout in the ladder. The remaining 4,615 capture records are recaptures by different means (as defined by **CaptureType**): 1,863 recaptures in the trap (372 of which resulted in death); 2,322 harvest reports (1,944 in the lake, 358 in the river, 20 in other or unknown locations); 76 reports of fish found dead; and 9 reports of catch-and-release fishing.

Further adaptation of this dataset to the survival analysis (Nater et al. (in prep.)) resulted in the exclusion of capture histories for 2015 individuals. These are flagged in the column "SurvivalAnalysis" in the published dataset. The 12,875 individual capture histories included in that analysis contain 1,588 trap recaptures and 2,252 harvest events (Table 3).

Technical description

Object name: SUSTAIN trout survival dataset

Character encoding: UTF-16

Format name: comma-separated values (csv)

Distribution: *[link to Dryad when available]*

Publication date: 2019-xx-xx *[will be inserted when available]*

Language: English

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Waiver: http://creativecommons.org/publicdomain/zero/1.0/. Thus, the data can be freely used for non-commercial purposes provided the source is acknowledged and this data paper is cited.

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Coverage

The temporal, spatial and taxonomic coverage of the SUSTAIN trout survival dataset is identical to that of the full SUSTAIN trout database, except that it excludes all smolt release events, and all recaptures of individuals released as smolt which never entered the fish ladder.

Data published through Dryad: *[link when available]*

Project details

Project title: Sustainable management of renewable resources in a changing environment: an integrates approach across ecosystems (SUSTAIN). https://www.sustain.uio.no/

Subproject: Work Package 1: Demographic structure in harvested ecosystems. https://www.sustain.uio.no/research/wp/work-package-1/

Case study: Mjøsa lake (brown trout). https://www.sustain.uio.no/research/case-studies/case_study_6/index.html

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Table 1. Description of the main fields of the SUSTAIN trout database (see Figure 8). The column "Published" indicates which fields are published in the SUSTAIN trout survival dataset.

Table name	Field name	Data type	Values (examples)	Comment	Main data source	Published
t_Individual	MarkNo	Text		Unique code of individual's tag. Key field.	Individual mark list	yes
t_Individual	MarkDate	Date/Time		Date of marking (if available)	Individual mark list	yes
t_Individual	MarkYear	Number (integer)		Year of marking (mandatory)	Individual mark list	yes
t_Individual	LengthAtMarking	Number (double)		Measured length at marking (mm)	Individual mark list	no
t_Individual	WeightAtMarking	Number (double)		Measured weight at marking (g)	Individual mark list	no
t_Individual	MarkType	Text	Carlin, Floy	Type of mark	Individual mark list	no
t_Individual	Sex	Text	female, male	Individual's sex	Individual mark list	yes
t_Individual	Origin	Text	wild, stocked	Individual's origin	Individual mark list; Mark series list	yes
t_Individual	ReleaseStage	Text	smolt, spawner	Life-history stage at the time of mark and release	Individual mark list; Mark series list	no
t_Individual	ReleaseSite	Text		Location of relese after marking	Individual mark list; Mark series list	no
t_Individual	ReleaseSeason	Text	fall, spring	Only for smolt releases: season of release	Individual mark list; Mark series list	no
t_Individual	CaptureNoMax	Number (integer)		The total number of captures per individual (from t_Capture)	Recaptures dataset	yes
t_Capture	MarkNo	Text		(Described above)	Recaptures dataset	no
t_Capture	CaptureNo	Number (integer)		Capture number (running number)	Recaptures dataset	yes
t_Capture	CaptureDate	Date/Time		Date of capture (if available)	Recaptures dataset	yes
t_Capture	CaptureYear	Number (integer)		Year of capture (mandatory)	Recaptures dataset	yes
t_Capture	LengthAtCapture	Number (double)		Measured length at capture (mm)	Recaptures dataset	yes
t_Capture	WeightAtCapture	Number (double)		Measured weight at capture (g)	Recaptures dataset	yes

t_Capture	AgeAtCapture	Number (integer)		Estimated age at capture (from scales)	Growth dataset	no
t_Capture	AgeMaxRiver	Number (integer)		Estimated maxiumum age in the river phase (before smolting, from scales)	Growth dataset	no
t_Capture	AgeMaxLake	Number (integer)		Estimated number of years since smolting, at the time of capture (from scales)	Growth dataset	no
t_Capture	AgeAtSmolting	Number (integer)		Estimated age at smolting (= AgeMaxRiver, from scales), alternatively from marking lists (for smolt releases)	Growth dataset; Individual mark list	no
t_Capture	LengthAtSmolting	Number (double)		Estimated length at smolting (med mer, from scales)	Growth dataset	no
t_Capture	AgeAtMaturation	Number (integer)		Estimated age at the first spawning event (from scales)	Growth dataset	no
t_Capture	LengthAtMaturation	Number (double)		Estimated length at the first spawning event (from scales)	Growth dataset	no
t_Capture	NoOfMigrations	Number (integer)		Estimated number of spawning events (from scales)	Growth dataset	no
t_Capture	HatchYear	Number (integer)		Estimated year of hatching (age = 0, from scales))	Growth dataset	no
t_Capture	CaptureLocation	Text		Detailed information on capture location (if available)	Recaptures dataset	no
t_Capture	CaptureArea	Text	river trap, river above, river below,	Standardised values derived from more detailed CaptureLocation	Recaptures dataset	yes

			river, lake, far away			
t_Capture	CaptureEquipment	Text	net, rod, trap, dead in trap, found dead	Standardised values derived from more detailed information	Recaptures dataset	yes
t_Capture	StatusBeforeCapture	Text	alive, dead	Standardised values derived from more detailed information	Recaptures dataset	no
t_Capture	StatusAfterCapture	Text	alive, dead	Standardised values derived from more detailed information	Recaptures dataset	no
t_Capture	CaptureType	Text	See Table 3	See Table 3	Recaptures dataset	yes
t_GrowthLake	AgeLake	Number (integer)		Estimated number of years since smolting	Growth dataset	no
t_GrowthRiver	AgeRiver	Number (integer)		Estimated number of years since smolting	Growth dataset	no
t_GrowthRiver	LengthRiver	Number (double)		Estimated length at the given AgeRiver	Growth dataset	no
t_GrowthLake	LengthLake	Number (double)		Estimated length at the given AgeLake	Growth dataset	no
t_Spawning	SpawningNo	Number (integer)		Spawning event number	Growth dataset	no
t_Spawning	SpawningYear	Number (integer)		Estimated year of the spawning event (derived from CaptureYear)	Growth dataset	no
t_Spawning	LengthAtSpawning	Number (double)		Estimated length at the given SpawningNo (mm)	Growth dataset	no
t_Spawning	AgeLakeAtSpawning	Number (integer)		Estimated AgeLake at the given SpawningNo	Growth dataset	no
t_Spawning	AgeAtSpawning	Number (integer)		Estimated total age at the given SpawningNo	Growth dataset	no
t_Spawning	SpawningNoMax	Number (integer)		Estimated total number of spawning events	Growth dataset	no

Table 2. Definition of the field CaptureType.

Capture Area	StatusBefore Capture	StatusAfter Capture	Other criteria	Capture Type
trap	alive	alive	ReleaseStage = smolt AND CaptureNo = 1	smolt release
trap	alive	alive	ReleaseStage ≠ smolt OR CaptureNo ≠ 1	trap alive
trap	alive	dead		trap dead
river or lake	alive	alive		catch release
river or lake	alive	dead		harvest
river or lake	dead	dead		found dead

Table 3. Overview of contents in the SUSTAIN trout database and the SUSTAIN trout survival dataset. Note: for individuals marked as smolt, the marking event is identical to CaptureType = “smolt release”.

SUSTAIN data object	**Stage at marking**	**No. of marked individuals** (CaptureNo = 1)	**No. of recaptured individuals** (CaptureNo > 1)	**No. of recaptures per type** (CaptureNo > 1)					**Total no. of recaptures** (all types)	**Total no. of captures** (including marking event)
				trap alive	**trap dead**	**har-vest**	**catch releas e**	**found dead**		
trout database	spawner	14 624	4 046	1 820	370	2 243	9	76	4 518	19 142
	smolt	13 149	10 861	238	8	10 662	21	29	10 958	24 107
trout survival dataset	spawner	14 891	4 141	1 836	372	2 322	9	76	4 615	19 506
trout survival dataset: selection for analysis	spawner	12 876	3 604	1 459	128	2 252	-	-	3 839	16 715

Figure 1. Example of Hunder trout with a body length of approximately 80 cm. Photo: Atle Rustadbakken.

Figure 2. Map of Lake Mjøsa and the river Gudbransdalslågen, where the Hunder brown trout occurs. The fish ladder and the hatchery are located at the Hunderfossen dam. Sources: The Norwegian Mapping Authority (https://www.kartverket.no) and ESRI (https://www.esri.com). After Aass et al. (2017).

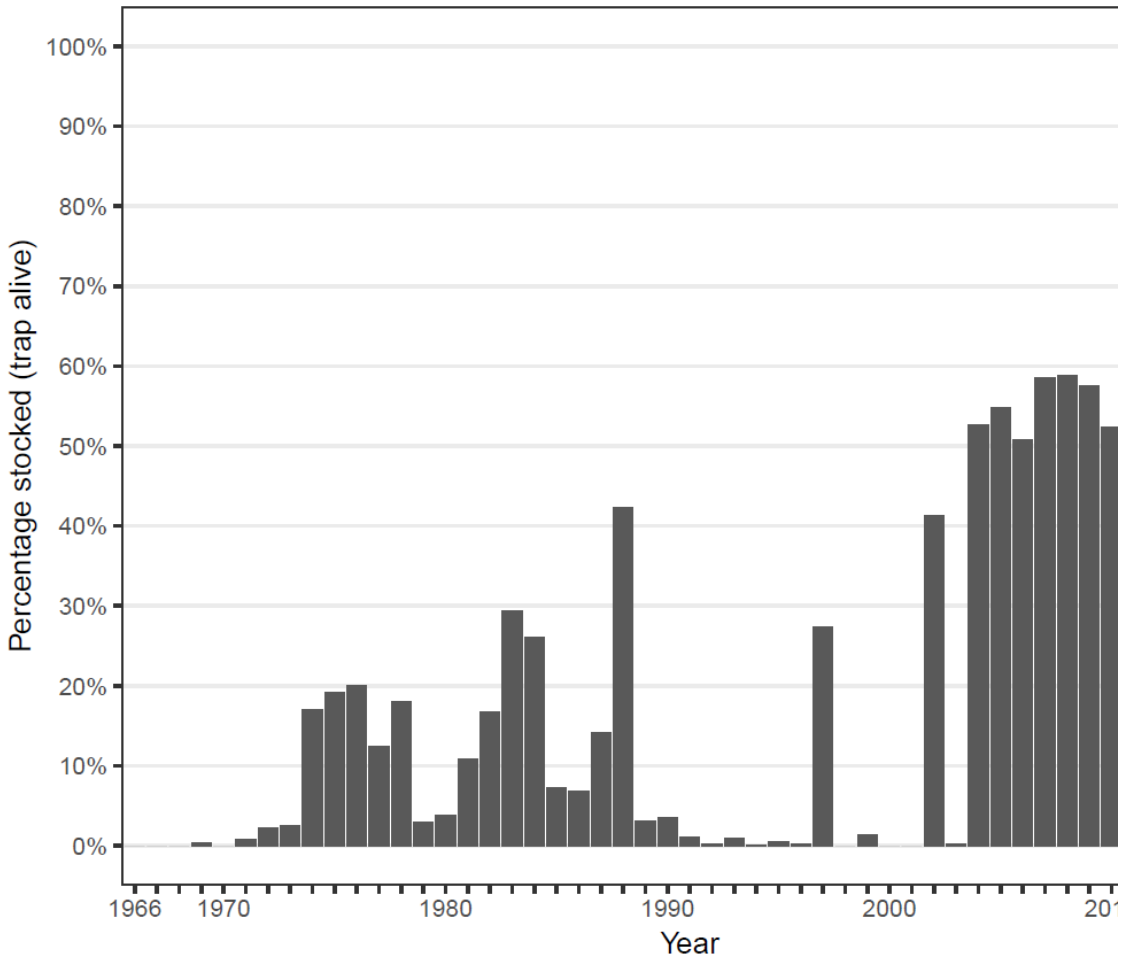

Figure 3. Percentage of stocked (as opposed to wild-born) individuals captured alive in the fish ladder trap over time (capture type = “trap alive”). The count is based on captures contained in the SUSTAIN trout survival dataset only.

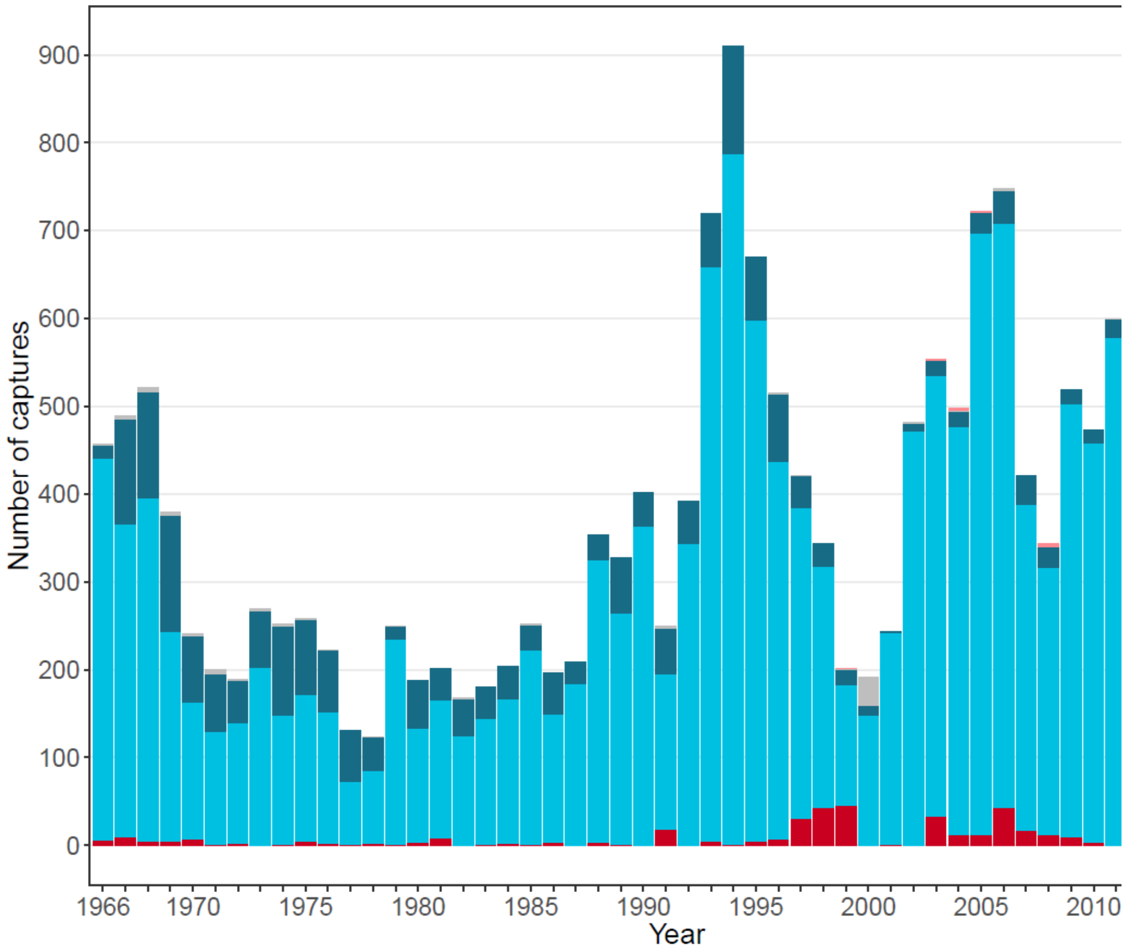

Figure 4. Count of trout captures per year in the SUSTAIN trout survival dataset, categorised by capture type. The capture types "trap dead" and "trap alive " are found in the fish ladder trap; "harvest" are captured alive elsewhere by fishers and killed; "catch release" are captured elsewhere by fishers and released alive, "found dead" are found dead anywhere else than the trap.

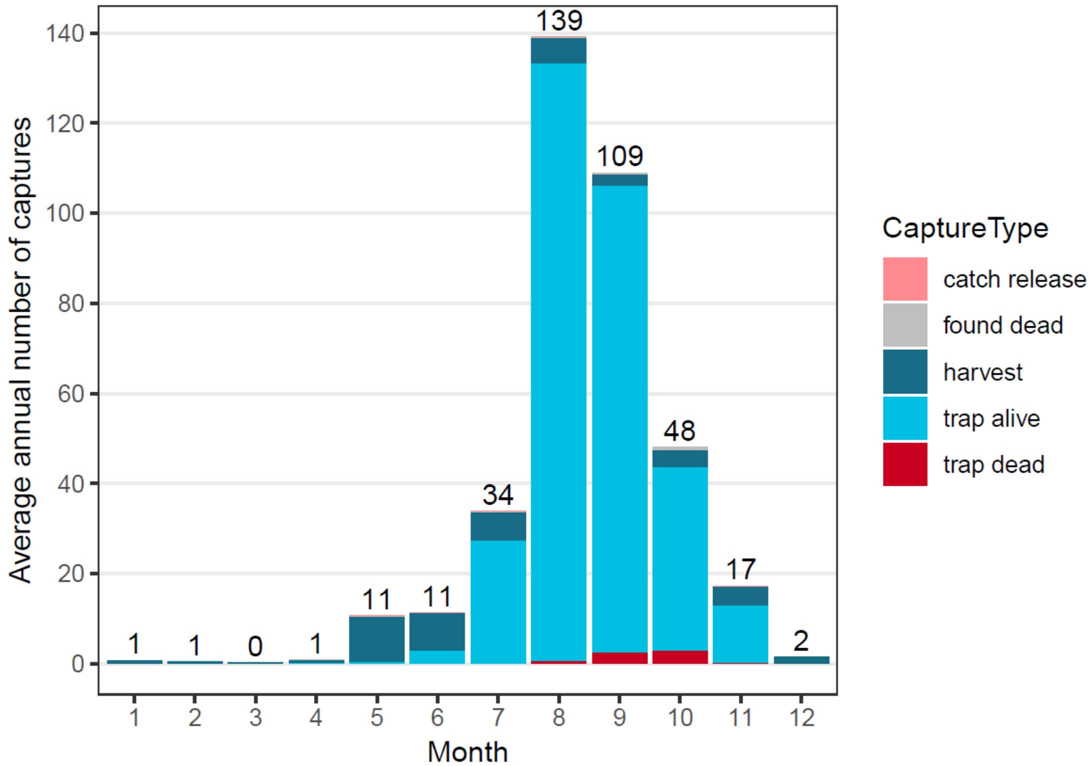

Figure 5. Average number of trout captures per month for the period 1966-2016, categorised by capture type. Digits above bars represent average numbers of all captures (all capture types combined) per month. For more details, see Fig. 5.

a)

b)

Figure 6. (a) Example of fish tagged with a Carlin tag. (b) Detail of a Carlin tag with individual code.

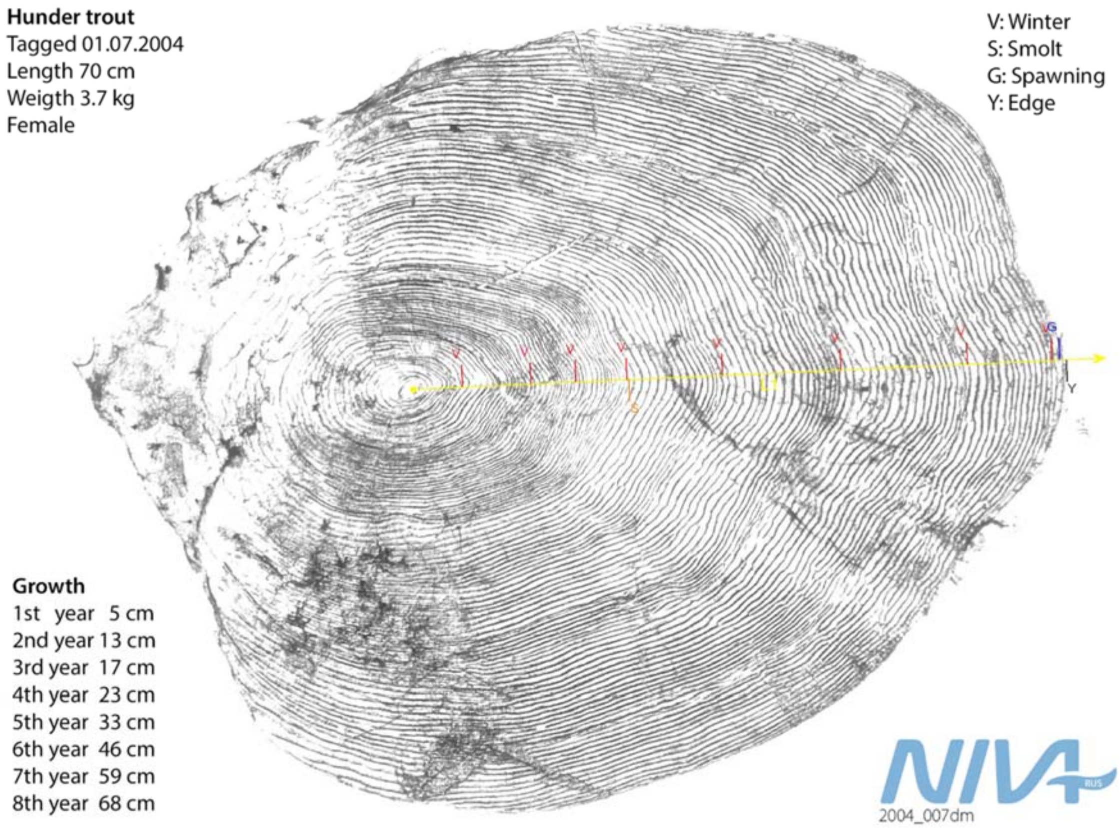

Figure 7. Illustration of a fish scale and interpretation of growth and spawning events. The yellow line represents the time line from hatching (centre) to the current age (the edge). Red lines indicate winters (marked "V"), where the growth is slower (denser growth curves). Smoltification ("S") after the 4th winter is indicated by subsequent rapid growth. Spawning ("G") is followed by very slow growth.

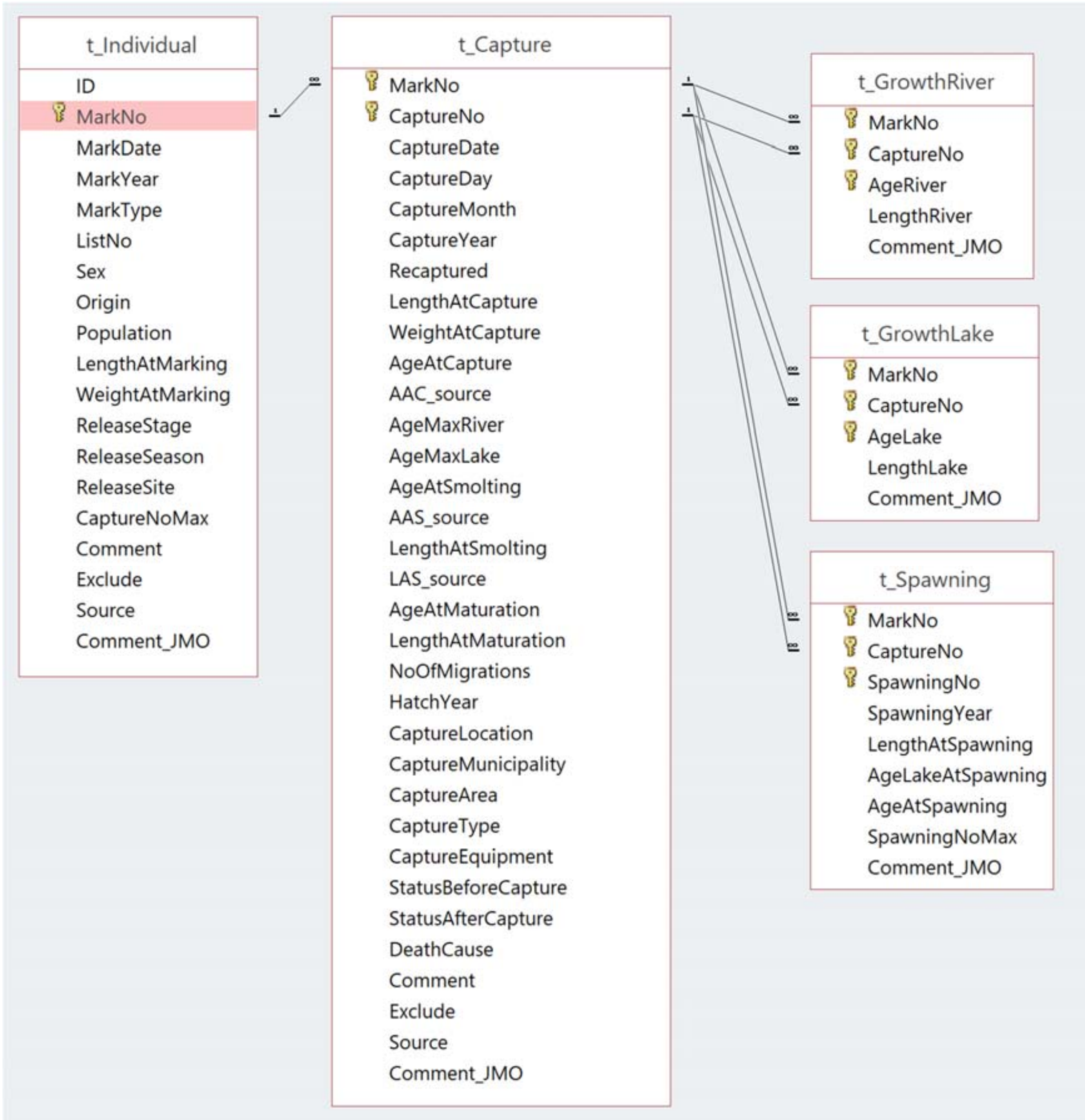

Figure 8. Illustration of the data model for the relational SUSTAIN trout database.The connecting lines illustrate one-to-many relationship from t_Individual to t_Capture, and from t_Capture to the three tables t_GrowthRiver, t_GrowthLake and t_Spawning. The key symbol illustrates the single or composite key field(s) identifying the unique records of each table.

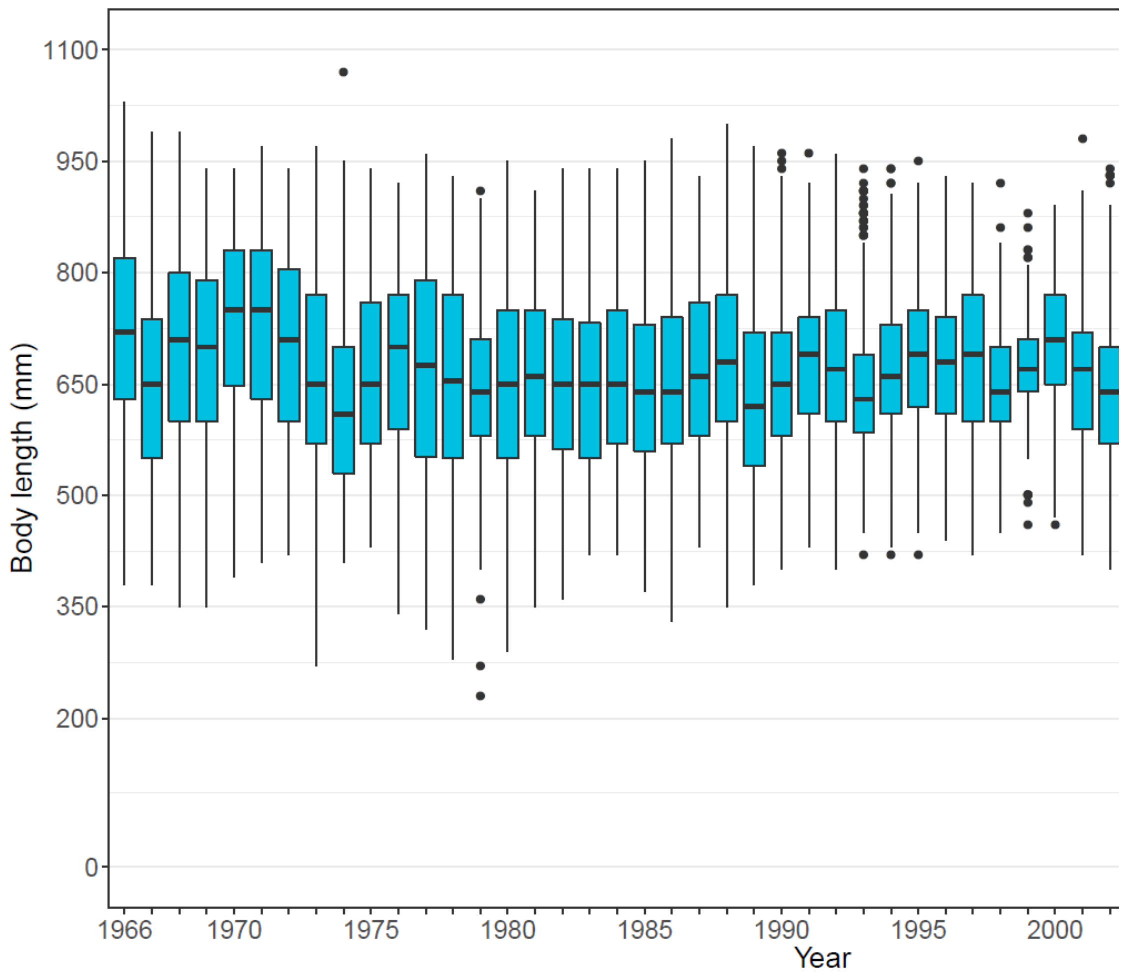

Figure 9. Distributions of individual body lengths per year in the SUSTAIN trout survival dataset. The box plot shows the median (horizontal bar), 25% and 75% quantiles (range of the box), largest and smallest values within 1.5 times the interquartile range (whiskers = vertical lines) and outliers (dots beyond whiskers). Note the decreasing trend in variation over the years (shorter vertical bars towards the end of the time series).

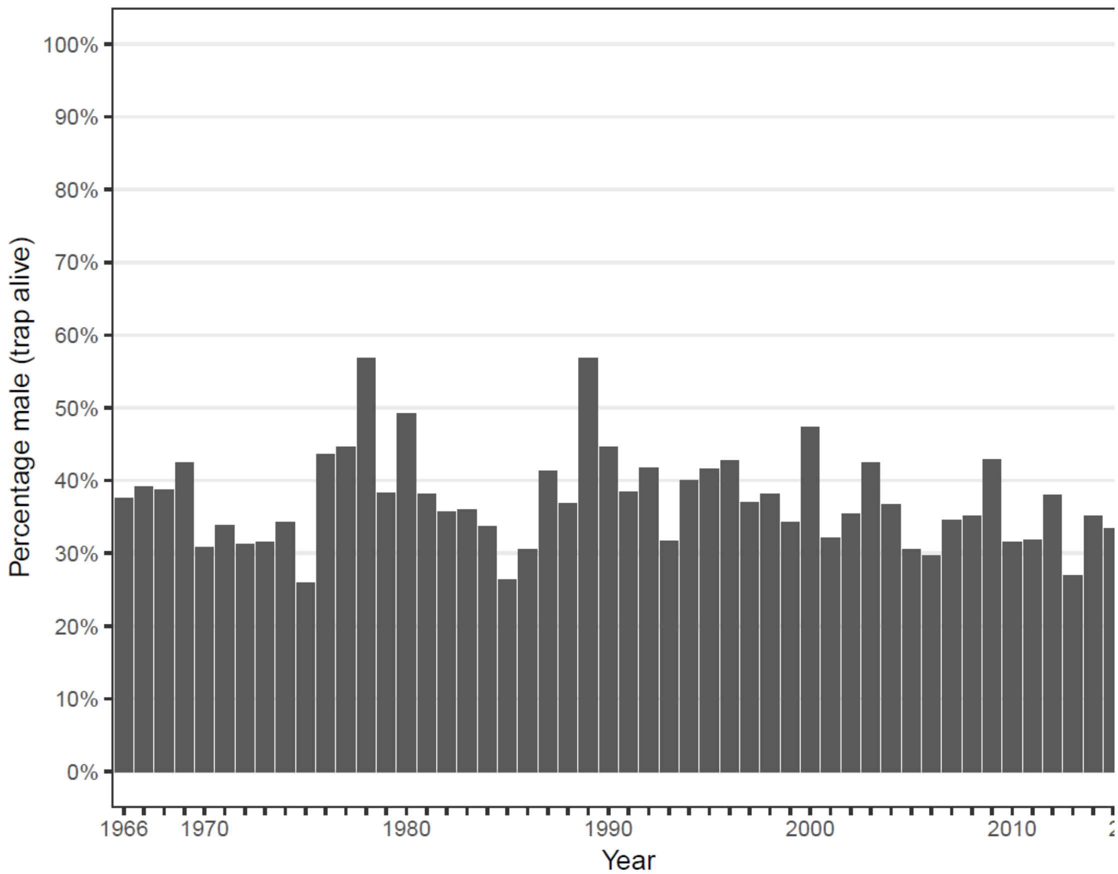

Figure 10. Percentage of male (relative to female) individuals captured alive in the fish ladder trap over time (capture type = "trap alive"). The count is based on captures contained in the SUSTAIN trout survival dataset only.