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Research Paper

A comparison of the survival and migration of wild and F1-hatchery-reared brown trout (*Salmo trutta*) smolts traversing an artificial lake

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ABSTRACT

Supplementing salmonid populations by stocking is a widely-used method to improve catch or to rehabilitate populations. Though, most studies found that survival and fitness of hatchery-reared salmonids is inferior to wild fish. We compared survival, emigration patterns, migration speed and return rates from the sea of wild and 1-year old F1-hatchery-reared brown trout smolts in a Danish lowland stream that contains an artificial lake using passive integrated transponder telemetry in the years 2011–2013 and 2016. The majority of hatchery-reared smolts descended within 72 h after their release, whereas wild fish migration was mainly triggered by increased water discharge. Increased probability of a successful lake passage was found at higher discharge. Within years, the groups differed in lake passage time, but without a significant overall difference. Overall, there was no difference in lake survival (wild: 30%, hatchery-reared: 32%) between the two groups, but survival differed between years. Only a single fish (0.9%) of the hatchery-reared smolts tagged in 2011–2013 returned from the sea compared to 11 (6.4%) wild smolts tagged in that period, which questions the value of supplementary stocking of smolts for conservation purposes.

1. Introduction

Brown trout (*Salmo trutta*) and, in particular, its anadromous form, sea trout, is a species of high economic value, due to its attractiveness as a game fish for recreational anglers and as a target for commercial fisheries (ICES, 2016). Whilst brown trout is not endangered on a species level, many genetically distinct populations are extinct or severely threatened by anthropogenic impact, for example by dams and weirs (Aarestrup and Koed, 2003), unfavorable flow regulations (Bunn and Arthington, 2002) and genetic introgression (Hindar et al., 1991). Considerable effort is undertaken by managers to conserve and support remaining brown trout populations and their genetic diversity. Besides habitat improvements and fishing regulations, a common method to support and maintain the populations of brown trout is stocking of hatchery-reared juvenile trout at various developmental stages.

In Denmark, the release of fry (fed for at least 3 weeks), half-year and 1-year old hatchery-reared trout is common practice to enhance wild populations. Depending on habitat conditions, water quality and natural production, stocking plans are developed to determine the amount of stocking (Rasmussen and Geertz-Hansen, 1998; Rasmussen and Pedersen, 2017). Furthermore, according to national stocking regulations, since 2006 all stocked fish have to be F1 offspring of wild fish from the same or a nearby stream. Thus, no domesticated fish that are genetically distant from the target population are released into nature by stocking programs.

Numerous studies have investigated the performance of hatchery-reared brown trout when released in the wild. Many of those studies show an inferior performance of hatchery-reared fish compared with wild fish in various aspects like riverine survival (Serrano et al., 2009; Aarestrup et al., 2014), marine survival and homing (Jonsson and Jonsson, 2014) or swimming performance (Pedersen et al., 2008). This is explained by differences in body composition and condition factor (hatchery-reared smolts normally have a higher concentration of lipids and a lower concentration of proteins (Serrano et al., 2009)), a lack of adaption to the target stream, monotonous hatchery environments and high rearing densities that can lead to fin erosion (Latremouille, 2003) and alter behavior (Johnsson et al., 2014). However, other studies found no differences in riverine survival (Dahl et al., 2006) and reproductive success (Dannewitz et al., 2004).

So far, no studies have compared the performance of wild and hatchery-reared brown trout smolt with regard to the passage of artificial waterbodies like shallow lakes or wetlands developed to reduce nutrient emissions to marine waters. High mortality of migrating smolts have been documented in such systems (Olsson et al., 2001; Schwinn et al., 2016). From a management perspective, it is crucial to know, if stocked fish perform differently in those systems compared to their wild

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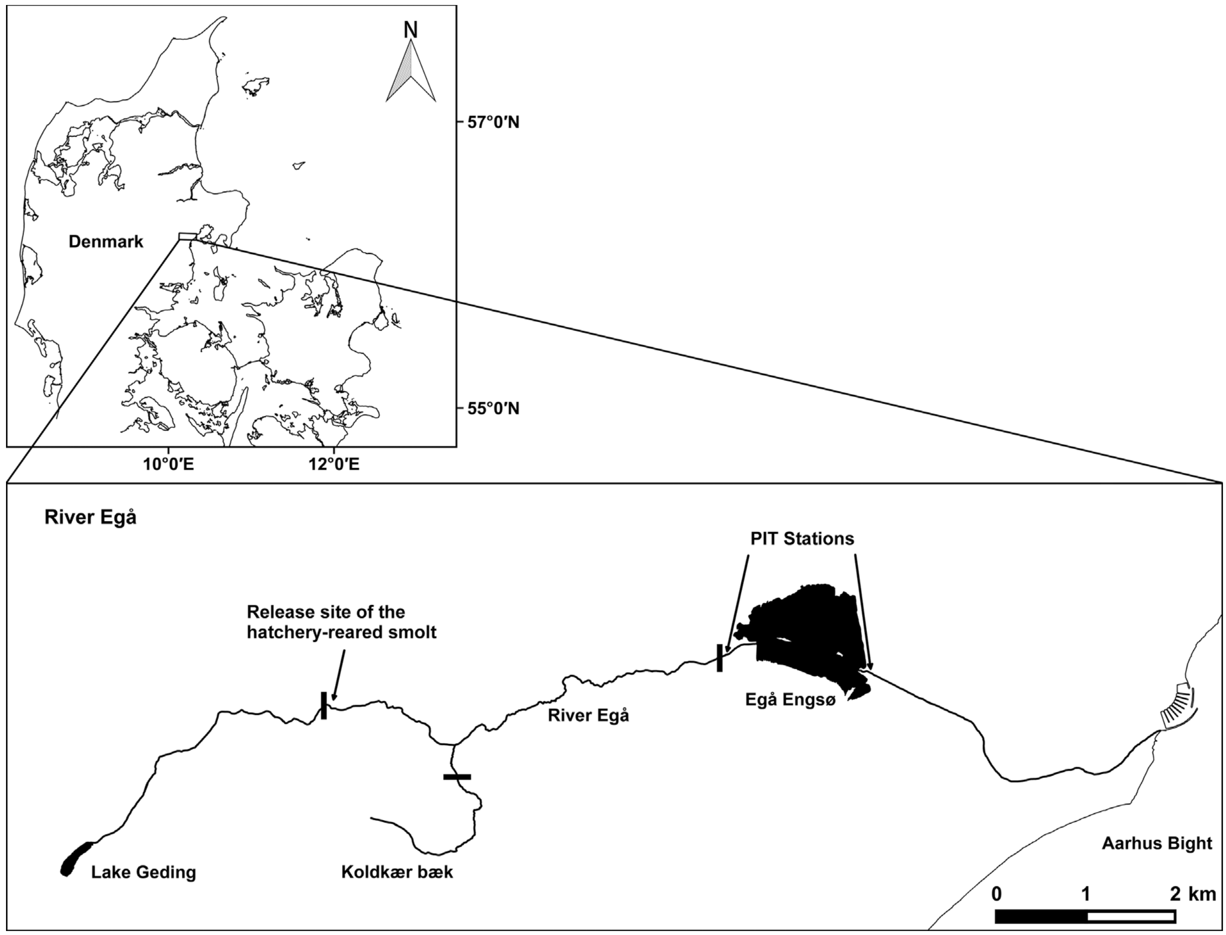

Fig. 1. Overview of the study area. Positions of the PIT-Stations and the release site of the hatchery-reared smolt are indicated by arrows. Black bars delimit the stretch of River Egå that has been electrofished. The distance between the PIT-Stations is 1500 m.

conspecifics and if increased stocking can mitigate the high mortality of wild smolts.

In this study, 1-year old hatchery-reared F1 offspring of wild brown trout were compared with wild fish in the Danish lowland River Egå. Focus was on the passage of the artificial lake Egå Engsø, using passive integrated transponder tags (PIT). This artificial lake was created in 2006 to reduce the nitrogen transport from River Egå to Kattegat Sea. Survival and passage time during the smolt runs of the years 2011, 2012, 2013 and 2016 are analyzed with respect to discharge, water temperature and Julian day of the year (DOY) as a measure of progression of spring. Smolt stocking in systems where lakes are developed for nutrient removal is evaluated.

2. Material and methods

2.1. Study area

Egå Engsø is an artificial lake/wetland established in October 2006 north of the city Aarhus in Denmark (56°13′N, 10°13′ E, Fig. 1). By stopping artificial drainage and building a low weir, a shallow lake with a mean depth of *c.* 0.8 m and a surface area of *c.* 1.12 km^2 emerged. The feeding river, River Egå, has its source *c.* 10 km upstream of Egå Engsø in Lake Geding and drains into Aarhus Bight *c.* 4.1 km downstream of the lake. The annual mean discharge of River Egå into the lake is 0.52 $m^3 s^{-1}$ and lake retention time is 21.9 d (governmental notice about the technical background for the aquatic environment plan for Aarhus bight, 2011; http://svana.dk/media/195290/17-arhusbugt-tekbaggrund011010.pdf, in Danish). Two stations, 250 m upstream of the inlet and 150 m downstream of the outlet provide water level data in 15 min intervals as a proxy for discharge.

2.2. Experimental fish and PIT telemetry

In the years 2011–2013 and 2016, wild brown trout were electrofished in February and/or March in a *c.* 5.5 km long river stretch upstream of the inlet to a sand trap close to Lake Geding and in a *c.* 500 m long stretch of the tributary Koldkær bæk (Fig. 1). Electrofishing was carried out using 500 V pulsed direct current, produced by a 2000 W generator (EU 20i, Honda, Japan). Hatchery fish were 1-year old F1 offspring of wild sea trout from the River Giber Å, located c. 15 km southerly. Prior to tagging, fork length (FL) (± 1 mm) was measured. Passive Integrated Transponder (PIT) tags (Type RI-Trp-RRHP, Texas Instruments, USA; half duplex, 134 kHz, length 23 mm, diameter 3.85 mm, weight 0.6 g in air) were implanted following the procedure described in Schwinn et al. (2016). Wild fish were released close to the location of capture. Hatchery fish were tagged and then transported in oxygenated tanks to the release location, *c.* 4 km downstream of Lake Geding. Exact dates of electrofishing, tagging and release of the experimental fish are given in Table 1. In total, 2973 wild and 1943 hatchery-reared trout were tagged. Lake entering and exiting experimental fish were registered by two arrays of paired swim-through PIT-antennas 300 upstream of the lakes inlet and 20 downstream of the outlet (Fig. 1). The antennas have a range of approximately 50 cm and are configured to use a cycle of 50/50 ms charging/listening time which results in 10 scans per second.

2.3. Handling of data and statistical analysis

A subset of initially 4916 tagged fish was selected for further analysis: Only fish that were recorded at one of the PIT antennas at the inlet