Master Thesis

Population characteristics of a Baltic sea trout spawning cohort from a small North German river: Age composition, spawning experience, growth and temporal genetic diversity

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September 2018

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1 Abstract

The sea trout (*Salmo trutta fario trutta*) is a popular target species for recreational and professional fisheries along the coasts of the Baltic Sea. Especially fishing tourism creates substantial economic value. Therefore, it is essential to maintain an efficient sea trout management system to ensure sustainable use of the resource sea trout and a high population status in the future. To address that, thorough system- and process-knowledge, combined with appropriate management measures and restoration programs are needed. The affiliated research in Schleswig-Holstein waters is conducted by the SMARRT-Project ("Smolt and Parr Produktion in Theorie und Praxis (SMARRT)" - Projekt zur Optimierung des Meerforellenmanagements in Schleswig-Holstein; C. Petereit et al., GEOMAR). This Master thesis investigated some aspects within the broader SMARRT research framework, addressing specific research questions related to the ecology and other characteristics of adult sea trout spawning cohorts by using classic fish scale reading and state-of-the-art population genetic methods. The investigations were conducted in the Farver Au, a small (~15km) North German river discharging into the Baltic Sea between Kiel and Fehmarn. The Farver Au was place to the last studies about sea trout spawning cohorts in the early 1970s by Gehlhaar.

During electro fishing seasons in 2015 to 2017 a total number of 898 adult sea trout were caught of which 367 were aged by scale reading. The sample selection followed several premises with selecting equal shares of both sexes and a manual selection of the ten biggest and smallest sea trout of each year. The smolt age that were found during the investigations differed from 75,9 % to 89,1 % (mean 83,3 %) of one-year old smolts. The remaining smolts were aged two years while no older smolts were found. The results match those of the most recent smolt trapping study in 2016 and 2017 in the comparable sized river Lipping Au (Rathjen, 2017). Six different sea age classes of returning sea trout varied over the sampling period with the most commonly found sea age being A.1+. This age class also represented most of the first-time spawners with a mean length of 48,8 cm. In total 70,5 % to 88,4 % of all scale-read fish were first-time spawners. Spawning marks were found on 76 scales, which equals a proportion of repeated spawners from 11,6 % to 29,5 % during 2015 to 2017. Growth rates were back-calculated and significant differences were observed when it comes to spawning experience. Post-smolt sea trout were able to grow up to 25 cm in an eight-month period during their first summer at sea. Maiden sea trout grew around 10 to 14 cm in each of the following sea years, while growth rates in spawning fish decreased due to reproduction losses. To validate scale reading results, sea trout were tagged with T-bar Tags during the fishing season 2016. Recaptures in the following season allowed to compare observed with back-calculated growth. Only a limited number of recaptures was available, however, in general a very high coincidence among the results could be shown.

The genetic diversity of the Farver Au spawning cohort was investigated over a six-year time series (2012-2017) based on the analysis of 12 microsatellites. Based on the STRUCTURE analysis and the calculation of Fst values, no significant differences in the genetic differentiation in the period of investigation were found. The effective population size (Ne) was calculated in each of the six years and showed no severe changes during 2014 – 2017 (Mean: 256,68, SD 35,91). Ne-values for 2012 and 2013 were differing (105 in 2012; 62,5 in 2013). The census population size was higher than the calculated effective size.

With respect to the results of this thesis, further optimizations in sea trout management options can be recommended. As well the mean size of spawners during the spawning season in the river as the back-calculated sizes at first-time spawning are above the minimum catch sizes in Schleswig-Holstein (40 cm) and Mecklenburg-Western Pomerania (45 cm). Regarding the calculated growth rates, it was observed that sea trout reach the length of 40 cm/45 cm before their first spawning run. It is to be expected that a majority of the 40 to 45 cm sized fish, which are caught during peak seasons of sea trout fishing in spring and autumn have never spawned before. Since each individual should have the opportunity to spawn at least once to contribute to the survival of the sea trout population, it is recommended to reconsider legal catch sizes in Schleswig-Holstein.

During the fishing seasons in November and December many silvery fish with lose scales were observed in the Farver Au, participating regularly in the spawning business. The maturity stages of these individuals were reaching from 4 (eggs tight in the peritoneal cavity) to 0 (spawning finished). The matter of coloration/lose scales is taken by the KüFO/KüFVO to differentiate protection between potential spawning and not-spawning sea trout. Due to the in-field observations, it is now to be assumed that the coloration is not correlating with the participation in spawning. Since the majority of spawning sea trout enter the spawning rivers just for several days up to three weeks, it cannot be guaranteed that silvery fish, caught during winter along the Baltic coasts are not participating in spawning. A general, coloration independent, closed season for all sea trout could lead to an enlargement of the spawning population und thus increase the amount of natural egg deposition in the spawning rivers.

The results in this thesis are based on a three to six-year period of investigation. Due to the high variability in the sea trout lifecycle, further and regular investigations of sea trout stocks are recommended. In particular, populations in larger rivers (e.g. Loiter Au) or streams (e.g. Trave and Schwentine) as well as in rivers draining into the North Sea or the Kiel Canal could provide different population characteristics due to higher discharge and different hydromorphology and therefore be in need of modified management measures.

2 Zusammenfassung

In den Anrainerstaaten der Ostsee ist die Meerforelle (*Salmo trutta fario trutta*) sowohl für die Freizeit- als auch für die kommerzielle Fischerei ein wichtiger Zielfisch. Der Fischereitourismus generiert zunehmend zu beachtende Umsätze entlang der Ostseeküste. Um der gesteigerten Aufmerksamkeit der Meerforelle als Zielfisch gerecht zu werden, ist sie als wichtige Ressource zu betrachten und ein Managementsystem zu etablieren, das auch in der Zukunft die nachhaltige Fischerei und somit gute Meerforellen Populationen sichert. Um Management- und Besatzmaßnahmen erfolgreich durchzuführen, ist es nötig, die Biologie der Meerforelle umfassend zu verstehen. Für schleswig-holsteinische Meerforellenbestände hat sich das SMARRT-Projekt ("Smolt and Parr Produktion in Theorie und Praxis (SMARRT)" Projekt zur Optimierung des Meerforellenmanagements in Schleswig-Holstein; C. Petereit et al., GEOMAR) dieser Aufgabe gewidmet. Diese Masterarbeit ist Teil des SMARRT-Projektes und beschäftigt sich mit der der Populationszusammensetzung der Farver Au, einem kleinen Bach (~15km Länge), der zwischen Kiel und Fehmarn in die Hohwachter Bucht, Ostsee mündet. Die Untersuchungen nutzen die gesammelten Probendaten der Jahre 2012 bis 2017. Zusätzlich stehen Vergleichswerte einer Arbeit von Claus Gehlhaar zu Beginn der 1970er Jahre zur Verfügung. Zum einen werden durch Schuppenanalysen relevante Populationscharakteristika ermittelt, die für die Fischbestandskunde entscheidend sind: Alter der Laichfische, Smoltalter und –länge, als sie als Smolts das Gewässer verlassen haben, realisiertes Längenwachstum im Meer, Anteil an Erstlaichern bzw. an Individuen, die schon einmal gelaicht haben. Es wurden jeweils 100 Individuen aus den drei Jahren 2015, 2016 und 2017 analysiert. Weiterhin wurde untersucht, ob und inwieweit sich die Laichfischpopulationen der letzten 6 Jahre genetisch unterschieden haben. Daraus wurde abgeleitet, ob verschiedene Teilpopulationen zum Laichaufstieg in der Farver Au beitragen.

Während der Elektrobefischungen der Jahre 2015 bis 2017 wurden insgesamt 898 Meerforellen gefangen und beprobt. Hiervon wurden 367 Exemplare ausgewählt und der Schuppenanalyse unterzogen. Aus jedem Jahr wurden 100 Tiere (männliche und weibliche zu je 50%) sowie die zehn größten und kleinsten Fische analysiert. Es traten überwiegend einjährige (1+) Smolts auf. Der Anteil der untersuchen Individuen lag zwischen 75,9 % und 89,1 % (Mittelwert 83,3 %). Bei dem verbleibenden Anteil handelte es sich um zweijährige Smolts, ältere Tiere wurden nicht gefunden. Die Altersverteilung der abwandernden Smolts deckte sich mit den Untersuchungen zur Smoltaltersverteilung von Rathjen (2017) aus der Lipping Au. Die zurückkehrenden Adultfische konnten in sechs verschiedene Meerjahresklassen eingeteilt werden. Die Verteilung unterschied sich zwischen den Jahren, die Meerjahresklasse A.1+ war in jedem Jahr die häufigste. Fische, die einen Winter auf See verbracht haben, bevor sie am ersten Laichvorgang teilnahmen, waren ebenfalls bei den Erstlaichern am häufigsten zu finden. Die durchschnittliche Länge der Erstlaicher betrug 48,8 cm. Insgesamt konnten auf 70,5 % bis 88,4 % der Schuppen keine Laichmarken festgestellt werden, es handelte sich folglich bei einem Großteil der untersuchten Fische um Tiere, die noch nicht vorher gelaicht hatten. Die Wachstumsraten wurden durch Zurückberechnung (Back-Calculation) bestimmt und wiesen im Hinblick auf die Laicherfahrung signifikante Unterschiede auf. Im ersten Sommer auf See war ein Längenwachstum von bis zu 25 cm zu beobachten. In den folgenden Jahren wuchsen Meerforellen, die nicht am Laichgeschäft teilnahmen im Schnitt 10 bis 14 cm pro Jahr. Tiere, die am Laichgeschäft teilnahmen, wiesen ein deutlich geringeres Wachstum auf. Um die Rückberechnungen zu validieren, konnten T-bar getaggte Fische, die in zwei aufeinanderfolgenden Jahren gefangen wurden, herangezogen werden. So wurde ein direkter Vergleich von beobachteten und zurückberechneten Längen ermöglicht. Obwohl nur eine geringe Zahl der Wiederfänge zur Verfügung

stand, zeigte sich doch eine zufriedenstellende Genauigkeit zwischen gemessener und zurückberechneter Länge.

Für die genetischen Untersuchungen basierend auf der Analyse von 12 Mikrosatelliten, konnte auf Gewebeproben von Individuen der Jahre 2012 bis 2017 zurückgegriffen werden. Die genetischen Daten wurden mithilfe einer STRUCTURE Analyse, einem Modell, welches die Individuen anhand ihrer Allelfrequenzen einer hypothetischen Anzahl von Populationen zuweist, ausgewertet. Sowohl die STRUCTURE Analyse als auch die Berechnung der Fst-Werte (Inzuchtkoeffizient; quantifiziert den Effekt der Inzucht in substrukturierten Populationen) konnten keine signifikanten Unterschiede in der genetischen Zusammensetzung der Laichkohorten über den Untersuchungszeitraum nachweisen. Die effektive Populationsgröße (Ne, Anzahl der sich tatsächlich auch genetisch fortpflanzenden Individuen) wurde für jedes Jahr berechnet und blieb mit Abweichungen 2012 und 2013 über die Vergleichsjahre weitgehend konstant (2012-2017 = Mittelwert 199,02, Standardabweichung 94,52; 2014-2017 = Mittelwert 256,68, Standardabweichung 35,91). Die tatsächliche Anzahl der aufsteigenden Laichfische liegt vermutlich deutlich über der berechneten effektiven Populationsgröße.

Aus den Ergebnissen der Schuppenlesungen können wichtige Informationen abgeleitet werden, die als Managementempfehlungen Beachtung finden sollten. Sowohl die durchschnittliche Längenzusammensetzung der Laichfische als auch die rückberechneten Längen für die Erstlaicher, liegen deutlich oberhalb der in Schleswig-Holstein (40cm) und Mecklenburg-Vorpommern (45cm) geltenden Mindestmaße. Mit Kenntnis des Wachstums im Jahresverlauf lässt sich feststellen, dass die Meerforellen die Länge von 40 cm bzw. 45 cm schon weit vor ihrer ersten Teilnahme am Laichgeschäft erreichen können. Zur Hauptfangzeit der Meerforellenangler im Frühjahr und im Herbst ist zu erwarten, dass ein Großteil der fangbaren Fische zwischen 40 und 45 cm noch nicht abgelaicht hat. Ein Individuum sollte innerhalb seines Lebens die Chance bekommen, sich mindestens einmal zu Vermehren und damit zum Fortbestand der Meerforellen Population beitragen zu können.

Während der Elektrobefischungen zur Laichzeit zwischen November und Dezember wurden zudem viele silberblanke Fische im Bach nachgewiesen, die regulär am Laichgeschäft teilnahmen. Die Reifestadien der silberblanken Individuen reichten von 4 (Eier noch fest in Bauchhöhle) bis hin zu 0 (Eier bereits abgelaicht). Es ist daher zu vermuten, dass das Kriterium der Färbung der Meerforellen, das in KüFO/KüFVO als ein Ansatz zum Schutz der Laichfische in der Ostsee herangezogen wird, nicht zwangsläufig mit der Teilnahme am Laichgeschäft korreliert. Da sich der Großteil der Meerforellen in kleinen Laichbächen oft nur für wenige Tage bis 3 Wochen aufhalten, ist nicht gewährleistet, dass silberblanke Meerforellen, die im Winter an den Ostseestränden gelandet werden, tatsächlich mit dem Laichgeschäft aussetzen. Daher könnte eine generelle Schonzeit, gültig für alle Meerforellen unabhängig ihrer Färbung, zu einer Vergrößerung der Laichfischpopulation führen, und damit die natürlich abgelegte Eianzahl in den Gewässern erhöhen.

Für alle Untersuchungsergebnisse in dieser Arbeit liegt ein Untersuchungszeitraum von 3 bis 6 Jahren zugrunde. Aufgrund der natürlich auftretenden hohen Variabilität im Lebenszyklus der Meerforellen ist eine weitere, regelmäßige Probenentnahme und Untersuchung der Bestände zu empfehlen. Dies trifft insbesondere für Meerforellenpopulationen der größeren Bäche (z.B. Loiter Au) oder Flüsse (z.B. Trave und Schwentine) zu; ebenso für die Nordsee- und Nordostseekanalgewässer. Durch den deutlich höheren Abfluss und die unterschiedliche Gewässermorphologie liegen dort vermutlich andere Populationscharakteristika oder Rekrutierungsbedingungen vor, als in den kleinen, kurzen, direkten und wasserärmeren Ostseebächen.

3 Introduction

The sea trout (*Salmo trutta fario trutta*) is a popular target species for recreational and professional fisheries along the coasts of the Baltic Sea. Especially the coastlines and rivers of Baltic states like Denmark, Sweden and Germany are favoured destinations for angling tourists to catch the "Baltic Silver". In these regions, the sea trout recreational fisheries represent a considerable share of the total tourism and maintains therefore a substantial economic value (Blicharska & Rönnbäck, 2018). Against the background of declining salmon catches (ICES, 2018), the sea trout, as most common salmonid species in the Baltic Sea, has also become a major subject of interest to professional fisherman.

Scientific institutions around the Baltic nations (like e.g. DTU Aqua, Denmark) compiled research activities over decades on questions about sea trout ecology and its management. Taking into account the increased sea trout catches over the last decade, particularly in Danish waters, this might reflect, that thorough system- and process-knowledge, combined with appropriate management measures and restoration programs are needed, to ensure a high sea trout population status. In Germany, activities supporting sea trout stocks have long tradition. Early work of Gehlhaar (1972, 1974) provided in the 1970th an overview on growth patterns and some other ecological characteristics of seatrout as a case study from one Baltic river. Broader information and more recent activities (but also including historic information) had been reviewed in a literature study on Sea trout in Schleswig-Holstein by Petereit et al. (2013).

Sea trout stocks have been supported with high financial and personnel effort by stocking activities in the last decades, but even before that, stocking has been performed for more than a century. This may not only have impacted the population structure but also the genetic compositions of these populations. However, some genetic population structure is still maintained in considerable numbers of Baltic Sea discharging systems (40-50%), where between rivers sea trout populations differ significantly (Petereit et al., 2018). Further scientific investigations about stocking success efficiency and sea trout stock characteristics are in general rare.

For a sustainable increase and permanently large sea trout population sizes, intensive knowledge and understanding of the sea trout life cycle and external factors influencing those, throughout all life stages, is needed. In Schleswig-Holstein the current SMARRT-Project ("Smolt and Parr Produktion in Theorie und Praxis (SMARRT)" - Projekt zur Optimierung des Meerforellenmanagements in Schleswig-Holstein; C. Petereit, GEOMAR), addresses some of these issues.

This Master thesis investigated some aspects within the broader SMARRT research framework, addressing specific research questions related to the ecology and other characteristics of adult sea trout spawning cohorts by using classic fish scale reading and state-of-the-art population genetic methods. The results are discussed in particular in relation to their importance for management implications.

In the continued Introduction chapter, general important species information is provided along with current regional key findings for sea trout and information about the main methods applied. This is followed by the overall and more specific research questions which are addressed by this thesis.

3.1 *Salmo trutta:* species facts, taxonomy, anadromy and broadscale distribution

The brown trout, *Salmo trutta*, was first described by Linnaeus in 1758. It is a polymorphic salmonid species that is separated into three morphs, referring to the respective life cycle. The non-migratory "baeck trout" *Salmo trutta f. fario* is a resident form of the brown trout which stays its entire life in rivers, streams and creeks. In contrast to that, two forms of migratory trout are distinguished by their route of migration. The lake trout *Salmo trutta f. lacustris* is an isolated form which is spending its adult life in lakes and migrates into surrounding running waters for spawning. The subject of this study, the sea trout *Salmo trutta f. trutta*, is known to be the origin of *Salmo trutta* variations (Gehlhaar, 1972) and is migrating between fresh water and saltwater. However, the separation of the different forms is hardly possible. Genetic differences can be found in isolated forms with separated spawning regions (Hindar et al., 1991), while, especially in small rivers and creeks discharging into the Baltic Sea, the habitats are occupied by both resident and migratory trout. Here, mating between forms is common practice (Elliott, 1989) and a separation is difficult.

The species of *Salmo trutta* shows facultative anadromy, meaning that some trout migrate to the sea while other individuals of the same population remain resident within their natal river. Anadromy results in higher fecundity due to better feeding conditions in saltwater and thus lager size. Residency is more often to be found in males and can give higher survival. Trout, remaining in their natal river avoid the energy expenditure required by anadromy. The decision whether choosing an anadromous or resident life history is a quantitative threshold issue. All costs and benefits of anadromy and residency are finely balanced, thus small changes in the controlling genes or the environmental factors can lead to changes in life history. Although there is a tendency to pursue the parental life history, sea trout can give rise to resident offspring as well as descendants of resident trout can migrate to the sea (Ferguson et al., 2017).

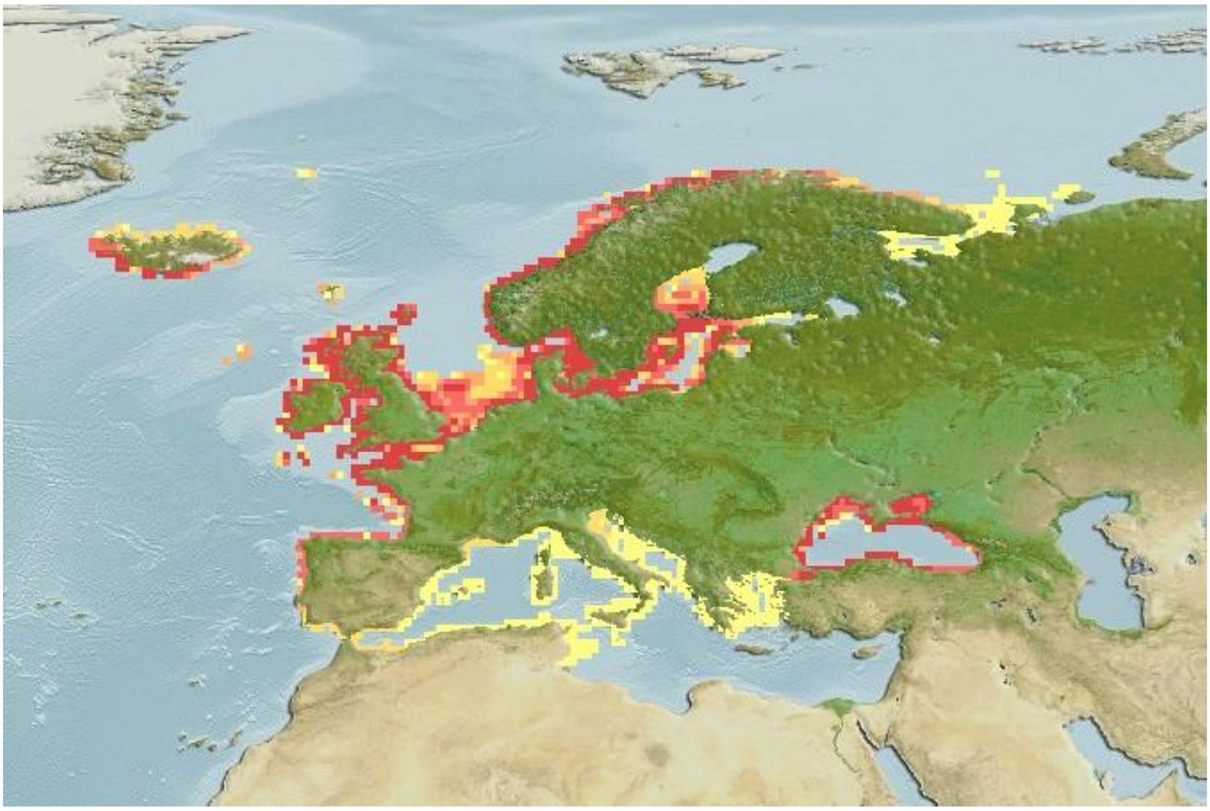


Figure 1: Currently known distribution: Europe and Asia: Atlantic, North, White and Baltic Sea basins, from Spain to Chosha Bay (Russia). Found in Iceland and northernmost rivers of Great Britain and Scandinavia. In Rhône drainage, native only to Lake Geneva basin, which it entered after last glaciation. Native to upper Danube and Volga drainages. Introduced widely. Several countries report adverse ecological impact after introduction (resource: www.fishbase.org). Colours indicate the frequency of occurrence (red=high, yellow = low).

Sea trout are widely spread over European coastal waters (Figure 1). They are found in western Europe from the boarder river Mino (Caballero et al., 2013) between Spain and Portugal, northwards to Scandinavia and north-west Russia, including the British Isles, Iceland and the entire Baltic Sea (Klemetsen et al., 2003). Sea trout are also found in the Mediterranean Sea (MacCrimmon and Marshall, 1968) and it was introduced successfully to other countries in North and South America, Asia, Africa and Australasia between the mid-1800s and mid 1900s (Elliott, 1994).

3.2 Fine-scale distribution, lifecycle and reproduction

The anadromous sea trout spends most of their lifetime in marine habitats. Migration routes of German sea trout populations are so far almost unknown. Present information for Mecklenburg-Western Pomerania sea trout are based on surveys concerning catch areas and depth (as well anglers and professional fisherman information) and some recaptured tagged fish (Hantke et al., 2010). Recent tagging studies of adult and juvenile fish in several rivers in Schleswig-Holstein show a mean recapture distance less than 50km from the home rivers with moderate to high variation between individuals (Petereit et al. 2018 - SMARRT, Final Report). Early post-smolt sea trout may be predominantly restricted to local coastal areas and they may enter estuaries and freshwater sections of other rivers than their natal rivers to feed or overwinter (Aldvén & Davidsen, 2017). Rasmussen and Pedersen (2018) report that most of the sea trout, tagged with Carlin tags, were caught within 100-200 km from the releasing point, while some trout migrated hundreds of km. The distance of marine migration is assumed to be dependent on domesticated or wild origin, with trout of wild origin migrating generally less (Rasmussen and Pedersen, 2018). A recent tagging study of northern Baltic sea trout stocks in Sweden showed a median migration distance at recapture of 27 km (Degerman et al., 2012). Both studies observe a dominating southward migration direction, which was also observed by Petereit et al. (2018). However, Information about the marine life phase and migration routes differentiate throughout the literature and latitude, with some trout even making long-distance migration of >1.000 km (Aldvén & Davidsen, 2017).

3.2.1 Spawning run

Suitable creeks and rivers have to provide clean water with high oxygen content and gravel substrate. The timing of sea trout spawning runs can be very diverse. While some fish start the fresh water migration already in May and can be caught by electrofishing for parr during summer, most of the fish will start the fresh water run during high water levels from October until December, sometimes end of January. The spawning run depends on the climate conditions and the latitude of the respective area (Klemetsen et al., 2003).

3.2.2 Nesting, mating, fertilization and kelt return to the sea

After moving upstream males and females mate, when they found suitable spawning conditions, characterized by shallow, oxygenic waters with gravely grounds. The female fish digs a spawning bed in the ground, with a mound of small stones downstream. This mound results from the digging and serves as cover for the dispensed eggs. Simultaneously to the oviposition of the female the male trout fertilizes the eggs by releasing sperm into the water. The fertilized eggs are positioned between the gaps and cavities of the stones by the river's flow and covered with stones by motion with the tail fin. The spawning process can be repeated several times. When the spawning terminates the often exhausted and injured fish migrate back to the sea. Petereit et al. (2018) determined the residence time (how long individuals stay in the river for spawning) by t-bar tagging. They found that 60-70% of the fish returned within two weeks after spawning and that only about 1/3rd of the spawning populations stayed longer up to more than 1.5 month (Petereit et al., 2018). On average, males stayed longer than females (Petereit et al., 2018). Returning fish are called “kelts”, which start feeding back in saltwater and recover quickly (Thomson, 2015).

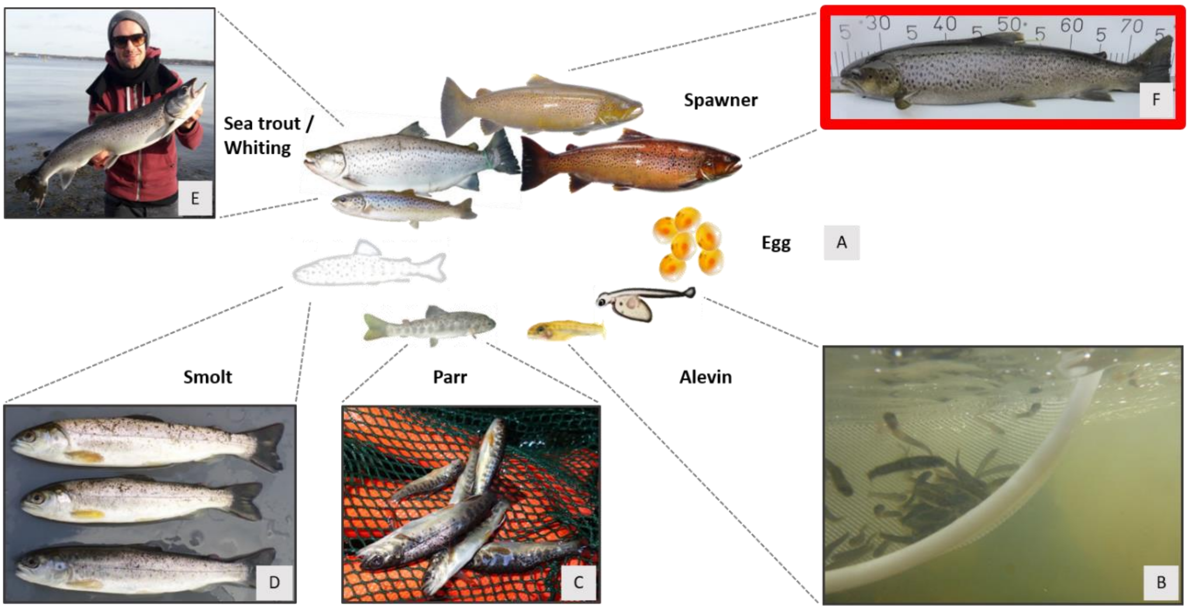


Figure 2: Stages of the sea trout life cycle. A: Eggs; B: Alevin; C: Parr; D: Smolt; E: Adult sea trout or whiting – a favourable goal for anglers; F: Spawning sea trout – main content of this thesis. Figure modified from Petereit et al. (2016).

3.2.3 Egg development, hatching, alevin, fry and parr stage

The eggs are sheltered in the gravel, where they are saved from drifting and covered from direct UV-radiation. The constant waterflow ensures oxygen supply until the eggs hatch after approximately 440-degree days (Elliott, 1994). The freshly hatched trout remain in the gravel receiving their nutrition from a yolk sac. They are called “alevin” until the exogenous reserve is largely consumed. Thereafter, the fish hatch from the gravel and are reliant to start active feeding at the soil. Fish at this stage are called “fry”. They develop into “parr” after a few weeks (Elliott, 1994), but this is a gradual transformation which is hard to determine. The parr stage occupies its own feeding grounds in which they stay and which they defend against other parr. With increasing energy requirement, the parr increase their territory (Thomson, 2015; Klemetsen et al., 2003), which limits the carrying capacity of each spawning river concerning reproduction. Parr show a colourful phenotype with typical marks on the lateral side (“Parrflecken”), which they lose when converting to the final freshwater stage, the smolt.

3.2.4 Smolt: Age and size

In North German latitudes individuals leave the freshwater after one to three years to the sea as smolts (Rathjen, 2017). Again, this transition from Parr to Smolt is not abrupt and the determination of the smolt only according coloration is difficult. Petereit et al. (2016) described four habitus types of freshwater leaving smolts, which are shown in figure 3. As mentioned, the age at freshwater escape (smolt age) in the analysed focus river Lippingau in North Germany was mostly one (85,85%) and partly two (14,15%) years (Rathjen, 2017). In general, it is correlated to the latitude and size of the river (discharge related) and can extend to six or seven-year-old smolts in northern Europe (Jonsson & L’Abee-Lund et al., 1993). Beside age, smolt size is also an important population characteristic. Older smolts are in general larger compared to younger smolts. Rathjen (2017) found in his studies from the Lipping Au mean sizes of 140,27 mm for 1+ smolts and 173,40 mm for 2+

smolts. The initial size at time of first sea entry also influences the capability of food selection and is also often related to swimming capacity. Gehlhaar (1972) described different smolt ages in his study rivers Farver Au and Rantzau. He found 39,77% (Farver Au) and 3,21 % (Rantzau) of 1+-smolts. The majority of smolts was aged 2+ (58,48%, 79,12%) with some smolts being 3+ (1,75%, 17,67%).

Figure 3: Different habitus types of smolt catches during the smolt trapping seasons 2016 and 2017 in the Lipping Au. A) „Super smolts", B) „smolts", C) "smolt with parr-spots", D) "Baek-trout habitus". From Petereit (2016)

3.2.5 Maiden individuals, repeated spawners and "Überspringer"

The time sea trout spent at sea until returning to their natal river to spawn varies from a few month (finnock, 0 SW) to eight years. The average sea residency time is generally decreasing with increasing latitude (L'Abée-Lund et al., 1989). Fish (both male and female) that have still to spawn for the first time are called maiden fish.

As a multiple spawner, most of the fish may survive the spawning activities and return to the same river in the next year. The proportion of those "multispawner" individuals from the overall spawning population may serve as an indication for survival at the sea and similarly reflects the dependency of the spawning population from specific cohorts. During 1969 and 1971, Gehlhaar (1972) found a proportion of 58,2% (Farver Au) and 66,3% (Rantzau) repeated spawners and concluded that the mortality during sea residence was rather low. According to recent personal information of Dr. Adam Lejk, we can expect a substantially lower proportion of repeated spawners today (8% repeated spawners and 0,5% multiple spawners in Poland). It is assumed that repeated spawning is associated with clear reproductive benefits. Older, larger males are expected to have greater reproduction success than younger, smaller males. As well, older, larger females own the ability to produce more eggs, implying higher reproduction (Christie et al., 2018). Knowledge about the proportion of repeated spawners allow an estimation of the spawning cohorts' overall reproduction sustainability. Information about length at (first) spawning can give important management implications, since length and number of eggs is correlated (Petereit et al., 2018). Information about which fish sizes contribute to the reproduction can also serve indications to useful minimum size regulations.

Some fish may skip the next spawning period and spend the winter along the Baltic coasts. These fish are a favourable goal for anglers and called "Überspringer". Due to the information of Dr. Adam Lejk (National Marine Fisheries Research Institute – Gdynia, Poland), these skipping fish are found in regions where sea trout must endure a long migration to their spawning beds. These fish will often spend the summer in the river and migrate back to sea not until the end of summer in the year of spawning and therefore do not participate in the next spawning season. If this behaviour can also be assigned on scales of the Farver Au's sea trout, will be analysed in this study. The proportion of skipping sea trout can provide indications about the vulnerability of a population with regard to environmental damages in the spawning river, for example manure accidents.

3.3 Scale Reading

Individual growth and age structures are measured by scientists to describe fish populations and to evaluate stock management (Leonardos, 2001; Yule et al., 2008). The interpretation of growth zones on hard parts of the fish like scales, otoliths or opercula is a commonly used method to estimate age and growth, especially in salmonid species (Elliott & Chambers, 1996). The most popular method among these is scale reading, as scale removal does not require the death of the fish, unlike the removal of most other hard structures. Scale reading is logistically much easier to realize than other methods like marking and tagging captured fish and then recapturing them. It is also more practicable than the analysis of a size frequency distribution of a large sample of fish (Elliott & Chambers, 1996). Nevertheless, the tagging methods made sense to check the accuracy of the scale reading on basis of direct growth determination and is used in this study too. The scale reading procedures in this study are based mainly based on three manuals:

1) Elliott and Chambers, 1996: A Guide to the Interpretation of Sea Trout Scales
2) Celtic Sea Trout Project, 2010: Manual on Sea Trout Ageing, Digital Scale Reading and Growth Methodology
3) WKADS Report, 2011: Report of the Workshop on Age Determination of Salmon

The methodology of the manuals was adopted, but several adjustments in the scale preparation were made. The proceedings in this study were arranged with help from several scientists who work on sea trout scales as well. By name these colleagues were Dr. Adam Lejk from the National Marine Fisheries Research Institute (Gdynia, Poland) and Simon Weltersbach/Tom Jankiewicz, from the Thünen Institute of Baltic Sea Fisheries (Rostock, Germany).

Age and growth determination were conducted by several studies in the past and are source to discuss the results presented below. One major study was recently summarized by Rasmussen and Pedersen (2018). In this study a total number of 1449 sea trout was aged. Due to the proximity of the Danish waters, the results allow a direct comparison to the results found in this study. In Schleswig-Holstein, Petereit et al. (2013) evaluated the sea trout science and the current state of knowledge. Sea trout investigations have basically been absent for the last 40 years. The latest study on adult spawning fish has been published by Gehlhaar in 1972 and 1974. The predominant sea age found in the Farver Au spawning cohort during 1969-1971 was A.1+ (34,29%, followed by A.2+ and A.0+ (26,86%, 23,43%). The Rantzau showed a deviant differentiation with A.2+ (40,16%) being the dominant sea age (Gehlhaar, 1972).

This study is the first work on scales since Gehlhaars' and the prerequisites of the population structure may have changed significantly since then. Today we have more than 40 years of stocking in Schleswig-Holstein waters, a fact that was not given in the early 70s (Petereit et al., 2013). Extended knowledge about sea trout spawning cohorts will allow providing updated management recommendations to support sustainable sea trout stocks in the future.

3.4 Temporal genetic diversity

The genetic diversity of a species between populations and between individuals of the same population results from the variation at different levels, such as nucleotides, genes, chromosome and genome (Dudu et al., 2015). As well the species and the population survival are influenced decisively by the presence of genetic variation. Furthermore, the genetic variation allows successful evolution to short- and long-term environmental changes (Soule and Wilcox, 1980). Consequently, reduced genetic diversity is correlated with enhancing the chances of extinction most-likely to human interventions like climate change, pollution, habitat loss or excessive fisheries exploitation (Dudu et al., 2015). To estimate the fragility of Baltic sea trout populations, the genetic diversity on a six-year time scale is analysed in the Farver Au using microsatellites. Comparative data are available for other Baltic rivers (Petereit et al., unpublished; Albrecht et al., unpublished). Microsatellites represent repetitive sequences in the genome with a significant level of polymorphism which develops because of a higher mutation rate than standard. (Dudu et al., 2015). Microsatellites are widely used for population genetic and conservation studies in fishes. The set-up of the genetic analysis in this study will be based on the work of Albrecht (2016), who established the microsatellite primer set for the work on sea trout on GEOMAR.

3.5 Management options

Several management tools are used to control recreational fisheries and to prevent growth- and recruitment overfishing. A widespread method to protect pre-spawning or immature fish from catching is the minimum legal catch size, which is the smallest size at which fish of a particular species can be legally retained if caught. Minimum sizes are used in both recreational and commercial fisheries and aim at an increasing proportion of fish reaching the spawning size (Hill, 1992). Alternative management options to protect small fish are gear restrictions which is most commonly used in commercial fisheries, e.g. by the regulation of mesh-sizes. In recreational fisheries, a regulation of minimum hook- and bait-size may equally contribute to size-selective catches (LLALF M-V[1]).

Closed areas are mostly used where juvenile and adult fish live in different areas or where spawning fish gather (Hickley et al., 1998). In closed areas fisheries can be banned complete or limited in time. To guarantee undisturbed reproduction, spawning fish can be in general protected by closed seasons, which are already implemented for sea trout in the Baltic Sea (KüFo S-H & KüFVO M-V). In Schleswig-Holstein the regulation of closed seasons is separated between KüFo (coasts and open Sea) and BiFVO (inland waters). Whereas all sea trout in rivers and streams are generally protected from 01.10. to 28.02., there is no general closed season in coastal waters.

[1] http://www.lallf.de/Schonbezirke.265.0.html, accessed 06.08.2018

Silvery fish with lose scales are allowed to be caught and removed all year, while coloured fish are protected from 01.10. to 31.12.

Another length-based approach to control recreational fisheries is a maximum catch size. A maximum catch size is used to secure the proportion of big, highly reproductive females (BOFF = Big old fat females) in stocks. The protection of big females is especially important in stocks with a low amounts of parent animals due to environmental destruction or overfishing (Arlinghaus et al., 2017).

3.6 This study

This study contributes to the SMARRT-Project. It investigates a sea trout spawning cohort in a typical small North German river, which serves as reference system to receive detailed understanding of processes in sea trout life history. Adult spawning fish were sampled weekly between 2015 and 2017 by electrofishing, during the main spawning season in November and December. The three-year sampling period results in a large-sized data collection providing information of almost 900 ascending spawning fish. The key questions concerning a spawning cohort will be answered by scale reading. This method enables access on information about age, growth and spawning experience of sea trout. Thus, it is possible to determine the composition of a spawning cohort concerning sex-ratio, age and length frequency. It will be analysed whether typical patterns can be found in a spawning cohort and if these vary over time. Changes between years will be discussed in respect to abiotic factors. The results will be compared with studies in neighbouring Baltic countries.

The results presented in this study will give potential explanations for differences or similarities between years or regions and figure out how this knowledge can be transferred or implemented into current or future management options. With knowledge of age, size and growth in adult sea trout it is possible to discuss current regulations in legal catch size (40 cm in SH, 45 cm in Mecklenburg-Western Pomerania (MV)), closed seasons (no in SH for silvery fish, 15.09-14.12. in MV), bag limit (no bag limit in SH, 3 fish/day in MV), protected or closed areas or to the production side (stocking, enhanced breeding). As well it is possible to support habitat renaturation measures, when more detailed information about spawning cohorts and their requirements in Baltic rivers are available.

Genetic samples of Farver Au spawning fish are available for the last six years. The genetic diversity and changes between the years will be detected using microsatellites. Information about the population’s genetic diversity allow to estimate the ability to adapt to environmental changes. It will be investigated whether the spawning cohort consists of one or more sub-population which may alternate between the spawning seasons. Furthermore, the effective population size will be calculated. It should be evaluated if major changes have occurred in the genetic differentiation over the last 6 years and what the order of change in effective population size (Ne) is on this temporal scale.

3.7 Scientific research questions

3.7.1 Age of an individual fish

What is the age composition of a typical sea trout spawning cohort from a small stream (Farver Au, regularly stocked/enhanced breeding with fry since decades) in Schleswig-Holstein?

How many seawinter have those fish experienced before returning? Do we have a system in the Farver Au which relies on mostly one (or two) age classes (cohorts) which potentially make the system vulnerable towards high mortality including strong harvest in the Sea by fishing & angling? Or will we measure rather complex age-structures within the contributing spawners – meaning that the cohorts consist of several age-classes build up by different ages of smolt cohorts?

What is the smolt-age (back-calculated size) of fish leaving the Farver Au to grow up in the Baltic Sea? How does the envisaged results compare to the published results from Gehlhaar (1972) from the 1970th? How is the result in comparison to the most recent smolt trapping results in 2016 and 2017 in the Lipping Au? (Master Thesis J-P. Rathjen, 2017)

3.7.2 Returning fish for spawning

What is the proportion of repeated spawners in the spawning population (detected by spawning marks / by T-bar tagged individuals from 2016)? Do differences between males and females exist? What is the minimum and maximum number of spawning migration events read from the individual scales?

3.7.3 Growth of the individual fish

What is the annual growth performance (in respect to growth rate) of the fish? (How many cm in growth can be achieved?). Is that different between sexes or different between years, spawning experience, or different between size classes?

3.7.4 Genetic information

How (diverse) temporarily stable is the genetic diversity of the adult spawning population of the Farver Au over a six-year time series based on the analyses of 12 microsatellites? Based on 50 analysed potential parents per year (2012-2017), what is the calculated effective population size (Ne) in each of the six years?

4 Material and Methods

4.1 River of interest

4.1.1 Farver Au in Schleswig-Holstein, Germany

The Farver Au (Testorfer Au in some publications), is the river of interest, located in Ostholstein in northern Germany (Figure 4). It is one of several rivers draining the territory around the Bungsberg. The Farver Au merges into the Randkanal which leads after 3,5 km into the “Oldenburger Graben” and downstream of the Weissenhaus sluice it discharges into the Hohwachter Bucht, Baltic Sea, between Kiel and Fehmarn. The Farver Au itself has a length of 14,4 km and a catchment area of approximately 89,7 km² (biota – Institut für ökologische Forschung und Planung GmbH, Bützow), which starts near Schönwalde and extends northwards until draining into the Randkanal (54°17'44.9"N, 10°48'07.6"E). The river has a channel-like lower section which provides fast upstream migration into areas with excellent conditions for sea trout reproduction, reaching from Gut Farve to the source (see 7.1). The width of the river is up to 3 m with a mean width, influenced by changing water levels, of ca. 1 m. The substratum is almost gravely with some sandy parts in-between. Shallow areas with water levels of minimum 5 cm alternate with deeper parts in curves and sections of fast current. The mean depth in the sampled area is about 20 to 40 cm. The upstream river sections are regularly drying out in late summer due to shortage of water. The Farver Au was for the last time subject to scientific studies on sea trout in the early 70s by Claus Gehlhaar (Gehlhaar, 1972).

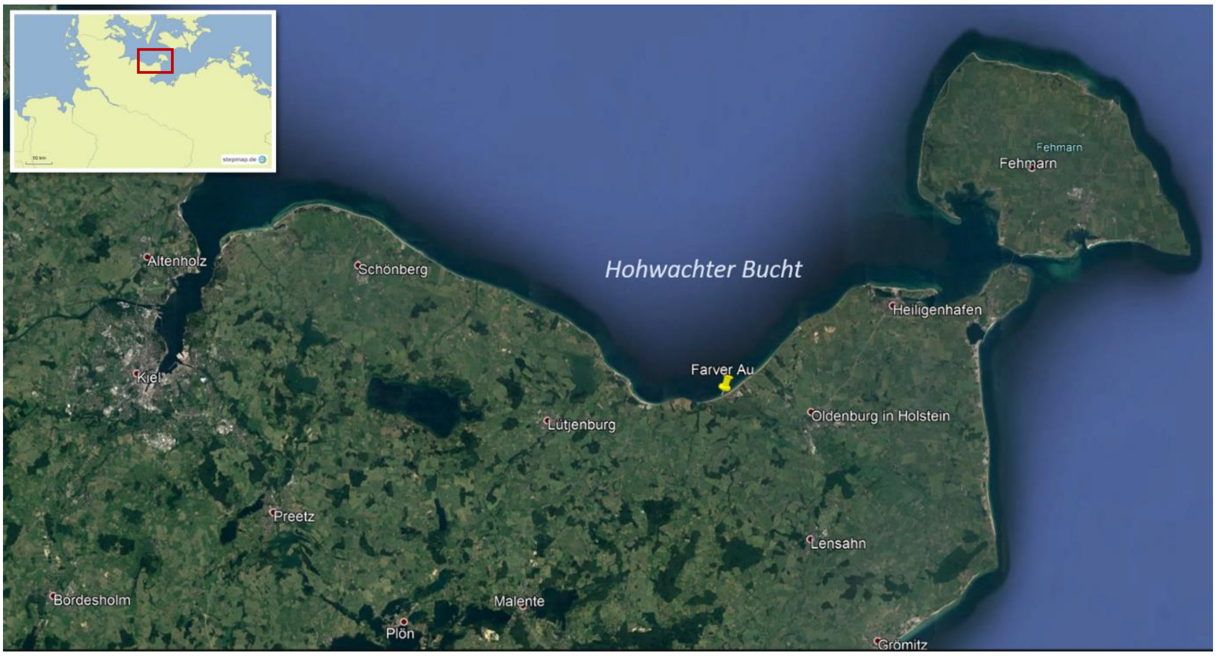


Figure 4: Farver Au draining into the „Hochwachter Bucht“ between Kiel and Fehmarn. Map taken from Google Maps.

4.1.2 Abiotic conditions

As a typical small river, the Farver Au has varying abiotic conditions concerning temperature and water level, which are expected to influence the sea trout spawning run (Campbell, 1977). Figure 5 show the temperature development (A) and the water level (B) over the sampling periods during November and December. The temperature diagram shows the mean value of the specific day which was taken from own logger data. The information of the water level was kindly provided by the company BWS (BWS GmbH, Gotenstraße 14, D-20097 Hamburg). The temperature was varying severely around November 14th between the years 2015 and 2016. The 2017 temperature development is more or less an average of the previous years. As also observed in studies at the Lipping Au (Rahtjen, 2017), the water level has a dramatic impact on sea trout migration. It is to expect, that times of rising water level triggered the fish to migrate as well downstream (smolts) and upstream (spawning fish). The development of the water level shows several clear peaks in which presumably a big part of the spawning cohort entered the river.

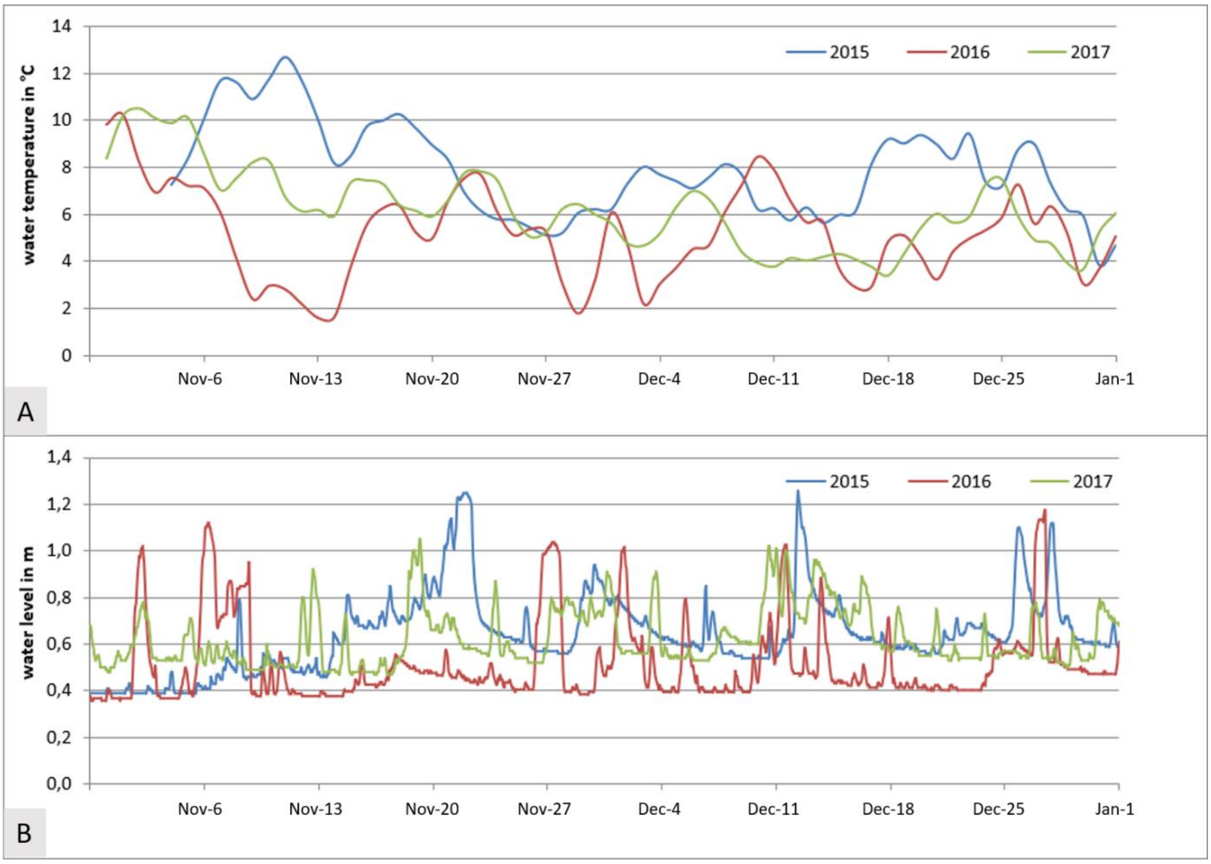


Figure 5: Temperature development from logger data during sampling periods during November – December 2015, 2016 and 2017 at the station „Brücken am Gut“. B. Information of the water level in the lower section of the Farver Au (Measurepoint OW-3; external Data kindly provided by BWS GmbH), Data from: Petereit et al., Endbericht SMARRT Projekt (2018).

4.2 Field Work

4.2.1 Electrofishing

The sea trout spawners were caught by electrofishing. The fishing was made with a TÜV-certified and authorized backpack electrofishing gear (type EFGI 650). The fishing events were executed weekly during November and December of the years 2015 until 2017 (see 7.2). Additionally, samples for the genetic analysis were taken from single fishing events in the years 2012, 2013 and 2014. The river was divided into 5 sections, starting at the point where the Farver Au discharges into the Randkanal (Figure 6). After the first station “Sandfang” there are about 2 km where fishing was not feasible. The following four sections were merging thus a continuously fishing was possible over the last four stations.

The fishing team consisted of five to seven people with each having different tasks. The central person was the electro fisher who was operating the electro fishing device in the river. The electro fisher was not changed during the fishing seasons to ensure consistent fishing success. Two “runners” were responsible to carry the fish to the car driving next to the river. Ventilated water tanks were mounted on the car’s trailer to keep the fish’s time out the water as short as possible. The fish were stored in the water tanks until they were put into the narcotic bath and the sampling begun. The measurements took place at the trailer’s back on a fixed measurement station described below. Christoph Petereit was responsible for the sampling procedures and had another two persons to his side, writing the protocol and supplying material. All sea trout with a total length of 20 cm und higher were sampled. Smaller fish were quickly released during the fishing. All animal related treatments were approved by the relevant authorities (MELUR SH; Schritte zur Optimierung des Meerforellenmanagements in Schleswig-Holstein – Prozessstudien und Populationsuntersuchungen, V242-229008/2015(4-1/16).

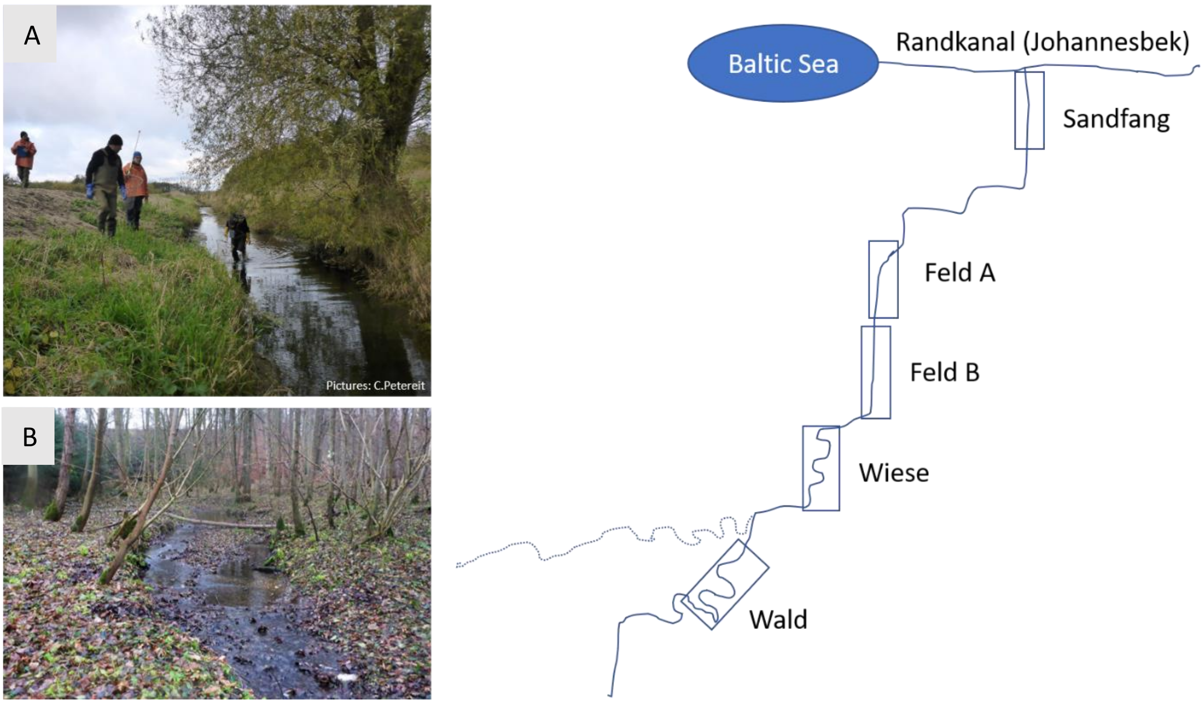


Figure 6: Farver Au sketch. A: lower channel like section “Sandfang”; B: section “Wald”. Note: Drawing not to scale!

4.2.2 Size and weight measurements

To facilitate the measurements, sampling and to prevent stress and injuries, the sea trout were put into a narcotic bath before the sampling procedures started off. The fish were removed from the narcotic bath when tilting to the side after about 30 to 60 seconds. A stopwatch was used to observe the time trout spent in the narcotic bath. Before the fish were subject to the measurements, they were washed in fresh water to get the narcotic water out of the gills. After the sampling was finished the fish were stored in fresh water for several minutes to recover before releasing them into river. All fish were released into the same river section in which they were caught to observe trout migration within the river.

Each individual was photographed, the sex was determined and the spawning state. The individual fish size was recorded on a measurement board (Figure 7). The total length of the fish is defined by measuring the maximum body span from the nose to the tip of the tail fin in natural position. Length measurement was conducted on the 1cm below.

The wet weight was recorded on a fixed field scale (wet weight in gram (g); accuracy ±10g). For a better handling the fish were weighed inside a bag.

4.2.3 Genetic fin clip tissue sample

Tissue for genetic analysis was taken from the upper part of the tail fin (Figure 7A). The fin clip was removed with a scissor and put into a prelabelled Eppendorf tube filled with 98%-Ethanol. For later identification, each fish got a unique number (Genetic ID) which was both written on the container and on a paper inside the Eppendorf tube.

4.2.4 Stable isotopes sample

For the stable isotopes analysis, a piece of muscle tissue was punched out of a defined section on the left side of the fish, under the dorsal fin (Figure 7B). The removal of the tissue was realized with a Biopsy Punch, 5,0 mm (Stiefel). The biopsy wound was closed just after removal of the tissue sample with antiseptic unction (Betaisodona). The samples were stored in Eppendorf tubes with another identification number (SI-number) and frozen at the end of the fishing day at -20°C for later analyses (not done within this thesis).

4.2.5 Scale sampling

Scale samples were taken with a forceps from the same body part of each fish (Figure 7C). They were taken from an area underneath the dorsal fin, before the adipose fin and above the lateral line. All scales were taken from the left side of the fish as recommended by the Celtic Sea Trout Project. Five to 20 scales were removed from each fish and stored dry in separate paper bags (otolith bags). The scale samples were organized by the genetic ID and kept dry at room temperature until analyses.

4.2.6 T-Bar Tags

Each fish got an individual T-Bar Tag („Hallprint Pty Ltd.“ (www.hallprint.com) Australia) for later identification in the river or in the Baltic Sea. The T-Bar Tags were deployed on the left side of the fish under the dorsal fin (Figure 7D). Tagging was performed by C. Petereit.

Figure 7: Measure board and sampling areas of the fish. A: Fin clip; B: Biopsy Punch for SI before being closed by antiseptic unction; C: Area for scale sampling; D: T-bar Tag

4.3 Scale Reading

4.3.1 Sample Selection

For the age determination a subsample of the collected sea trout scales was taken. For each year 2015, 2016 and 2017 100 fish were chosen randomly, but considering specific prerequisites. The distribution of the fish over die fishing dates was considered. The percentage share of fish sampled on one day equals the percentage of the random fish taken from that day. An equal sex ratio male to female was also chosen. Additionally, the scales of as well the ten biggest and the ten smallest fish were read. At the end the scales of the recaptures fish were added, when not being in the random selection. Finally, the sample for further preparation contained scales of 367 fish in total.

4.3.2 Scale preparation

The most difficult part of scale reading is to find suitable scales which are representative for the whole lifespan of the fish. A lot of scales are replacement scales with a disproportionate or damaged nucleus, making it impossible to determine the age of the fish. Other scales were mechanically damaged during the sampling process or showed erosion as consequence of fungal attacks during storage. Almost all scales were covered with mucus, algae and other dirt which was hardened throughout the drying process.

All scales were carefully scratched out of the otolith bag using a scalpel and regarded under the stereo microscope. From each sample the best two to four scales were put into 1mol-sodium hydroxide for 30 seconds. Afterwards they were washed with distilled water and the scale was carefully cleaned by scratching the dirt away with the scalpel. The cleaned scales were dried with a paper tissue and placed on a microscope slide. A cover slip was fixed with adhesive tape and the number on the otolith bag was transferred onto the microscope slide. Prepared scales were stored appropriately (Figure 8). The scale preparation was conducted based on the scale reading manuals “Manual on Sea Trout Ageing, Digital Scale Reading and Growth Methodology (Celtic Sea Trout Project, 2010) and “A Guide to the Interpretation of Sea Trout Scales (Institute of Freshwater Ecology, 1996). It was customized as recommended by the Polish expert Dr. Adam Lejk.

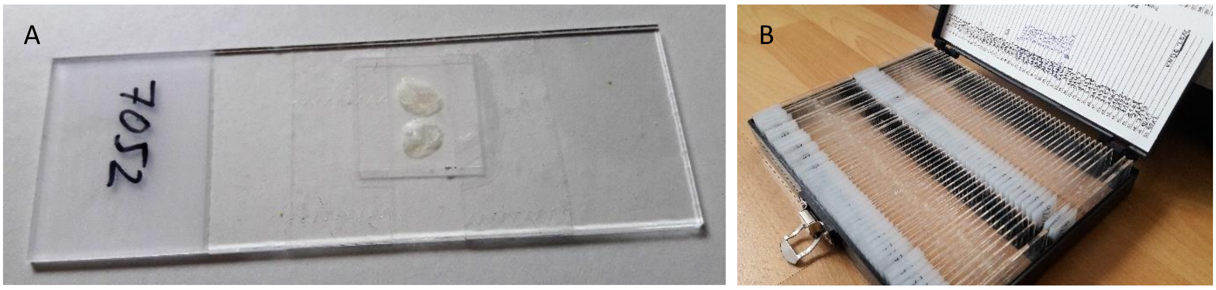


Figure 8: Scale preparation on microscope slides (A) and storage (B).

For the final age determination, the scales were photographed using a compound microscope mounted with a digital camera and the Image Pro Insight Software (v. 8.0). The picture of the scale was saved as tif-picture and named as the identical genetic number on the slide. From every scale several pictures with different magnifications or close-ups on different areas were taken. These information were added to the file name. E.g.: 9228-1-2,0 for the first scale of the fish with the genetic ID 9228 in 2,0 magnification. 9228-1-3,2-foc is a detailed view on the scale’s focus.

The scale pictures were optimized automatically with Lightroom 5.7.1 to improve contrast and brightness. This step is important to see light and dark bands clearly and to finally identify annuli.

Measurements on the scale were realized using the program ImageJ v. 1.48. All data were stored in Excel for further calculations.

4.3.3 Interpretation of sea trout scales

The relationship between the marks on a scale and the age of the fish were first recognized by van Leeuwenhook in the seventeenth century (Elliott & Chambers, 1996). Especially salmon and sea trout were model organisms to scale reading due to the large size of the scale and the clear distinction between summer and winter growth, which is the essential for the interpretation of sea trout scales. Unfortunately, sea trout scales are rarely clear, and they offer a lot space for subjective interpretation and disagreements between readers. In this study, scales were cross read and discussed by several scientists (Dr. Adam Lejk, National Marine Fisheries Research Institute (Gdynia, Poland) and Simon Weltersbach/Tom Jankiewicz, Thünen Institute of Baltic Sea Fisheries (Rostock, Germany)) to ensure that scales were interpreted in a consistent manner. The scale reading was conducted without prior knowledge of the fish size to avoid observer bias. The following part describes the commonly used terms to describe structures in scale reading (Figure 9 A+B).

4.3.3.1 Focus

The Focus is the starting point for scale growth and represents the beginning of the body growth. It is also called nucleus and the centre of the concentric lines.

4.3.3.2 Circuli

The Circuli are the typical growth marks on a fish scale and appear as concentric lines around the focus. The space between single circuli represent growing events and can form dark and light bands (compare 3.3.3.3).

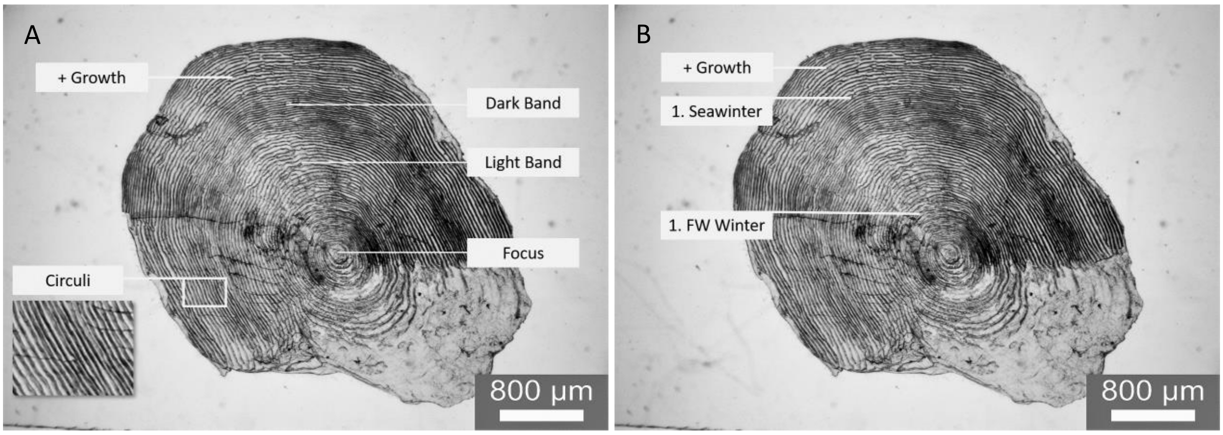


Figure 9: Structures on a sea trout scale. One light band and one dark band result in one annual zone. Age of the fish: 1.1+.

4.3.3.3 Summer- and winter growth

Light bands are formed during times of rapid growth, usually during warmer periods in spring and summer. These light bands represent summer growth and are also named summer bands. The circuli appear widely spaced during fast growth. In contrast to that, the winter growth is represented by dark bands with narrow spaced circuli. In general, there are fewer circuli forming a dark band than there are circuli forming a light band. Sometimes a fish has a period of slow growth within the regular summer growth. This phenomenon is called summer check and a major issue in scale reading, as inconstant growth during a growing period is very common. Here circuli are also narrow spaced, generally fewer in number, as in a winter band.

4.3.3.4 *Annual zone*

The annual zone is the combination of a light band and a dark band and represents a completed year in a sea trout's life cycle. The Annulus is the theoretical boundary between two successive annual zones. During the scale reading the reader looks for annual zones which are a direct indication for completed years on a sea trout scale. The number of annuli is equal to the age of the fish.

4.3.3.5 *Plus-growth*

The plus-growth is the region of wide spaced circuli after the last completed annual zone. It represents the growth from the last winter until the time of the catch, when a year of growth is not yet completed.

4.3.3.6 *Freshwater- and saltwater growth*

Due to better growing conditions, the circuli of saltwater-growth are generally wider spaced than they are during freshwater-growth. On a scale there is often a clear increase of the circuli size when the fish is leaving its home river for the first time. However, the point of freshwater escape leaves mostly occasions for discussion.

4.3.3.7 *Run-out or B-type smolt*

A run-out represents a period of plus-growth after the last winter in freshwater before leaving the river. Run-out growth was found on all scales of the Lipping Au smolts examined by Rahtjen (2017). It is expected that the creation of the last winter-band is finished earlier in the year, although the convention takes April 1st as date for a completed year in a sea trout life cycle.

4.3.3.8 *Spawning Mark (SM)*

Spawning marks are simply defined as erosions associated with the spawning migration. Erosions mean the reabsorption of the edge and sometimes of the surface of the scale. In varying extent, the winter-band is rubbed away. This is leaving characteristic marks on the scale (Figure 10).

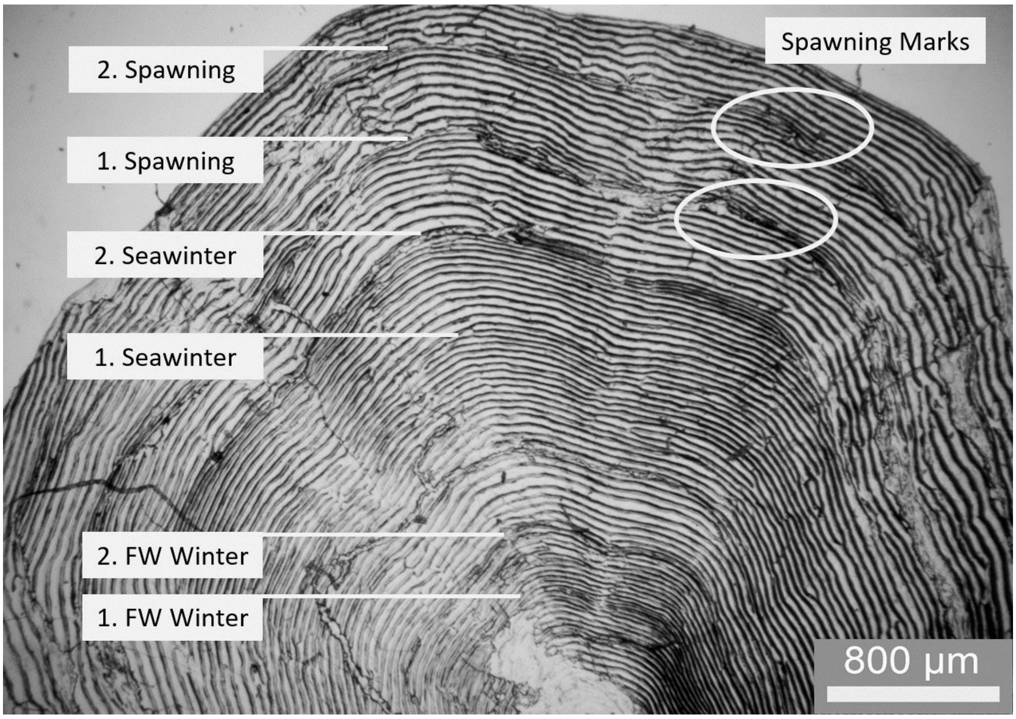


Figure 10: Multiple spawner. Left river as 2-year-old smolt, then spent 2 seawinter before returning for spawning in two consecutive years. Fish came into freshwater for the third time at the time of the catch. New winter band is not yet shaped. Age: 2.2+2SM+.

4.3.3.9 Damaged scales

As mentioned a large part of the scales showed different sorts of damage. Replacement scales (Figure 11 A+B) are characterized by the extraordinary size and form of the focus. Reasons for the loss of scales can vary but are often related to predation and other physical impacts. When a fish loses a scale, the resulting gap is filled by a new scale as fast as possible. Not until the gap is fully closed, the new scale starts to grow simultaneously to the original scales and concentric lines are generated. Replacement scales should not be used for scale reading since it is unclear how much the replaced scale varies in size from the original scale. The earlier in life the scale was replaced, the smaller is the difference to an ordinary scale, thus it is sometimes possible to determine the saltwater age anyhow. Figure 11B shows mechanical damage which is associated with the sampling procedure. The scales, especially from males, are often deeply stuck in the leathery skin. A removal is therefore difficult and damage through the forceps is common.

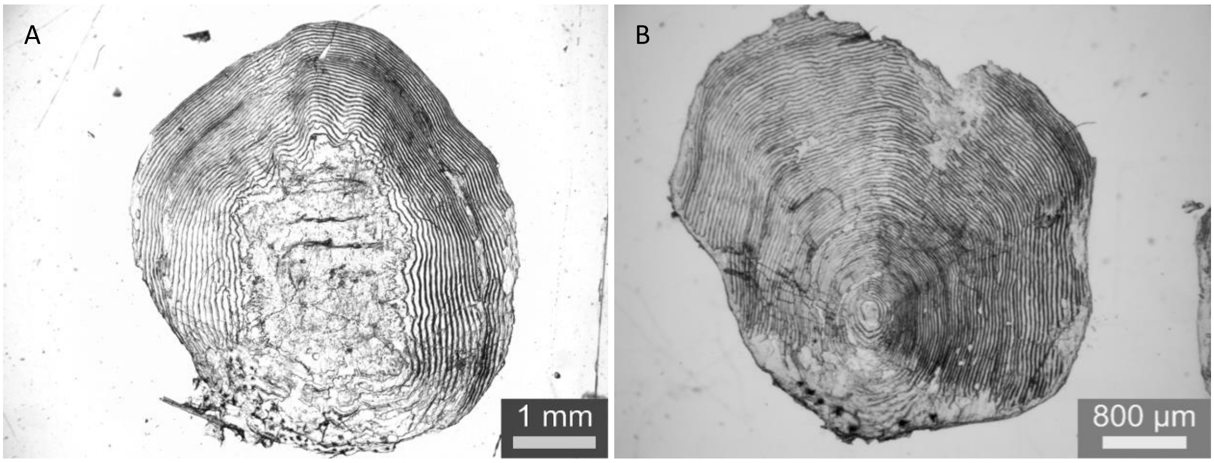


Figure 11: Examples for damaged scales. A. Replacement scale; B: Mechanical damage due to sampling procedure.

4.3.4 Notation

This study is following the international standard nomenclature proposed by Allan & Ritter (1977). A numerical number describes pre-smolt and post-smolt life history with a decimal point separating between river and marine life phase. The number before the decimal point presents the smolt age at the time the fish is leaving the river. The number behind the decimal point records the number of completed post-smolt sea winters. The + symbol marks plus growth, both in fresh- (run-out) and in saltwater. Spawning marks are marked as SM. Here comes another convention into play. The + symbol also represents the time between maiden sea growth and the first spawning. The qualifying date for notation is April 1st. For some evaluations, the smolt age is not important. Results are then represented by sea-year-classes which take only the sea winter into account.

Examples of sea trout ages:

2+	two-year smolt with additional spring growth
1.0+	one-year old smolt returning to fresh water in the same year of the FW-escape
2.1+	two-year smolt spent one sea winter in saltwater and returning as a maiden fish to spawn for the first time
2.1+1SM+	same fish one year later, one spawning mark found
A.2+	fish with unknown smolt age which spent two winter at sea

4.3.5 Back-calculation

The scale size and annual increments were measured along the anterior-posterior line from the focus to the scale's edge. Growth was back-calculated using the Fraser-Lee equation (Lee, 1920), which is defined as follows:

$L_t = S_t/S_c \times (L_c\text{-}c)+c$

with L_t being the length at age t, L_c the total length, S_t the radius of a scale annulus at age t, S_c the total scale radius an c the empirical constant. In this study, the constant c was disregarded, making the back-calculation a simple rule of proportion, as it is assumed that the body:length relationship in salmonid species is linear (Elliott & Chambers, 1996). Figure 12 shows a scale from a recaptured fish (see 4.3.7) of the Lipping Au tagged fish with measurement point used for back-calculation.

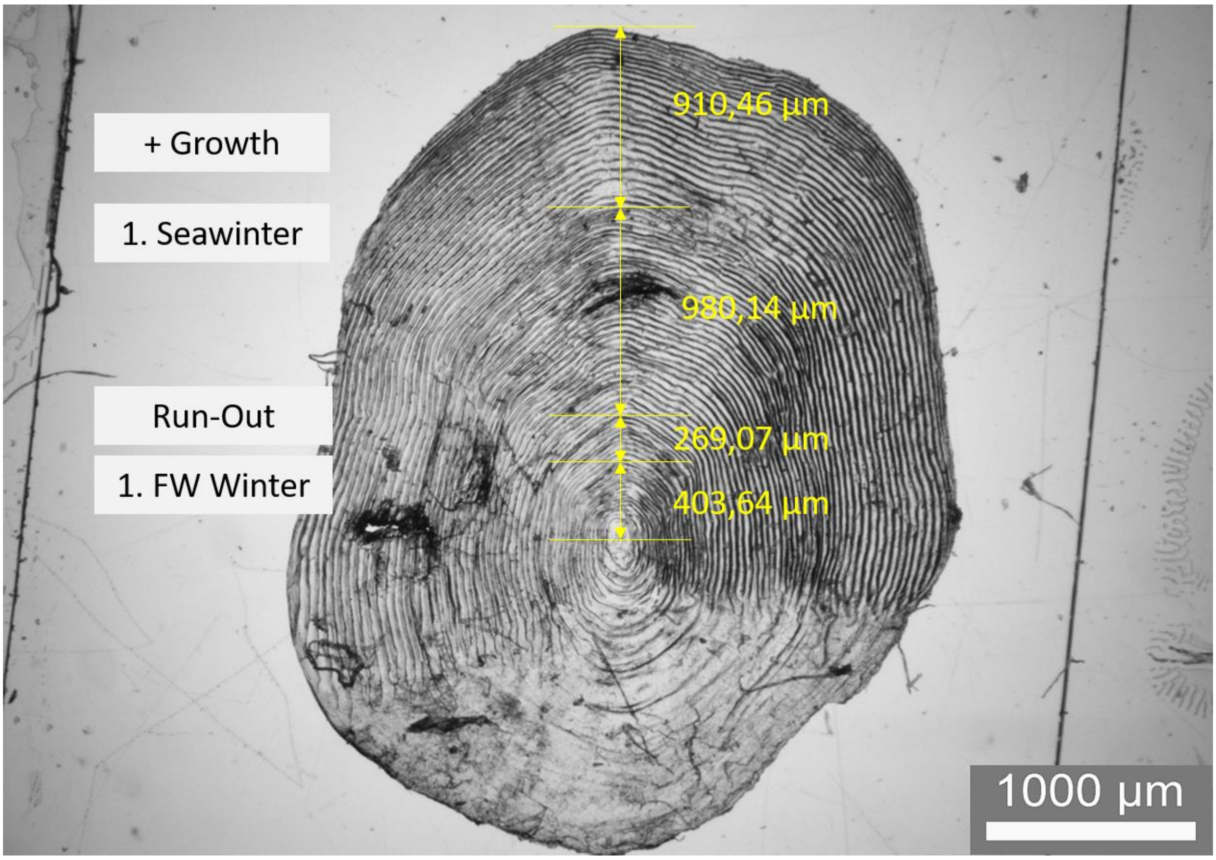


Figure 12: 1+.1+ fish with distances and measurement points used for back-calculation. The known length of 48 cm makes it possible to back-calculate length at yellow lines, which represent first freshwater winter, smolt escape and first seawinter.

4.3.6 Difficulties in scale reading

The theory of scale reading is quite simple. Typical patterns on sea trout scales represent different growth events in the sea trout life cycle. The fish grow faster at times of warm temperatures and adequate food supply and slower during the winter. When preparing for a spawning run, the fish spent their energy rather in reproduction than in length increment. These patterns are sometimes hard to observe. Mentioned summer-checks can occur multiple times during a summer band, thus it can be very difficult to identify a year in the sea trout's life cycle. Whitings and maiden fish often return to the estuary during winter. Typical patterns become blurred in this case and the time of fresh water escape is difficult to determine. Spawning marks arise from erosion during the spawning event. It is expected that the shaping of the spawning marks is dependent on the time the fish spent in freshwater. A fish coming just for several days to the spawning river would have less clear spawning marks than a fish who spends several weeks in the river. Finally, the growth rates differ a lot within sea trout. The length increment can differ from a few centimetres up to 30 or 40 cm during a year at sea. A scale reader must be clear that there are de facto no clear patterns that can be found on all scales. Every fish's life history forms individual patterns on the scale. This makes scale reading complicated to interpret and the correctness of the indicated age of the fish cannot be guaranteed. It is therefore important to get an unbiased view on the scales when reading.

4.3.7 Validation

In this study, two opportunities for the validation of scale reading results are available. Tagging and recapturing is described below (see 5.2.5). Furthermore the 2016 and 2017 smolts of the Lipping Au, tagged with an internal RFID Tag (PIT tag). These smolts were age determined by Rahtjen (2017). Recaptured sea trout with such a tag can be used to reconstruct the life history since the tagging date. In fact, the first fish, sized 48 cm, with an internal tag was caught by an angler in February 2018. This fish was captured in the Lipping Au smolt trap in April 2016 and aged 1+ at a smolt size of 12,8 cm. The back-calculated smolt size was 12,61 cm (mean of four scales). The adult sea trout fish was aged 1+.1+ with no spawning marks found on the scale. Thus, the smolt left its birth river in 2016, spent one winter at sea and grew 36 cm in 22 month which means an average length increment of 1,63 cm per month (Figure 13).

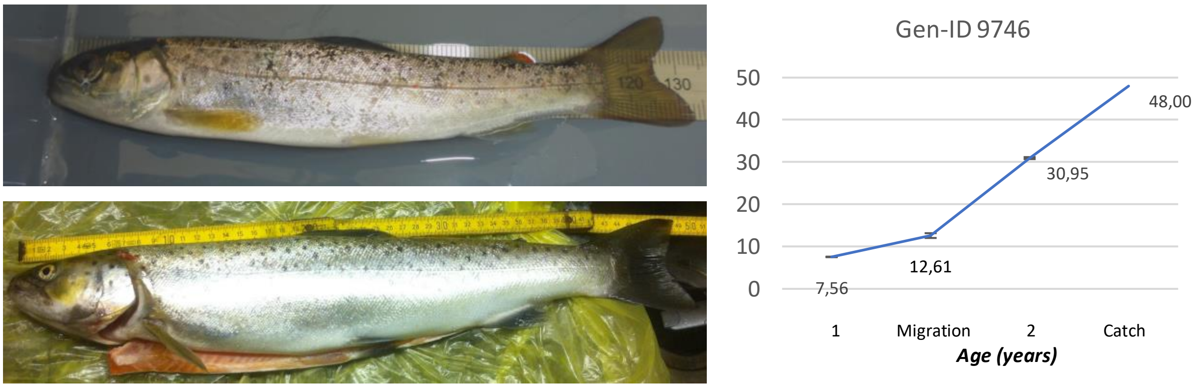


Figure 13: 12,8 cm sized smolt of the Lipping Au; below: angler's catch. Pictures: C. Petereit. Right: Back-calculated growth diagram.

4.4 Genetic analysis

4.4.1 Sample selection

For the year 2012 only 30 samples were available, consequently every sample was genotyped. For the following years 50 samples per year were chosen randomly. For the years 2015 to 2017 was considered that only those samples were chosen that have been used for scale reading as well. In total 280 fish were genotyped using 12 microsatellite markers.

4.4.2 Gene extraction, PCR and Sequencing

Genetic samples were stored in 98% ethanol and kept at -20°C before analyses. After thawing the selected samples, a small piece of the fin clip was cut with a scissor and transferred into round-well blocks. The DNA was extracted following the user manual "NucleoSpin® 96 Tissue" of the "All-round kit: MN-Genomic DNA from tissue" (Macherey-Nagel GmbH & Co. KG, Düren, Germany). The remaining fin clip tissue was again stored at -20 °C and kept as backup. After every sample the forceps and scissor were cleaned using ethanol to avoid cross contamination. A total of 96 samples was stored in one round-well block. For exact attribution, the adjustment of the samples was recorded carefully. Finally, 3 PCR-plates (280 samples) with DNA extract were frozen.

The DNA extract serves as source for the following PCR with 12 different microsatellites. The primer selection was adapted from a previous work on sea trout genetics by Albrecht (2016). Two primer pools were used to avoid hybridization between the different primers (pool 1: SSsp2201, Ssa197, Ssa407, Ssosl417, OneU9, Ssa85 and Str73INRA; pool 2: Strutta58, Ssosl311, Str60INRA, BS131 and Ssosl438 (all Primers by Eurofin)). For further primer details see 7.3.

Table 1: Mastermix and Volume.

Mastermix	Chemicals	Volume (µL)
PCR-Mastermix	Primerpool P1 / P2	100
	2x Quiagen Multiplex PCR Mastermix (KIT)	500
	RNAse free water	300
SEQ-Mastermix	GeneScan™ 500 LIZ™ size standard	25
	HiDi-Formamide	875

Two prepared PCR-Mastermixes (Figure 14) have been mixed with 100 µL of each primerpool 1 and 2. On two new PCR-plates 1 µL of the DNA-extract was mixed with 9 µL of the PCR-Mastermix. Each DNA-extraction plate yielded two PCR-product plates, one with primerpool 1 and one with primerpool 2. The PCR has been accomplished following the thermocycler settings (Figure 15) used by Albrecht (2016).

Table 2: Thermocycler programme by Albrecht (2016).

Step	Temperature [°C]	Time [min]	Repeat
1) First Denaturation	95	15	
2) PCR	94	0,5	30x
	60	1,5	
	72	1	
3) Final Elongation	60	30	
4) Storage	4-8	∞	

After the PCR, the product was ready for sequencing. Again 1 µL of the PCR product was transferred in a new PCR-plate. 9 µL of the Sequencing-Mastermix was added. Before sequencing starts, the samples were denaturized in the Thermocycler for two minutes at 95 °C. The Sequencing was realized at a 3130xl Genetic Analyzer (Applied Biosystems Inc. Foster City, California, USA) with w/EDTA 10x buffer and 25 ml of running buffer and POP7 Polymer. The final data were saved on the local computer and could be transferred to the laptop for further analysis.

4.4.3 Genotyping

The genotyping of the sequencing data was made with GeneMarker v1.91 (Hulce et al., 2011). This program visualizes and calls different alleles of the 12 different loci. With two different panels, created by Sebastian Albrecht, the program calls the alleles within every section of each marker automatically. Nevertheless, it is necessary to double-check every sample and make corrections when required. The scoring was double checked by B.Sc. Sebastian Albrecht.

4.4.3 Population analysis

The allele results from GeneMarker were analysed with STRUCTURE v. 2.3.2.1 (Pritchard et al., 2000). The STRUCTURE analysis is a model-based clustering method for multilocus genotype data to estimate population structure and assign individuals to populations. Each of the populations is characterized by a set of allele frequencies at each locus. During the analysis the following parameters were used: burning-length = 100.000; 1.000.000 Markov Chain Monte Carlo (MCMC) repetitions after burning, an admixture model with LOCPRIOR for the year, K=2 – K=5 with 5 iterations each. The first run was conducted with all available fish (n=279) mentioned in the sample selection (4.4.1). An additional run was conducted containing the 150 aged fish (caught 2015-2017, 50 samples available each year), arranged by the year of birth.

In the next step the effective population sizes (N_e) were calculated with NeEstimator 2.01 (Do et al., 2013) using a P_{crit} = 0.02. All calculations of the $\mathrm{F_{ST}}$ were done with GenePop 4.7.0 (Rousset, 2008).

4.5 Statistical methods for data analysis

Following statistical tests were used to determine differences in age and size throughout the three-year sampling period:

4.5.1 D'Agostino & Pearson normality test

The D'Agostino & Pearson normality test was used to determine if the data was normally distributed or not. The result of the test decided which further tests for statistical analysis of the data was used subsequently. The test was conducted using the program GraphPad Prism 7.

4.5.2 One-way ANOVA

The one-way ANOVA is a test for normally distributed data. It investigates if the data of more than to sample groups differ significantly by comparing their means. The test was conducted using the program GraphPad Prism 7.

4.5.3 Mann-Whitney U Test

The Mann-Whitney U Test is a non-parametric test. It investigates the data of two samples for significant differences by comparing their medians. The test was conducted using the program GraphPad Prism 7.

4.5.4 T-Test

The T-test is a parametric test for normally distributed data. It investigates the data of two samples for significant differences. The test was conducted using the program GraphPad Prism 7.

4.5.5 Kruskal-Wallis test

The Kruskal-Wallis test compares if data of more than one sample group differ significantly by comparing their means. It is designed for non-parametric data. The test was conducted with the program GraphPad Prism 7.

4.5.6 ROUT test

The ROUT test detects any number of outliners in a sample group. It was conducted with GraphPad Prism 7 before analysing the growth rates with Q = 1%.

All results from statistical tests can be found in the appendix 7.4.

5 Results

5.1 Electro fishing

5.1.1 Total capture

Table 1 shows the total catchments of the fishing seasons 2015 until 2017. In every year, more females than males were caught. The gender ratio differs from 1:1,2 to 1:1,9 among the years. The total catch of 2017 doubles the numbers of the previous years. In 2017 more whitings and smolts were caught. As these fish are unimportant to the studies in the Farver Au, it is assumed that these fish were also caught and quick released during electro fishing in previous years.

Table 3: Total catch by years and overall.

	2015	**2016**	**2017**	**total**
total	216	220	462	898
female	140	116	232	488
male	74	99	192	365
Whiting / smolt	2	5	38	45
M:F ratio	1:1,9	1:1,2	1:1,2	1:1,3

5.1.2 Length frequency

Figures 14 – 16 show the length frequency of the three fishing seasons. To get a more comprehensive look to the length classes of interest, the total catch is shown in 5cm-classes in figures 17 – 19. Figure 20 shows the percentage distribution to the specific length classes. 2017 differs from the previous years with a lot more fish with a length of 40 to 55 cm. These fish mostly make the difference in the total catchment numbers.

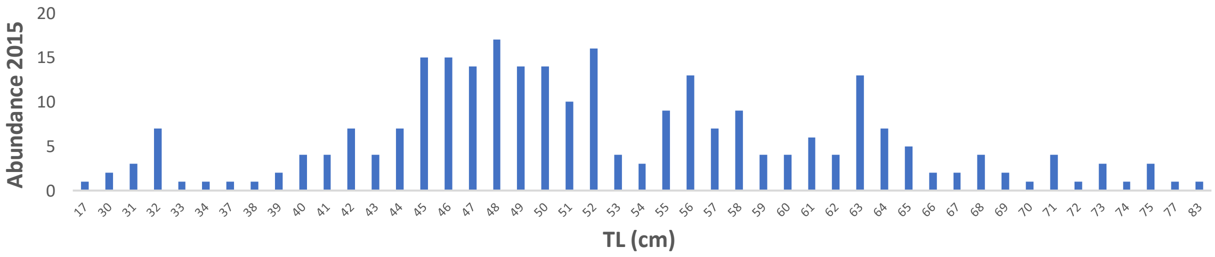


Figure 14: Length frequency of the total catch 2015 per cm.

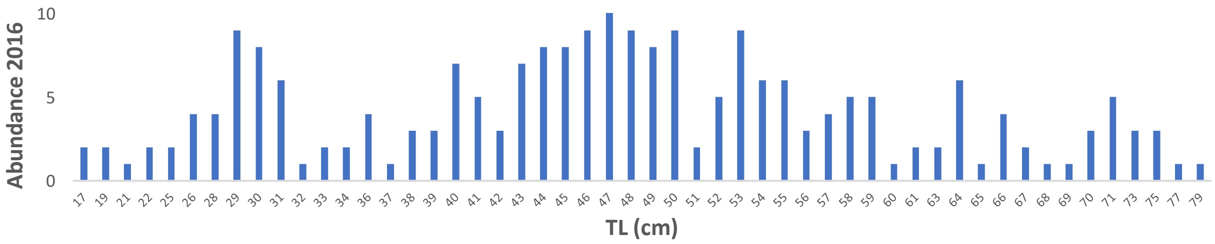


Figure 15: Length frequency of the total catch 2016 per cm.

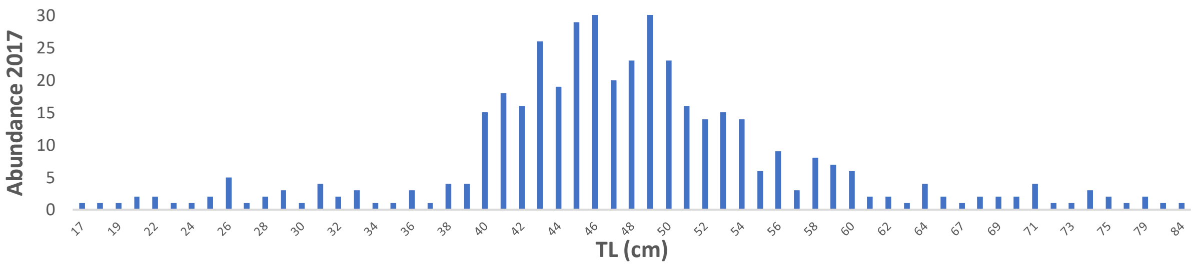


Figure 16: Length frequency of the total catch 2017 per cm.

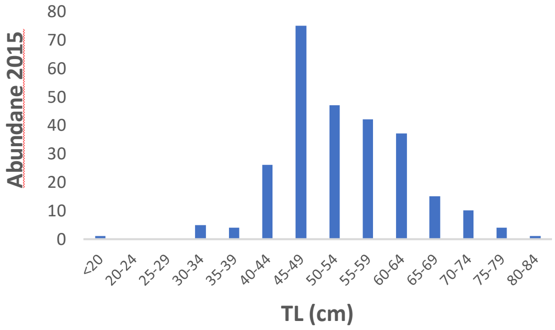


Figure 17: Abundance 2015: 5-cm-length classes.

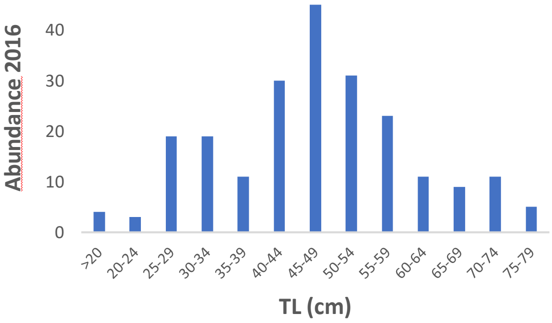


Figure 18: Abundance 2016: 5-cm-length classes.

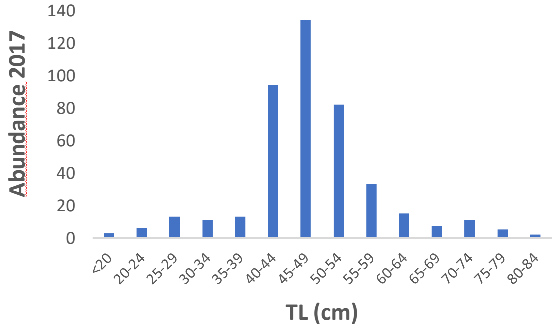


Figure 19: 5-cm-length classes.

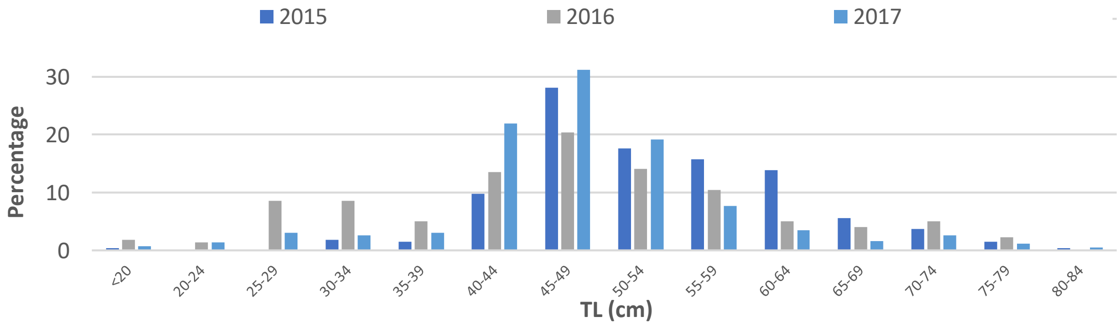


Figure 20: Percentage distribution of the fish to the 5-cm-length classes.

5.2 Scale reading

5.2.1 Sample selection

The following table 2 shows how many fish were chosen for the scale reading procedure. As mentioned the sample consisted of 50 fish per year plus the ten biggest and the ten smallest fish of each year. Male and female fish were chosen equally. The irregularities result from the percentage distribution of the samples to the single fishing dates. It was not always possible to get an equal male:female ratio in the years 2015 and 2016. Additionally, 9 fish were chosen after the random selection, representing recaptured tagged fish in 2017.

Table 4: Overview of the selected samples.

	2015	2016	2017	total
total	120	127	120	367
female	51	53	50	154
male	49	54	50	153
biggest 10/smallest 10	20	20	20	60
Additional recaptures		4	5	9

The figures 21 – 23 show the percentage of fish in the different length classes (LC) of each the total catchment and the sample. The random selection represents the total catchment. Due to the manual selection of the biggest and the smallest fish, these are overrepresented in the sample.

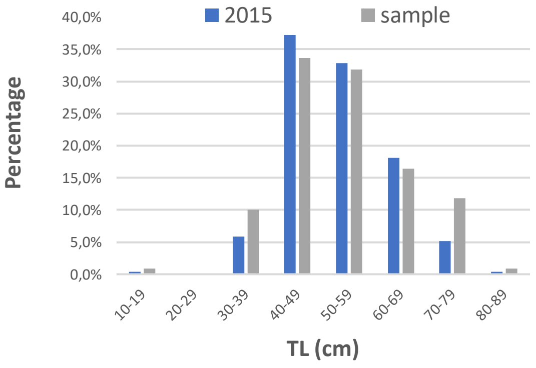


Figure 21: Percentage LC - sample vs. overall catch 2015.

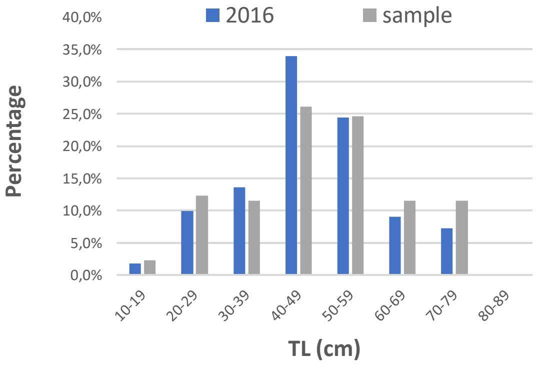


Figure 22: Percentage LC - sample vs. overall catch 2016.

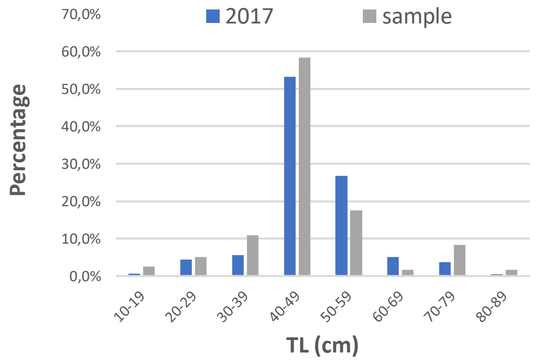


Figure 23: Percentage LC – sample vs. overall catch 2017

5.2.2 Smolt age

The smolt age is summarized into two groups of one-year and two-year old smolts. It is not considered if the specific smolt is a B-type smolt or not. The share of one-year old smolts differs from 75,9 % in 2015 to 89,1 % in 2017 (Figure 24).

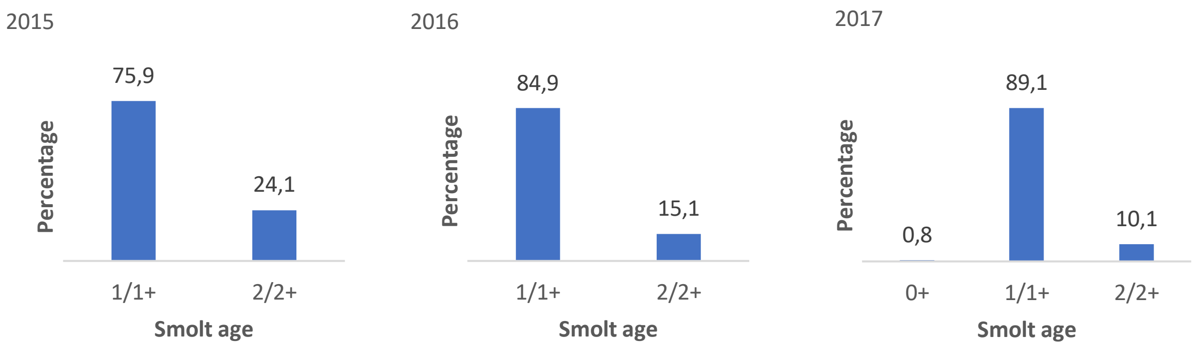


Figure 24: Percentage share of 1-year vs. 2-year smolts found in the Farver Au.

5.2.3 Sea age

The sea age is described independently from the smolt age. The age distribution of 2015 and 2016 is similar, while in 2017 the age group A.1+ is substantially larger. Table 5 shows all investigated samples with their mean length. The values contain only the measured length. Back-calculated values are not included. The following figures 25 – 27 show the distribution of sea age classes as well in absolute values and as percentage.

Table 5: Sea age and mean length of the aged adult sea trout during 2015 – 2017 (n=339).

	2015			**2016**		
Sea Age	No. M+F	total length cm	%	No. M+F	total length cm	%
A.0+	13	34,9	12,38	24	30,0	19,51
A.1+	47	48,9	44,76	50	47,2	40,65
A.2+	33	62,9	31,43	29	57,8	23,58
A.3+	11	70,0	10,48	9	67,4	7,32
A.4+	1	70,0	0,95	7	71,7	5,69
A.5+	0	-	0,00	4	75,5	3,25
total No.	105	57,3	100,00	123	58,3	100,00

	2017			**total 15-17**		
Sea Age	No. M+F	total length cm	%	No. M+F	total length cm	%
A.0+	5	29,4	4,50	42	31,4	12,39
A.1+	84	46,3	75,68	181	47,5	53,39
A.2+	11	58,4	9,91	73	59,7	21,53
A.3+	7	73,3	6,31	27	70,2	7,96
A.4+	2	79,5	1,80	10	73,7	2,95
A.5+	2	71,5	1,80	6	73,5	1,77
total No.	111	59,7	100,00	339	59,3	100,00

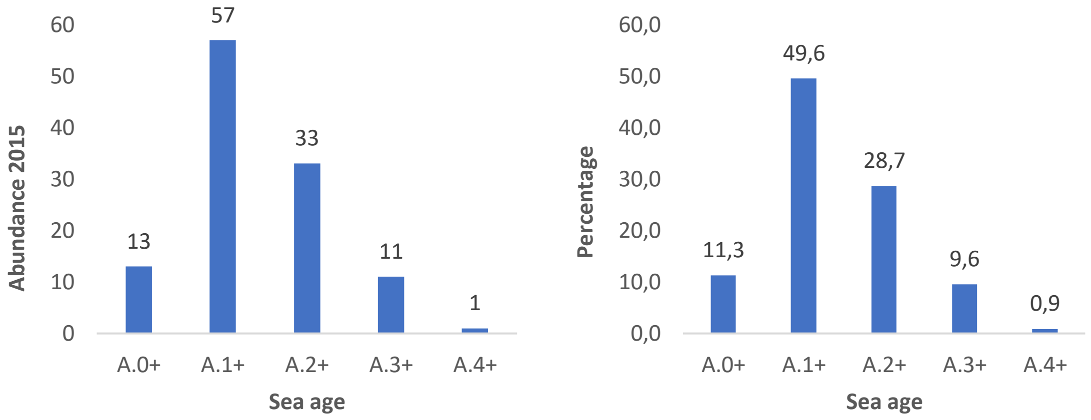


Figure 25: Sea age distribution of the 2015 spawning cohort. Left: Abundance; Right: Percentage.

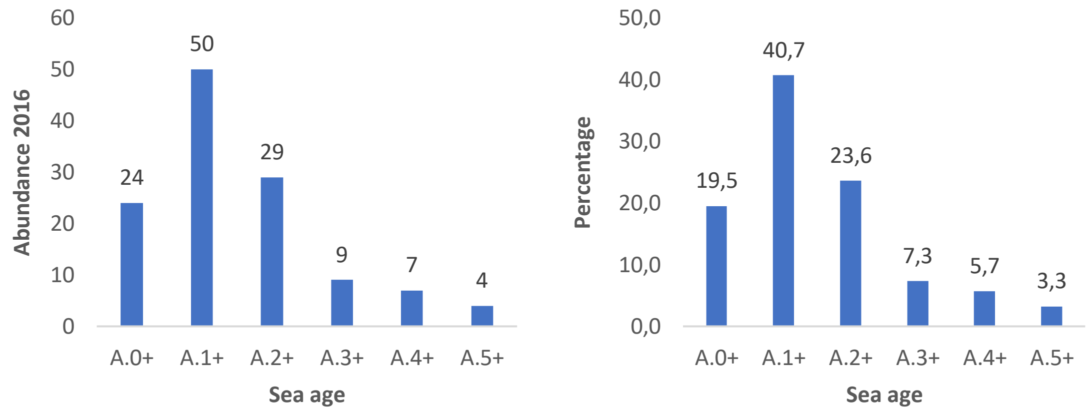


Figure 26: Sea age distribution of the 2016 spawning cohort. Left: Abundance; Right: Percentage.

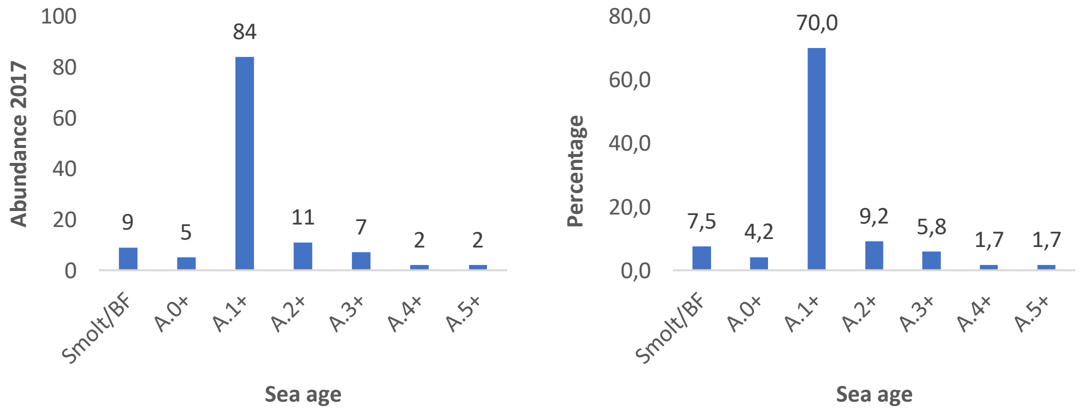


Figure 27: Sea age distribution of the 2017 spawning cohort. Left: Abundance; Right: Percentage.

5.2.4 Spawning Marks

In total 76 scales with spawning marks were found. Fish with spawning for the first time in the previous year were classified as second time spawners. Fish having spawned more than one time in the past were classified as multiple spawners. Maiden fish entering the river for the first spawning run were accordingly classified as first-time spawners. The share of first-time spawners varies from 70 to 88 percent in total. Difference between males and females can be observed, with male fish showing significantly more first-time spawners than female fish. Percentage shares are shown in figure 28. Additionally, the shares seatrout with or without spawning experience per age is shown in figure 29. It is not considered whether the spawning experience includes multiple or single spawning events. A more detailed figure is shown in appendix 7.5.1.

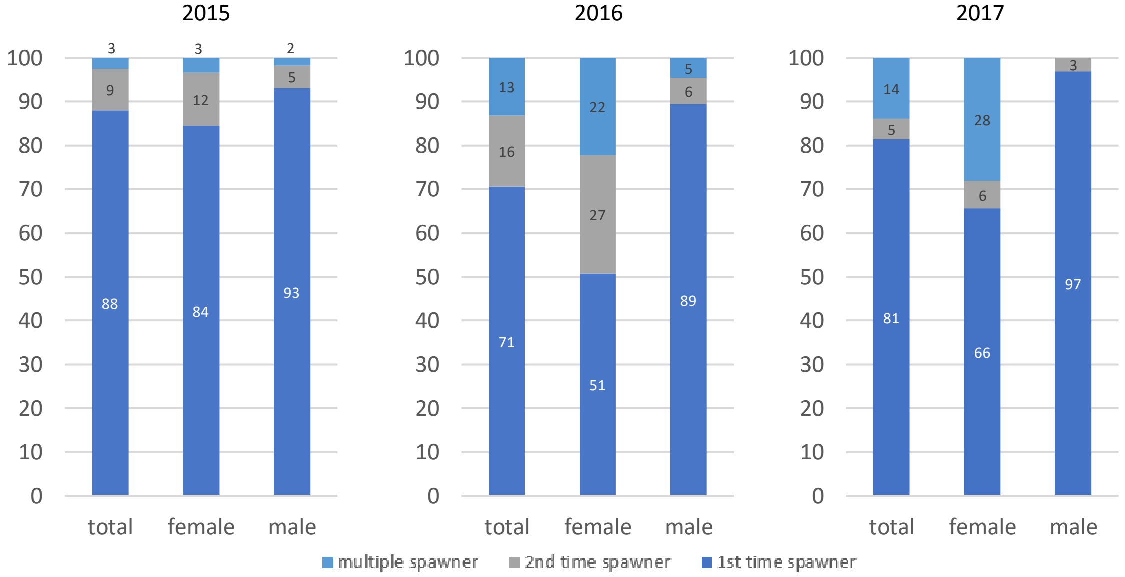


Figure 28: Percentage shares of individuals with spawning experience during the three spawning seasons 2015-2017 in the Farver Au (n=367 fish). Percentage share of individuals without spawning mark („1st time spawner“; blue); with one spawning experience in the previous year (“2nd time spawner”; grey) or with more than one spawning experience (“multiple spawners”; light blue) in comparison of male and female fish.

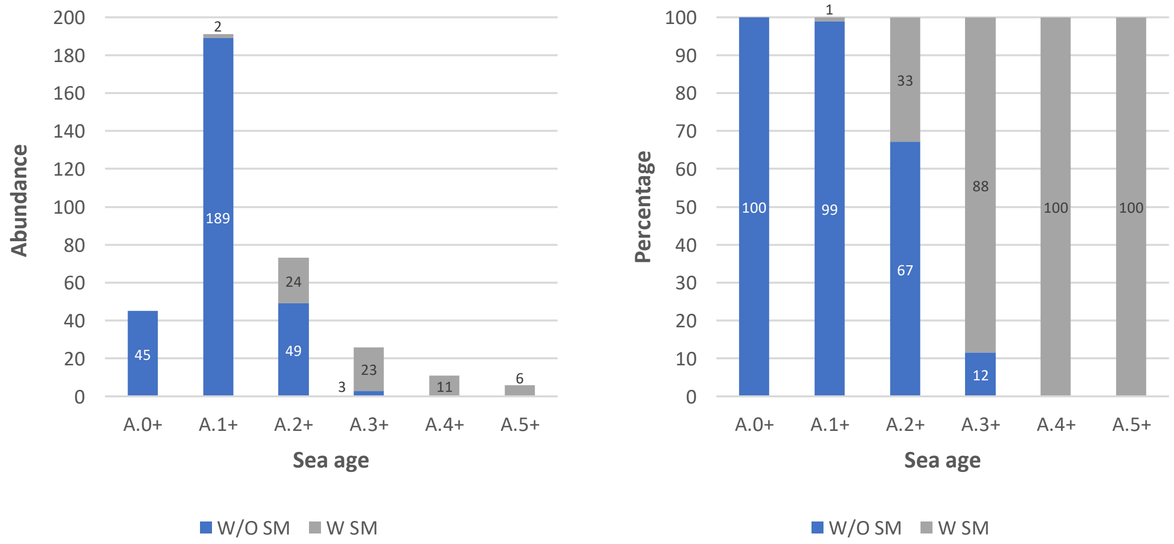


Figure 29: Spawning experience in relation to the sea age during the three spawning seasons 2015 – 2017 in the Farver Au (n=367 fish). Abundance or percentage share of the individuals without spawning experience (W/O SM; „without spawning mark“; blue) in contrast to the abundance or the percentage share of individuals with spawning experience (W SM; „with spawning mark; grey) in relation to the age, represented by sea age classes.

5.2.5 Age and length of first-time spawners

The identification of the spawning marks made it possible to determine as well the age and the length of the first-time spawners. Again, 2015 and 2016 showed similarities due to the matching length frequencies in both years. The spawning cohort 2017 contained mainly of A.1+ fish, which also represent the first-time spawners (Figure 30).

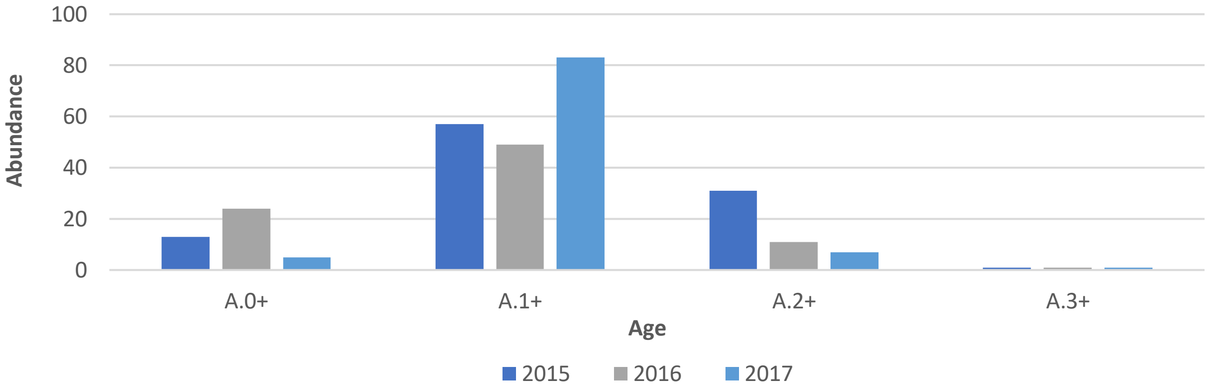


Figure 30: Abundance of the first time spawner in relation to their age, represented by sea age classes, during the spawning seasons 2015 – 2017.

The length at the time of first spawning was back-calculated throughout the whole sample. The three-year average size of first-time spawners is 48,86 ± 10,68 cm, with significant differences throughout the years. Differences between years and sexes are shown in figure 31 and 32. No significant differences in first-time spawning size could be found between male and female fish in the years 2015 and 2017. In 2016 the comparison of mean and median values indicated a significant difference, with male fish being significantly smaller (see 7.4.3). First-time spawners were found in every length class over the three years. Due to the manual selection of the biggest and the smallest fish, the classes 25-29 and 70-74 seems to be over-represented. Figure 33 gives an overview over the length of all first-time spawners.

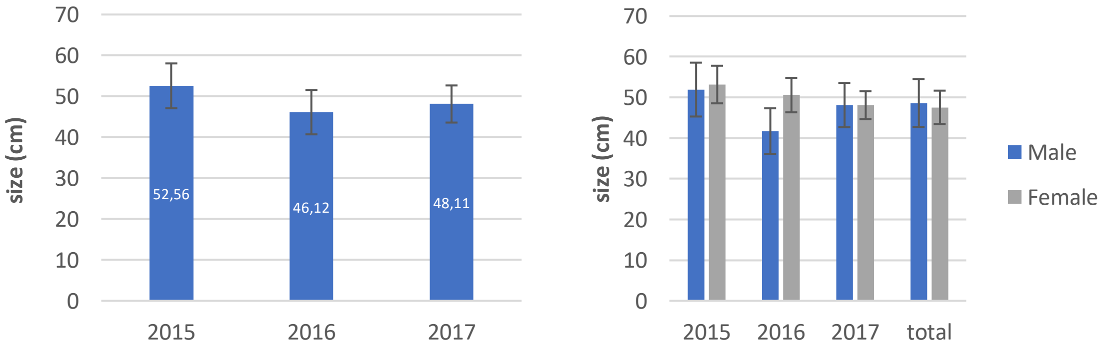


Figure 31: Mean size of first-time spawners during 2015 – 2017 with standard deviation.

Figure 32: Mean size of male and female first-time spawners during 2015 - 2017.

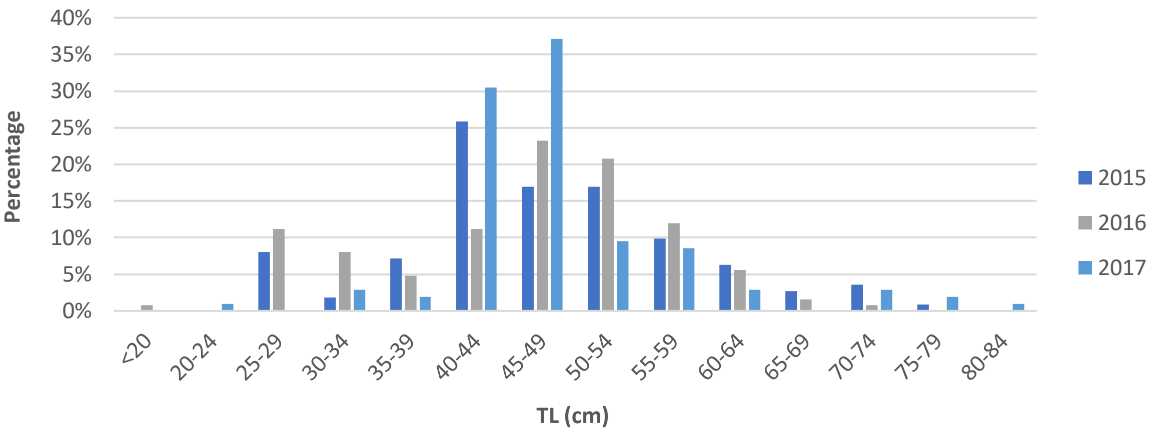


Figure 33: Size distribution of first-time spawners in percentage shares in 5-cm-length classes.

5.2.6 Growth

Table 6 shows the observed length and the growth between sea age classes. The smolt size is back-calculated. With increasing age, the growth rates decrease. The growth at higher ages are to be considered with care since the sample size of old fish is limited.

Table 6: Observed length and growth of adult sea trout (maturity stage 0-3) during the spawning seasons in the Farver Au (n=339 fish).

	2015			**2016**		
Sea Age	No. M+F	total length cm	growth	No. M+F	total length cm	growth
smolt		14,1			13,8	
A.0+	13	34,9	20,81	24	30,0	16,18
A.1+	47	48,9	14,00	50	47,2	17,20
A.2+	33	62,9	14,00	29	57,8	10,60
A.3+	11	70,0	7,10	9	67,4	9,60
A.4+	1	70,0	0,00	7	71,7	4,30
A.5+	-			4	75,5	3,80
total No.	105	57,34		123	58,27	

	2017			**total 15-17**		
Sea Age	No. M+F	total length cm	growth	No. M+F	total length cm	growth
smolt		13,6			13,8	
A.0+	5	29,4	15,81	42	31,4	17,60
A.1+	84	46,3	16,90	181	47,5	16,03
A.2+	11	58,4	12,10	73	59,7	12,23
A.3+	7	73,3	14,90	27	70,2	10,53
A.4+	2	79,5	6,20	10	73,7	3,50
A.5+	2	71,5	-8,00	6	73,5	-0,23
total No.	111	59,73		339	59,34	

Table 7 shows the back-calculated growth rates (2015 – 2017 combined) of male and female sea trout with respect to the spawning experience for the growth periods (e.g. Smolt to sea age class A.0+ = growth during the first summer at sea). The statistical analysis (see 7.4.4) shows no significant for growth differences between sexes, if the state of spawning experience is equal. Significant growth can be observed between older fish (growth period A.1+ to A.2+ in females and older; growth period A.2+ to A.3+ in males) if having spawning experience or not. Since no data for the growth of fish older than A.3+ without spawning marks was available, it was not possible to compare growth rates for these fish.

Table 7: 2015-2017 growth rates of male (M) and female (F) sea trout with respect to the spawning experience (SE); w/o = without spawning experience, w = with spawning experience. * = 2 samples available; ** = 1 sample available.

Growth period	M, w/o SE	M, w SE	F, w/o SE	F, w SE
Smolt - A.0+	21,9	22,2	22,3	23,5
A.0+ - A.1+	13,2	13,7	11,6	12,6
A.1+ - A.2+	10,4	9,1	9,2	7,6
A.2+ - A.3+	11,2*	7	4,1**	6,4
A.3+ - A.4+		6		4,6
A.4+ - A.5+		5,9		4,2
average	14,2	10,7	11,8	9,8

To get a more detailed overview about growth rates, all back-calculated values are shown in table 8. To estimate different growth in fish with or without spawning experience as well as for differently aged smolts, the sample is split in sex, smolt age and spawning experience (Figure 34). The statistical analysis (see 7.4.4) showed no significant difference in growth rates of one-year and two-year old smolts. The only exception was the Smolt to A.0+ growth in two-year old female smolts with spawning experience compared to one-year old female smolts with spawning experience. The p-value is 0,0249, the two compared medians are 22,51 cm (n=43) and 25,95 cm (n=23). With respect to the sample size, the accuracy of field measurements, the significant difference cannot be accepted with certainty.

Table 8: Back-calculated length and specific growth of the aged sea trout sample during 2015 – 2017. The values are divided by smolt age. (1-year or 2-year smolt) and spawning experience (w/o sm = without spawning mark = no spawning experience; w sm = with spawning mark = at least one spawning experience.

	1yr smolt female w/o sm		**2yr smolt female w/o sm**		**1yr smolt female w sm**		**2 yr smolt female w sm**	
Sea Age	total length cm	growth cm	total length cm	growth cm	total length cm	growth cm	total length cm	growth cm
smolt	12,98		19,02		13,92		18,86	
A.0+	35,19	22,21	40,81	21,79	36,28	22,36	44,24	25,38
A.1+	47,01	11,82	51,53	10,72	49,76	13,48	55,32	11,08
A.2+	61,33	14,32	64,8	13,27	58,05	8,29	62,5	7,18
A.3+	75	13,67			66,68	8,63	69,51	7,01
A.4+					72,7	6,02	72,44	2,93
A.5+					74	1,3	75	2,56

	1yr smolt male w/o sm		**2yr smolt female w/o sm**		**1yr smolt female w sm**		**2 yr smolt female w sm**	
Sea Age	total length cm	growth cm	total length cm	growth cm	total length cm	growth cm	total length cm	growth cm
smolt	12,57		17,05		12,73		16,93	
A.0+	33,85	21,28	39,99	22,94	35,43	22,7	40,74	23,81
A.1+	48,49	14,64	52,73	12,74	49,98	14,55	55,32	14,58
A.2+	62,88	14,39	60,33	7,6	58,41	8,43	65,58	10,26
A.3+	76,5	13,62			67,73	9,32	72	6,42
A.4+					75	7,27		

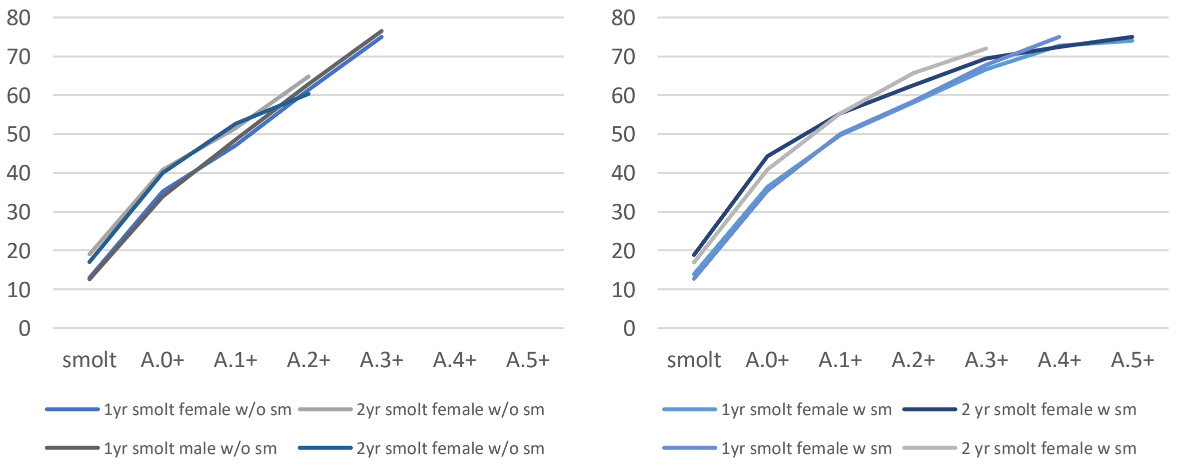


Figure 34: Comparison of sea growth between one- and two-year old smolts. Left: without (w/o) spawning experience; Right: with (w) spawning experience. The growth diagrams show similar shapes, 2-year-old smolts are in general longer at specific ages.

Different growth rates for fish with spawning experience and those who spawn for the first time are expected. Therefore, the back-calculated data for the three years of investigation are separated into fish with spawning marks, meaning those who have spawned in at least one previous season, and into fish with no spawning marks, meaning those who visit the freshwater for the first time to spawn. The figures 35 – 40 one the next three pages, show every single fish whose scales were read. It can be observed that fish without spawning marks show a much more varying behaviour when it comes to growth. It is easily possible to reach 70 to 80 cm of length in one or two winters at sea, which means a length increment of 30 to 40 cm per year at sea (see below). In contrast to that, fish with spawning marks show reduced growth from the time they first spawned.

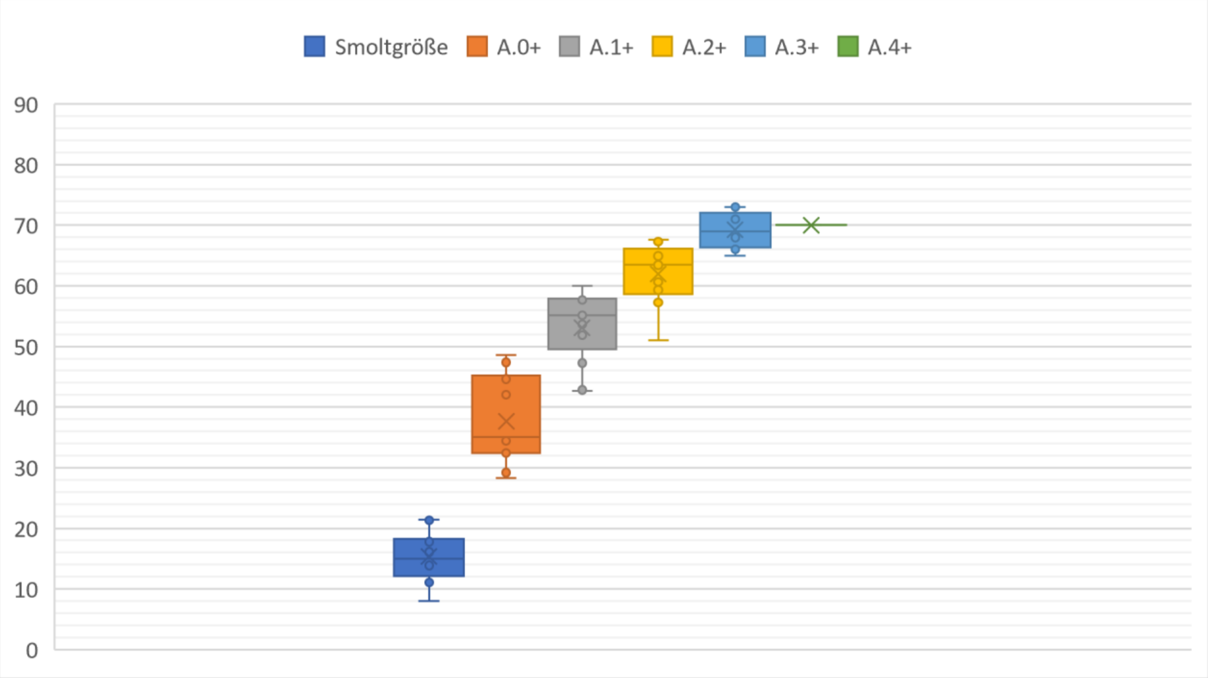


Figure 35: 2015 sample with spawning marks.

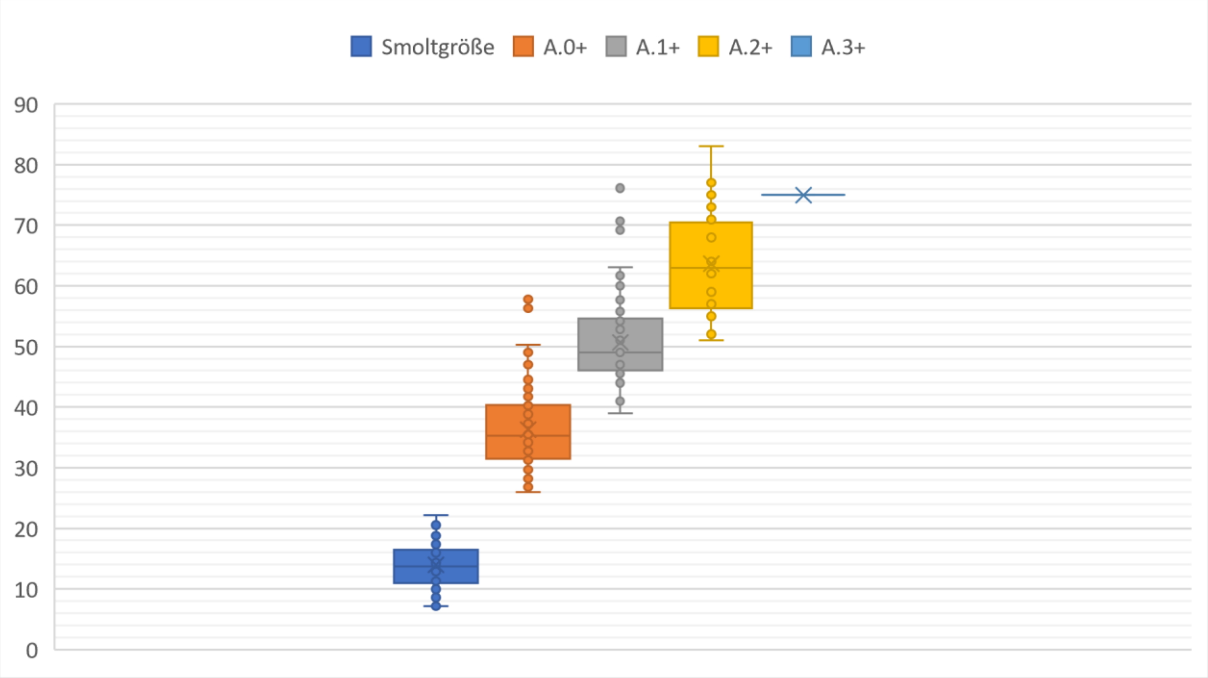


Figure 36: 2015 sample without spawning marks

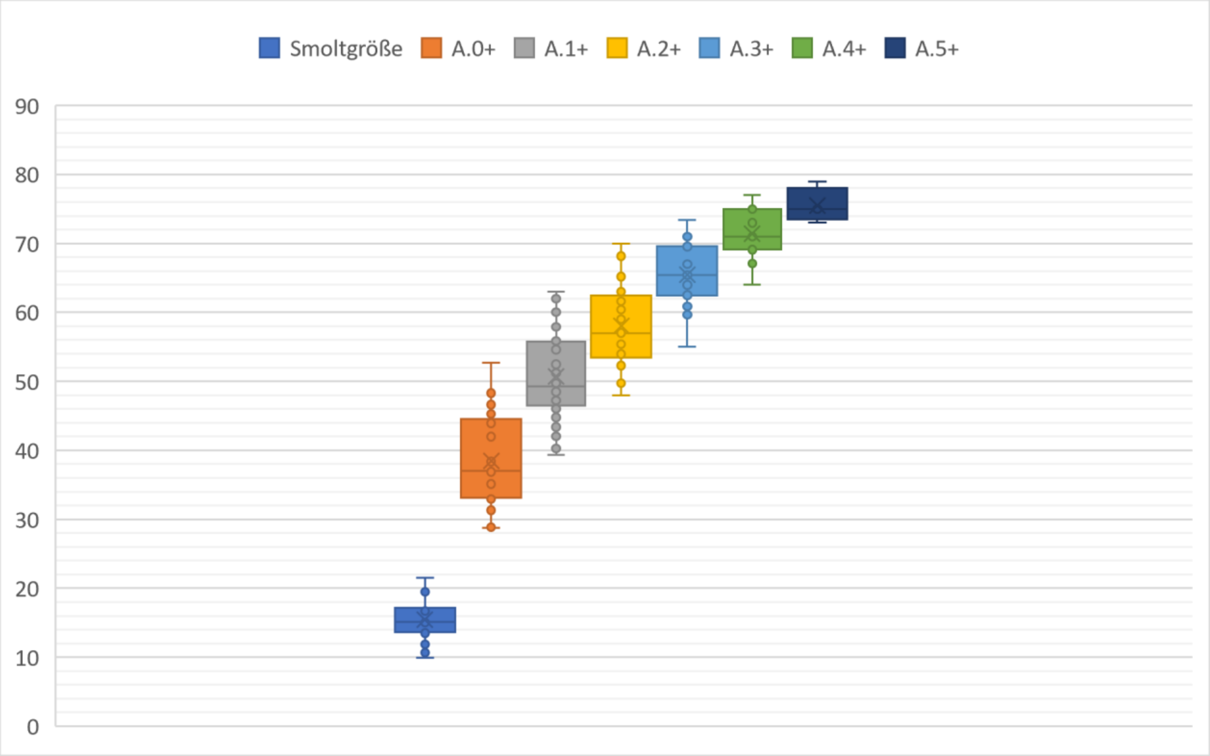


Figure 37: 2016 sample with spawning marks.

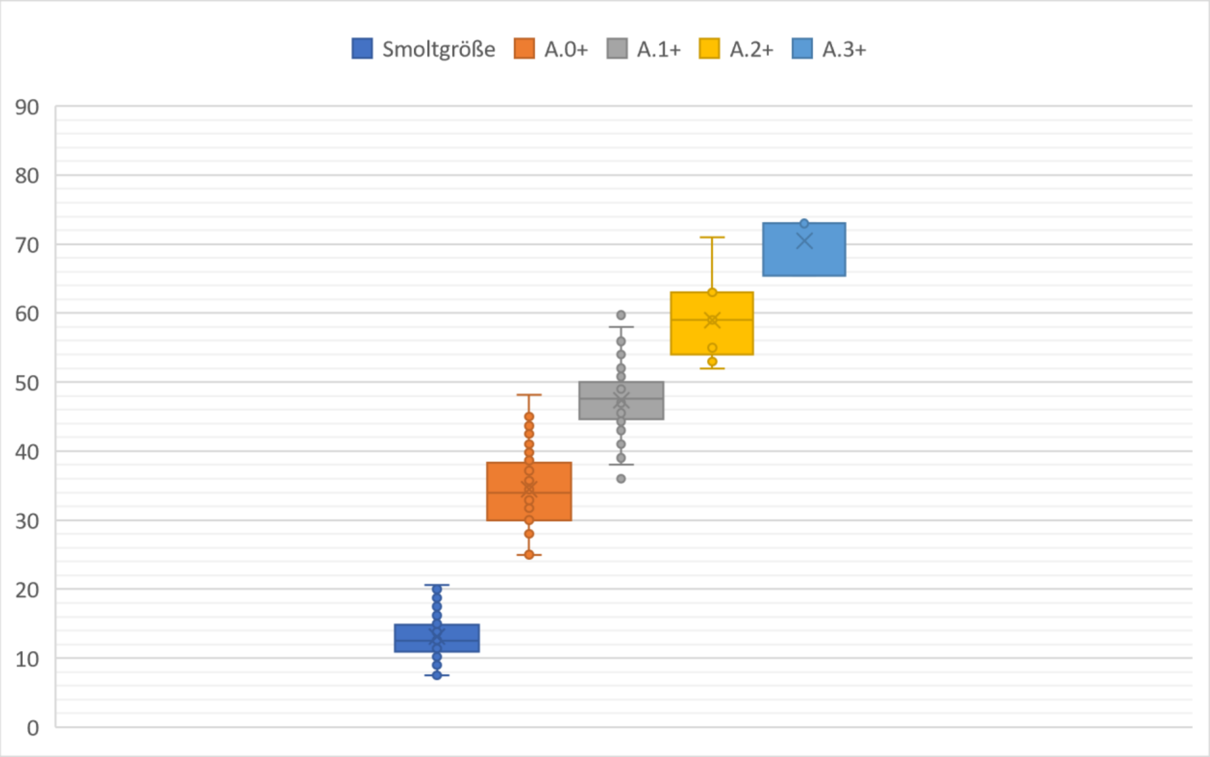


Figure 38: 2016 sample without spawning marks.

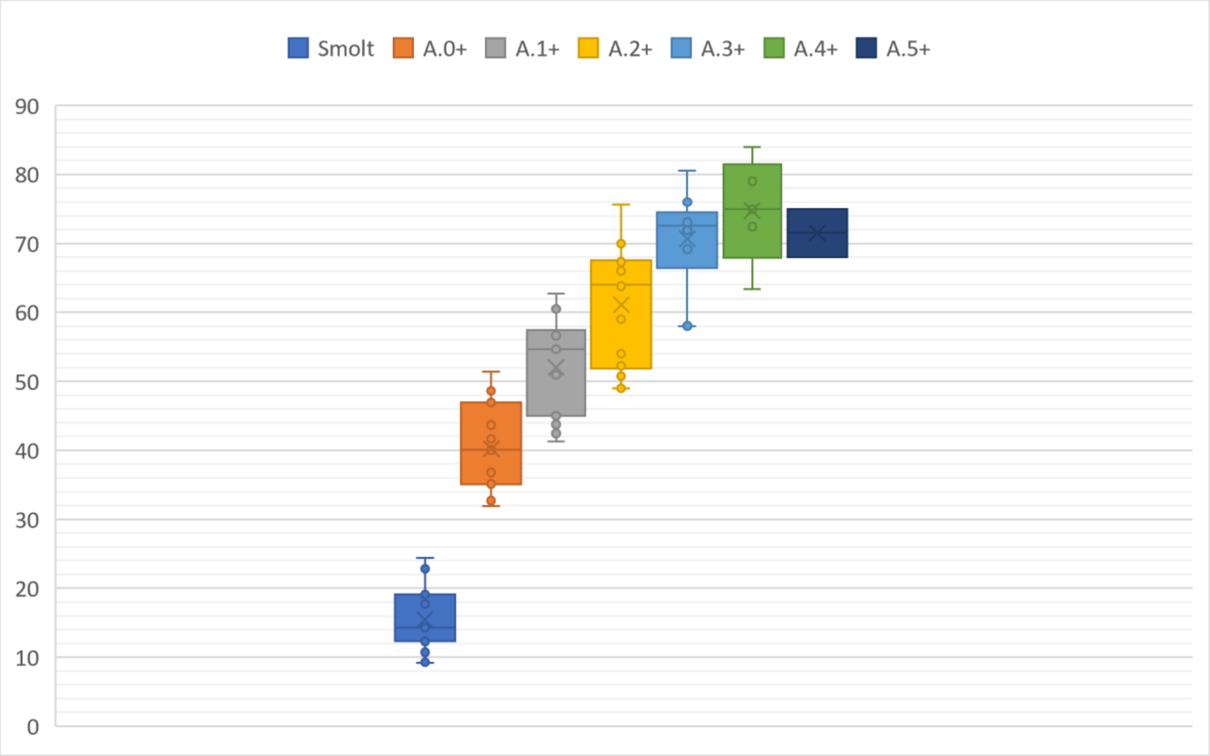


Figure 39: 2017 sample with spawning marks.

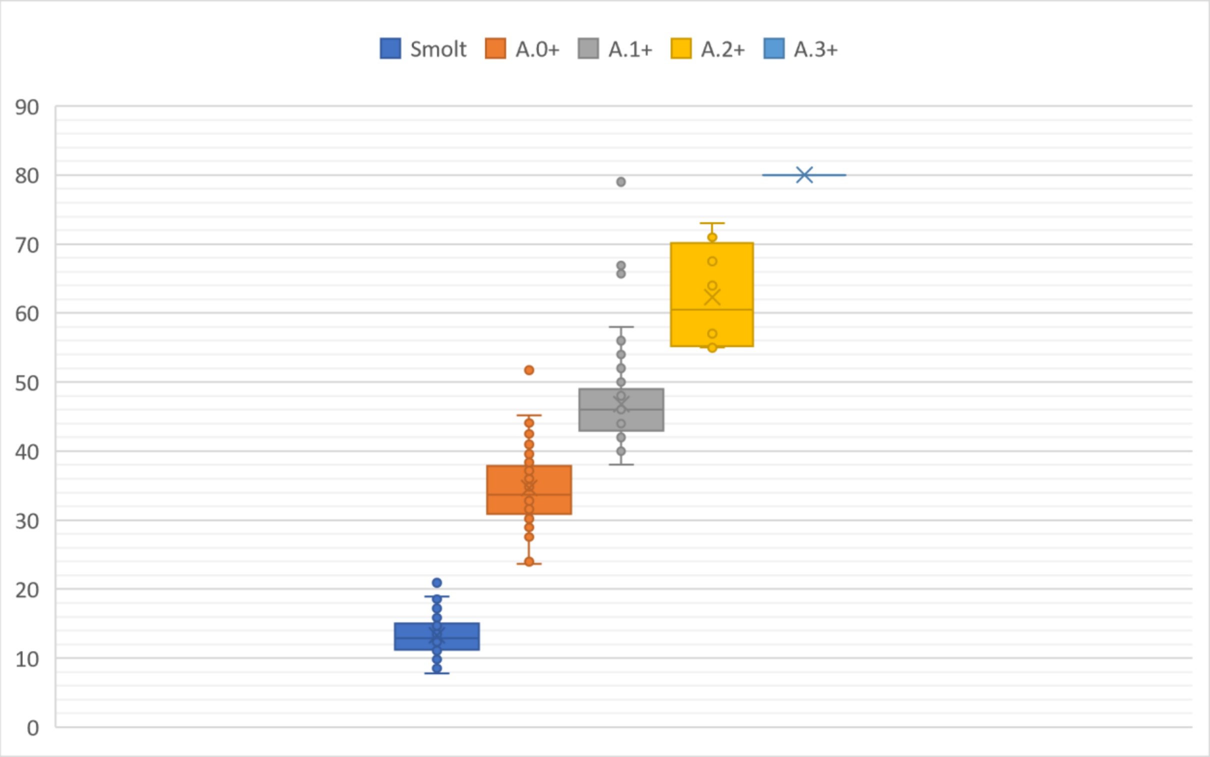


Figure 40: 2017 sample without spawning marks.

The following figures 41 – 43 show the growth of male and female sea trout according to spawning experience. The left-hand figures show the growth of fish which have already spawned at least one time. The right-handed figures are growth diagrams of first-time spawners. For the female fish, a slightly faster growth during the first year at sea can be observed both in fish with spawning marks and in fish without spawning marks. This observation could not be proved statistically.

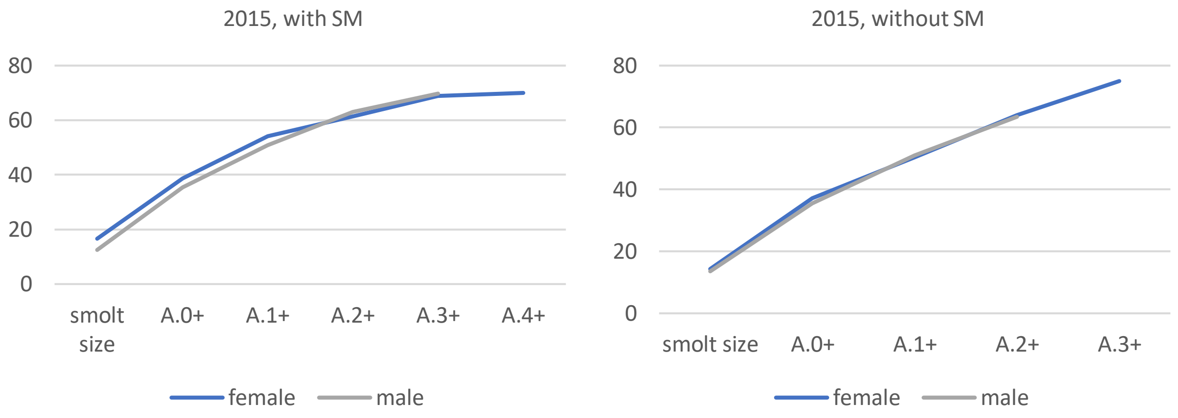


Figure 41: Growth comparison of 2015 males and females with and without spawning marks.

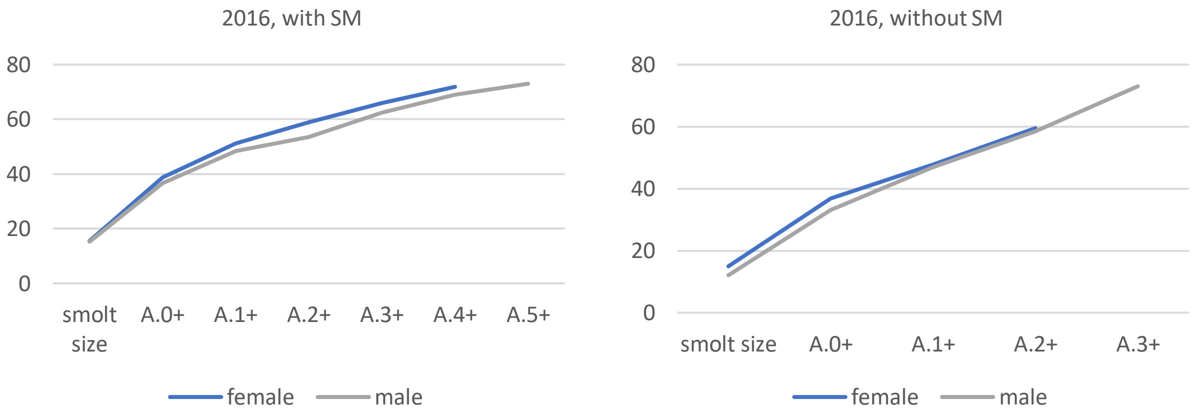


Figure 42: Growth comparison of 2016 males and females with and without spawning marks.

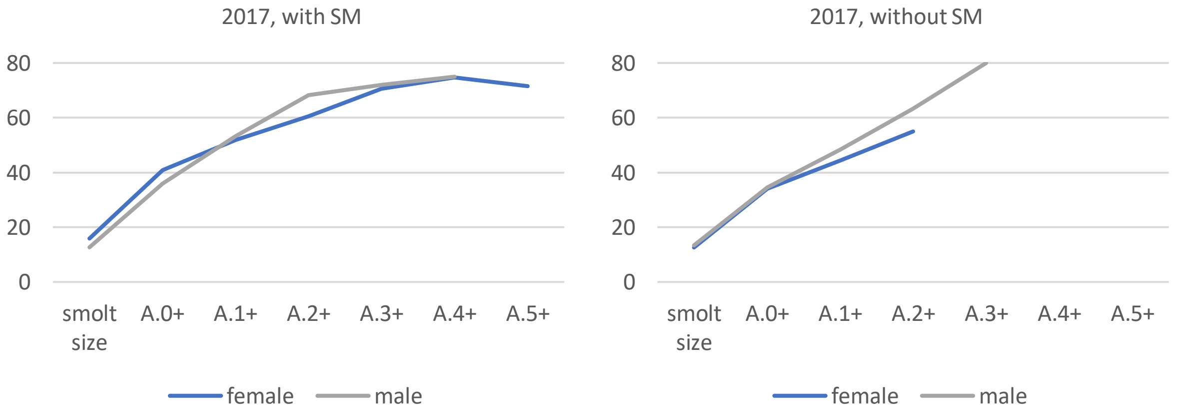


Figure 43: Growth comparison of 2017 males and females with and without spawning marks.

The following figures 44 – 46 show the growth diagrams of males and females compared by the spawning experience. In general, it can be seen, that fish with spawning marks show less length growth from their first spawning season, compared to the fish which have not yet spawned. Nevertheless, this could not be observed in every subsample since the sample size varies over the years.

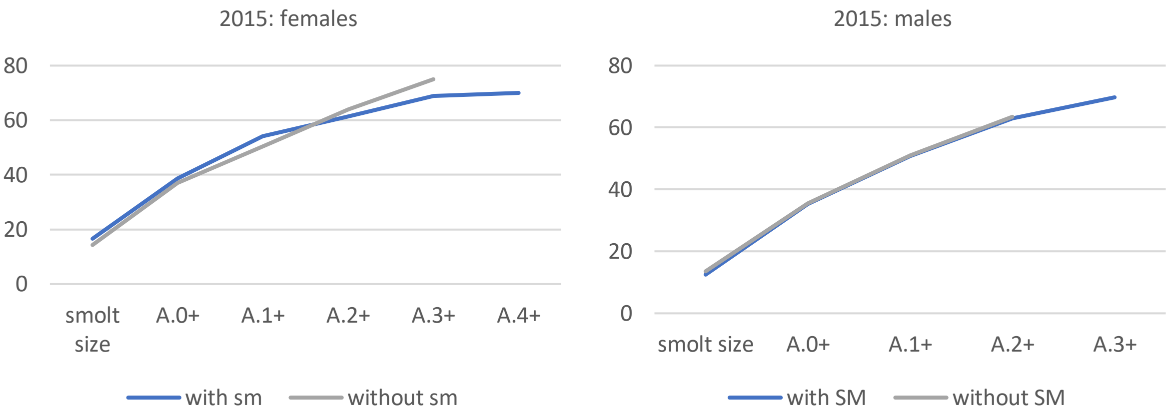


Figure 44: Within sex comparison of growth with or without spawning mark 2015.

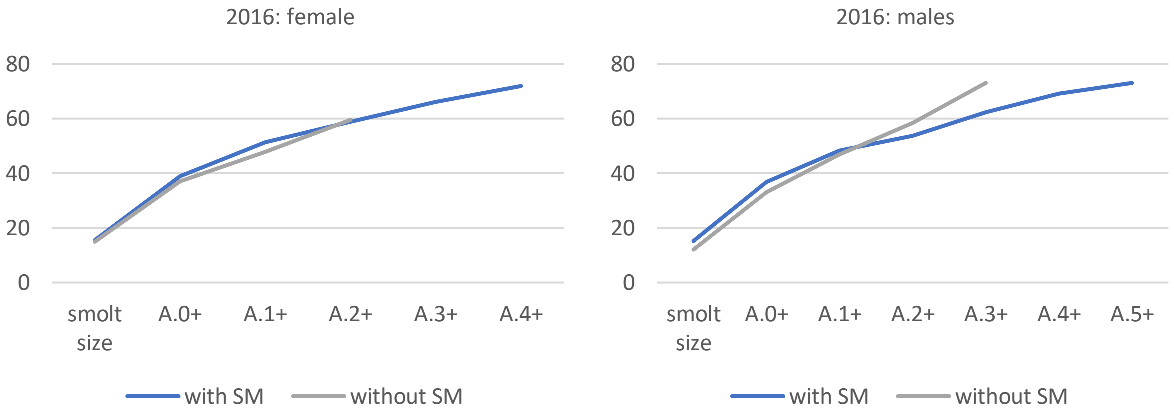


Figure 45: Within sex comparison of growth with or without spawning mark 2016.

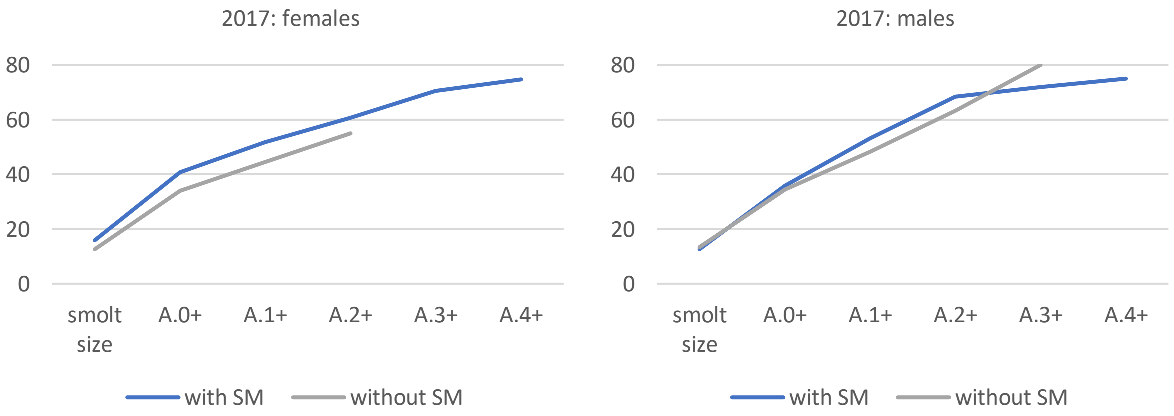


Figure 46: Within sex comparison of growth with or without spawning mark 2017.

5.2.7 Recaptures

During November and December 2016 and 2017, approximately 1000 fish were tagged with a T-bar tag in the Farver Au. In total 7 of 2016-tagged fish were recaptured in 2017 (Table 9). These fish allow to estimate the accuracy of back-calculation. As we know that these fish spawned in the previous year, the 2017-scales give helpful indications to identify spawning marks. Indeed, all fish were aged concordant and the spawning marks created in 2016 were well visible on the next year's scales. The back-calculated lengths were diverging at some points (see discussion). While the back-calculated length of some fish match between the years, there are especially the spawning fish which show diverging values. Additionally, some of the sampled scales were replacement scales, thus it was necessary to estimate the point of freshwater escape.

Table 9: Overview of the recaptured fish of 2016 and 2017. The same T-bar tag ID identifies the same individuals with the first genetic ID (6800 – 7133) representing the year of tagging 2016; the second genetic ID (>9000) representing the year of recapture in the Farver Au 2017. E.g.: The fish with T-bar tag 3154 was recaptured in 2016 (GENID = 6968) with a length of 31 cm at age A.0+. Same fish was caught in 2017 (GENID = 9043) with a length of 44 cm at age A.1+. The back-calculated length was 32,85 cm for age A.0+, which also represents the size at first spawning since spawning marks for 2016 were visible.

T-bar Tag	GENID	Length	Sex	Age	Sea age	Smolt age	Smolt size	A.0+	A.1+	A.2+	A.3+	A.4+	A.5+	Size 1st SM
3154	6968	31	M	1+.0+	A.0+	1+	12,40	31,00						31,00
3154	9043	44	M	1+.0+1SM+	A.1+	1+	12,22	32,85	44,00					32,85
3292	7020	56	M	1+.1+	A.1+	1+	13,90	32,00	56,00					56,00
3292	9663	70	M	1+.1+1SM+	A.2+	1+	14,29	33,93	62,81	70,00				62,18
3306	7032	70	F	2.1+1SM+	A.2+	2	17,06	48,32	62,97	70,00				62,97
3306	9228	76	F	2+.1+2SM+	A.3+	2+	20,03	51,36	62,73	69,97	76,00			62,73
3112	6800	50	F	1+.1+	A.1+	1+	16,00	39,63	50,00					50,00
3112	9232	60	F	RS.1+1SM+	A.2+	1+	24,00	49,00	56,00	60,00				56,00
3278	7007	64	F	2.2+2SM+	A.4+	2	15,97	32,96	46,03	52,84	59,65	64,00		52,83
3278	9249	68	F	2.2+3SM+	A.5+	1+	14,97	32,72	45,92	52,25	58,04	63,42	68,00	52,25
3300	7028	73	F	2.1+3SM+	A.4+	2	22,64	46,35	55,68	62,83	69,09	73,00		55,60
3300	9256	75	F	2+.1+4SM+	A.5+	2+	24,44	48,64	56,63	63,79	69,19	72,43	75,00	56,63
3403	7133	71	F	2.1+.1SM+	A.2+	2	21,56	47,51	58,48	71,00				58,48
3403	9393	74	F	2.1+2SM+	A.3+	2	19,11	46,95	57,40	67,60	74,00			57,40

Exemplarily, the size at first-time spawning was taken for the recaptures to show the standard deviation between observed and back-calculated length on figure 47.

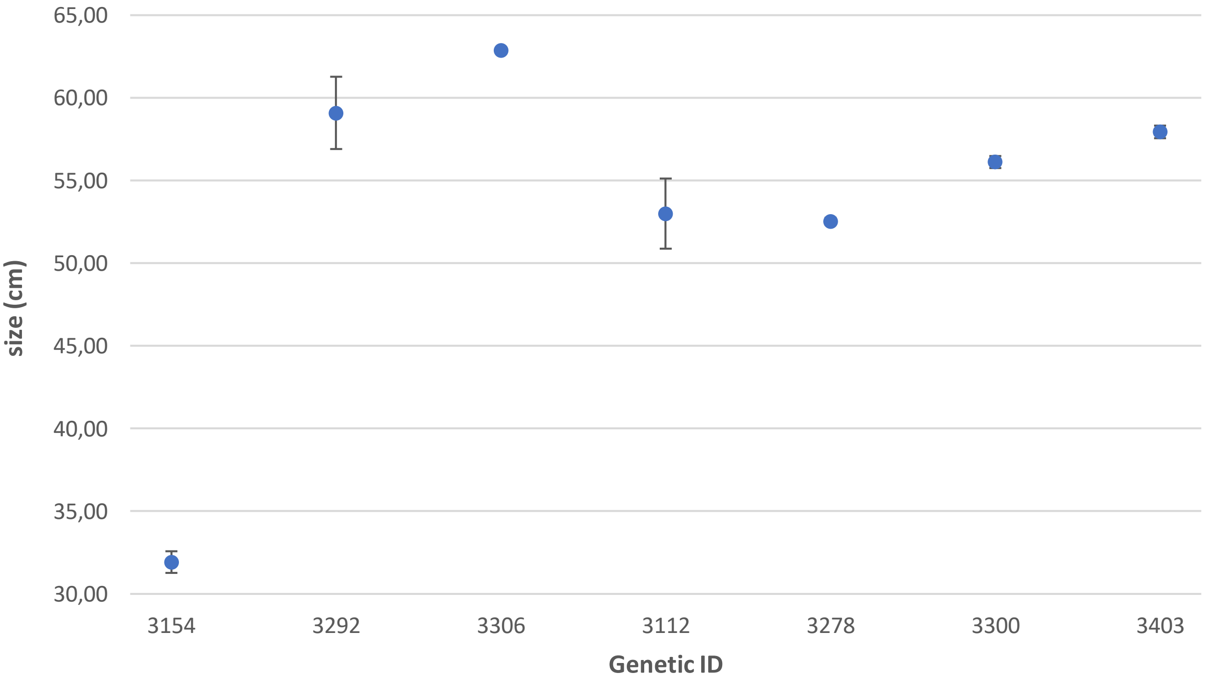


Figure 47: Size at first-time spawning run. Standard deviation between back-calculated and observed length for all individuals.

5.2.8 Silvery fish

During the electrofishing in the Farver Au and in other rivers like the Lipping Au, many silvery coloured fish were caught, taking part at the regular spawning runs. 2017, in the Farver Au 28 fish were recorded with the comment “silvery fish”. Due to the KüFo of Schleswig-Holstein these fish are not protected from being caught and removed by commercial or recreational fishermen since they are excluded from the closed season. The percentage share in 2017 was 6,25 %. Silvery fish were found at any maturity stage (0-4, according to Petereit et al., 2017). Figure 48 is showing a female fish with the mature state 0, which has already spawned successfully when it was caught.

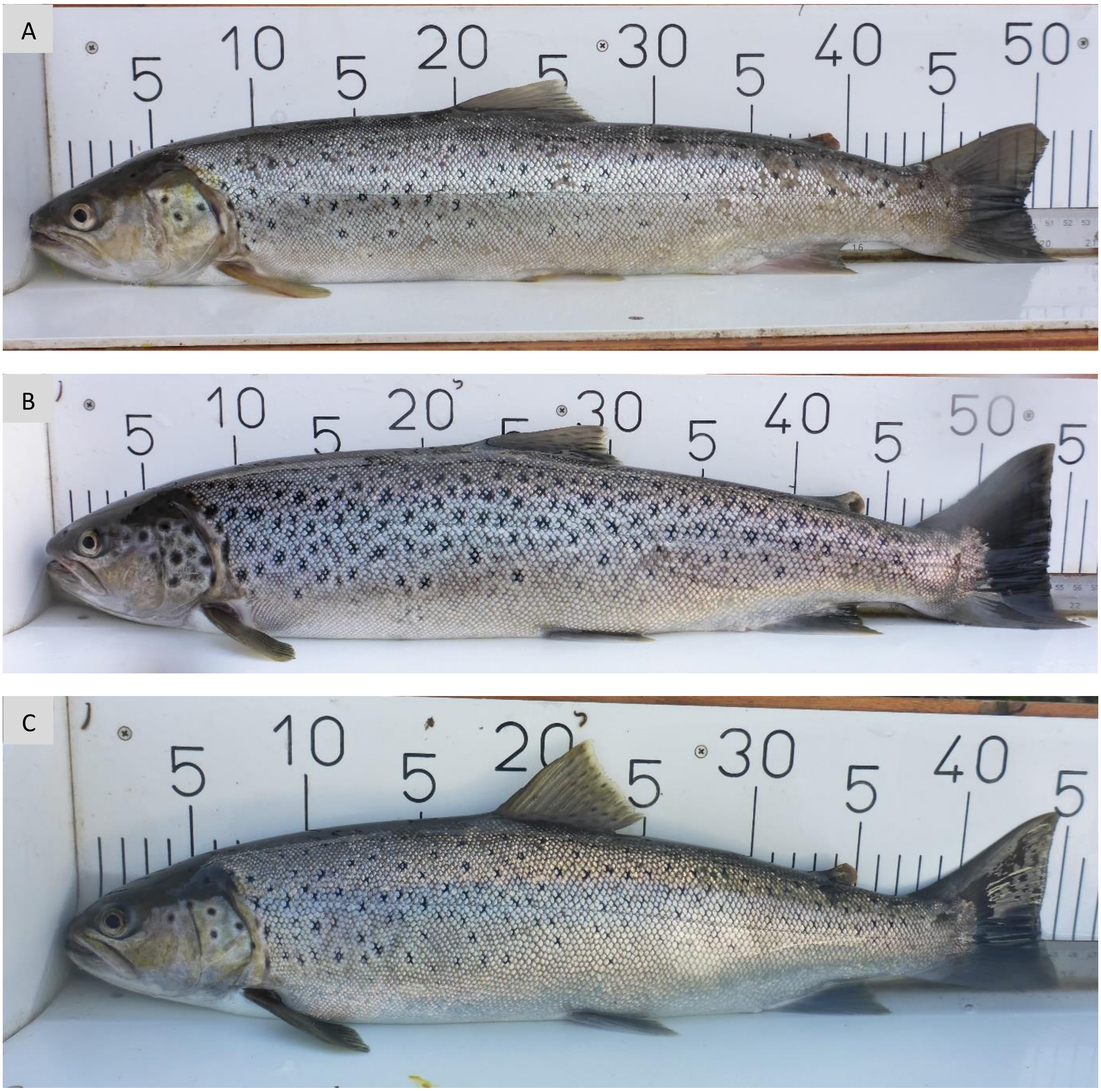


Figure 48: Three examples of silvery fish with different maturity stages. A: Silvery, female sea trout that has already spawned (maturity stage 0). Also lose scales had been present at time of capture (see adipose fin region); B: Silvery, female sea trout partially spawned (maturity stage 1); C: Silvery, female sea trout with maturity stage 3 – not yet spawned. Photos by C. Petereit.

5.3 Temporal genetic diversity

After genotyping, microsatellite data for 279 fish were available. One sample did not work and was excluded. Furthermore, one marker (Str15INRA) was removed from the marker pool, because it showed a significantly different Fst value during the STRUCTURE and GenePop analysis. The analysis was conducted with 12 microsatellite markers.

5.3.1 STRUCTURE results – Sample ordered by the year of birth

Figure 49 shows the graphical output from the STRUCTURE analysis. The results are presented for different K-values. According to the scale reading results, the samples were grouped by the year of birth. The bar diagram shows a mixed distribution of genotypes with a slightly different genotype composition in 2014. But overall no significant (Fst = 0.0029) differences in the genetic structure between the years could be detected.

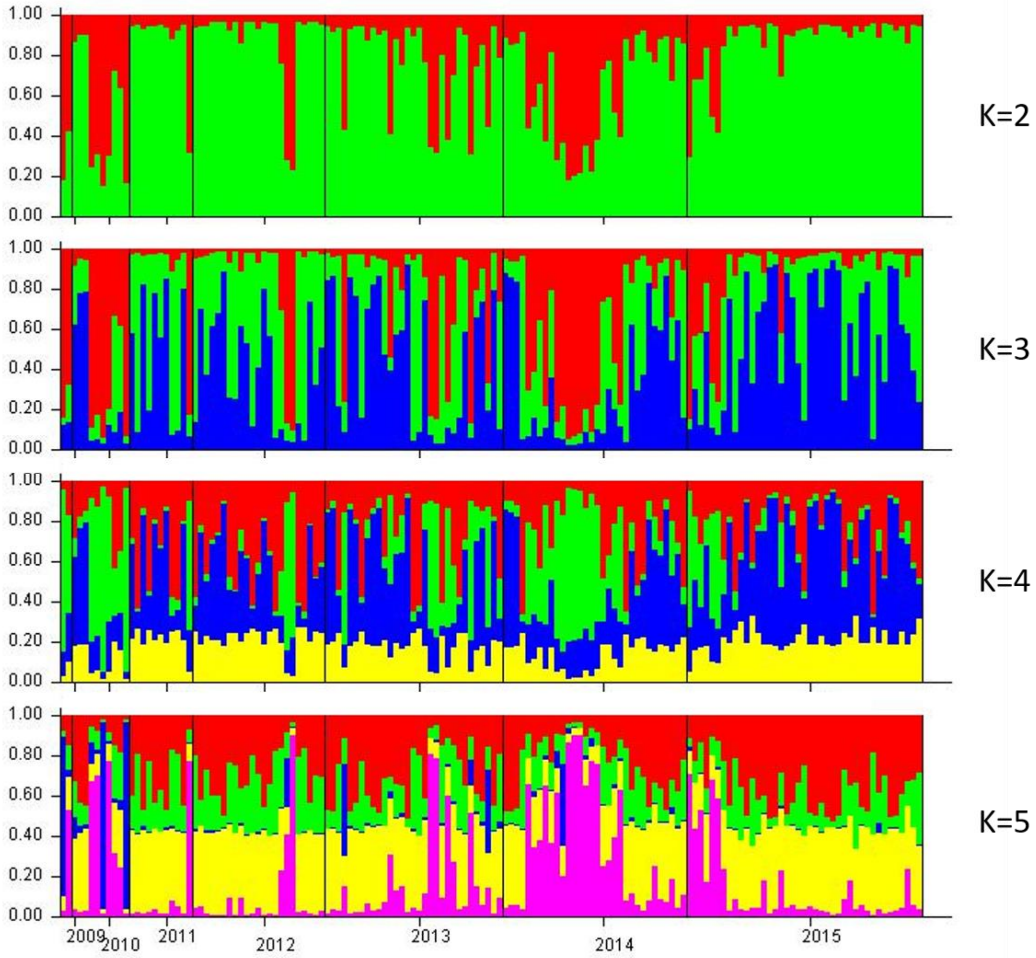


Figure 49: STRUCTURE results. K2 – K5. 50 fish of each sample group 2015 – 2017, ordered by the year of birth Fst=0.0029.

5.3.2 Effective population size – Sample ordered by the year of birth

The effective population size (Ne) (Table 10) could not be calculated for each of the seven years since the sample size of older fish in the sampling group was limited. Nevertheless, the results of the 2013 to 2015-born fish produced varying effective population sizes from 105 to 453 fish.

Table 10: Estimated Ne results. Linkage Disequilibrium Method. Lowest Allele Frequency used: 0,020.

Year of birth	Sample size	Estimated Ne	95% CI for Ne
2009	2	Infinite	Infinite
2010	10	75,1	23,7
2011	11	Infinite	Infinite
2012	23	Infinite	228,6
2013	31	105,3	64,3
2014	32	452,6	132,9
2015	40	235,1	127,2

5.3.3 STRUCTURE results – Sample ordered by spawning cohorts

Figure 50 shows the STRUCTURE analysis of all samples ordered by the year of sampling. Consequently, the genetic structure of the different spawning cohorts during 2012 to 2017 are shown.

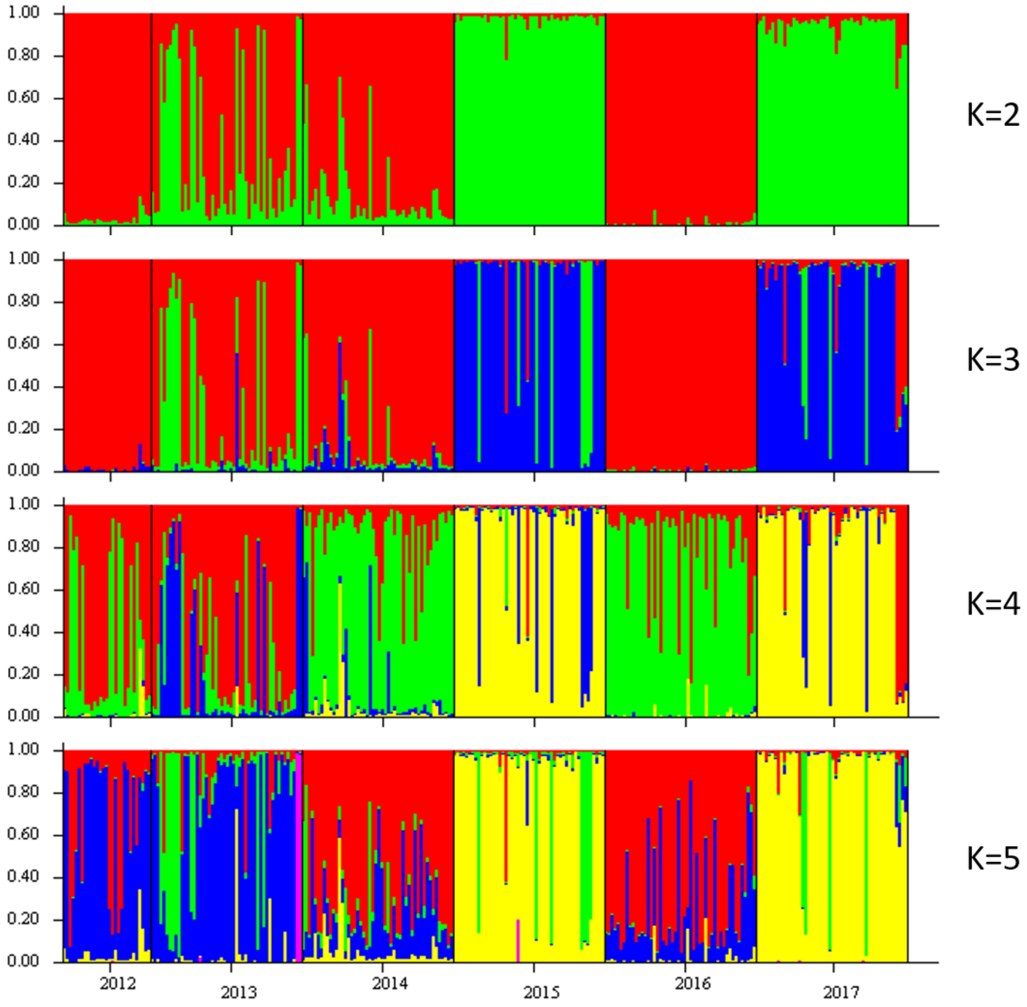


Figure 50: STRUCTURE results. K2 – K5, 29 fish in sampling group 2012; 50 fish in each sampling group 2013 – 2017.

The results show differences between the years. 2012 and 2013 showed a similar genetic structure that was not found again in the following years. From 2014 to 2017 a two-year cycle can be observed with equal genetic structures in 2014 and 2016 as well as in 2015 and 2017. Two fish in the 2013 spawning cohort can be observed (K=5, pink) that showed a genetic structure different to all other fish found in the Farver Au. Nevertheless, when calculating the Fst values via GENEPOP they showed no significant differences (overall Fst = 0.0119; detailed table 5.3.5).

5.3.4 Effective population size – Sample ordered by spawning cohorts

The effective population size (Table 11) showed comparable values for the years 2014 – 2017. The values for the first two years showed significantly smaller effective population sizes.

Table 11: Estimated Ne results. Linkage Disequilibrium Method. Lowest Allele Frequency used: 0,020. *Lowest Allele Frequency used: 0,010 in 2015.

Spawning cohort	Sample size	Estimated Ne	95% CI for Ne
2012	29	105	327,3
2013	50	62,4	76,5
2014	50	248,7	698,5
2015*	50	210,5	341,5
2016	50	293,9	944,4
2017	50	273,6	864,6

5.3.5 Calculated Fst-values – sample ordered by spawning cohort

Table 12 shows the calculated paired Fst-values for the spawning cohorts 2012 to 2017. No significant differences between the cohorts could be proved (Significance level: 0,05).

Table 12: Fst values, estimates for all loci (diploid). Fst values for differences between the spawning cohorts from 2012 to 2017.

Population	**2012**	**2013**	**2014**	**2015**	**2016**
2013	0,0018				
2014	0,0067	0,0072			
2015	0,0178	0,0136	0,0187		
2016	0,0035	0,0133	0,004	0,0279	
2017	0,0109	0,0099	0,0129	0,0019	0,0196

6 Discussion

6.1 Electro fishing derived sea trout spawner characteristics

6.1.1 Total catch

The total catch of 853 adult sea trout was not equally distributed over the three years in which the electrofishing was conducted during the spawning seasons. In 2017 (49,7 % of the total catch) nearly twice as many fish were caught than in each of the two previous years (2015 = 25,1 %; 2016 = 25,3 %). In 2015, however, only 6 instead of 9 electrofishing campaigns were performed, which may, to a small extent, have had an influence on the total number. If most of the fish stayed one winter at sea (see 5.2.2), the parr abundance in 2015 can be given as explanation for the high number of spawners in 2017. During five-year investigations of parr abundances in the Farver Au, 2015 showed the highest parr abundance (which are offspring of the 2014 parent spawner pool), only exceeded by the abundance in 2017 (Petereit et al., 2018).

The total catch during the period from 1969 to 1971 was lower with 29, 76 and 70 caught sea trout (Gehlhaar, 1972). The fishing success was judged by the author to be “good”, so it is to be expected that the share of missed fish during the electrofishing was comparable to the fisheries in this study. As the spawning run is expected to be influenced by rising water levels in combination with appropriate temperatures, it is therefore restricted to the autumn and winter. Gehlhaar (1972) conducted electrofishing also apart from the main spawning season, but only in February 1971 more sea trout were caught. All other sampled fish were caught during October or November. However, fishing was only conducted once per month in many months of the year, however, with no December electrofishing in all three years at all. This makes the direct comparisons of the results of the total catch and an estimation of the stock development among the studies impossible.

6.1.2 Length frequency distribution, egg production and legal size in fishery

The length frequencies of the years 2015 and 2016 showed similar distributions. In 2016 more small fish (25 – 30 cm) were caught, shifting the distribution to smaller mean length and higher proportion of smaller length classes. It is assumed that some of these smaller fish were also in the river in 2015, but not sampled representatively in that year (Petereit et al., 2017). In 2017 the distribution and the mean length of the spawning cohort was significantly smaller with the mean length being 6 cm smaller than in 2015 (see appendix 7.4.1). 53 % of the fish were between 40 cm and 49 cm in length (2015 = 38 %; 2016 = 34 %). The origin of the smaller fish will be discussed regarding the observed age in 5.2.2.

The observed length and weight of female fish give information about the expected number of eggs that are produced in the Farver Au. Thus, it is possible to name the length classes of the fish that contribute the most to the river’s total reproduction. A length-based egg production model has been developed and is presented elsewhere (Petereit et al., 2018). The largest contribution to the egg production is spawned by the length groups with mean length of 48cm, 62cm and sometimes also 70cm (Petereit et al., 2018). Knowledge of the most important length classes for the reproduction is essential to identify fish length classes which need to be especially protected by management options.

The length of the total catch is organized in 5-cm classes (Figure 23). This classification allowed the quantification of how many fish (total and percentage) contribute to the length classes of interest. The minimum legal sizes are 40 cm in Schleswig-Holstein (Landesverordnung über die Ausübung der

Fischerei in Küstenwässern (KüFo) vom 11.11.2008) and 45 cm in Mecklenburg-Western-Pomerania (Verordnung zur Ausübung der Fischerei in den Küstengewässern (Küstenfischereiverordnung - KüFVO M-V) vom 28. November 2006). In the Farver Au, 75 % (2016) to 96 % (2015) of all spawning fish were larger than 40 cm and thus above the minimum legal size in Schleswig-Holstein. As mentioned in chapter 2.5, the minimum legal size is a management option to protect small or immature fish from being removed by anglers or commercial fisheries before they have spawned for the first time (Hill, 1992). Based only on these facts, 75-90% of the individual fish enter far too early in the fisheries even before being able to reproduce to the first time in their life.

Nevertheless, observed length-frequency distributions alone are not appropriate to discuss the minimum legal size. It is necessary and possible to calculate the length at first-time spawning for every single fish by scale reading and to identify the real length frequency of fish that are spawning the first time (46 cm to 52,5 cm; mean: 48,8 cm; see coming section 6.2.4).

6.1.3 Sample selection

Chapter 4.2.1 showed the length frequencies of the total catch compared to the length frequencies of the selected samples that were used for scale reading. The sample selection did not represent the total catch completely since the ten biggest and the ten smallest fish were chosen manually. Also, it was taken care of choosing male and female fish in equal shares. Besides that, the length frequency of the sampled fish represented the catch. Consequently, it can be assumed, that the results of the scale reading represented the total spawning cohort.

6.2 Scale Reading

6.2.1 Smolt age

The scale reading method to estimate smolt age can be expected to be a highly reliable model to characterise the age structure of smolt populations (Rathjen, 2017). During the scale reading of a spawning cohort, the smolt size can only be identified by back-calculation (described in 3.3.5.). Although there were some difficulties in assessing the timing of freshwater escapement on adult sea trout scales, the back-calculation is a commonly used method. As before in the studies performed in the Lipping Au (Rathjen, 2017; Kramer, 2017) only two different smolt ages were detected in the Farver Au individuals. The majority of the smolts was aged 1 or 1+, while the share of these one-year old smolts varied over the years from 75,9 % in 2015 to 89,1 % in 2017. In both, Lipping Au and Farver Au, no older smolts than 2 / 2+ were found. Comparing the results of the Farver Au to the results of the two mentioned studies in the Lipping Au, there was a high agreement in the age structure of migrating sea trout smolts (2016: 85,9 %, 2017: 89,6 % aged 1 / 1+). As the smolt age during the migration is correlated to the latitude (Jonsson & L'Abeé-Lund, 1993), these similar results were expected (Farver Au: 54,3°N; Lipping Au: 54,5°N). However, the smolt age at a latitude of 54°N is reported by Jonsson and L'Abeé-Lund to be mostly 2+, while significantly older smolts (mainly 4+ to 5+) are found northwards at 70°N. The comparatively younger smolts in both Schleswig-Holstein rivers could be explained by the low mean water discharge, which is expected to have an impact on the smolt run. Jonsson et al. (2001) showed that smolt age and variation in smolt age inside a population raised with increasing mean water discharge. Both Farver Au and Lipping Au are comparatively small streams with low water discharge. A lower mean smolt age than 2 / 2+ and a variation over several years could be expected (Rahtjen, 2017). Gehlhaar (1972) described a mean smolt age of 1.6 years in the Farver Au. In another investigated river, the Rantzau (Stör river system - North Sea), Gehlhaar found a higher smolt age of 2,1 years. Gehlhaar also explained the difference in smolt age with the difference in mean water discharge of the river, which was 10 times higher in the Rantzau. Including the percentages of one-year old smolts, it is notable that the share over three years is only 39,77 % in the Farver Au in Gehlhaars study, which is significantly lower than the results found in this present study. Gehlhaar found the majority (58,48%) of smolts to be two years old and also found smolts aged 3+ (1,75%). The smolts of the Rantzau were even older. It can be assumed that the water temperatures could also have an impact on the smolt run, with higher temperature affecting the smolts to leave earlier because of faster in-river growth (Gehlhaar, 1972). Unfortunately, no time series of river water temperature over such long period exists for the Farver Au or similar nearby systems which could prove the hypothesis, that today's higher temperatures and as a result in conjunction with a lower mean water discharge could have shifted the mean age of leaving smolts towards younger (the 1+) age groups.

Skrupskelis et al. (2012) studied smolt populations in three different river systems in comparable latitudes (55°N to 55,3°N) and found a higher 1+ share (up to 82%) in at least one of three analysed rivers. High fluctuations in the share of the 1+ group are assumed to be attributable to stocking measures. The study revealed that reared 1+ aged sea trout smolts were significantly larger than natural specimen and thus able to leave the river earlier. The impact of stocking was obvious in 2008, one year after the stocking ended, when the share of 1+ age group decreased significantly but increased drastically one year later when the stocking program was reinstated (Skrupskelis et al., 2012). Changes of age structures in migrating salmonid smolts affected by stocks of artificially-reared fish, with faster growing reared fish that reach the critical smolt size for freshwater escapement earlier, was also observed from other salmonid populations in Europe (Piggins and Mills, 1985; Klemetsen et al., 2003). As stocking was not common practice in the early 70s, when Gehlhaar's investigations took place, this could be another possible explanation for today's younger smolt age. However, the latter seems potentially less likely. Since recent studies from two Baltic north German small rivers indicated only few stocked fish to survive (Albrecht, 2016; Rathjen, 2017; Webers, in preparation) it can be assumed that most of todays´ Farver Au individuals come from individuals of wild origin.

6.2.2 Sea age

During the scale reading of the Farver Au sea trout individuals a total of six different sea age classes were identified (six age classes in 2016 and 2017 (A.0+ to A.5+), in 2015 the age class A.5+ was not present). Besides that, the distribution of the investigated fish to the different age classes was almost similar in the years 2015 and 2016, with the only difference that more A.0+ fish were identified in 2016. As mentioned, the total catch contained a substantially different size distribution in 2017 with a lot more fish sized 40 to 50 cm. Since the sample selection was made randomly these fish were proportionally equally represented in the scales reading. Thus, the age distribution differed significantly in 2017, with 70 % of the fish showing an age of A.1+. These fish have mean lengths of 46,3 cm and had left the river as smolt in spring 2016. Accordingly, going one step back in the sea trout's life cycle, these fish had to be found as in parr stage during summer 2015. Indeed, Petereit et al. (2018) found the second highest parr abundance (65 parr per 100 m²) in 2015 with about twice as many parr compared to the previous year 2014. The highest parr abundance in the 5-year-time scale was found in 2017 with 160 parr per 100m². Consequently, most of these fish are expected to return in autumn/winter 2019.

The sea age class A.1+ was the most common age class over the three years (53,39 %), followed by A.2+ (21,53 %) and A.0+ (12,39 %). The age classes A.3+ to A.5+ are represented in decreasing dimension from 8 % down to 1,77 %. Compared to the results of Gehlhaar (1972), the sea age classes were equally ranked in percentage, although the percentage shares were closer together. A.0+ was higher represented (+10 percentage points) while the predominant group A.1+ had percentage share of only 34,29 %. Additionally, Gehlhaar found a higher proportion of older animals, which he ascribed to low mortality rates at sea. As previously mentioned, sea trout are a target species for both recreational and professional fisherman with increasing catches (ICES, 2018). Consequently, the mortality at sea today is most likely higher than 40 years ago, which might explain the higher shares of comparatively younger fish that participate in the sea trout reproduction in recent years.

Rasmussen and Pedersen (2018) mentioned investigations in the river Gudenaa with a total of 1449 scales read, where different age distribution was described. The most common age class was A.2+ (33,1 %), followed by A.0+ (32,4 %) which were in nearly equal proportions. A.1+ (16,8 %) and A.3+ (14,0 %) were also quite similarly distributed. However, the river Gudenaa, being the longest river in Denmark (158 km), is not comparable with the Farver Au (<15km). A majority of A.2+ spawners was also found by Gehlhaar (1972) in the river Rantzau, which also has a higher water discharge compared to the Farver Au.

6.2.3 Age of first-time spawners

Scale reading offers the opportunity to identify spawning marks and to draw conclusions about spawning experiences. It is possible to analyse the age of returning fish and to back-calculate the size of these specific fish on their first spawning run. As mentioned in Gehlhaar (1972), the age of first-time spawners depended on geographical location. Typically, the sea age at the first spawning run increased with the latitude (L'Abée-Lund et al., 1989; Jonsson & L'Abée-Lund, 1993). The more north- or eastwards the spawning rivers are located, the later sea trout reached sexual maturity. In the river Vistula half of the sampled fish spent two summers at sea, one third even three, before returning for the first spawning run (Chrzan, 1959). In the Finnish river Kemi, draining into the Gulf of Bothnia, 50% of the first-time spawners were even aged A.3+ (Järvi, 1940).

Gehlhaar (1972) expected that the sea trout in North German rivers reached maturity earlier, which depended on ecological conditions found during sea growth. Sea growth having a more important impact on sea age at first spawning than in-river growth (smolt size) was also concluded by L'Abée-Lund (1994). Rasmussen and Pedersen (2018) described first-time spawners from four different sea age classes (A.0+ to A.3+) in the Danish river Gudenaa. The most commonly found age class in first-time spawners was A.2+ (41,3 %) in females and A.0+ (59,1 %) in males.

In this study the age of first-time spawners was predominantly A.1+ but differed in percentages between males and females. 57% of all male fish without previous spawning experience were found in age group A.1+. In females, this proportion was significantly higher with 78%. Males were also found in age class A.0+ (23%) and A.2+ (19%) in high numbers, while the females were only detected at age A.2+ in noteworthy numbers. A small amount of first-time spawners was aged A.3+ but no older fish were found. Fittingly, the fish with spawning marks, which have experienced at least one spawning event before, are aged most frequently A.2+ in females, with no younger females found. Males were aged A.1+ to A.5+.

The age class A.1+ was also identified by Gehlhaar (1972) as most common age class in first-time spawners in the Farver Au (88,66 %). In the river Rantzau he found 94,6% of the first-time spawners with an age of A.2+. This leads to the presumption that the rivers discharge influenced time of the first freshwater return.

6.2.4 Size of first-time spawners: predictions and evaluation of current minimum size

The minimum legal size should protect small and immature fish from being removed from the stock too early. It should guarantee that every fish had the opportunity to spawn at least once. By back-calculating real length of fish on their first-spawning run it is possible to estimate the efficiency of current regulations.

The size at first-spawning was calculated each year during 2015 to 2017, as well as the mean size. In all three years the average size of first-time spawners (46 cm to 52,5 cm; mean: 48,8 cm) is higher than the current minimum legal size in Schleswig-Holstein (40 cm). With knowledge of average growths rates calculated in this study (1,6 cm per month) along with the information that most first-time spawners were aged A.1+, forecasts could be made about size development during the year.

A post-smolt individual can easily reach 40 cm before returning to the river as A.1+ fish for its first spawning run (mean length: 46 cm). Assuming constant growth, a 14 cm smolt, leaving its birth river in April (mean smolt size 2015-2017 = 13,83 cm), will reach 40 cm in August of the following year, three months before the main spawning season. The 45 cm, which are the minimum legal size in Mecklenburg-Western Pomerania, are reached in November/December when the fish enter the river for the first spawning run as A.1+ fish. As the assumption of constant growth likely underrepresents the real-life growth pattern during early months at sea, individual fish reach 40 cm likely even earlier. According to Petereit et al. (2018) the age class A.1+ with a mean average size of 44-48 cm has the most impact in terms of eggs produced during the whole spawning. Thus, it is recommended to set the minimum legal size in a way that these fish are protected to at least allow a first-time spawning!

6.2.5 Proportion of repeated spawners

As mentioned above, a total of 76 scales contained spawning marks, reflecting 12% to 30% of all participating spawners - which proportions varied over the three years. The highest proportion was found in 2016 with both, second-time and multiple spawners (spawning for the third time or more) having a proportion of more than 10% of the total sample. This could have reflected rather low mortality during the sea summer period compared to the years 2015 and 2017 and alternatively a lower survival of early post-smolts in the sea reducing the share of the new upcoming cohort and therefore increasing the relative share of the repeated spawners.

In general, female fish have higher proportions when it comes to multiple spawning. Fish which skipped spawning for one year were not found! Proportions found in this study are significantly lower than the share of repeated spawners found by Gehlhaar in the early 70s. In his sample 58,2% of all investigated scales in the Farver Au (Rantzau: 66,3%) showed at least one spawning mark. He observed that sea trout, when having spawned for the first time were returning every consecutive year. He has only found one fish in the Rantzau which has skipped spawning once. Since the emergence of spawning marks is dependent on the time of the fresh water stay and the intensity of the spawning procedure (Dr. Adam Lejk, personal communication), it is not sure if this fish has really skipped spawning or just did not show an adequate spawning mark. However, Gehlhaar (1972) has found an exceptionally high proportion of repeated spawners, which could not be proved in comparative studies he referred to (e.g. Järvi, 1940; Chrzan, 1959). The high percentage share was expected to be based on low mortality rates during sea residence (Gehlhaar, 1972). Today in times of high fishing pressure by both recreational and commercial fisheries, the share of repeated and multiple spawners is expected to be lower. Dr. Adam Lejk (unpublished results) reported values to be expectable of around 8% repeated spawners and 0,5% multiple spawners in Polish river systems.

6.2.6 Growth

Growth of all fish can be calculated and sorted by spawning experience, sex or smolt age. The results of Farver Au sea trout showed no different growth patterns between sexes. As well the smolt age had no influence on growth rates. Nevertheless, two-year old smolts reached the minimum legal size earlier, since they leave the river in a bigger size. All fish showed the biggest growth rates in their first year at sea. The difference is observed when it comes to spawning experience. While maiden fish grow constantly at 10 to 15 cm per year, the growth rates decrease dramatically when individuals had spawning experience in the same or previous year.

The growth of sea trout is very individual and dependent on the environmental conditions during the stay at sea (Gehlhaar, 1972). When leaving the river as one-year old smolt with a mean length of 14 cm, the mean growth until the first sea winter (age A.0+, 6 to 9 months at sea) is up to 23 cm, which results in a mean length of 30 to 36 cm. Two-year old smolts showed similar growth rates during their first summer at sea and reached, due to their higher smolt size of 17 to 20 cm, mean lengths of up to 44 cm at age A.0+. Some sampled fish showed exceptional growth with a length of 49 cm (observed) and the highest back-calculated length at A.0+ of 57,8 cm. This fish (Gen-ID: 4478) was captured in 2015 with a total length of 83 cm. No spawning marks were found, the age was determined, and the results and scale cross-checked by Dr. Adam Lejk as 1+.2+ individual. Very similar growth rates of about 2,5 cm per month in an eight-month growth period was also found in tagging results from domesticated sea trout (Pedersen and Rasmussen, 2000) and in scale analysis from wild sea trout in the Limfjord (Frier, 1994).

The growth during the second summer until reaching the age of A.1+ was lower throughout sex, smolt age and spawning experience. Mean growth rates were found from 10 to 15 cm. This mean growth remained constant during consecutive years in fish without spawning marks. Again, the growth potential is very individual and exceptions in both higher and lower growth were frequently found. Fish that showed spawning marks showed significantly smaller growth, decreasing with every sea age class. This so-called “reproduction loss” was discussed by Rasmussen and Pedersen (2018). It includes the effects of reduction of weight and mass because of spawning migration, stop of feeding in fresh and saltwater and the loss of gametes. In different models the spawning loss was of about 40 % and showed no statistical difference between the two sexes (Rasmussen and Pedersen, 2018).

Gehlhaar (1974) found a back-calculated smolt-size of 15,5 cm during his investigations in the Farver Au. The observed and back-calculated sea age sizes are shown in appendix 6.3. Due to the large deviation between both – especially at younger sea ages – the sea growth is compared by the observed values.

Analogically to the results in this study, the biggest sea growth was observed during the first year at sea. The mean length at age A.0+ was 35,6 cm (= 20,1 cm growth; Gehlhaar (1974)) which is comparable to the length observed in this study (A.0+ = 29,4 – 34,9 cm). The following growth until the age of A.1+ was only 6,85 cm with a mean length of 42,45 cm. This was substantially smaller than today’s observed sizes. Growth rates in the following years at sea decreased as expected since the fish took part at spawning seasons. Overall, the mean length at specific sea ages are smaller which suggests, that the growth conditions today are more favourable for the sea trout growth at sea.

However, the observed maximum lengths were comparable to the results in this study, although the degree of correlation cannot be estimated since the sample size of big fish (>70 cm) is comparatively small.

The growth conditions at sea are mainly influenced by water temperature and food availability (Gehlhaar, 1972; Rasmussen and Pedersen, 2018). Due to the climate change the water temperature of the Baltic Sea showed increasing surface temperatures with the most dramatic increases since the 1980s (Dailidiene et al., 2011; Reckermann et al, 2014). Since critical temperatures are not yet reached it is assumed that the current temperatures are supporting faster sea growth (Elliott, 2010).

Studies about the food range or behaviour in relation to thermoclines in the sea of sea trout which could be affected by clime change are still to be conducted and could provide explanations for potentially increasing growth rates.

6.2.7 Recaptures

Lower precision in age and growth estimation is reported in scale reading compared to investigations with other calcified structures, like otoliths, fin rays or skull bones (van der Meulen et al., 2013). Many endogenous and exogenous stress factors such as disease, injury, food and nutrition unavailability, maturation, spawning behaviour and temperature are associated with irregularities in annuli formation on scales (Beamish and McFarlane, 1983; Závorka et al., 2014). Especially back-calculation results are affected by unequal scale formation. Thus, it is recommended not to undertake back-calculation from scales with spawning marks (Celtic Sea Trout Project, 2010). To check the accuracy of back-calculation results the individually T-bar tagged and one year later recaptured sea trout individuals in this study give helpful indications for direct comparison between back-calculated and observed growth.

The observed and back-calculated lengths were most commonly differing within a 2 cm size range. If having experienced the first-time spawning (e.g. having spawned in 2016 for the first time), the back-calculated length did not exceed this 2 cm (T-bar Tag IDs: 3154). The second spawning mark of fish 3403 showed a back-calculated difference of 3.5 cm, while the first spawning mark matched with a difference of 1 cm. Increasing inaccuracy with increasing spawning experience was also observed by Závorka et al. (2014). That spawning marks did not influence the accuracy of the back-calculated values was also observed in several other individuals (IDs: 3278 and 3300). The limited number of recaptures prevented a complete judgment of the accuracy in this study, however, in general a very high coincidence among the results could be shown. Back-calculated length should always be treated with care. However, the failure should be decreasing with the high number of samples in this study, since the exemplarily showed diagram of the size of first-time spawners showed high standard deviations for only two out of the seven fish.

6.2.8 Silvery fish – closed seasons

The KüFo of Schleswig-Holstein does not regulate catches of silvery sea trout in the Baltic Sea during the spawning seasons, since silvery fish are not expected to take part in the reproduction. Silvery winter trout ("Überspringer") are even promoted (by fishing magazines, team anglers and other influencers of the angler scene) to be favourable goals for recreational anglers. Only coloured sea trout are protected and need to be released when caught during 1.10. – 31.12 (KüFo SH). In rivers the sea trout are under control of the BiFVO and protected by closed seasons during the spawning season (1.10. – 28.02.).

During the investigations in the Farver Au and several other rivers in Schleswig-Holstein, substantial proportions of silvery fish were caught during scientific electrofishing for spawners. This could later be proven by the frequency of additional comment in the fishing protocols "as individual in silvery state". Only in the Farver Au in the 2017 campaign, 6,25 % of all captured individuals were silvery. It became manifested, that uncoloured, silver spawners were found in each maturity stage (3 to 0 - see Petereit et al., 2018 for classifications), in both male and female fish. Thus, the state of colouration might not to be an appropriate method to decide if a fish will take part in the reproduction within one spawning season or not. With fish entering the river during the spawning season for 6 to 13 days on average it is still likely that fish caught in the Baltic during November will enter the rivers in December or even later. A general, coloration independent, closed season for all sea trout could lead to an enlargement of the spawning population und thus increase the amount of natural egg deposition in the spawning rivers.

6.3 Temporal genetic differentiation

The survival of a species or a population is highly influenced by the presence of genetic variation. The occurrence of different genotypes within a population offers the opportunity to adapt quickly to short- or long-term environmental changes (Soule and Wilcox, 1980), ensuring the survival of at least a part of the population. In times of increasing human interventions like climate change, pollution, habitat loss or excessive fisheries exploitation, reduced genetic diversity is correlated with enhancing the chance of extinction (Dudu et al., 2015). Especially sea trout populations are threatened as well in rivers and at the open sea. Diverse genetic structures within sea trout stocks are therefore expected to improve successful adaptation to changing environmental conditions.

The temporal genetic differentiation of the Farver Au sea trout spawning cohort was investigated on a six-year time scale. With assistance of the scale reading results, the sample group of the aged fish of the years 2015 to 2017 could be ordered by the year of birth to picture the genetic structure of each cohort. The results showed a homogenous distribution of genotypes throughout the years, with some genotypes being more successful in specific years. The 2014 cohort differed slightly, but these differences are to expect within populations and can be caused by varying selection pressures on the cohorts or varying success of hatchery-bred trout, which are released into the Farver Au (Linløkken et al., 2017). Due to the small sample size of older sea trout born before 2013, the calculation of the effective population size was not continuously possible. Estimated effective population sizes differed between 105 and 453, with the 95% confidence interval showing up to 1118 animals in 2015.

The initial question concerning the temporal genetic diversity of the spawning cohort should be answered with the second STRUCTURE analysis of all available samples of the years 2012 – 2017. The results showed three different genotypes with one occurring only in 2012 and 2013, and two others alternating between 2014 to 2017. According to these graphical results, three different populations participate in the Farver Au’s spawning events. One population was present in 2012 and 2013 and absent since then. Two other populations alternate in the following years. These results could neither be proved by the first STRUCTURE analysis when the sampled fish were ordered by the year of birth nor the GenePop analysis calculating the Fst values. Also, the two-year pattern in repeated spawning, with spawning in one year and river absence in the next year (skipped spawning) could not be proved by scale reading. The scale reading results clearly show that fish who have spawned for the first time will repeat spawning in every consecutive year. This behaviour is assumed to be typical for sea trout spawning in small rivers like the Farver Au (personal communication Dr. Adam Lejk). A technical artefact could be excluded for this phenomenon, since repeated DNA extractions and mixed plates during PCR and resequencing showed the same results. The two-year cycle was also observed in microsatellite analysis of spawning fish in the comparable river Lipping Au (Petersen, 2017), but could be avoided by excluding additional marker. The responsible marker in the project by Petersen (2017) (Str60INRA) was also excluded on trial in the Farver Au data but the pattern stayed the same and the marker itself only had a calculated Fst of 0.0026. In the end there is no hypothesis that could explain the occurrence of this pattern and it is to assume that based on the calculated Fst values, the Farver Au spawning cohorts do not consist of various, genetically differentiated populations that alternate in spawning. Reduced genetic diversity within sea trout populations spawning in the same river are observed in intensively stocked rivers), but not in rivers with a majority of wild fish. (Bernas et al, 2014; Linløkken et al., 2017; Was-Barcz et al., 2017). Since the share of identified stocked (during fry stage) fish in comparable Schleswig-Holstein rivers was very low (Rathjen, 2017; Weber, in preparation) it is to assume that also in the Farver Au the majority of the sea trout are from wild origin.

The effective population size Ne is consistent during 2014 to 2017 and showed values between 210 and 290 in these years. The first two years of the investigation showed significantly different effective population sizes with 105 and 62,4 animals.

For the years of regular electrofishing 2015, 2016 and 2017, a comparison between the number of caught (and the upraised numbers from t-bar tagging) sea trout and the number of the calculated effective population size, derived by 50 individual spawners each year, was possible. The t-bar extrapolated numbers were 430 (2015), 300 (2016) and 624 (2017) (Petereit et al., 2018). As mentioned, the effective population sizes (2015 = 210; 2016 = 293; 2017 = 273) were similar between the years and lower than the extrapolated census population sizes. With a similar effective population size and more actually present fish over the three-year sampling period, it is suggestable that not the amount of fish, but the survival of the recruited offspring is reduced. Nevertheless, the results in this study offer potential for further investigations on sea trout genetics.

7 Appendix

7.1 Location and course of the Farver Au

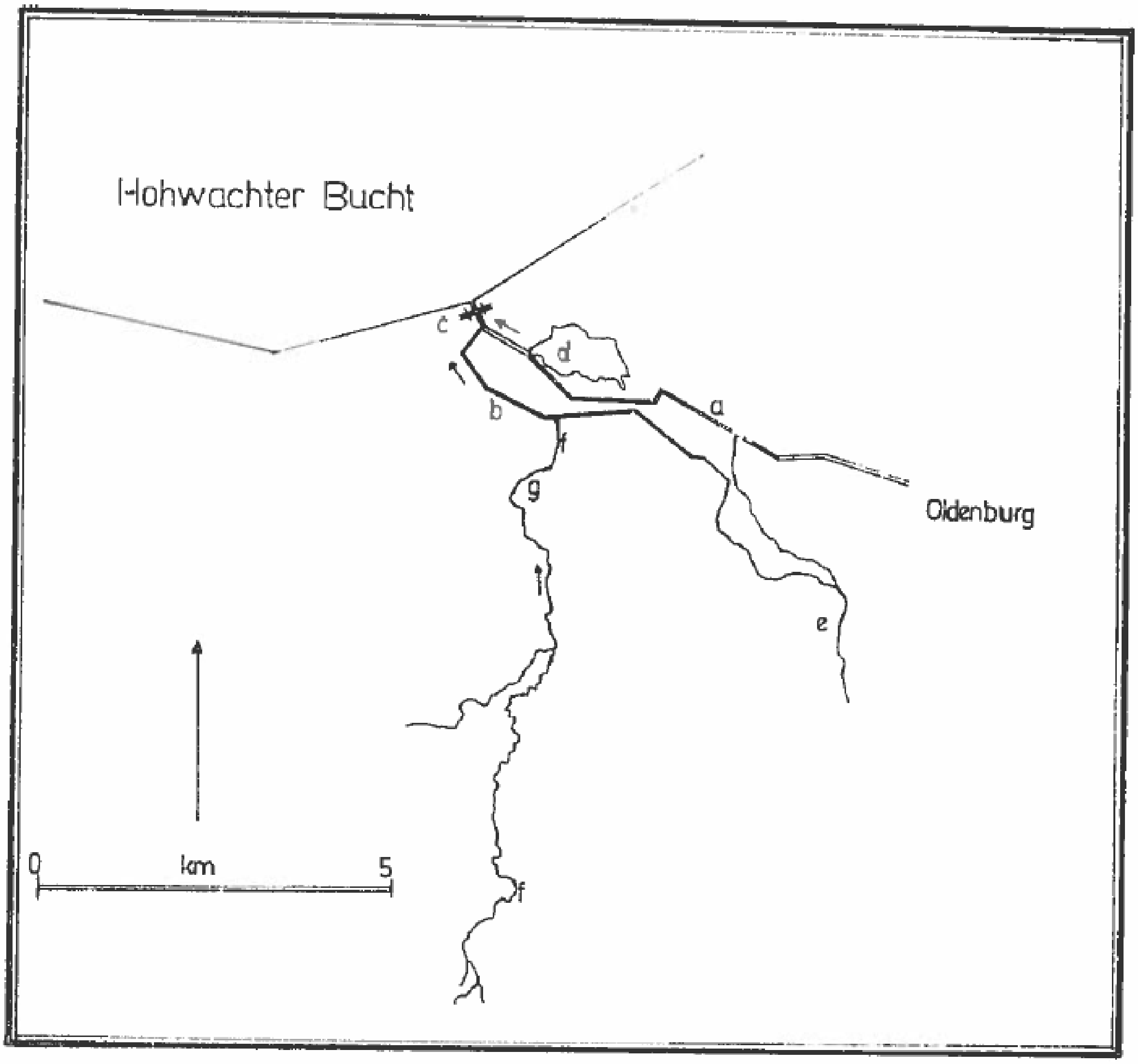


Abb. 4 Die Lage der Farver Au

a Oldenburger Graben
b Oldenburger Randkanal
c Pumpwerk Weißenhaus
d Wesseker See
e Johannisbek
f Farver Au
g Gut Farve

Figure 51: Location and course of the Faver Au. Mentionable: g: Gut Farve, start of appropriate spawning conditions upstream to the source. Figure taken from Gehlhaar (1972).

7.2 Dates of the electrofishing season

Table 13: Dates of the electrofishing season 2015 – 2017. No. of fish = New fish, recaptures not considered.

2015	No. of fish	2016	No. of fish	2017	No. of fish
-		02.11.	13	01.11.	103
-		09.11.	2	08.11.	73
-		16.11.	2	15.11.	25
25.11.	79	23.11.	66	22.11.	63
02.12.	52	30.11.	23	29.11.	52
09.12.	43	07.12.	14	06.12.	42
16.12.	20	14.12.	70	13.12.	31
23.12.	17	21.12.	14	20.12.	34
30.12.	5	28.12.	16	28.12.	23

7.3 Primerpool 1 and 2 according to Albrecht (2016)

Table 14: Information of the markers and the dilutions for the final primer pools 1 and 2 in detail. Taken from Albrecht (2016).

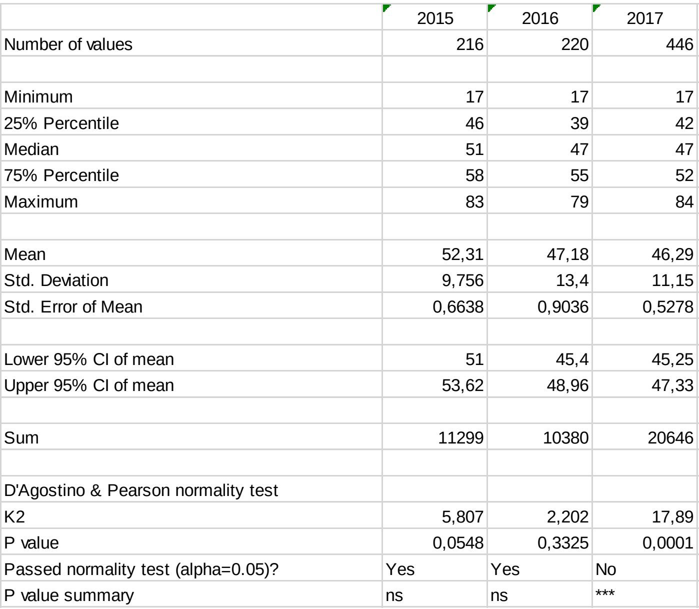
Pool 1	**Dye**	**Size Range [nm]**	**c [µM]**	**µl in PCR [µl]**	**100µl Pool [µl]**	**from Stock [µl]**	**1:10 predilution [µl]**	**final addition [µl]**
SSsp2201	6FAM	202-354	0.03	1.3	1.3	0.13	1.3	2.6
Ssa197	NED	126-154	0.02	0.2	0.2	0.2	2	4
Ssa407	NED	206-300	0.15	1.5	1.5	1.5	15	30
Ssosl417	PET	174-194	0.04	1.4	1.4	2.8	2.8	2.8
OneU9	VIC	198-208	0.03	1.3	1.3	1.3	13	26
Ssa85	VIC	100-124	0.02	0.2	0.2	0.2	2	4
Str73INRA	VIC	140-148	0.04	1.4	1.4	1.4	14	28
Total [µl]:				**97.4**				
H2O [µl]:				**2.6**				

Pool 2	**Dye**	**Size Range [nm]**	**c [µM]**	**µl in PCR [µl]**	**100µl Pool [µl]**	**from Stock [µl]**	**1:10 predilution [µl]**	**final addition [µl]**
Str15INRA	6FAM	222-228	0.05	1.1	1.1	0.11	1.1	2.2
Strutt58	6FAM	100-186	0.3	3	3	3	-	6
Ssosl311	NED	131-161	0.07	0.7	0.7	0.7	7	14
SSsp1605	NED	310-590	0.04	0.4	0.4	0.04	0.4	0.8
Str60INRA	PET	98-102	0.05	0.5	0.5	0.5	5	10
BS131	VIC	143-171	0.03	0.3	0.3	3	-	6
Ssosl438	VIC	100-108	0.07	0.7	0.7	3	-	6
Total [µl]:				**45**				
H2O [µl]:				**55**				

7.4 Statistic analysis

7.4.1 Total catch

Table 15: Column statistics and D'Agostino & Pearson test for normality in the total catch in 2015, 2016 and 2017.



	2015	2016	2017
Number of values	216	220	446
Minimum	17	17	17
25% Percentile	46	39	42
Median	51	47	47
75% Percentile	58	55	52
Maximum	83	79	84
Mean	52,31	47,18	46,29
Std. Deviation	9,756	13,4	11,15
Std. Error of Mean	0,6638	0,9036	0,5278
Lower 95% CI of mean	51	45,4	45,25
Upper 95% CI of mean	53,62	48,96	47,33
Sum	11299	10380	20646
D'Agostino & Pearson normality test			
K2	5,807	2,202	17,89
P value	0,0548	0,3325	0,0001
Passed normality test (alpha=0.05)?	Yes	Yes	No
P value summary	ns	ns	***

Table 16: Kruskal-Wallis test for significant difference in the size distribution of the total catch during 2015, 2016 and 2017. Significant distribution is investigated.

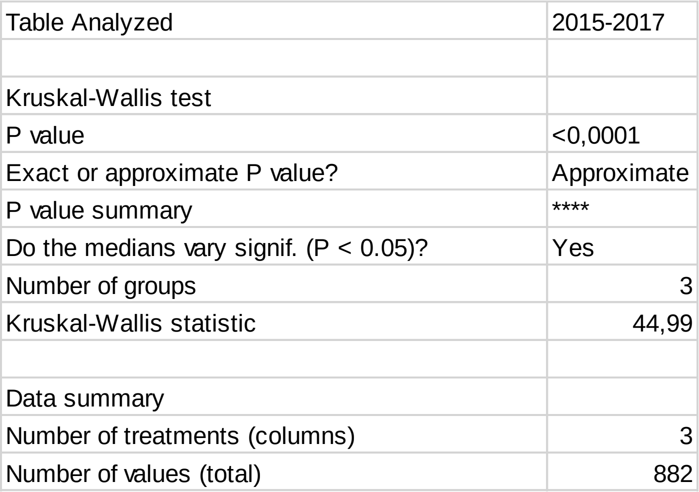
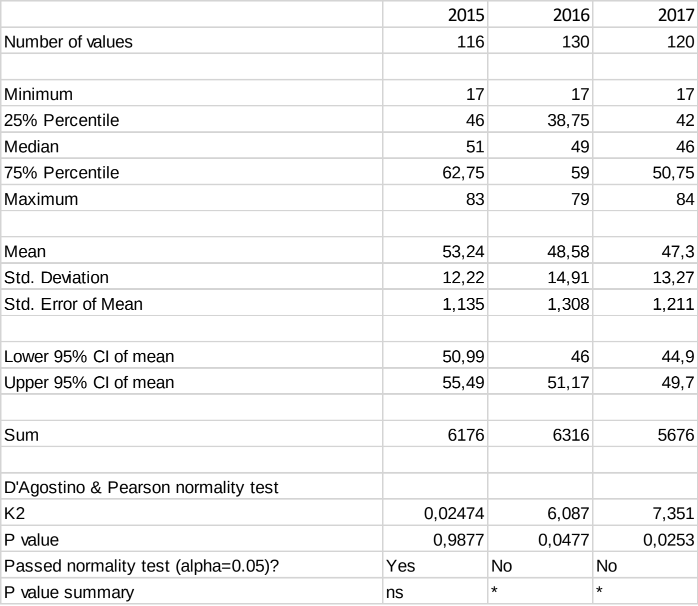


Table Analyzed	2015-2017
Kruskal-Wallis test	
P value	<0,0001
Exact or approximate P value?	Approximate
P value summary	****
Do the medians vary signif. (P < 0.05)?	Yes
Number of groups	3
Kruskal-Wallis statistic	44,99
Data summary	
Number of treatments (columns)	3
Number of values (total)	882

7.4.2 Sample selection

Table 17: Column statistics and D'Agostino & Pearson test for normality in the sample selection in 2015, 2016 and 2017.



	2015	2016	2017
Number of values	116	130	120
Minimum	17	17	17
25% Percentile	46	38,75	42
Median	51	49	46
75% Percentile	62,75	59	50,75
Maximum	83	79	84
Mean	53,24	48,58	47,3
Std. Deviation	12,22	14,91	13,27
Std. Error of Mean	1,135	1,308	1,211
Lower 95% CI of mean	50,99	46	44,9
Upper 95% CI of mean	55,49	51,17	49,7
Sum	6176	6316	5676
D'Agostino & Pearson normality test			
K2	0,02474	6,087	7,351
P value	0,9877	0,0477	0,0253
Passed normality test (alpha=0.05)?	Yes	No	No
P value summary	ns	*	*

Table 18: Kruskal-Wallis test for significant difference in the size distribution of the selected samples during 2015, 2016 and 2017. Significant distribution is investigated.

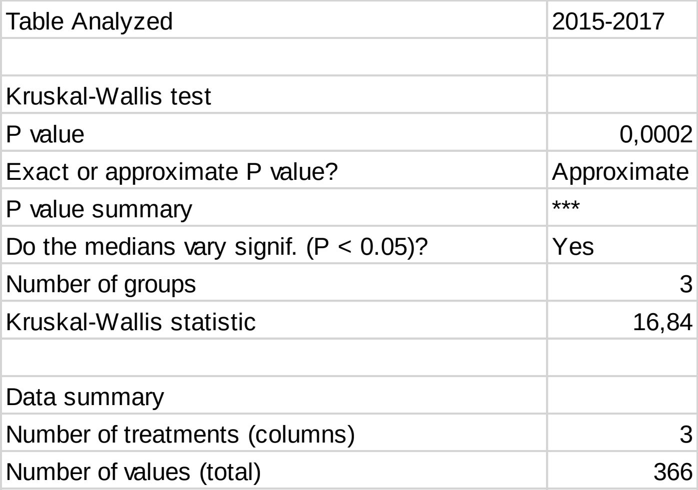


Table Analyzed	2015-2017
Kruskal-Wallis test	
P value	0,0002
Exact or approximate P value?	Approximate
P value summary	***
Do the medians vary signif. (P < 0.05)?	Yes
Number of groups	3
Kruskal-Wallis statistic	16,84
Data summary	
Number of treatments (columns)	3
Number of values (total)	366

7.4.3 Size of first-time spawners

Table 19: Column Statistics and D’Agostino & Pearson test for normality in length of male and female first-time spawners during 2015, 2016 and 2017.

	F 2015	M 2015	F 2016	M 2016	F 2017	M 2017
Number of values	58	57	62	63	55	55
Minimum	32	30	29,85	19	38	24
25% Percentile	46,75	44,5	44,75	30	43	43
Median	50,5	52	51,12	45	46	46
75% Percentile	58,25	62	55,9	49	50	53
Maximum	75	83	71	63	75,66	80
Mean	53,17	51,93	50,58	41,73	47,57	48,65
Std. Deviation	9,246	12,52	8,491	11,19	6,858	10,88
Std. Error of Mean	1,214	1,658	1,078	1,41	0,9247	1,468
Lower 95% CI of mean	50,74	48,61	48,42	38,91	45,72	45,71
Upper 95% CI of mean	55,6	55,25	52,74	44,55	49,43	51,59
Sum	3084	2960	3136	2629	2617	2676
D'Agostino & Pearson normality test						
K2	5,769	0,1146	0,6298	13,4	30,35	13,49
P value	0,0559	0,9443	0,7299	0,0012	<0,0001	0,0012
Passed normality test (alpha=0.05)?	Yes	Yes	Yes	No	No	No
P value summary	ns	ns	ns	**	****	**
P value summary	**	ns	****	ns	****	*

Table 20: T test for significant difference in length of male and female first-time spawners 2015.

Column B	M 2015
vs.	vs,
Column A	F 2015
Unpaired t test	
P value	0,5452
P value summary	ns
Significantly different (P < 0.05)?	No
One- or two-tailed P value?	Two-tailed
t, df	t=0,6068 df=113
How big is the difference?	
Mean ± SEM of column A	53,17 ± 1,214, n=58
Mean ± SEM of column B	51,93 ± 1,658, n=57
Difference between means	-1,244 ± 2,05
95% confidence interval	-5,305 to 2,817
R squared (eta squared)	0,003248

Table 21: T test and Mann Whitney test for significant difference in length of male and female first-time spawners 2016.

Column D	M 2016
vs.	vs,
Column C	F 2016
Unpaired t test	
P value	<0,0001
P value summary	****
Significantly different (P < 0.05)?	Yes
One- or two-tailed P value?	Two-tailed
t, df	t=4,977 df=123
How big is the difference?	
Mean ± SEM of column C	50,58 ± 1,078, n=62
Mean ± SEM of column D	41,73 ± 1,41, n=63
Difference between means	-8,852 ± 1,779
95% confidence interval	-12,37 to -5,332
R squared (eta squared)	0,1676

Mann Whitney test	
P value	<0,0001
Exact or approximate P value?	Exact
P value summary	****
Significantly different (P < 0.05)?	Yes
One- or two-tailed P value?	Two-tailed
Sum of ranks in column C,D	4785 , 3090
Mann-Whitney U	1074
Difference between medians	
Median of column C	51,12, n=62
Median of column D	45, n=63
Difference: Actual	-6,115
Difference: Hodges-Lehmann	-8

Table 22: Mann Whitney test for significant difference in length of male and female first-time spawners 2017.

Column F	M 2017
vs.	vs,
Column E	F 2017
Mann Whitney test	
P value	0,7283
Exact or approximate P value?	Exact
P value summary	ns
Significantly different (P < 0.05)?	No
One- or two-tailed P value?	Two-tailed
Sum of ranks in column E,F	2994 , 3111
Mann-Whitney U	1454
Difference between medians	
Median of column E	46, n=55
Median of column F	46, n=55
Difference: Actual	0
Difference: Hodges-Lehmann	0

Overall comparison of the first-time spawner size throughout 2015 to 2017

Table 23: Column statistics and D'Agostino & Pearson test for normality in length distribution of first-time spawners during 2015, 2016 and 2017.

	2015	2016	2017
Number of values	115	125	110
Minimum	30	19	24
25% Percentile	46	39,72	43
Median	51	48	46
75% Percentile	59	54	50,94
Maximum	83	71	80
Mean	52,56	46,12	48,11
Std. Deviation	10,96	10,85	9,071
Std. Error of Mean	1,022	0,9708	0,8649
Lower 95% CI of mean	50,53	44,2	46,4
Upper 95% CI of mean	54,58	48,04	49,83
Sum	6044	5765	5292
D'Agostino & Pearson normality test			
K2	1,129	5,076	35,12
P value	0,5688	0,079	<0,0001
Passed normality test (alpha=0.05)?	Yes	Yes	No
P value summary	ns	ns	****

Table 24: Kruskal-Wallis test for significant difference of first-time spawning size between 2015, 2016 and 2017.

Kruskal-Wallis test	
P value	<0,0001
Exact or approximate P value?	Approximate
P value summary	****
Do the medians vary signif. (P < 0.05)?	Yes
Number of groups	3
Kruskal-Wallis statistic	21,2
Data summary	
Number of treatments (columns)	3
Number of values (total)	350

7.4.4 Growth statistics

Column statistics and D'Agostino & Pearson test for normality of growth rates. The columns contain back-calculated growth within growth periods (e.g. Smolt to A.0+ growth = growth during the first summer at sea). Sample group is divided by sex and spawning experience (0 = without spawning experience, 1 = with spawning experience).

Table 25: Growth statistics for Smolt to A.0+ and A.0+ to A.1+ growth.

	male 0	male 1	female 0	female 1	male 0	male 1	female 0	female 1
	S to A.0+	S to A.0+	S to A.0+	S to A.0+	A.0+ to A.1+	A.0+ to A.1+	A.0+ to A.1+	A.0+ to A.1+
Number of values	125	13	117	53	124	13	117	53
Minimum	9,73	14,85	12,63	14,83	5,62	7,36	4,14	3,93
25% Percentile	18,28	17,21	18,38	18,63	10,26	8,975	7,815	8,385
Median	22,12	23,92	22,03	23,17	12,57	13,03	10,47	11,37
75% Percentile	25,43	24,97	25,53	27,72	15,89	17,31	14,7	15,78
Maximum	42,8	29,84	40,12	32,57	30,37	26,24	24,81	25,55
Mean	22,1	22,2	22,28	23,5	13,48	13,65	11,57	12,58
Std. Deviation	5,141	4,599	4,849	5,225	4,746	5,422	4,447	5,469
Std. Error of Mean	0,4598	1,276	0,4483	0,7177	0,4262	1,504	0,4111	0,7512
Lower 95% CI of mean	21,19	19,42	21,39	22,06	12,64	10,37	10,76	11,07
Upper 95% CI of mean	23,01	24,98	23,16	24,94	14,32	16,92	12,38	14,08
Sum	2762	288,6	2606	1246	1671	177,4	1354	666,5
D'Agostino & Pearson normality test								
K2	13,34	0,731	7,172	10,67	26,74	4,023	6,498	6,612
P value	0,0013	0,6939	0,0277	0,0048	<0,0001	0,1338	0,0388	0,0367
Passed normality test (alpha=0.05)?	No	Yes	No	No	No	Yes	No	No
P value summary	**	ns	*	**	****	ns	*	*

Table 26: Growth statistics for A.1+ to A.2+ and A.2+ to A.3+ growth.

	male 0	male 1	female 0	female 1	male 0	male 1	female 0	female 1
	A.1+ to A.2+	A.1+ to A.2+	A.1+ to A.2+	A.1+ to A.2+	A.2+ to A.3+	A.2+ to A.3+	A.2+ to A.3+	A.2+ to A.3+
Number of values	31	11	20	53	2	8	1	32
Minimum	5,29	4	4,2	4,03	9,96	3,56	4,07	3,68
25% Percentile	7,24	6,15	7,633	6,525	9,96	4,768	4,07	5,025
Median	10,3	8,17	8,23	7,47	11,23	7,855	4,07	5,945
75% Percentile	12,2	11,94	11,7	8,825	12,5	8,603	4,07	7,408
Maximum	17,52	16,31	15	15,97	12,5	9,74	4,07	11,25
Mean	10,44	9,099	9,15	7,871	11,23	7,016	4,07	6,39
Std. Deviation	3,224	3,77	2,682	2,325	1,796	2,225	0	1,817
Std. Error of Mean	0,5791	1,137	0,5997	0,3194	1,27	0,7866	0	0,3212
Lower 95% CI of mean	9,256	6,567	7,895	7,23	-4,907	5,156		5,735
Upper 95% CI of mean	11,62	11,63	10,41	8,512	27,37	8,876		7,045
Sum	323,6	100,1	183	417,2	22,46	56,13	4,07	204,5
D'Agostino & Pearson normality test								
K2	0,9585	1,499	0,8107	20,32	N too small	1,393	N too small	5,54
P value	0,6192	0,4725	0,6667	<0,0001		0,4982		0,0627
Passed normality test (alpha=0.05)?	Yes	Yes	Yes	No		Yes		Yes
P value summary	ns	ns	ns	****		ns		ns

Table 27: Growth statistics for A.3+ to A.4+ and A.4+ to A.5+ growth.

	male 0	male 1	female 0	female 1	male 0	male 1	female 0	female 1
	A.3+ to A.4+	A.3+ to A.4+	A.3+ to A.4+	A.3+ to A.4+	A.4+ to A.5+	A.4+ to A.5+	A.4+ to A.5+	A.4+ to A.5+
Number of values	0	3	0	8	0	1	0	4
Minimum		3,07		3,24		5,93		2,57
25% Percentile		3,07		3,52		5,93		2,85
Median		6,49		4,505		5,93		4,135
75% Percentile		8,53		5,773		5,93		5,57
Maximum		8,53		6,05		5,93		5,9
Mean		6,03		4,591		5,93		4,185
Std. Deviation		2,759		1,137		0		1,408
Std. Error of Mean		1,593		0,4018		0		0,7042
Lower 95% CI of mean		-0,8235		3,641				1,944
Upper 95% CI of mean		12,88		5,541				6,426
Sum		18,09		36,73		5,93		16,74
D'Agostino & Pearson normality test								
K2	N too small	N too small	N too small	3,368	N too small	N too small	N too small	N too small
P value				0,1856				
Passed normality test (alpha=0.05)?				Yes				
P value summary				ns				

The next three figures show the column statistics and the D'Agostino & Pearson test for normality of the growth rates above after excluding outliners with the ROUT test.

Table 28: Growth statistics of Smolt to A.0+ and A.0+ to A.1+ growth.

	male 0	male 1	female 0	female 1	male 0	male 1	female 0	female 1
	S to A.0+	S to A.0+	S to A.0+	S to A.0+	A.0+ to A.1+	A.0+ to A.1+	A.0+ to A.1+	A.0+ to A.1+
Number of values	124	13	117	53	122	13	117	53
Minimum	9,73	14,85	12,63	14,83	5,62	7,36	4,14	3,93
25% Percentile	18,28	17,21	18,38	18,63	10,24	8,975	7,815	8,385
Median	22,06	23,92	22,03	23,17	12,5	13,03	10,47	11,37
75% Percentile	25,32	24,97	25,53	27,72	15,83	17,31	14,7	15,78
Maximum	35,02	29,84	40,12	32,57	27,26	26,24	24,81	25,55
Mean	21,93	22,2	22,28	23,5	13,22	13,65	11,57	12,58
Std. Deviation	4,809	4,599	4,849	5,225	4,308	5,422	4,447	5,469
Std. Error of Mean	0,4319	1,276	0,4483	0,7177	0,39	1,504	0,4111	0,7512
Lower 95% CI of mean	21,08	19,42	21,39	22,06	12,44	10,37	10,76	11,07
Upper 95% CI of mean	22,79	24,98	23,16	24,94	13,99	16,92	12,38	14,08
Sum	2720	288,6	2606	1246	1612	177,4	1354	666,5
D'Agostino & Pearson normality test								
K2	0,9008	0,731	7,172	10,67	15,01	4,023	6,498	6,612
P value	0,6374	0,6939	0,0277	0,0048	0,0005	0,1338	0,0388	0,0367
Passed normality test (alpha=0.05)?	Yes	Yes	No	No	No	Yes	No	No
P value summary	ns	ns	*	**	***	ns	*	*

Table 29: Growth statistics of A.1+ to A.2+ and A.2+ to A.3+ growth.

	male 0	male 1	female 0	female 1	male 0	male 1	female 0	female 1
	A.1+ to A.2+	A.1+ to A.2+	A.1+ to A.2+	A.1+ to A.2+	A.2+ to A.3+	A.2+ to A.3+	A.2+ to A.3+	A.2+ to A.3+
Number of values	31	11	20	51	2	8	1	32
Minimum	5,29	4	4,2	4,03	9,96	3,56	4,07	3,68
25% Percentile	7,24	6,15	7,633	6,41	9,96	4,768	4,07	5,025
Median	10,3	8,17	8,23	7,29	11,23	7,855	4,07	5,945
75% Percentile	12,2	11,94	11,7	8,72	12,5	8,603	4,07	7,408
Maximum	17,52	16,31	15	11,9	12,5	9,74	4,07	11,25
Mean	10,44	9,099	9,15	7,569	11,23	7,016	4,07	6,39
Std. Deviation	3,224	3,77	2,682	1,776	1,796	2,225	0	1,817
Std. Error of Mean	0,5791	1,137	0,5997	0,2487	1,27	0,7866	0	0,3212
Lower 95% CI of mean	9,256	6,567	7,895	7,069	-4,907	5,156		5,735
Upper 95% CI of mean	11,62	11,63	10,41	8,069	27,37	8,876		7,045
Sum	323,6	100,1	183	386	22,46	56,13	4,07	204,5
D'Agostino & Pearson normality test								
K2	0,9585	1,499	0,8107	0,5158	N too small	1,393	N too small	5,54
P value	0,6192	0,4725	0,6667	0,7727		0,4982		0,0627
Passed normality test (alpha=0.05)?	Yes	Yes	Yes	Yes		Yes		Yes
P value summary	ns	ns	ns	ns		ns		ns

Table 30: Growth statistics of A.3+ to A.4+ and A.4+ to A.5+ growth.

	male 0	male 1	female 0	female 1	male 0	male 1	female 0	female 1
	A.3+ to A.4+	A.3+ to A.4+	A.3+ to A.4+	A.3+ to A.4+	A.4+ to A.5+	A.4+ to A.5+	A.4+ to A.5+	A.4+ to A.5+
Number of values	0	3	0	8	0	1	0	4
Minimum		3,07		3,24		5,93		2,57
25% Percentile		3,07		3,52		5,93		2,85
Median		6,49		4,505		5,93		4,135
75% Percentile		8,53		5,773		5,93		5,57
Maximum		8,53		6,05		5,93		5,9
Mean		6,03		4,591		5,93		4,185
Std. Deviation		2,759		1,137		0		1,408
Std. Error of Mean		1,593		0,4018		0		0,7042
Lower 95% CI of mean		-0,8235		3,641				1,944
Upper 95% CI of mean		12,88		5,541				6,426
Sum		18,09		36,73		5,93		16,74
D'Agostino & Pearson normality test								
K2	N too small	N too small	N too small	3,368	N too small	N too small	N too small	N too small
P value				0,1856				
Passed normality test (alpha=0.05)?				Yes				
P value summary				ns				

Test for statistical differences between male and female fish in the same growth period with the same state of spawning experience.

Table 31: Mann Whitney test for difference between male and female growth Smolt to A.0+ without spawning experience (left) and with spawning experience (right).

Column C	female 0, S to A,0+
vs.	vs,
Column A	male 0, S to A,0+
Mann Whitney test	
P value	0,6958
Exact or approximate P value?	Approximate
P value summary	ns
Significantly different (P < 0.05)?	No
One- or two-tailed P value?	Two-tailed
Sum of ranks in column A,C	14792 , 14369
Mann-Whitney U	7042
Difference between medians	
Median of column A	22,06, n=124
Median of column C	22,03, n=117
Difference: Actual	-0,03
Difference: Hodges-Lehmann	0,255

Column D	female 1, S to A,0+
vs.	vs,
Column B	male 1, S to A,0+
Mann Whitney test	
P value	0,4711
Exact or approximate P value?	Exact
P value summary	ns
Significantly different (P < 0.05)?	No
One- or two-tailed P value?	Two-tailed
Sum of ranks in column B,D	390 , 1821
Mann-Whitney U	299
Difference between medians	
Median of column B	23,92, n=13
Median of column D	23,17, n=53
Difference: Actual	-0,75
Difference: Hodges-Lehmann	1,32

Table 32: Mann Whitney test for difference between male and female growth A.0+ to A.1+ without spawning experience (left) and with spawning experience (right).

Column G	female 0, A,0+ to A,1+
vs.	vs,
Column E	male 0, A,0+ to A,1+
Mann Whitney test	
P value	0,0028
Exact or approximate P value?	Approximate
P value summary	**
Significantly different (P < 0.05)?	Yes
One- or two-tailed P value?	Two-tailed
Sum of ranks in column E,G	16240 , 12440
Mann-Whitney U	5537
Difference between medians	
Median of column E	12,5, n=122
Median of column G	10,47, n=117
Difference: Actual	-2,03
Difference: Hodges-Lehmann	-1,67

Column H	female 1, A,0+ to A,1+
vs.	vs,
Column F	male 1, A,0+ to A,1+
Mann Whitney test	
P value	0,404
Exact or approximate P value?	Exact
P value summary	ns
Significantly different (P < 0.05)?	No
One- or two-tailed P value?	Two-tailed
Sum of ranks in column F,H	488 , 1723
Mann-Whitney U	292
Difference between medians	
Median of column F	13,03, n=13
Median of column H	11,37, n=53
Difference: Actual	-1,66
Difference: Hodges-Lehmann	-1,07

Table 33: Mann Whitney test for difference between male and female growth A.1+ to A.2+ without spawning experience (left) and with spawning experience (right).

Column K	female 0, A,1+ to A,2+
vs.	vs,
Column I	male 0, A,1+ to A,2+
Mann Whitney test	
P value	0,1931
Exact or approximate P value?	Exact
P value summary	ns
Significantly different (P < 0.05)?	No
One- or two-tailed P value?	Two-tailed
Sum of ranks in column I,K	874 , 452
Mann-Whitney U	242
Difference between medians	
Median of column I	10,3, n=31
Median of column K	8,23, n=20
Difference: Actual	-2,07
Difference: Hodges-Lehmann	-1,37

Column L	female 1, A,1+ to A,2+
vs.	vs,
Column J	male 1, A,1+ to A,2+
Mann Whitney test	
P value	0,3523
Exact or approximate P value?	Exact
P value summary	ns
Significantly different (P < 0.05)?	No
One- or two-tailed P value?	Two-tailed
Sum of ranks in column J,L	398 , 1555
Mann-Whitney U	229
Difference between medians	
Median of column J	8,17, n=11
Median of column L	7,29, n=51
Difference: Actual	-0,88
Difference: Hodges-Lehmann	-0,88

Table 34: Mann Whitney test for difference between male and female growth A.2+ to A.3+ with spawning experience (left) and A.3+ to A.4+ with spawning experience (right).

Column P	female 1, A,2+ to A,3+
vs.	vs,
Column N	male 1, A,2+ to A,3+
Mann Whitney test	
P value	0,4375
Exact or approximate P value?	Exact
P value summary	ns
Significantly different (P < 0.05)?	No
One- or two-tailed P value?	Two-tailed
Sum of ranks in column N,P	187,5 , 632,5
Mann-Whitney U	104,5
Difference between medians	
Median of column N	7,855, n=8
Median of column P	5,945, n=32
Difference: Actual	-1,91
Difference: Hodges-Lehmann	-0,845

Column T	female 1, A,3+ to A,4+
vs.	vs,
Column R	male 1, A,3+ to A,4+
Mann Whitney test	
P value	0,497
Exact or approximate P value?	Exact
P value summary	ns
Significantly different (P < 0.05)?	No
One- or two-tailed P value?	Two-tailed
Sum of ranks in column R,T	22 , 44
Mann-Whitney U	8
Difference between medians	
Median of column R	6,49, n=3
Median of column T	4,505, n=8
Difference: Actual	-1,985
Difference: Hodges-Lehmann	-1,955

Test for statistical difference of male and female fish with different states of spawning experience.

Table 35: Smolt to A.0+ growth. T test for difference between males (left) with and without spawning experience and Mann Whitney test for difference between females (right) with and without spawning experience.

Column B	male 1, S to A,0+
vs.	vs,
Column A	male 0, S to A,0+
Unpaired t test	
P value	0,8474
P value summary	ns
Significantly different (P < 0.05)?	No
One- or two-tailed P value?	Two-tailed
t, df	t=0,1928 df=135
How big is the difference?	
Mean ± SEM of column A	21,93 ± 0,4319, n=124
Mean ± SEM of column B	22,2 ± 1,276, n=13
Difference between means	0,2693 ± 1,397
95% confidence interval	-2,493 to 3,032
R squared (eta squared)	0,0002754
F test to compare variances	
F, DFn, Dfd	1,093, 123, 12
P value	0,9306
P value summary	ns
Significantly different (P < 0.05)?	No

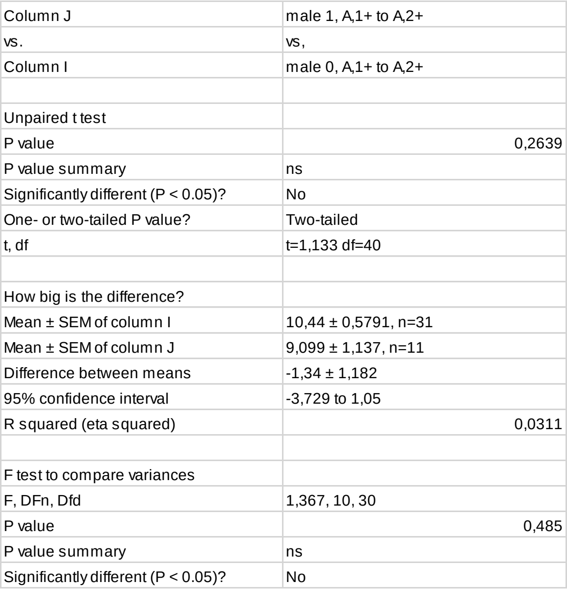
Column D	female 1, S to A,0+
vs.	vs,
Column C	female 0, S to A,0+
Mann Whitney test	
P value	0,1491
Exact or approximate P value?	Exact
P value summary	ns
Significantly different (P < 0.05)?	No
One- or two-tailed P value?	Two-tailed
Sum of ranks in column C,D	9574 , 4961
Mann-Whitney U	2671
Difference between medians	
Median of column C	22,03, n=117
Median of column D	23,17, n=53
Difference: Actual	1,14
Difference: Hodges-Lehmann	1,3

Table 36: A.0+ to A.1+ growth. Mann Whitney test for difference between males (left) with and without spawning experience and Mann Whitney test for difference between females (right) with and without spawning experience.

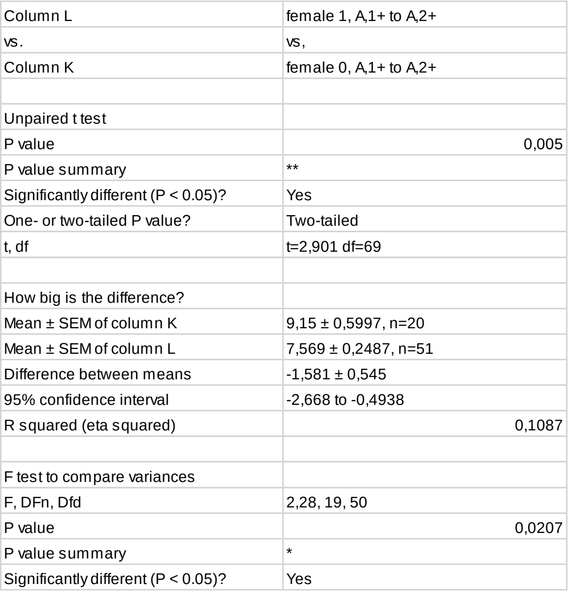
Column F	male 1, A,0+ to A,1+
vs.	vs,
Column E	male 0, A,0+ to A,1+
Mann Whitney test	
P value	0,9808
Exact or approximate P value?	Exact
P value summary	ns
Significantly different (P < 0.05)?	No
One- or two-tailed P value?	Two-tailed
Sum of ranks in column E,F	8293 , 887,5
Mann-Whitney U	789,5
Difference between medians	
Median of column E	12,5, n=122
Median of column F	13,03, n=13
Difference: Actual	0,53
Difference: Hodges-Lehmann	0,04

Column H	female 1, A,0+ to A,1+
vs.	vs,
Column G	female 0, A,0+ to A,1+
Mann Whitney test	
P value	0,4134
Exact or approximate P value?	Exact
P value summary	ns
Significantly different (P < 0.05)?	No
One- or two-tailed P value?	Two-tailed
Sum of ranks in column G,H	9760 , 4776
Mann-Whitney U	2857
Difference between medians	
Median of column G	10,47, n=117
Median of column H	11,37, n=53
Difference: Actual	0,9
Difference: Hodges-Lehmann	0,65

Table 37: A.1+ to A.2+ growth. T test for difference between males (left) with and without spawning experience and T test for difference between females (right) with and without spawning experience.

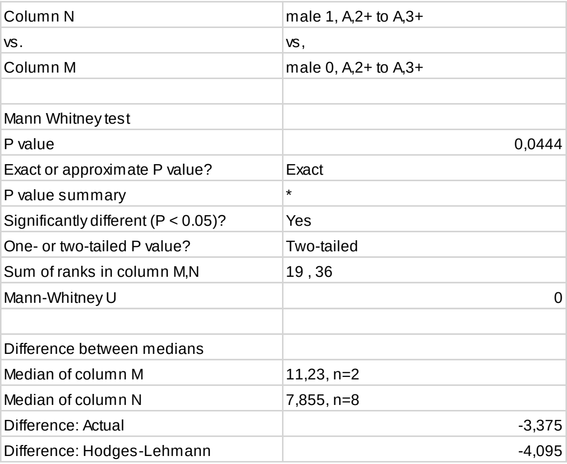


Column J	male 1, A,1+ to A,2+
vs.	vs,
Column I	male 0, A,1+ to A,2+
Unpaired t test	
P value	0,2639
P value summary	ns
Significantly different (P < 0.05)?	No
One- or two-tailed P value?	Two-tailed
t, df	t=1,133 df=40
How big is the difference?	
Mean ± SEM of column I	10,44 ± 0,5791, n=31
Mean ± SEM of column J	9,099 ± 1,137, n=11
Difference between means	-1,34 ± 1,182
95% confidence interval	-3,729 to 1,05
R squared (eta squared)	0,0311
F test to compare variances	
F, DFn, Dfd	1,367, 10, 30
P value	0,485
P value summary	ns
Significantly different (P < 0.05)?	No



Column L	female 1, A,1+ to A,2+
vs.	vs,
Column K	female 0, A,1+ to A,2+
Unpaired t test	
P value	0,005
P value summary	**
Significantly different (P < 0.05)?	Yes
One- or two-tailed P value?	Two-tailed
t, df	t=2,901 df=69
How big is the difference?	
Mean ± SEM of column K	9,15 ± 0,5997, n=20
Mean ± SEM of column L	7,569 ± 0,2487, n=51
Difference between means	-1,581 ± 0,545
95% confidence interval	-2,668 to -0,4938
R squared (eta squared)	0,1087
F test to compare variances	
F, DFn, Dfd	2,28, 19, 50
P value	0,0207
P value summary	*
Significantly different (P < 0.05)?	Yes

Table 38: A.2+ to A.3+ growth. Mann Whitney test for difference between males with and without spawning experience.



Column N	male 1, A,2+ to A,3+
vs.	vs,
Column M	male 0, A,2+ to A,3+
Mann Whitney test	
P value	0,0444
Exact or approximate P value?	Exact
P value summary	*
Significantly different (P < 0.05)?	Yes
One- or two-tailed P value?	Two-tailed
Sum of ranks in column M,N	19 , 36
Mann-Whitney U	0
Difference between medians	
Median of column M	11,23, n=2
Median of column N	7,855, n=8
Difference: Actual	-3,375
Difference: Hodges-Lehmann	-4,095

Test for statistical difference of growth rates according to smolt age.

Table 39: Column statistics and D'Agostino & Pearson test for normality of one-year and two-year smolts in the different growth periods, divided by spawning experience. Column statistics of sample group with outliners excluded by ROUT test.

	1yr SE 4+-5+	2yr S-0+	2yr 0-1	2yr 1-2	2yr SE S-0+	2yr SE 0+-1+	2yr SE 1-2	2yr SE 2-3	2yr SE 3-4	2yr SE 4-5
Number of values	3	38	32	8	23	22	21	16	4	2
Minimum	3,69	13,5	4,92	8	16,1	6,29	4,09	3,68	3,24	2,57
25% Percentile	3,69	18,21	9,08	8,23	20,84	8,25	6,12	5,288	3,348	2,57
Median	4,58	21,96	11,64	10,03	25,95	9,89	7,15	5,945	4,785	4,235
75% Percentile	5,93	26,25	13,93	11,19	30,73	13,25	8,87	7,848	6,013	5,9
Maximum	5,93	31,96	18,6	11,84	32,57	18,97	9,94	8,87	6,05	5,9
Mean	4,733	22,24	11,4	9,84	25,18	10,93	7,308	6,371	4,715	4,235
Std. Deviation	1,128	4,757	3,444	1,463	5,443	3,412	1,754	1,57	1,467	2,355
Std. Error of Mean	0,6512	0,7718	0,6089	0,5173	1,135	0,7275	0,3828	0,3926	0,7334	1,665
Lower 95% CI of mean	1,932	20,68	10,16	8,617	22,82	9,421	6,509	5,534	2,381	-16,92
Upper 95% CI of mean	7,535	23,81	12,64	11,06	27,53	12,45	8,106	7,207	7,049	25,39
Sum	14,2	845,3	364,9	78,72	579,1	240,5	153,5	101,9	18,86	8,47
D'Agostino & Pearson normality test										
K2	N too small	0,9486	0,2608	1,439	3,217	2,886	0,8736	1,04	N too small	N too small
P value		0,6223	0,8778	0,4869	0,2002	0,2362	0,6461	0,5946		
Passed normality test (alpha=0.05)?		Yes	Yes	Yes	Yes	Yes	Yes	Yes		
P value summary		ns	ns	ns	ns	ns	ns	ns		

	1yr S-0+	1yr 0+-1+	1yr 1+-2+	1yr 2+-3+	1yr SE S-0+	1yr SE 0+-1+	1yr SE 1+-2+	1yr SE 2+-3+	1yr SE 3+-4+
Number of values	242	209	44	3	43	43	39	24	7
Minimum	9,73	4,14	0	4,07	14,83	3,93	4	3,56	3,07
25% Percentile	18	9,52	7,015	4,07	18,11	8,84	6,41	4,863	3,47
Median	21,61	11,74	9,795	9,96	22,51	12,65	7,74	6,25	5,06
75% Percentile	24,96	15,88	12,13	12,5	25,16	18,84	8,59	8,23	6,49
Maximum	40,12	30,37	17,52	12,5	31,76	26,24	11,94	11,25	8,53
Mean	21,59	12,73	9,725	8,843	22,22	13,46	7,741	6,612	5,137
Std. Deviation	4,86	4,838	3,578	4,325	4,649	5,852	1,904	2,106	1,909
Std. Error of Mean	0,3124	0,3346	0,5394	2,497	0,709	0,8924	0,3048	0,4298	0,7217
Lower 95% CI of mean	20,98	12,07	8,637	-1,899	20,78	11,66	7,124	5,723	3,371
Upper 95% CI of mean	22,21	13,39	10,81	19,59	23,65	15,26	8,358	7,501	6,903
Sum	5226	2660	427,9	26,53	955,3	578,7	301,9	158,7	35,96
D'Agostino & Pearson normality test									
K2	8,827	25,15	0,4258	N too small	2,749	3,669	1,556	1,776	N too small
P value	0,0121	<0,0001	0,8082		0,253	0,1597	0,4592	0,4115	
Passed normality test (alpha=0.05)?	No	No	Yes		Yes	Yes	Yes	Yes	
P value summary	*	****	ns		ns	ns	ns	ns	

Test for significant differences between 1yr and 2yr with and without spawning experience.

Table 40: Mann Whitney test for smolt to A.0+ growth of one-year and two-year smolts (left) and T test of A.0+ to A.1+ growth of one-year and two-year smolts (right), both without spawning marks.

Column K	2yr Smolt to A.0+
vs.	vs,
Column A	1yr Smolt to A.0+
Mann Whitney test	
P value	0,3851
Exact or approximate P value?	Exact
P value summary	ns
Significantly different (P < 0.05)?	No
One- or two-tailed P value?	Two-tailed
Sum of ranks in column A,K	33597 , 5744
Mann-Whitney U	4194
Difference between medians	
Median of column A	21,61, n=242
Median of column K	21,96, n=38
Difference: Actual	0,35
Difference: Hodges-Lehmann	0,78

Column L	2yr A0+ to A.1+
vs.	vs,
Column B	1yr A0+ to A.1+
Unpaired t test	
P value	0,1369
P value summary	ns
Significantly different (P < 0.05)?	No
One- or two-tailed P value?	Two-tailed
t, df	t=1,492 df=239
How big is the difference?	
Mean ± SEM of column B	12,73 ± 0,3346, n=209
Mean ± SEM of column L	11,4 ± 0,6089, n=32
Difference between means	-1,326 ± 0,8885
95% confidence interval	-3,076 to 0,4242
R squared (eta squared)	0,009234
F test to compare variances	
F, DFn, Dfd	1,973, 208, 31
P value	0,0264
P value summary	*
Significantly different (P < 0.05)?	Yes

Table 41: T test for A.1+ to A.2+ growth of one-year and two-year smolts without spawning experience.

Column M	2yr A.1+ to A.2+
vs.	vs,
Column C	1yr A.1+-A.2+
Unpaired t test	
P value	0,9292
P value summary	ns
Significantly different (P < 0.05)?	No
One- or two-tailed P value?	Two-tailed
t, df	t=0,08933 df=50
How big is the difference?	
Mean ± SEM of column C	9,725 ± 0,5394, n=44
Mean ± SEM of column M	9,84 ± 0,5173, n=8
Difference between means	0,1155 ± 1,293
95% confidence interval	-2,481 to 2,712
R squared (eta squared)	0,0001596
F test to compare variances	
F, DFn, Dfd	5,978, 43, 7
P value	0,0191
P value summary	*
Significantly different (P < 0.05)?	Yes

Table 42: Mann Whitney test for smolt to A.0+ growth of one-year and two-year smolts (left) and T test for A.1+ to A.2+ growth of one year and two-year smolts (right), both with spawning experience.

Column N	2yr Smolt to A.0+ w SE
vs.	vs,
Column E	1yr Smolt to A.0+ w SE
Mann Whitney test	
P value	0,0249
Exact or approximate P value?	Exact
P value summary	*
Significantly different (P < 0.05)?	Yes
One- or two-tailed P value?	Two-tailed
Sum of ranks in column E,N	1275 , 936,5
Mann-Whitney U	328,5
Difference between medians	
Median of column E	22,51, n=43
Median of column N	25,95, n=23
Difference: Actual	3,44
Difference: Hodges-Lehmann	3,23

Column P	2yr A.1+ to A.2+ w SE
vs.	vs,
Column G	1yr A.1+ to A.2+ w SE
Unpaired t test	
P value	0,3915
P value summary	ns
Significantly different (P < 0.05)?	No
One- or two-tailed P value?	Two-tailed
t, df	t=0,8634 df=58
How big is the difference?	
Mean ± SEM of column G	7,741 ± 0,3048, n=39
Mean ± SEM of column P	7,308 ± 0,3828, n=21
Difference between means	-0,4332 ± 0,5017
95% confidence interval	-1,437 to 0,571
R squared (eta squared)	0,01269
F test to compare variances	
F, DFn, Dfd	1,178, 38, 20
P value	0,7107
P value summary	ns
Significantly different (P < 0.05)?	No

Table 43: T test for A.2+ to A.3+ growth of one-year and two-year smolts (left) and T test for A.3+ to A.5+ growth of one year and two-year smolts (right), both with spawning experience.

Column Q	2yr A.2+ to A.3+ w SE
vs.	vs,
Column H	1yr A.2+ to A.3+ w SE
Unpaired t test	
P value	0,6983
P value summary	ns
Significantly different (P < 0.05)?	No
One- or two-tailed P value?	Two-tailed
t, df	t=0,3906 df=38
How big is the difference?	
Mean ± SEM of column H	6,612 ± 0,4298, n=24
Mean ± SEM of column Q	6,371 ± 0,3926, n=16
Difference between means	-0,241 ± 0,6172
95% confidence interval	-1,49 to 1,008
R squared (eta squared)	0,003998
F test to compare variances	
F, DFn, Dfd	1,798, 23, 15
P value	0,2429
P value summary	ns
Significantly different (P < 0.05)?	No

Column R	2yr A.3+ to A.4+ w SE
vs.	vs,
Column I	1yr A.3+ to A.4+ w SE
Unpaired t test	
P value	0,713
P value summary	ns
Significantly different (P < 0.05)?	No
One- or two-tailed P value?	Two-tailed
t, df	t=0,3796 df=9
How big is the difference?	
Mean ± SEM of column I	5,137 ± 0,7217, n=7
Mean ± SEM of column R	4,715 ± 0,7334, n=4
Difference between means	-0,4221 ± 1,112
95% confidence interval	-2,938 to 2,093
R squared (eta squared)	0,01576
F test to compare variances	
F, DFn, Dfd	1,695, 6, 3
P value	0,7126
P value summary	ns
Significantly different (P < 0.05)?	No

Table 44: T test for A.4+ to A.5+ growth of one-year and two-year smolts with spawning experience.

Column S	2yr A.4+ to A.5+ w SE
vs.	vs,
Column J	1yr A.4+ to A.5+ w SE
Unpaired t test	
P value	0,7614
P value summary	ns
Significantly different (P < 0.05)?	No
One- or two-tailed P value?	Two-tailed
t, df	t=0,3325 df=3
How big is the difference?	
Mean ± SEM of column J	4,733 ± 0,6512, n=3
Mean ± SEM of column S	4,235 ± 1,665, n=2
Difference between means	-0,4983 ± 1,499
95% confidence interval	-5,269 to 4,272
R squared (eta squared)	0,03553
F test to compare variances	
F, DFn, Dfd	
P value	
P value summary	
Significantly different (P < 0.05)?	

7.5 Scale reading results

7.5.1 Overall results: age, back-calculation and size at first-time spawning

The following table includes all aged fish during the spawning seasons 2015 – 2017. In the table following short cuts were used: TL = total body length, SA = Smolt age; FEW = year of freshwater escape; SE = Spawning experience (0 = no experience, first-time spawner; 1 = one spawning experience; 2 = 2 or more spawning experience, multiple spawner); Size FTS = Size at first spawning.

Year	GenID	TL	Sex	Age	Sea age	SA	FWE	Birth	SE	Smolt size	A.0+	A.1+	A.2+	A.3+	A.4+	A.5+	Size FTS
2015	4458	48	**F**	1+.1+	A.1+	1+	2014	2013	0	17,22	29,85	48,00					48,00
2015	4460	70	**F**	2+.1+3SM+	A.4+	2+	2011	2009	2	21,34	47,35	53,64	60,65	66,33	70,00		53,64
2015	4463	59	**F**	1+.2+	A.2+	1+	2013	2012	0	11,28	33,96	51,39	59,00				59,00
2015	4465	55	**F**	1+.1+	A.1+	1+	2014	2013	0	14,91	32,27	55,00					55,00
2015	4466	68	**M**	1+.2+	A.2+	1+	2013	2012	0	10,30	31,95	55,30	68,00				68,00
2015	4471	45	**F**	1+.1+	A.1+	1+	2014	2013	0	9,95	28,59	45,00					45,00
2015	4474	66	**F**	1+.1+2SM+	A.3+	1+	2012	2011	2	14,94	45,84	51,84	59,31	66,00			51,84
2015	4475	49	**F**	2.0+	A.0+	2	2015	2013	0	21,43	49,00						49,00
2015	4476	62	**M**	1.2+	A.2+	1	2013	2012	0	9,78	29,00	50,07	62,00				62,00
2015	4478	83	**M**	1+.2+	A.2+	1+	2013	2012	0	15,00	57,80	76,13	83,00				83,00
2015	4479	52	**M**	1+.1+	A.1+	1+	2014	2013	0	16,54	42,99	52,00					52,00
2015	4484	69	**M**	2.2+	A.2+	2	2013	2011	0	16,00	45,15	57,65	69,00				69,00
2015	4488	50	**F**	1+.1+	A.1+	1+	2014	2013	0	12,85	29,47	50,00					50,00
2015	4491	31	**M**	1.0+	A.0+	1	2015	2014	0	8,20	31,00						31,00
2015	4492	55	**F**	2+.1+	A.1+	2+	2014	2012	0	20,86	49,06	55,00					55,00
2015	4494	56	**M**	2.1+	A.1+	2	2014	2012	0	20,54	41,22	56,00					56,00
2015	4497	50	**M**	1+.1+	A.1+	1+	2014	2013	0	14,00	35,89	50,00					50,00
2015	4501	48	**F**	1+.1+	A.1+	1+	2014	2013	0	14,80	42,26	48,00					48,00
2015	4503	51	**F**	2.1+	A.1+	2	2014	2012	0	17,60	42,00	51,00					51,00
2015	4507	41	**M**	1.1+	A.1+	1	2014	2013	0	13,27	32,76	41,00					41,00
2015	4508	57	**M**	2.2+	A.2+	2	2013	2011	0	13,99	29,37	46,28	57,00				57,00
2015	4510	52	**M**	1+.1+	A.1+	1+	2014	2013	0	18,11	40,95	52,00					52,00
2015	4512	71	**F**	2.2+1SM+	A.3+	2	2012	2010	1	21,38	44,63	58,43	67,32	71,00			67,32
2015	4514	65	**F**	1+.2+1SM+	A.3+	1+	2012	2011	1	14,94	42,05	55,15	60,54	65,00			60,54
2015	4516	67	**M**	1.2+1SM+	A.3+	1	2012	2011	1	8,02	29,20	42,81	57,26	67,00			57,26
2015	4519	49	**M**	1+1+	A.1+	1+	2014	2013	0	15,40	33,13	49,00					49,00
2015	4523	38	**M**	2.0+	A.0+	2	2015	2013	0	19,75	38,00						38,00
2015	4524	75	**F**	1+.2+	A.2+	1+	2013	2012	0	12,50	42,50	60,00	75,00				75,00
2015	4525	50	**F**	1+.1+	A.1+	1+	2014	2013	0	14,35	36,75	50,00					50,00
2015	4527	45	**F**	1+.1+	A.1+	1+	2014	2013	0	10,08	28,55	45,00					45,00
2015	4529	50	**M**	2.1+	A.1+	2	2014	2012	0	19,75	40,26	50,00					50,00
2015	4531	45	**M**	1+.1+	A.1+	1+	2014	2013	0	11,04	33,16	45,00					45,00
2015	4532	73	**M**	2+.1+2SM+	A.3+	2+	2012	2010	2	18,73	48,57	57,68	67,58	73,00			57,68
2015	4533	77	**M**	1+.2+	A.2+	1+	2013	2012	0	13,50	47,19	70,65	77,00				77,00
2015	4534	72	**F**	1+.2+1SM+	A.3+	1+	2012	2011	1	13,90	33,70	58,10	64,90	72,00			64,90
2015	4562	63	**F**	2.2+	A.2+	2	2013	2011	0	18,78	38,96	53,11	63,00				63,00
2015	4565	44	**M**	1+.1+	A.1+	1+	2014	2013	0	11,83	36,77	44,00					44,00

Year	GenID	TL	Sex	Age	Sea age	SA	FWE	Birth	SE	Smolt size	A.0+	A.1+	A.2+	A.3+	A.4+	A.5+	Size FTS
2015	4566	31	**M**	1.0+	A.0+	1	2015	2014	0	8,70	31,00						31,00
2015	4567	75	**F**	1+.3+	A.3+	1+	2012	2011	0	16,20	56,32	63,06	70,93	75,00			75,00
2015	4568	74	**F**	1.2+	A.2+	1	2013	2012	0	10,69	44,53	61,70	74,00				74,00
2015	4569	46	**F**	1+.1+	A.1+	1+	2014	2013	0	13,32	31,59	46,00					46,00
2015	4571	64	**M**	1+.2+	A.2+	1+	2013	2012	0	15,00	35,68	53,70	64,00				64,00
2015	4573	32	**M**	1+.0+	A.0+	1+	2015	2014	0	8,57	32,00						32,00
2015	4574	63	**M**	1+.2+	A.2+	1+	2013	2012	0	18,08	35,22	52,82	63,00				63,00
2015	4578	46	**M**	1+.1+	A.1+	1+	2014	2013	0	14,44	38,15	46,00					46,00
2015	4580	65	**F**	2.2+	A.2+	2	2013	2011	0	19,28	43,05	57,00	65,00				65,00
2015	4583	47	**F**	1+.1+	A.1+	1+	2014	2013	0	17,50	35,50	47,00					47,00
2015	4585	51	**M**	1.2+	A.2+	1	2013	2012	0	13,90	28,20	42,10	51,00				51,00
2015	4588	65	**M**	1.2+	A.2+	1	2013	2012	0	12,39	34,17	54,19	65,00				65,00
2015	4590	47	**F**	1.1+	A.1+	1	2014	2013	0	16,31	39,17	47,00					47,00
2015	4595	62	**M**	1+.2+	A.2+	1+	2013	2012	0	13,80	29,87	48,19	62,00				62,00
2015	4597	57	**M**	2.1+	A.1+	2	2014	2012	0	17,30	41,70	57,00					57,00
2015	4600	58	**F**	2.1+1SM+	A.2+	2	2013	2011	1	17,77	35,11	52,02	58,00				52,02
2015	4601	44	**F**	1+.1+	A.1+	1+	2014	2013	0	9,42	39,86	44,00					44,00
2015	4603	58	**F**	2.1+	A.1+	2	2014	2012	0	20,00	47,23	58,00					58,00
2015	4607	50	**F**	1+.1+	A.1+	1+	2014	2013	0	13,34	33,59	50,00					50,00
2015	4610	56	**F**	1+.2+	A.2+	1+	2013	2012	0	13,44	32,46	49,70	56,00				56,00
2015	4611	73	**F**	2.2+	A.2+	2	2013	2011	0	17,37	42,56	61,16	73,00				73,00
2015	4614	56	**M**	2.1+	A.1+	2	2014	2012	0	16,50	43,00	56,00					56,00
2015	4616	46	**F**	1+.1+	A.1+	1+	2014	2013	0	9,51	29,86	46,00					46,00
2015	4619	49	**M**	1+.1+	A.1+	1+	2014	2013	0	11,60	37,90	49,00					49,00
2015	4621	32	**M**	2.0+	A.0+	2	2015	2013	0	11,78	32,00						32,00
2015	4622	56	**F**	1.2+	A.2+	1	2013	2012	0	12,30	32,90	46,20	56,00				56,00
2015	4624	68	**M**	1+.2+	A.2+	1+	2013	2012	0	16,00	34,65	55,80	68,00				68,00
2015	4626	58	**F**	1+.2+	A.2+	1+	2013	2012	0	18,00	35,80	46,10	58,00				58,00
2015	4628	44	**M**	1+.1+	A.1+	1+	2014	2013	0	13,54	31,82	44,00					44,00
2015	4630	46	**F**	1+.1+	A.1+	1+	2014	2013	0	13,27	36,21	46,00					46,00
2015	4631	47	**F**	1+.1+	A.1+	1+	2014	2013	0	17,61	39,06	47,00					47,00
2015	4633	17	**M**	1+	Smolt			2014	0								
2015	4635	64	**M**	1+.2+	A.2+	1+	2013	2012	0	15,31	35,76	52,26	64,00				64,00
2015	4639	52	**F**	2.1+	A.1+	2	2014	2012	0	18,40	42,32	52,00					52,00
2015	4641	32	**M**	1+.0+	A.0+	1+	2015	2014	0	12,24	32,00						32,00
2015	4642	71	**M**	2.2+1SM+	A.3+	2	2012	2010	1	12,20	28,30	47,27	63,58	71,00			63,58
2015	4645	48	**F**	2.1+	A.1+	2	2014	2012	0	16,42	40,50	48,00					48,00
2015	4648	49	**F**	1+.1+	A.1+	1+	2014	2013	0	7,18	30,08	49,00					49,00
2015	4650	63	**M**	1+.2+	A.2+	1+	2013	2012	0	14,54	29,68	51,49	63,00				63,00
2015	4651	31	**M**	1.0+	A.0+	1	2015	2014	0	11,66	31,00						31,00
2015	4652	42	**M**	1+.1+	A.1+	1+	2014	2013	0	13,09	32,10	42,00					42,00
2015	4657	68	**M**	1+.2+1SM+	A.3+	1+	2012	2011	1	11,06	35,50	55,28	63,45	68,00			63,45
2015	4658	57	**M**	1+.1+	A.1+	1+	2014	2013	0	16,45	40,98	57,00					57,00
2015	4661	69	**F**	1+.2+1SM+	A.3+	1+	2012	2011	1	16,10	32,42	55,34	64,14	69,00			64,14

Year	GenID	TL	Sex	Age	Sea age	SA	FWE	Birth	SE	Smolt size	A.0+	A.1+	A.2+	A.3+	A.4+	A.5+	Size FTS
2015	4664	75	**M**	1+.2+	A.2+	1+	2013	2012	0	15,50	38,83	69,20	75,00				75,00
2015	4665	45	**F**	1.1+	A.1+	1	2014	2013	0	12,40	38,87	45,00					45,00
2015	4666	48	**M**	1+.1+	A.1+	1+	2014	2013	0	10,50	36,62	48,00					48,00
2015	4669	44	**M**	1+.1+	A.1+	1+	2014	2013	0	9,44	32,72	44,00					44,00
2015	4671	71	**F**	1+.2+	A.2+	1+	2013	2012	0	9,89	38,19	63,00	71,00				71,00
2015	4674	50	**M**	1+.1+	A.1+	1+	2014	2013	0	11,00	36,24	50,00					50,00
2015	4679	39	**F**	2.0+	A.0+	2	2015	2013	0	22,13	39,00						39,00
2015	4683	52	**M**	1.2+	A.2+	1	2013	2012	0	8,08	30,67	42,21	52,00				52,00
2015	4685	44	**F**	1+.1+	A.1+	1+	2014	2013	0	8,05	30,33	44,00					44,00
2015	4714	45	**F**	1+.1+	A.1+	1+	2014	2013	0	9,45	31,48	45,00					45,00
2015	4716	52	**M**	1+.2+	A.2+	1+	2013	2012	0	12,00	28,00	45,50	52,00				52,00
2015	4718	32	**F**	1.0+	A.0+	1+	2015	2014	0	10,00	32,00						32,00
2015	4719	46	**F**	1+.1+	A.1+	1+	2014	2013	0	10,18	27,48	46,00					46,00
2015	4728	47	**F**	1.1+	A.1+	1	2014	2013	0	9,85	35,34	47,00					47,00
2015	4730	30	**M**	1+.0+	A.0+	1+	2015	2014	0	10,59	30,00						30,00
2015	4733	47	**M**	2.0+	A.0+	2	2015	2013	0	19,26	47,00						47,00
2015	4736	53	**F**	2.1+	A.1+	2	2014	2012	0	20,94	42,86	53,00					53,00
2015	4737	46	**M**	1.1+	A.1+	1	2014	2013	0	7,14	31,50	46,00					46,00
2015	4740	57	**F**	1+.1+	A.1+	1+	2014	2013	0	16,30	41,86	57,00					57,00
2015	4741	51	**F**	1.1+1SM+	A.2+	1	2013	2012	1	12,11	32,51	42,64	51,00				42,64
2015	4743	47	**M**	1+.1+	A.1+	1+	2014	2013	0	10,99	25,97	47,00					47,00
2015	4744	46	**M**	1+.1+	A.1+	1+	2014	2013	0	11,59	35,16	46,00					46,00
2015	4746	45	**M**	1+.1+	A.1+	1+	2014	2013	0	8,87	31,25	45,00					45,00
2015	4747	48	**F**	1+.1+	A.1+	1+	2014	2013	0	8,29	34,36	48,00					48,00
2015	4749	55	**F**	1+.1+	A.1+	1+	2014	2013	0	15,53	35,00	55,00					55,00
2015	4750	30	**M**	1+.0+	A.0+	1+	2015	2014	0	13,22	30,00						30,00
2015	4754	56	**M**	1+.2+	A.2+	1+	2013	2012	0	13,92	26,84	47,00	56,00				56,00
2015	4758	48	**F**	1+.1+	A.1+	1+	2014	2013	0	12,00	39,58	48,00					48,00
2015	4760	50	**F**	1+.1+	A.1+	1+	2014	2013	0	14,30	36,10	50,00					50,00
2015	4761	73	**F**	1+.2+1SM+	A.3+	1+	2012	2011	1	16,96	34,45	60,00	67,28	73,00			60,00
2015	4763	52	**F**	1+.2+	A.2+	1+	2013	2012	0	11,00	26,91	38,96	52,00				52,00
2015	4768	46	**F**	1+.1+	A.1+	1+	2014	2013	0	17,31	34,26	46,00					46,00
2015	4769	62	**M**	2.1+	A.1+	2	2014	2012	0	18,77	50,30	62,00					62,00
2015	4780	55	**M**	1.2+	A.2+	1	2013	2012	0	16,33	34,36	47,97	55,00				55,00
2015	4781	59	**F**	2.2+	A.2+	2	2013	2011	0	17,90	37,27	50,32	59,00				59,00
2016	6758	39	**M**	1.1+	A.1+	1	2015	2014	0	9,58	33,38	39,00					39,00
2016	6759	31	**F**	1+.0+	A.0+	1+	2016	2015	0	15,80	31,00						31,00
2016	6761	30	**M**	1+.1+	A.0+	1+	2016	2015	0	12,50	30,00						30,00
2016	6763	33	**F**	2.0+	A.0+	2	2016	2014	0	17,30	33,00						33,00
2016	6765	21	**F**	1+	Smolt	1+		2015	0								
2016	6767	26	**M**	1+	BF	1+		2015	0	12,90	26,00						26,00
2016	6768	26	**M**	1+	BF	1+		2015	0								
2016	6770	30	**M**	1.0+	A.0+	1	2016	2015	0	10,00	30,00						30,00
2016	6771	22	**M**	1+	Smolt	1+		2015	0								

Year	GenID	TL	Sex	Age	Sea age	SA	FWE	Birth	SE	Smolt size	A.0+	A.1+	A.2+	A.3+	A.4+	A.5+	Size FTS
2016	6772	28	**M**	1+.0+	A.0+	1+	2016	2015	0	15,28	28,00						28,00
2016	6773	17		1+	BF			2015	0								
2016	6776	55	**F**	1+.2+	A.2+	1+	2014	2013	0	11,13	37,31	50,80	55,00				55,00
2016	6778	56	**F**	1+.2+	A.2+	1+	2014	2013	0	12,50	30,15	47,62	56,00				56,00
2016	6779	43	**M**	1+.1+	A.1+	1+	2015	2014	0	12,81	31,73	43,00					43,00
2016	6784	48	**F**	1+.1+	A.1+	1+	2015	2014	0	11,50	40,70	48,00					48,00
2016	6787	45	**M**	1+.1+	A.1+	1+	2015	2014	0	15,50	35,50	45,00					45,00
2016	6788	40	**F**	1+.1+	A.1+	1+	2015	2014	0	18,10	33,30	40,00					40,00
2016	6793	64	**F**	1+.1+2SM+	A.3+	1+	2013	2012	2	12,64	41,96	49,27	57,69	64,00			49,20
2016	6794	49	**F**	1+.1+	A.1+	1+	2015	2014	0	15,00	41,00	49,00					49,00
2016	6796	53	**F**	1.2+	A.2+	1	2014	2013	0	16,13	28,90	44,30	52,00				52,00
2016	6797	54	**M**	1.0+2SM+	A.2+	1	2014	2013	2	17,77	34,08	45,51	54,00				54,00
2016	6800	50	**F**	1+.1+	A.1+	1+	2015	2014	0	14,79	39,63	50,00					50,00
2016	6803	30	**M**	1+.0+	A.0+	1+	2016	2015	0	12,90	30,00						30,00
2016	6804	53	**F**	1+.1+1SM+	A.2+	1+	2014	2013	1	11,88	28,87	46,59	53,00				53,00
2016	6805	29	**M**	1+.0+	A.0+	1+	2016	2015	0	10,80	29,00						29,00
2016	6806	75	**F**	2.1+3SM+	A.4+	2	2012	2010	2	19,74	42,91	51,84	60,70	69,57	75,00		51,84
2016	6808	53	**M**	1.1+1SM+	A.2+	1	2014	2013	1	13,50	37,80	49,00	53,00				49,00
2016	6810	49	**M**	1+.1+	A.1+	1+	2015	2014	0	12,00	39,00	49,00					49,00
2016	6811	43	**M**	1+.1+	A.1+	1+	2015	2014	0	13,30	35,70	43,00					43,00
2016	6812	67	**F**	1.2+1SM+	A.3+	1	2013	2012	1	10,66	33,23	44,76	55,75	67,00			55,75
2016	6944	52	**M**	1+.2+	A.2+	1+	2014	2013	0	13,20	42,50	52,00					52,00
2016	6946	55	**F**	1+.1+2SM+	A.2+	1+	2013	2012	2	15,03	29,86	49,08	55,00				29,85
2016	6947	53	**F**	2.1+	A.1+	2	2015	2013	0	20,81	43,68	53,00					53,00
2016	6948	30	**M**	1+.0+	A.0+	1+	2016	2015	0	16,50	30,00						30,00
2016	6951	48	**M**	1+.1+	A.1+	1+	2015	2014	0	10,00	35,50	48,00					48,00
2016	6953	41	**F**	1+.1+	A.1+	1+	2015	2014	0	14,50	32,70	41,00					41,00
2016	6955	40	**M**	1+.0+	A.0+	1+	2016	2015	0	11,70	40,00						40,00
2016	6958	59	**F**	1+.2+	A.2+	1+	2014	2013	0	11,96	36,52	51,99	59,00				59,00
2016	6959	50	**M**	1+.1+	A.1+	1+	2015	2014	0	14,20	39,00	50,00					50,00
2016	6963	50	**F**	1.0+2SM+	A.2+	1	2014	2013	2	12,88	39,44	43,36	50,00				39,43
2016	6964	46	**M**	2.1+	A.1+	2	2015	2013	0	15,79	37,78	46,00					46,00
2016	6966	28	**M**	1+.0+	A.0+	1+	2016	2015	0	14,60	28,00						28,00
2016	6967	19	**M**	1+	Smolt	1+		2015	0								
2016	6968	31	**M**	1+.0+	A.0+	1+	2016	2015	0	12,40	31,00						31,00
2016	6969	49	**M**	1+.1+	A.1+	1+	2015	2014	0	14,76	34,44	49,00					49,00
2016	6970	55	**F**	2.1+1SM+	A.2+	2	2014	2012	1	15,02	42,30	50,44	55,00				42,30
2016	6971	75	**F**	1+.2+3SM+	A.5+	1+	2011	2010	2	14,44	35,13	48,67	57,39	65,44	71,48	75,00	57,30
2016	6972	66	**F**	1+.1+1SM+	A.2+	1+	2014	2013	1	17,24	42,39	61,97	66,00				61,97
2016	6973	34	**M**	1+.0+	A.0+	1+	2016	2015	0	16,20	34,00						34,00
2016	6974	28	**M**	1+.0+	A.0+	1+	2016	2015	0	11,60	28,00						28,00
2016	6975	48	**F**	1+.1+1SM+	A.2+	1+	2014	2013	1	15,27	33,62	40,25	48,00				40,25
2016	6977	42	**F**	1+.1+	A.1+	1+	2015	2014	0	17,50	32,46	42,00					42,00
2016	6982	26	**M**	1+.0+	A.0+	1+	2016	2015	0	11,80	26,00						26,00

Year	GenID	TL	Sex	Age	Sea age	SA	FWE	Birth	SE	Smolt size	A.0+	A.1+	A.2+	A.3+	A.4+	A.5+	Size FTS
2016	6983	25	**M**	1.0+	A.0+	1	2016	2015	0	11,50	25,00						25,00
2016	6984	29	**M**	1+.0+	A.0+	1+	2016	2015	0	10,10	29,00						29,00
2016	6985	25	**M**	1+.0+	A.0+	1+	2016	2015	0	10,00	25,00						25,00
2016	6986	48	**M**	1+.1+	A.1+	1+	2015	2014	0	14,14	37,69	48,00					48,00
2016	6987	44	**F**	2.1+	A.1+	2	2015	2013	0	20,58	38,65	44,00					44,00
2016	6988	52	**F**	1+.1+	A.1+	1+	2015	2014	0	13,50	41,20	52,00					52,00
2016	6989	48	**M**	1+.1+	A.1+	1+	2015	2014	0	11,50	38,22	48,00					48,00
2016	6990	29	**M**	1+.0+	A.0+	1+	2016	2015	0	14,20	29,00						29,00
2016	6992	36	**M**	1.1+	A.1+	1	2015	2014	0	12,97	30,11	36,00					36,00
2016	6994	45	**F**	1+.1+	A.1+	1+	2015	2014	0	14,67	39,33	45,00					45,00
2016	6998	26	**M**	1.0+	A.0+	1	2016	2015	0	7,50	26,00						26,00
2016	7000	61	**F**	2.1+1SM+	A.2+	2	2014	2012	1	15,82	32,20	56,91	61,00				56,90
2016	7001	46	**M**	1.1+	A.1+	1	2015	2014	0	10,67	37,54	46,00					46,00
2016	7004	41	**F**	2.1+	A.1+	2	2015	2013	0	20,00	33,50	41,00					41,00
2016	7005	19	**M**	1+	Smolt	1+		2015	0								19,00
2016	7006	48	**M**	1+.1+	A.1+	1+	2015	2014	0	11,44	37,14	48,00					48,00
2016	7007	64	**F**	2.2+2SM+	A.4+	2	2012	2010	2	15,97	32,96	46,03	52,84	59,65	64,00		52,83
2016	7008	71	**F**	1.2+2SM+	A.4+	1	2012	2011	2	11,54	31,31	39,32	50,39	60,87	71,00		50,39
2016	7009	29	**M**	1+.0+	A.0+	1+	2016	2015	0	11,00	29,00						29,00
2016	7010	54	**F**	1+.1+	A.1+	1+	2015	2014	0	15,43	48,16	54,00					54,00
2016	7014	29	**M**	1.0+	A.0+	1	2016	2015	0	7,50	29,00						29,00
2016	7016	47	**F**	1+.1+	A.1+	1+	2015	2014	0	9,80	29,00	47,00					47,00
2016	7019	64	**M**	1+.2+1SM+	A.3+	1+	2013	2012	1	17,15	35,26	49,23	55,37	64,00			55,37
2016	7020	56	**M**	1+.1+	A.1+	1+	2015	2014	0	13,90	32,00	56,00					56,00
2016	7024	49	**M**	1+.1+	A.1+	1+	2015	2014	0	14,00	38,00	49,00					49,00
2016	7027	66	**F**	1+.1+1SM+	A.2+	1+	2014	2013	1	16,76	45,30	57,94	66,00				57,67
2016	7028	73	**F**	2.1+3SM+	A.4+	2	2012	2010	2	14,35	46,35	55,68	61,94	67,80	73,00		55,60
2016	7030	34	**M**	1.0+	A.0+	1	2016	2015	0	9,00	34,00						34,00
2016	7032	70	**F**	2.1+1SM+	A.2+	2	2014	2012	1	17,06	48,32	62,97	70,00				62,90
2016	7033	59	**M**	1+.2+	A.2+	1+	2014	2013	0	10,78	33,37	46,09	59,00				59,00
2016	7034	52	**F**	1+.1+	A.1+	1+	2015	2014	0	15,73	41,30	52,00					52,00
2016	7036	77	**F**	2.1+3SM+	A.4+	2	2012	2010	2	20,10	52,68	60,04	68,14	73,40	77,00		60,03
2016	7037	58	**M**	2.1+	A.1+	2	2015	2013	0	13,07	45,02	58,00					58,00
2016	7038	63	**M**	1+.2+	A.2+	1	2014	2013	0	18,75	33,54	47,84	63,00				63,00
2016	7041	57	**F**	1+.1+1SM+	A.2+	1+	2014	2013	1	14,35	36,86	49,75	57,00				49,75
2016	7042	53	**M**	1+.2+	A.2+	1+	2014	2013	0	11,98	31,01	45,76	53,00				53,00
2016	7044	67	**F**	1+.2+1SM+	A.3+	1+	2013	2012	1	14,19	29,32	48,47	59,53	67,00			59,53
2016	7045	56	**F**	2.1+	A.1+	2	2015	2013	0	20,49	42,15	56,00					56,00
2016	7047	45	**M**	1+.1+	A.1+	1+	2015	2014	0	8,16	35,33	45,00					45,00
2016	7049	50	**F**	1+.1+	A.1+	1+	2015	2014	0	12,00	43,00	50,00					50,00
2016	7052	66	**F**	1+.1+2SM+	A.3+	1+	2013	2012	2	12,82	36,87	43,06	49,74	55,00			43,06
2016	7053	50	**F**	1+.1+	A.1+	1+	2015	2014	0	15,68	39,82	50,00					50,00
2016	7054	54	**M**	1+.1+	A.1+	1+	2015	2014	0	10,97	43,75	54,00					54,00
2016	7056	47	**M**	1+.1+	A.1+	1+	2015	2014	0	13,70	31,00	47,00					47,00

Year	GenID	TL	Sex	Age	Sea age	SA	FWE	Birth	SE	Smolt size	A.0+	A.1+	A.2+	A.3+	A.4+	A.5+	Size FTS
2016	7058	43	**F**	1+.1+	A.1+	1+	2015	2014	0	11,20	32,90	43,30					43,30
2016	7060	71	**F**	1+.1+3SM+	A.4+	1+	2012	2011	2	16,68	44,59	52,45	61,64	65,94	71,00		52,45
2016	7061	73	**M**	1+.2+3SM+	A.5+	1+	2011	2010	2	9,97	37,04	44,40	52,29	60,57	67,07	73,00	52,28
2016	7062	64	**F**	2.2+	A.2+	2	2014	2012	0	20,80	38,86	55,92	64,00				64,00
2016	7064	45	**M**	1+.1+	A.1+	1+	2015	2014	0	13,00	30,00	45,00					45,00
2016	7065	59	**F**	2.1+1SM+	A.2+	2	2014	2012	1	15,52	46,60	54,89	59,00				54,89
2016	7067	75	**F**	2.2+3SM+	A.5+	2	2011	2009	2	17,59	35,52	46,82	54,53	63,05	69,10	75,00	54,53
2016	7068	46	**M**	1.1+	A.1+	1	2015	2014	0	11,40	34,00	46,00					46,00
2016	7133	71	**F**	2.1+3SM+	A.3+	2	2012	2010	2	21,56	47,51	60,25	66,05	71,00			47,50
2016	7136	65	**F**	2.2+1SM+	A.3+	2	2013	2011	1	19,96	43,92	51,22	60,39	65,00			60,38
2016	7137	63	**F**	2+.1+1SM+	A.2+	2+	2014	2013	1	19,50	47,02	55,86	63,00				55,86
2016	7138	43	**M**	1+.1+	A.1+	1+	2015	2014	0	10,70	36,80	43,00					43,00
2016	7139	55	**F**	1+.1+1SM+	A.2+	1+	2014	2013	1	13,71	28,79	47,82	55,00				47,82
2016	7140	48	**M**	1+.1+	A.1+	1+	2015	2014	0	9,98	35,58	48,00					48,00
2016	7141	55	**F**	1+.1+1SM+	A.2+	1+	2014	2013	1	13,82	36,98	48,89	55,00				48,89
2016	7142	64	**F**	1+.1+1SM+	A.2+	1+	2014	2013	1	16,90	44,49	54,61	64,00				54,61
2016	7144	39	**F**	1.1+	A.1+	1	2015	2014	0	11,17	32,20	39,00					39,00
2016	7145	49	**M**	1+.1+	A.1+	1+	2015	2014	0	10,46	43,31	49,00					49,00
2016	7147	54	**M**	1+.2+	A.2+	1+	2014	2013	0	10,78	29,06	45,04	54,00				54,00
2016	7149	79	**F**	1+.2+3SM+	A.5+	1+	2011	2010	2	16,00	33,42	57,89	65,18	71,36	75,31	79,00	65,17
2016	7152	38	**F**	1+.1+	A.1+	1+	2015	2014	0	9,60	28,30	38,00					38,00
2016	7153	42	**M**	1.1+	A.1+	1	2015	2014	0	8,50	34,70	42,00					42,00
2016	7155	31	**M**	1.0+	A.0+	1	2016	2015	0	9,20	31,00						31,00
2016	7156	53	**M**	1.1+1SM+	A.2+	1	2014	2013	1	14,06	38,38	47,22	53,00				53,00
2016	7157	71	**F**	1+.2+	A.2+	1+	2014	2013	0	16,48	38,15	59,72	71,00				71,00
2016	7158	73	**M**	1+.3+	A.3+	1+	2013	2012	0	11,67	28,07	45,52	63,04	73,00			63,00
2016	7161	47	**F**	1+.1+	A.1+	1+	2015	2014	0	13,79	36,54	47,00					47,00
2016	7162	71	**M**	1+.2+2SM+	A.4+	1+	2012	2011	2	14,13	28,99	42,01	53,95	62,47	71,00		53,90
2016	7165	50	**F**	1+.1+	A.1+	1+	2015	2014	0	12,59	43,23	50,00					50,00
2016	7167	46	**F**	1+.1+	A.1+	1+	2015	2014	0	12,42	38,20	46,00					46,00
2016	7168	70	**F**	1+.2+1SM+	A.3+	1+	2013	2012	1	11,66	32,25	50,10	66,07	70,00			66,07
2016	7169	61	**M**	2.0+1SM+	A.1+	2	2015	2013	1	19,86	45,35	61,00					45,35
2016	7170	36	**M**	1.0+	A.0+	1	2016	2015	0	10,20	36,00						36,00
2017	9011	46	**F**	1+.1+	A.1+	1+	2016	2015	0	14,53	30,27	46,00					46,00
2017	9012	22	**M**	1+	Smolt	1+		2016	0								
2017	9015	52	**M**	1+.1+	A.1+	1+	2016	2015	0	13,51	41,57	52,00					52,00
2017	9016	41	**F**	1+.1+	A.1+	1+	2016	2015	0	11,10	28,26	41,00					41,00
2017	9020	41	**F**	1+.1+	A.1+	1+	2016	2015	0	8,54	33,79	41,00					41,00
2017	9021	49	**F**	1+.1+	A.1+	1+	2016	2015	0	13,79	30,19	49,00					49,00
2017	9029	57	**M**	1+.2+	A.2+	1+	2015	2014	0	15,03	29,55	42,36	57,00				57,00
2017	9032	40	**F**	1+.1+	A.1+	1+	2016	2015	0	10,05	30,34	40,00					40,00
2017	9037	22	**M**	1+	Smolt	1+		2016	0								
2017	9039	20	**M**	1+	Smolt	1+		2016	0								
2017	9050	46	**M**	1+.1+	A.1+	1+	2016	2015	0	13,26	33,37	46,00					46,00

Year	**GenID**	**TL**	**Sex**	**Age**	**Sea age**	**SA**	**FWE**	**Birth**	**SE**	**Smolt size**	**A.0+**	**A.1+**	**A.2+**	**A.3+**	**A.4+**	**A.5+**	**Size FTS**
2017	9053	46	**F**	1+.1+	A.1+	1+	2016	2015	0	12,93	38,05	46,00					45,00
2017	9056	38	**F**	1+.1+	A.1+	1+	2016	2015	0	10,99	32,41	38,00					38,00
2017	9057	45	**M**	1+.1+	A.1+	1+	2016	2015	0	9,84	30,98	45,00					45,00
2017	9064	71	**M**	1+.2+	A.2+	1+	2015	2014	0	15,68	37,02	65,71	71,00				71,00
2017	9065	56	**M**	1.2+	A.2+	1+	2015	2014	0	9,51	27,58	46,17	56,00				56,00
2017	9066	47	**F**	1+.1+	A.1+	1+	2016	2015	0	12,08	30,66	47,00					47,00
2017	9070	26	**M**	1.0+	A.0+	1	2017	2016	0								
2017	9073	43	**M**	1.1+	A.1+	1+	2016	2015	0	8,71	29,48	43,00					43,00
2017	9076	53	**M**	1+.1+	A.1+	1+	2016	2015	0	11,33	41,45	53,00					53,00
2017	9081	46	**F**	1+.1+	A.1+	1+	2016	2015	0	12,33	28,94	46,00					47,00
2017	9082	40	**F**	1+.1+	A.1+	1+	2016	2015	0	11,72	32,78	40,00					45,00
2017	9087	49	**M**	1+.1+	A.1+	1+	2016	2015	0	12,35	31,84	47,00					41,00
2017	9090	42	**F**	1+.1+	A.1+	1+	2016	2015	0	12,61	33,29	42,00					42,00
2017	9097	45	**M**	1+.1+	A.1+	1+	2016	2015	0	10,95	34,81	45,00					45,00
2017	9098	44	**F**	1+.1+	A.1+	1+	2016	2015	0	12,13	36,49	44,00					44,00
2017	9115	41	**M**	1+.1+	A.1+	1+	2016	2015	0	10,66	33,01	41,00					41,00
2017	9123	43	**F**	1.1+	A.1+	1+	2016	2015	0	15,00	29,51	43,00					43,00
2017	9135	55	**F**	1+.2+	A.2+	1+	2015	2014	0	12,03	35,93	48,88	55,00				55,00
2017	9136	18	**M**	1+	Smolt	1+		2016	0								
2017	9143	50	**F**	2.1+	A.1+	2	2016	2014	0	15,43	38,36	50,00					50,00
2017	9146	49	**F**	1+.1+1SM+	A.2+	1+	2015	2014	1	10,69	35,26	43,74	49,00				43,70
2017	9147	44	**F**	1.1+	A.1+	1+	2016	2015	0	14,05	38,56	44,00					44,00
2017	9148	24	**M**	1.0+	A.0+	1	2017	2016	0	7,80							24,00
2017	9149	46	**M**	1+.1+	A.1+	1+	2016	2015	0	12,22	35,82	46,00					46,00
2017	9152	64	**M**	1+.2+	A.2+	1+	2015	2014	0	17,22	37,19	53,07	64,00				64,00
2017	9161	47	**M**	1.1+	A.1+	1+	2016	2015	0	10,67	30,94	47,00					47,00
2017	9163	40	**M**	1+.1+	A.1+	1+	2016	2015	0	14,62	32,36	40,00					40,00
2017	9164	31	**M**	1+.0+	A.0+	1+	2017	2016	0	16,23	31,00						31,00
2017	9172	33	**M**	1+.0+	A.0+	1+	2017	2016	0	10,14	33,00						33,00
2017	9174	46	**M**	1+.1+	A.1+	1+	2016	2015	0	9,84	34,85	46,00					46,00
2017	9179	49	**M**	1.1+	A.1+	1	2016	2015	0	15,20	29,84	49,00					49,00
2017	9181	44	**F**	1+.1+	A.1+	1+	2016	2015	0	14,93	33,63	44,00					45,00
2017	9186	41	**F**	1.1+	A.1+	1	2016	2015	0	12,90	30,53	41,00					41,00
2017	9189	45	**M**	1.1+	A.1+	1	2016	2015	0	10,16	33,73	45,00					45,00
2017	9194	25	**M**	1+	Smolt	1+		2016	0								
2017	9197	17	**M**	0+	Smolt	0+		2017	0								
2017	9200	19	**M**	1+	Smolt	1+		2016	0								
2017	9202	48	**M**	1+.1+	A.1+	1+	2016	2015	0	14,44	30,87	48,00					48,00
2017	9203	49	**F**	1.1+1SM+	A.2+	1	2015	2014	1	9,26	31,93	41,26	49,00				49,00
2017	9205	46	**F**	1+.1+	A.1+	1+	2016	2015	0	11,97	37,57	46,00					46,00
2017	9206	44	**M**	1+.1+	A.1+	1+	2016	2015	0	14,26	33,05	44,00					44,00
2017	9209	41	**F**	1+.1+	A.1+	1+	2016	2015	0	13,13	30,97	41,00					41,00
2017	9218	42	**F**	1+.1+	A.1+	1+	2016	2015	0	12,67	35,63	42,00					42,00
2017	9221	41	**M**	1+.1+	A.1+	1+	2016	2015	0	13,02	30,85	41,00					41,00

Year	GenID	TL	Sex	Age	Sea age	SA	FWE	Birth	SE	Smolt size	A.0+	A.1+	A.2+	A.3+	A.4+	A.5+	Size FTS
2017	9223	42	**M**	1+.1+	A.1+	1+	2016	2015	0	13,98	30,20	42,00					42,00
2017	9227	47	**F**	1+.1+	A.1+	1+	2016	2015	0	11,36	40,95	47,00					47,00
2017	9228	76	**F**	2+.1+2SM+	A.3+	2+	2014	2012	2	20,03	51,36	62,73	69,97	76,00			62,73
2017	9234	46	**M**	1+.1+	A.1+	1+	2016	2015	0	14,05	34,97	46,00					46,00
2017	9236	58	**F**	1+.1+2SM+	A.3+	1+	2014	2013	2	14,28	33,18	42,46	50,78	58,00			42,46
2017	9242	44	**M**	1+.1+	A.1+	1+	2016	2015	0	10,92	29,77	44,00					44,00
2017	9244	84	**F**	1+.2+2SM+	A.4+	1+	2013	2012	2	12,31	41,66	60,50	75,66	80,53	84,00		75,66
2017	9248	47	**F**	1.1+	A.1+	1	2016	2015	0	9,00	31,09	47,00					47,00
2017	9249	68	**F**	1+.2+3SM+	A.5+	1+	2012	2011	2	14,97	32,72	45,92	52,25	58,04	63,42	68,00	52,25
2017	9252	43	**M**	1+.1+	A.1+	1+	2016	2015	0	12,41	33,69	43,00					43,00
2017	9256	75	**F**	2+.1+4SM+	A.5+	2+	2012	2010	2	24,44	48,64	56,63	63,79	69,19	72,43	75,00	56,63
2017	9258	49	**F**	2.1+	A.1+	2	2016	2014	0	17,71	44,08	49,00					49,00
2017	9264	20	**M**	1+	Smolt	1+		2016	0								
2017	9265	46	**M**	1+.1+	A.1+	1+	2016	2015	0	10,64	37,80	46,00					46,00
2017	9267	51	**F**	1+.1+	A.1+	1+	2016	2015	0	14,74	41,26	51,00					51,00
2017	9269	79	**F**	2.2+2SM+	A.4+	2	2014	2012	2	22,82	43,66	55,20	64,32	73,10	79,00		64,32
2017	9271	45	**M**	1.0+1SM+	A.1+	1	2016	2015	1	12,88	36,80	45,00					36,80
2017	9276	23	**M**	1+	Smolt	1+		2016	0								
2017	9350	59	**F**	1+.1+1SM+	A.2+	1+	2015	2014	1	9,22	40,98	50,92	59,00				50,92
2017	9351	54	**F**	1.1+1SM+	A.2+	1	2015	2014	1	13,34	35,81	45,41	54,00				45,41
2017	9353	74	**F**	2.1+2SM+	A.3+	2	2014	2012	2	18,15	48,88	57,40	66,01	74,00			57,40
2017	9355	50	**M**	1+.1+	A.1+	1+	2016	2015	0	11,54	36,00	50,00					50,00
2017	9360	80	**M**	1.3+	A.3+	1	2014	2013	0	8,76	36,53	50,11	67,50	80,00			80,00
2017	9362	72	**F**	1+.1+2SM+	A.3+	1+	2014	2013	2	17,71	40,06	54,67	66,57	72,00			54,67
2017	9367	48	**M**	1.1+	A.1+	1	2016	2015	0	11,25	33,62	48,00					48,00
2017	9370	46	**M**	1.1+	A.1+	1	2016	2015	0	15,96	32,79	46,00					46,00
2017	9376	58	**M**	1+.1+	A.1+	1+	2016	2015	0	18,91	45,23	58,00					58,00
2017	9379	79	**M**	1+.1+	A.1+	1+	2016	2015	0	16,71	51,74	79,00					79,00
2017	9382	42	**F**	1+.1+	A.1+	1+	2016	2015	0	11,44	29,73	42,00					42,00
2017	9383	50	**M**	1+.1+	A.1+	1+	2016	2015	0	15,05	37,32	50,00					50,00
2017	9389	40	**F**	1.1+	A.1+	1	2016	2015	0	12,22	29,16	40,00					40,00
2017	9390	48	**F**	1+.1+	A.1+	1+	2016	2015	0	11,07	38,79	48,00					48,00
2017	9393	74	**F**	2.1+2SM+	A.3+	2	2014	2012	2	19,11	46,95	57,40	67,34	74,00			57,40
2017	9395	46	**M**	1+.1+	A.1+	1+	2016	2015	0	13,98	35,70	46,00					46,00
2017	9463	49	**F**	1+.1+	A.1+	1+	2016	2015	0	15,88	42,68	49,00					49,00
2017	9472	45	**M**	1+.1+	A.1+	1+	2016	2015	0	9,90	36,38	45,00					45,00
2017	9473	45	**F**	1+.1+	A.1+	1+	2016	2015	0	17,71	31,60	45,00					45,00
2017	9478	44	**F**	1+.1+	A.1+	1+	2016	2015	0	11,99	33,56	44,00					44,00
2017	9485	54	**M**	2.1+	A.1+	2	2016	2014	0	16,28	42,49	54,00					54,00
2017	9487	53	**M**	1+.1+	A.1+	1+	2016	2015	0	17,30	43,53	53,00					53,00
2017	9492	43	**M**	1+.1+	A.1+	1+	2016	2015	0	12,92	25,01	43,00					43,00
2017	9496	47	**M**	1+.1+	A.1+	1+	2016	2015	0	12,89	38,24	47,00					47,00
2017	9497	46	**F**	1.1+	A.1+	1	2016	2015	0	10,74	31,71	46,00					46,00
2017	9500	75	**M**	1+.3+1SM+	A.4+	1+	2013	2012	1	12,41	35,10	61,34	68,37	71,93	75,00		71,93

Year	GenID	TL	Sex	Age	Sea age	SA	FWE	Birth	SE	Smolt size	A.0+	A.1+	A.2+	A.3+	A.4+	A.5+	Size FTS
2017	9501	49	**F**	1+.1+	A.1+	1+	2016	2015	0	9,98	39,35	49,00					49,00
2017	9503	43	**F**	2.1+	A.1+	2	2016	2014	0	14,73	35,66	43,00					43,00
2017	9506	33	**M**	1+.0+	A.0+	1+	2017	2016	0	15,33	33,00						33,00
2017	9511	40	**F**	1+.1+	A.1+	1+	2016	2015	0	12,41	28,67	40,00					40,00
2017	9517	53	**M**	1+.1+	A.1+	1+	2016	2015	0	16,42	37,18	53,00					53,00
2017	9525	50	**M**	1+.1+	A.1+	1+	2016	2015	0	18,56	39,56	50,00					50,00
2017	9527	46	**F**	1+-1+	A.1+	1+	2016	2015	0	15,32	39,65	46,00					46,00
2017	9650	44	**F**	1+-1+	A.1+	1+	2016	2015	0	14,70	33,81	44,00					44,00
2017	9652	42	**M**	1+.1+	A.1+	1+	2016	2015	0	13,91	23,63	42,00					42,00
2017	9656	41	**F**	1+.1+	A.1+	1+	2016	2015	0	11,30	33,72	41,00					41,00
2017	9662	43	**M**	1+.1+	A.1+	1+	2016	2015	0	14,50	29,39	43,00					43,00
2017	9665	45	**M**	2.1+	A.1+	2	2016	2014	0	18,05	33,37	45,00					45,00
2017	9668	54	**F**	2.1+	A.1+	2	2016	2014	0	17,51	39,01	54,00					54,00
2017	9671	45	**M**	1+.1+	A.1+	1+	2016	2015	0	11,82	34,84	45,00					45,00
2017	9673	73	**M**	1+.2+	A.2+	1+	2015	2014	0	14,12	41,27	66,92	73,00				73,00
2017	9675	50	**F**	1+.1+	A.1+	1+	2016	2015	0	13,12	44,26	50,00					50,00
2017	9724	55	**M**	2.2+	A.2+	2	2015	2013	0	18,95	33,17	44,84	55,00				55,00
2017	9733	56	**M**	1+.1+	A.1+	1+	2016	2015	0	16,47	41,01	56,00					56,00
2017	9737	44	**M**	1+.1+	A.1+	1+	2016	2015	0	10,80	33,24	44,00					44,00
2017	9739	49	**F**	1+.1+	A.1+	1+	2016	2015	0	15,56	38,24	49,00					49,00
2017	9740	48	**F**	2+.1+	A.1+	2+	2016	2014	0	20,92	37,81	48,00					48,00

7.5.2 Spawning experience: distribution in sex and age classes

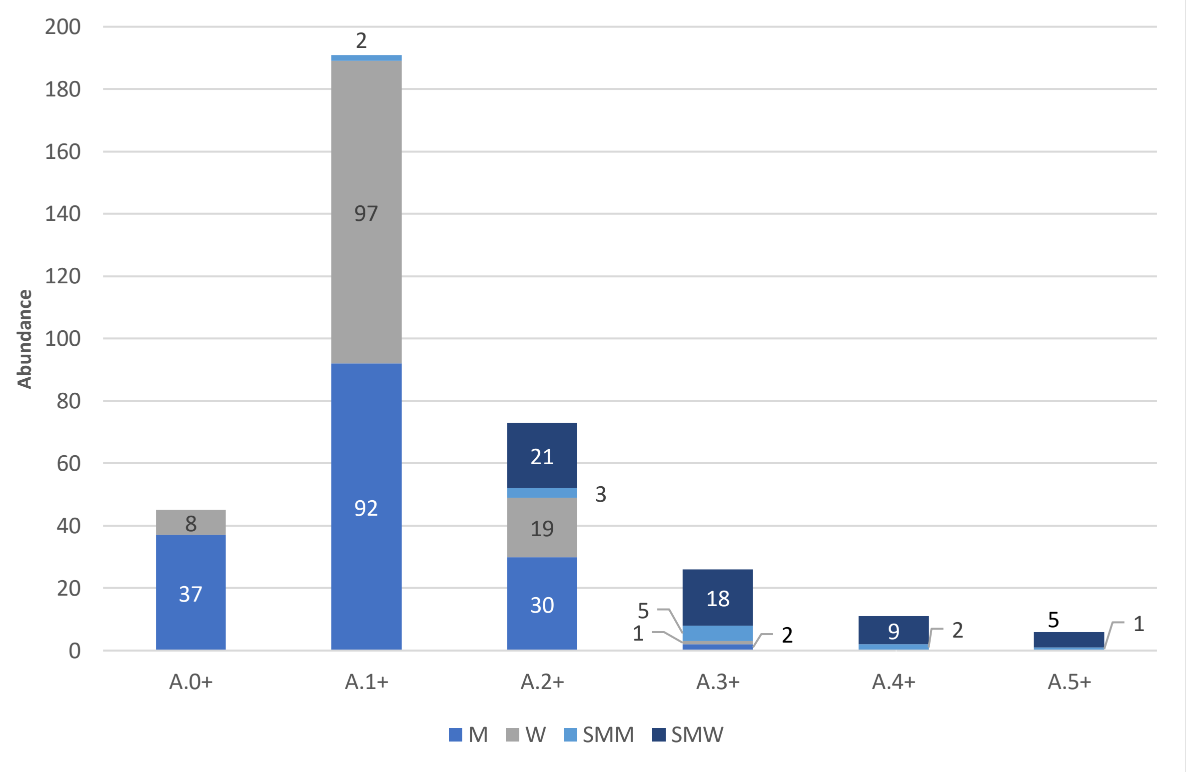


Figure 52: Spawning experience divided by sex. Abundance. M = Male; W = Female; SMM = Male with SM; SMW = Female with SM.

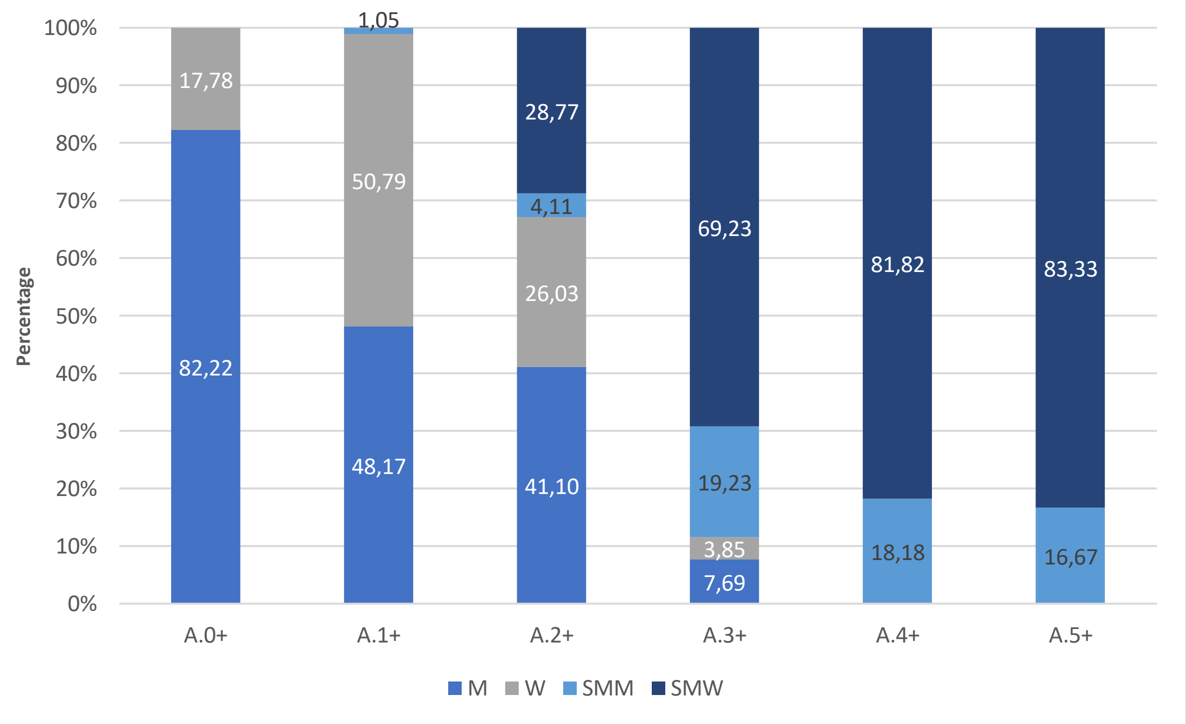


Figure 53: Spawning experience by sex. Percentage. M = Male; W = Female; SMM = Male with SM; SMW = Female with SM.

7.6 Genetic results

7.6.1 Sample selection

Date	Gen-ID	Length [cm]	Sex	T-bar Tag ID	Stab.-Iso. 1=analysed	Stabiso_ID	Age	Plate	Well
12.17.2012	65	79	F					3	A01
12.17.2012	66	75	F					3	B01
12.17.2012	67	77	F					3	C01
12.17.2012	68	67	F					3	D01
12.17.2012	69	73	F					3	E01
12.17.2012	70	63	F					3	F01
12.17.2012	71	81	F					3	G01
12.17.2012	72	60	F					3	H01
12.17.2012	73	57	F					3	A02
12.17.2012	74	77	F					3	B02
12.17.2012	75	62	F					3	C02
12.17.2012	76	56	F					3	D02
12.17.2012	77	47	F					3	E02
12.17.2012	78	51	F					3	F02
12.17.2012	79	67	F					3	G02
12.17.2012	80	59	F					3	H02
12.17.2012	81	49	F					3	A03
12.17.2012	82	71	F					3	B03
12.17.2012	83	69	F					3	C03
12.17.2012	84	69	F					3	D03
12.17.2012	85	49	F					3	E03
12.17.2012	86	47	F					3	F03
12.17.2012	87	51	M					3	G03
12.17.2012	88	57	M					3	H03
12.17.2012	89	56	M					3	A04
12.17.2012	90	50	M					3	B04
12.17.2012	91	47	M					3	C04
12.17.2012	92	49	M					3	D04
12.17.2012	93	46	M					3	E04
12.17.2012	94	48	M					3	F04
11.30.2013	1108	48	M					3	G04
11.30.2013	1111	57	F					3	H04
11.30.2013	1112	46	F					3	A05
11.30.2013	1117	46	M					3	B05
11.30.2013	1119	54	F					3	C05
11.30.2013	1120	50	F					3	D05
11.30.2013	1121	50	F					3	E05
11.30.2013	1127	48	M					3	F05
11.30.2013	1130	53	F					3	G05
11.30.2013	1131	53	M					3	H05
11.30.2013	1132	53	M					3	A06

Date	Gen-ID	Length [cm]	Sex	T-bar Tag ID	Stab.-Iso. 1=analysed	Stabiso_ID	Age	Plate	Well
11.30.2013	1139	45	M					3	C06
11.30.2013	1140	61	F					3	D06
11.30.2013	1141	46	F					3	E06
11.30.2013	1147	46	M					3	F06
11.30.2013	1148	43	F					3	G06
11.30.2013	1151	46	F					3	H06
11.30.2013	1153	54	M					3	A07
11.30.2013	1155	46	M					3	B07
11.30.2013	1156	48	M					3	C07
11.30.2013	1158	44	M					3	D07
11.30.2013	1160	51	F					3	E07
11.30.2013	1161	44	F					3	F07
11.30.2013	1162	46	M					3	G07
11.30.2013	1165	69	F					3	H07
11.30.2013	1171	46	F					3	A08
11.30.2013	1174	38	M					3	B08
12.13.2013	1454	52	F					3	C08
12.13.2013	1457	41	F					3	D08
12.13.2013	1459	59	M					3	E08
12.13.2013	1461	51	M					3	F08
12.13.2013	1462	45	M					3	G08
12.13.2013	1463	56	M					3	H08
12.13.2013	1464	48	M					3	A09
12.13.2013	1466	58	M					3	B09
12.13.2013	1468	54	M					3	C09
12.13.2013	1470	52	M					3	D09
12.13.2013	1472	57	M					3	E09
12.13.2013	1473	45	M					3	F09
12.13.2013	1475	48	M					3	G09
12.13.2013	1476	46	M					3	H09
12.13.2013	1481	62	F					3	A10
12.13.2013	1486	50	F					3	B10
12.13.2013	1487	49	F					3	C10
12.13.2013	1488	56	F					3	D10
12.13.2013	1491	49	F					3	E10
12.13.2013	1492	41	F					3	F10
12.13.2013	1495	66	F					3	G10
12.13.2013	1497	68	F					3	H10
11.4.2014	2964	67	F					2	A01
11.4.2014	2966	59	F					2	B01
11.4.2014	2967	37	F					2	C01
11.4.2014	2982	58	M					2	D01
11.4.2014	2987	52	F					2	E01
11.4.2014	2989	31	M					2	F01

Date	Gen-ID	Length [cm]	Sex	T-bar Tag ID	Stab.-Iso. 1=analysed	Stabiso_ID	Age	Plate	Well
11.28.2014	3200	46	F					2	G01
11.28.2014	3203	48	M					2	H01
11.28.2014	3204	47	M					2	A02
11.28.2014	3205	35	M					2	B02
11.28.2014	3209	55	F					2	C02
11.28.2014	3211	56	F					2	D02
11.28.2014	3212	72	F					2	E02
11.28.2014	3213	52	F					2	F02
11.28.2014	3216	41	M					2	G02
11.28.2014	3219	49	F					2	H02
11.28.2014	3222	57	M					2	A03
11.28.2014	3223	77	F					2	B03
11.28.2014	3226	48	M					2	C03
11.28.2014	3230	27	W					2	D03
11.28.2014	3231	44	F					2	E03
11.28.2014	3232	54	M					2	F03
11.28.2014	3234	35	M					2	G03
11.28.2014	3237	55	F					2	H03
11.28.2014	3239	48	M					2	A04
11.28.2014	3241	26	M					2	B04
11.28.2014	3242	31	M					2	C04
11.28.2014	3243	55	M					2	D04
11.28.2014	3245	51	F					2	E04
11.28.2014	3250	49	M					2	F04
11.28.2014	3253	55	F					2	G04
11.28.2014	3257	37	M					2	H04
11.28.2014	3258	52	F					2	A05
11.28.2014	3266	43	M					2	B05
11.28.2014	3267	53	F					2	C05
11.28.2014	3272	38	M					2	D05
11.28.2014	3277	39	M					2	E05
11.28.2014	3278	52	M					2	F05
11.28.2014	3279	47	F					2	G05
11.28.2014	3283	34	F					2	H05
11.28.2014	3292	41	F					2	A06
11.28.2014	3297	45	M					2	B06
11.28.2014	3298	48	M					2	C06
12.12.2014	3342	57	F					2	D06
12.12.2014	3344	55	F					2	E06
12.12.2014	3345	50	F					2	F06
12.12.2014	3350	46	F					2	G06
12.12.2014	3354	59	M					2	H06
12.12.2014	3355	47	M					2	A07
12.12.2014	3357	48	M					2	B07

Date	Gen-ID	Length [cm]	Sex	T-bar Tag ID	Stab.-Iso. 1=analysed	Stabiso_ID	Age	Plate	Well
11.25.2015	4460	70	F				2+.1+3SM+	1	A01
11.25.2015	4465	55	F				1+.1+	1	B01
11.25.2015	4466	68	M				1+.2+	1	C01
11.25.2015	4471	45	F				1+.1+	1	D01
11.25.2015	4476	62	M				1.2+	1	E01
11.25.2015	4478	83	M				1+.2+	1	F01
11.25.2015	4491	31	M				1.0+	1	G01
11.25.2015	4494	56	M				2.1+	1	H01
11.25.2015	4497	50	M				1+.1+	1	A02
11.25.2015	4501	48	F				1+.1+	1	B02
11.25.2015	4503	51	F				2.1+	1	C02
11.25.2015	4508	57	M				2.2+	1	D02
11.25.2015	4510	52	M				1+.1+	1	E02
11.25.2015	4512	71	F				2.2+1SM+	1	F02
11.25.2015	4514	65	F				1+.2+1SM+	1	G02
11.25.2015	4516	67	M				1.2+1SM+	1	H02
11.25.2015	4523	38	M				2.0+	1	A03
11.25.2015	4529	50	M				2.1+	1	B03
11.25.2015	4532	73	M				2+.1+2SM+	1	B07
11.25.2015	4533	77	M				1+.2+	1	C03
11.25.2015	4534	72	F				1+.2+1SM+	1	D03
12.2.2015	4567	75	F				1+.3+	1	E03
12.2.2015	4569	46	F				1+.1+	1	F03
12.2.2015	4571	64	M				1+.2+	1	G03
12.2.2015	4578	46	M				1+.1+	1	H03
12.2.2015	4597	57	M				2.1+	1	A04
12.2.2015	4600	58	F				2.1+1SM+	1	B04
12.2.2015	4611	73	F				2.2+	1	C04
12.2.2015	4616	46	F				1+.1+	1	D04
12.2.2015	4621	32	M				2.0+	1	E04
12.9.2015	4626	58	F				1+.2+	1	F04
12.9.2015	4630	46	F				1+.1+	1	G04
12.9.2015	4633	17	M				1+	1	H04
12.9.2015	4639	52	F				2.1+	1	A05
12.9.2015	4642	71	M				2.2+1SM+	1	B05
12.9.2015	4651	31	M				1.0+	1	C05
12.9.2015	4661	69	F				1+.2+1SM+	1	D05
12.9.2015	4666	48	M				1+.1+	1	E05
12.9.2015	4671	71	F				1+.2+	1	F05
12.9.2015	4679	39	F				2.0+	1	G05
12.9.2015	4685	44	F				1+.1+	1	H05
12.16.2015	4716	52	M				1+.2+	1	A06
12.16.2015	4736	53	F				2.1+	1	B06
12.16.2015	4741	51	F				1.1+1SM+	1	C06

Date	Gen-ID	Length [cm]	Sex	T-bar Tag ID	Stab.-Iso. 1=analysed	Stabiso_ID	Age	Plate	Well
12.16.2015	4743	47	M				1+.1+	1	D06
12.23.2015	4746	45	M				1+.1+	1	E06
12.23.2015	4750	30	M				1+.0+	1	F06
12.23.2015	4758	48	F				1+.1+	1	G06
12.23.2015	4761	73	F				1+.2+1SM+	1	H06
12.30.2015	4781	59	F				2.2+	1	A07
11.23.2016	6778	56	F	3088	1	5	1+.2+	2	C07
11.23.2016	6779	43	M	3089	1	6	1+.1+	2	D07
11.23.2016	6784	48	F	3094	1	8	1+.1+	2	E07
11.23.2016	6797	54	M	3109	1	11	1.0+2SM+	2	F07
11.23.2016	6800	50	F	3112	0		1+.1+	2	G07
11.23.2016	6806	75	F	3119	1	13	2.1+3SM+	2	H07
11.23.2016	6812	67	F	3125	1	14	1.2+1SM+	2	A08
11.30.2016	6969	49	M	3156	1	16	1+.1+	2	B08
11.30.2016	6970	55	F	3157	1	17	2.1+1SM+	2	C08
11.30.2016	6971	75	F	3158	1	18	1+.2+3SM+	2	D08
11.30.2016	6972	66	F	3159	1	19	1+.1+1SM+	2	E08
11.30.2016	6973	34	M	3160	1	20	1+.0+	2	F08
11.30.2016	6974	28	M	3161	1	21	1+.0+	2	G08
11.30.2016	6975	48	F	3162	1	22	1+.1+1SM+	2	H08
11.30.2016	6977	42	F	3164	1	23	1+.1+	2	A09
11.30.2016	6982	26	M	3169	1	24	1+.0+	2	B09
11.30.2016	6984	29	M	3171	1	25	1+.0+	2	C09
11.30.2016	6986	45	M	3173	1	26	1+.1+	2	D09
11.30.2016	6987	44	F	3174	1	27	2.1+	2	E09
11.30.2016	6988	52	F	3175	1	28	1+.1+	2	F09
11.30.2016	6989	48	M	3176	1	29	1+.1+	2	G09
11.30.2016	6990	29	M	3177	1	30	1+.0+	2	H09
12.7.2016	7005	19	M		1	40	1+	2	A10
12.14.2016	7010	54	F	3281	1	74	1+.1+	2	B10
12.14.2016	7014	29	M	3285	1	78	1.0+	2	C10
12.14.2016	7016	47	F	3287	1	80	1+.1+	2	D10
12.14.2016	7019	64	M	3291	1	83	1+.2+1SM+	2	E10
12.14.2016	7028	73	F	3300	1	91	2.1+3SM+	2	F10
12.14.2016	7033	59	M	3307	0		1+.2+	2	G10
12.14.2016	7036	77	F	3310	1	96	2.1+3SM+	2	H10
12.14.2016	7047	45	M	3324	1	103	1+.1+	2	A11
12.14.2016	7056	47	M	3333	1	105	1+.1+	2	B11
12.14.2016	7061	73	M	3338	1	107	1+.2+3SM+	2	C11
12.14.2016	7067	75	F	3352	1	110	2.2+3SM+	2	D11
12.21.2016	7141	55	F	3374	1	126	1+.1+1SM+	2	E11
12.21.2016	7142	64	F	3375	1	127	1+.1+1SM+	2	F11
12.21.2016	7145	49	M	3378	1	130	1+.1+	2	G11
12.21.2016	7147	54	M	3402	1	132	1+.2+	2	H11

Date	Gen-ID	Length [cm]	Sex	T-bar Tag ID	Stab.-Iso. 1=analysed	Stabiso_ID	Age	Plate	Well
12.21.2016	7149	79	F	3405	1	134	1+.2+3SM+	2	A12
12.21.2016	7152	38	F	3408	1	137	1+.1+	2	B12
12.21.2016	7153	42	M	3409	1	138	1.1+	2	C12
12.28.2016	7155	31	M	3419	1	146	1.0+	2	D12
12.28.2016	7156	53	M	3420	1	147	1.1+1SM+	2	E12
12.28.2016	7161	47	F	3427	1	152	1+.1+	2	F12
12.28.2016	7162	71	M	3428	1	153	1+.2+2SM+	2	G12
12.28.2016	7165	50	F	3431	1	156	1+.1+	2	H12
12.28.2016	7167	46	F	3433	1	157	1+.1+	3	A11
12.28.2016	7168	70	F	3434	1	158	1+.2+1SM+	3	B11
12.28.2016	7169	61	M	3435	1	159	2.0+1SM+	3	C11
12.28.2016	7170	36	M	3436	1	160	1.0+	3	D11
11.1.2017	9015	52	M	4008	1	167	1+.1+	1	C07
11.1.2017	9020	41	F	4013	1	172	1+.1+	1	D07
11.1.2017	9029	57	M	4022	1	181	1+.2+	1	E07
11.1.2017	9032	40	F	4025	1	184	1+.1+	1	F07
11.1.2017	9053	46	F	4039	1	199	1+.1+	1	G07
11.1.2017	9064	71	M	4051	1	210	1+.2+	1	H07
11.1.2017	9065	56	M	4052	1	211	1.2+	1	A08
11.1.2017	9073	44	M	4060	1	219	1.1+	1	B08
11.1.2017	9076	53	M	4063	1	222	1+.1+	1	C08
11.1.2017	9087	49	M	4074	1	233	1+.1+	1	D08
11.1.2017	9090	42	F	4077	1	236	1+.1+	1	E08
11.1.2017	9098	44	F	4191	1	244	1+.1+	1	F08
11.8.2017	9135	55	F	4119	1	277	1+.2+	1	G08
11.8.2017	9143	50	F	4127	1	285	2.1+	1	H08
11.8.2017	9147	44	F	4131	1	289	1.1+	1	A09
11.8.2017	9152	64	M	4136	1	294	1+.2+	1	B09
11.8.2017	9163	40	M	4148	1	305	1+.1+	1	C09
11.8.2017	9181	44	F	4167	1	323	1+.1+	1	D09
11.8.2017	9186	41	F	4172	1	328	1.1+	1	E09
11.15.2017	9202	48	M	4185	1	344	1+.1+	1	F09
11.15.2017	9203	49	F	4186	1	345	1.1+1SM+	1	G09
11.15.2017	9205	46	F	4188	1	347	1+.1+	1	H09
11.15.2017	9206	44	M	4189	1	348	1+.1+	1	A10
11.22.2017	9218	42	F	4200	1	360	1+.1+	1	B10
11.22.2017	9244	84	F	4222	1	386	1+.2+2SM+	1	C10
11.22.2017	9252	43	M	4230	1	394	1+.1+	1	D10
11.22.2017	9256	75	F	3300	1	398	2+.1+4SM+	1	E10
11.22.2017	9265	46	M	4242	1	407	1+.1+	1	F10
11.22.2017	9269	79	F	4247	1	411	2.2+2SM+	1	G10
11.22.2017	9271	45	M	4248	1	413	1.0+1SM+	1	H10
29.11.2017	9351	54	F	4322	1	476	1.1+1SM+	1	A11
29.11.2017	9360	80	M	4331	1	485	1.3+	1	B11

Date	Gen-ID	Length [cm]	Sex	T-bar Tag ID	Stab.-Iso. 1=analysed	Stabiso_ID	Age	Plate	Well
29.11.2017	9362	72	F	4333	1	487	1+.1+2SM+	1	C11
29.11.2017	9370	43	F	4341	1	495	1.1+	1	D11
29.11.2017	9376	58	M	4348	1	501	1+.1+	1	E11
29.11.2017	9379	79	M	4352	1	504	1+.1+	1	F11
29.11.2017	9383	50	M	4356	1	508	1+.1+	1	G11
29.11.2017	9393	74	F	3403	1	518	2.1+2SM+	1	H11
06.12.2017	9497	46	F	4487	1	622	1.1+	1	A12
06.12.2017	9500	75	M	4490	1	625	1+.3+1SM+	1	B12
12.13.2017	9506	33	M	4495	1	631	1+.0+	1	C12
12.13.2017	9511	40	F	4500	1	635	1+.1+	1	D12
12.13.2017	9517	53	M	4508	1	642	1+.1+	1	E12
12.20.2017	9652	42	M	4647	1	755	1+.1+	1	F12
12.20.2017	9656	41	F	4651	1	759	1+.1+	1	G12
12.20.2017	9668	54	F	4662	1	771	2.1+	1	H12
12.20.2017	9671	45	M	4665	1	774	1+.1+	3	E11
12.28.2017	9724	55	M	4719	1	823	2.2+	3	F11
12.28.2017	9737	44	M	4732	1	836	1+.1+	3	G11
12.28.2017	9740	48	F	4736	1	839	2+.1+	3	H11

7.6.2 STRUCTURE results by the year of birth

Figure 54: Runs of the STRUCTURE analysis with K=2. Aged fish from 2015 to 2017 are organized by the back-calculated year of birth. N=150.

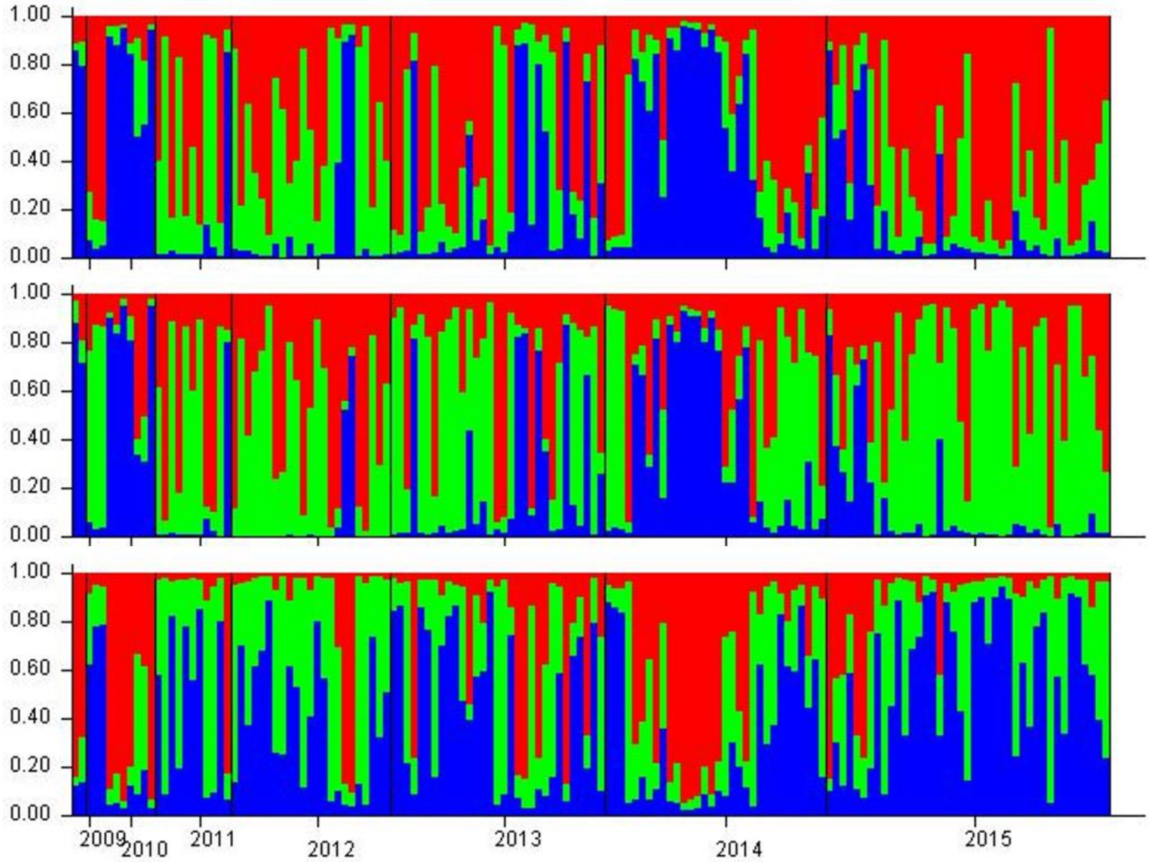


Figure 55: Runs of the STRUCTURE analysis with K=3. Aged fish from 2015 to 2017 are organized by the back-calculated year of birth. N=150.

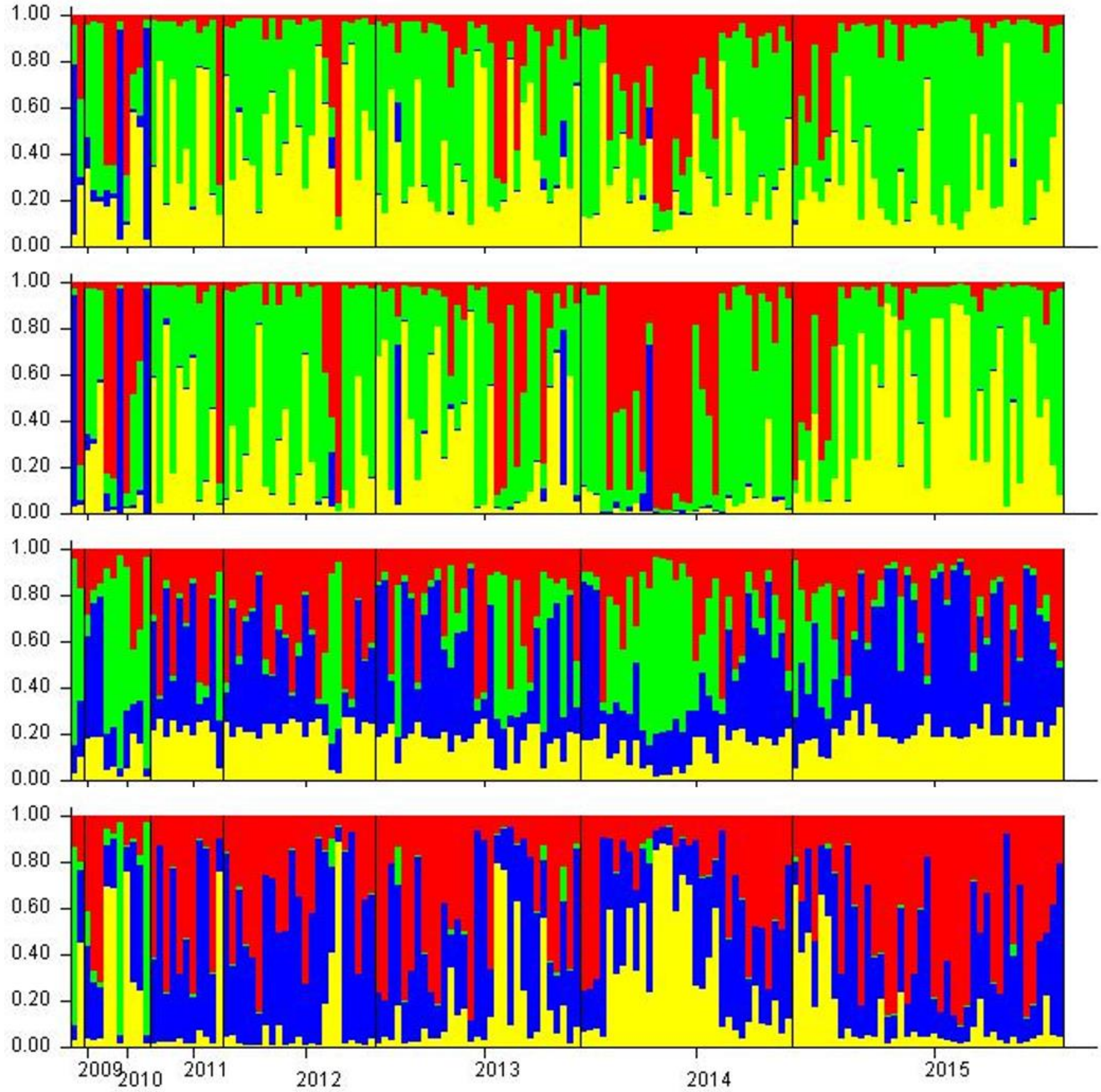


Figure 56: Runs of the STRUCTURE analysis with K=4. Aged fish from 2015 to 2017 are organized by the back-calculated year of birth. N=150.

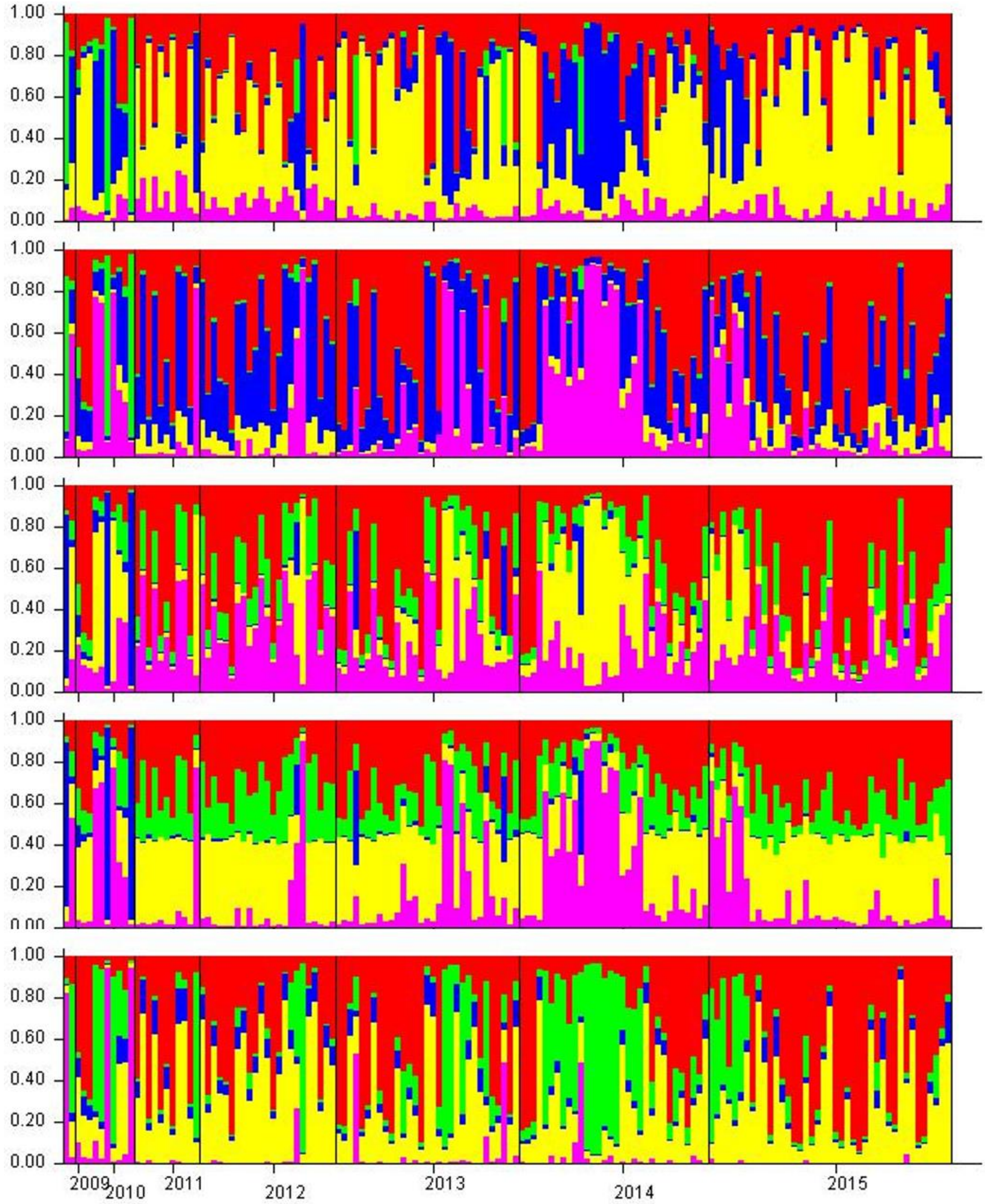


Figure 57: Runs of the STRUCTURE analysis with K=5. Aged fish from 2015 to 2017 are organized by the back-calculated year of birth. N=150.

7.6.3 STRUCTURE results by the year of sampling

Figure 58: Runs of the STRUCTURE analysis with K=2. Sample group is organized by the year of catch from 2012 to 2017. N=279.

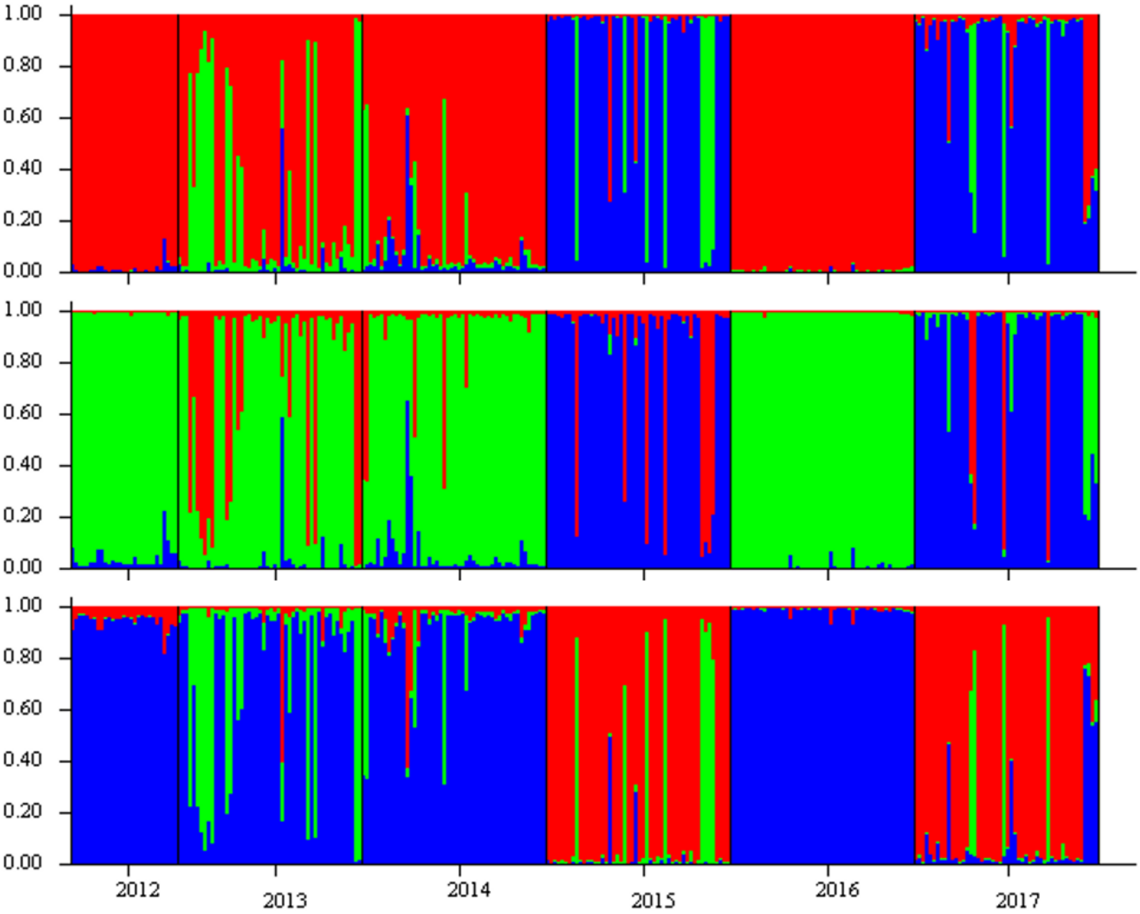


Figure 59: Runs of the STRUCTURE analysis with K=3. Sample group is organized by the year of catch from 2012 to 2017. N=279.

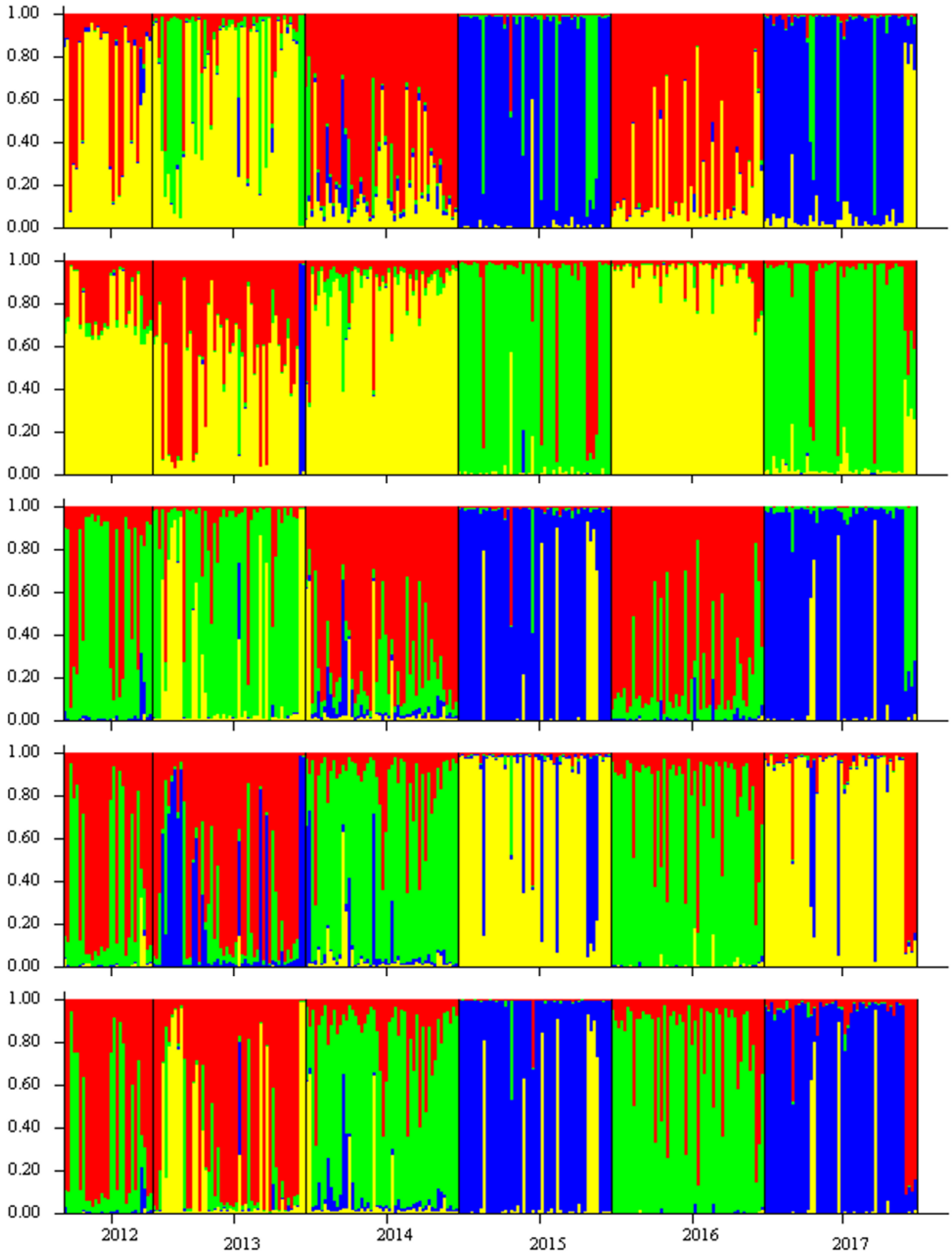


Figure 60: Runs of the STRUCTURE analysis with K=4. Sample group is organized by the year of catch from 2012 to 2017. N=279.

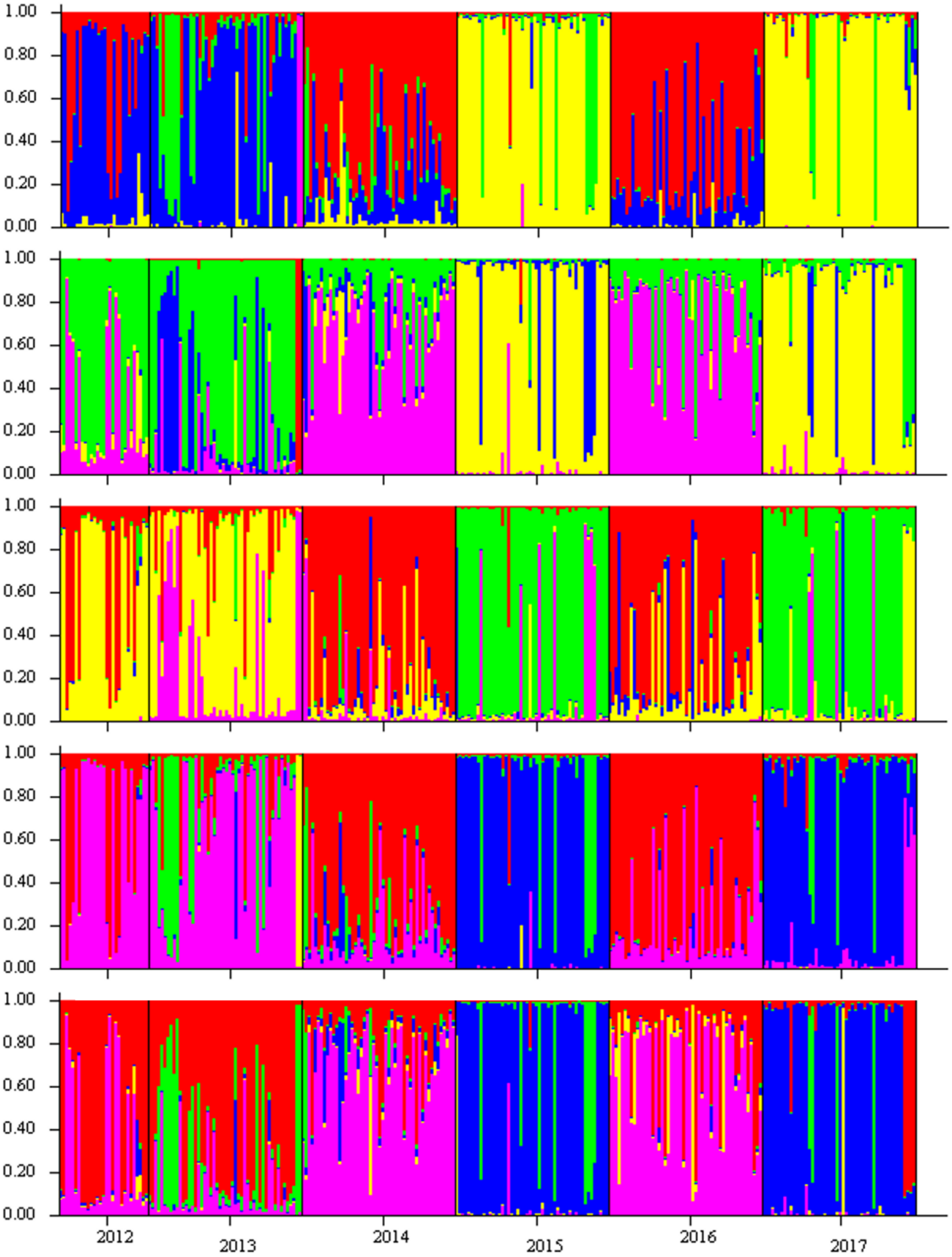
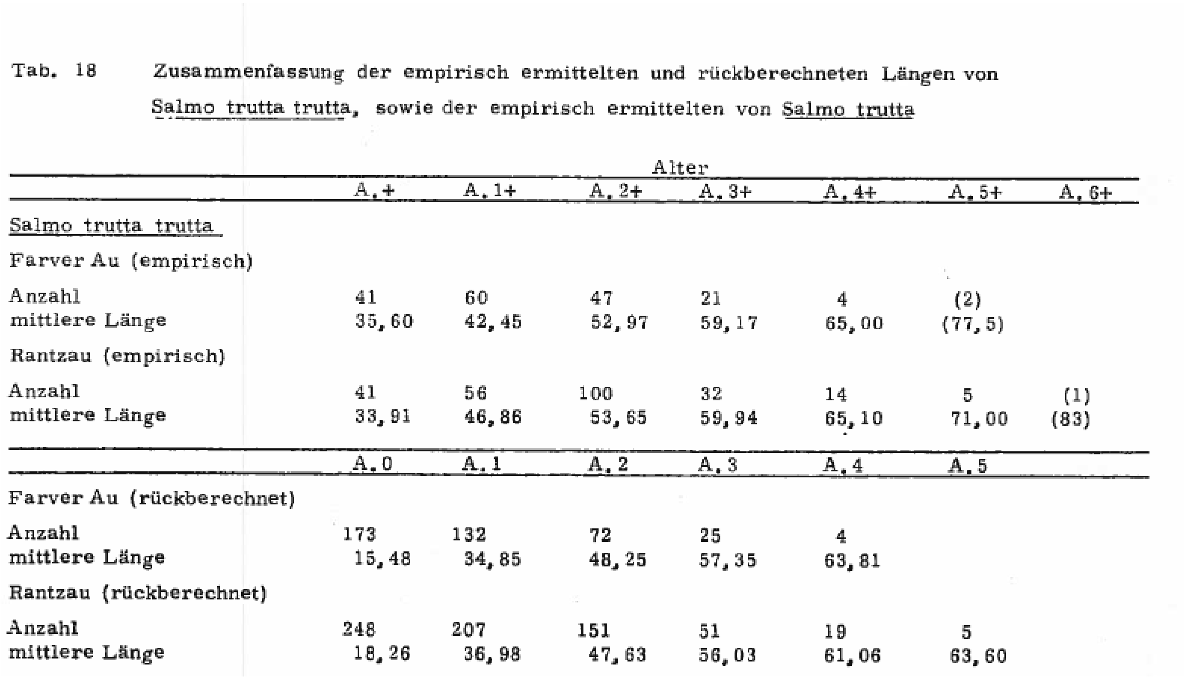


Figure 61: Runs of the STRUCTURE analysis with K=5. Sample group is organized by the year of catch from 2012 to 2017. N=279.

7.7 Observed mean length and growth in Gehlhaar (1972)

Table 45: Observed and back-calculated mean length at specific sea age. Taken from Gehlhaar (1972).



Tab. 18 Zusammenfassung der empirisch ermittelten und rückberechneten Längen von Salmo trutta trutta, sowie der empirisch ermittelten von Salmo trutta

	Alter						
	A.+	A.1+	A.2+	A.3+	A.4+	A.5+	A.6+
Salmo trutta trutta							
Farver Au (empirisch)							
Anzahl	41	60	47	21	4	(2)	
mittlere Länge	35,60	42,45	52,97	59,17	65,00	(77,5)	
Rantzau (empirisch)							
Anzahl	41	56	100	32	14	5	(1)
mittlere Länge	33,91	46,86	53,65	59,94	65,10	71,00	(83)
	A.0	A.1	A.2	A.3	A.4	A.5	
Farver Au (rückberechnet)							
Anzahl	173	132	72	25	4		
mittlere Länge	15,48	34,85	48,25	57,35	63,81		
Rantzau (rückberechnet)							
Anzahl	248	207	151	51	19	5	
mittlere Länge	18,26	36,98	47,63	56,03	61,06	63,60	

Table 46: Mean length and calculated growth from Gehlhaar (1972) - data.

	Farver Au mean length and growth 1969-1972		
	No. M+F	total length (cm)	Growth (cm)
Smolt size		15,5	
A.0+	41	35,6	20,10
A.1+	60	42,45	6,85
A.2+	47	52,17	9,72
A.3+	21	59,17	7,00
A.4+	4	65	5,83
A.5+	2	77,5	12,50
Total	175	59,34	

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9 Danksagung

Mein Dank gilt Prof. Dr. Günther B. Hartl und Prof. Dr. Oscar Puebla für die Betreuung und Korrektur dieser Arbeit.

Ganz besonders möchte ich mich bei Dr. Christoph Petereit und seinem Team für die Möglichkeit bedanken, meine Arbeit in seinem Meerforellenprojekt schreiben zu können.

Weiterhin danke ich den Kollegen Dr. Adam Lejk, Simon Weltersbach und Tom Jankiewicz, die mich bei Fragen zum Scale Reading tatkräftig unterstützt haben, Richard Schwarz für das Anlernen der Bildbearbeitungssoftware und Diana Gill für die geduldige Beantwortung aller Fragen rund um die Laborarbeit.

10 Erklärung

Hiermit erkläre ich, dass ich die vorliegende Arbeit selbständig und ohne fremde Hilfe angefertigt und keine anderen als die angegebenen Quellen und Hilfsmittel verwendet habe.

Die eingereichte schriftliche Fassung der Arbeit entspricht der auf dem elektronischen Speichermedium.

Weiterhin versichere ich, dass diese Arbeit noch nicht als Abschluss an anderer Stelle vorgelegen hat.

Kiel, den ____ (Hauke Kramer)