Fisheries Research 165 (2015) 85–95

Contents lists available at ScienceDirect

Fisheries Research

journal homepage: www.elsevier.com/locate/fishres

Differences between wild and reared *Salmo salar* stocks of two northern Baltic Sea rivers

Irma Kallio-Nyberg[a,*], Atso Romakkaniemi[b], Erkki Jokikokko[c], Irma Saloniemi[d], Eero Jutila[e]

[a] Natural Resources Institute Finland, Korsholmanpuistikko 16, FI-65100 Vaasa, Finland
[b] Natural Resources Institute Finland, Paavo Havaksentie 3, FI-90014 University of Oulu, Oulu, Finland
[c] Natural Resources Institute Finland, Laivurintie 6, FI-94450 Keminmaa, Finland
[d] University of Turku, Department of Biology, FI-20014 Turku, Finland
[e] Natural Resources Institute Finland, PO Box 2, FI-00791 Helsinki, Finland

ARTICLE INFO

Article history:
Received 23 June 2014
Received in revised form 21 October 2014
Accepted 26 December 2014
Handling Editor B. Morales-Nin

Keywords:
Atlantic salmon
Natural stock
Smolt release
Recapture rate
Sea migration
Sea age at maturity

ABSTRACT

The phenotypic divergence between natural salmon stocks and the corresponding hatchery-reared stocks was investigated in two Atlantic salmon (*Salmo salar*) populations from the Tornionjoki and Simojoki Rivers, where hatchery reared smolts of local origin were released during the second half of the last century. The reared salmon were larger as smolts and also heavier at sea than wild salmon in both stocks. The recapture rate was highest for wild Tornionjoki salmon (mean 2.8%) and lowest for reared Simojoki salmon (mean 1.2%). During 1999–2008, survival was higher in wild than reared fish, while the overall survival of tagged smolts declined. Survival was close to similar in Tornionjoki and Simojoki salmon when the year, background (wild or reared) and smolt length were taken into account. Migration distances differed between wild and reared stocks. In the second winter at sea, the majority of wild salmon (94–96%) were captured in the southern part of the Baltic Sea, while the reared salmon, especially those of the Simojoki stock, remained closer to their native river in the northern parts of the Baltic. Rearing also decreased the duration of the sea migration before the first maturation in Simojoki salmon, but not in Tornionjoki salmon. Of the wild Simojoki salmon, 64% returned to their home river as multi-sea-winter (MSW) fish compared to 40% of the reared fish. The population and rearing background, but not smolt length, explained the probability of maturing as one-sea-winter instead of MSW fish. Rearing produced 1.60 times more grilse than occurred among wild salmon. The reared salmon showed different life-history patterns from wild fish, and especially in the Simojoki River, the salmon stock as a whole presently deviates from previously documented wild rivers. Even though population sizes appear to be recovering, it may take time before the stocks regain their adaptive potential following the period of collapse and supportive releases.

1. Introduction

Stocks of the Atlantic salmon (*Salmo salar*) show adaptive variation in life history traits (Garcia de Leaniz et al., 2007). In the management of weakened salmon stocks, releases of reared salmon parr and smolts have been seen as a means to enhance the reduced natural stocks (Jutila et al., 2003a; Romakkaniemi et al., 2003; Horreo et al., 2012). The reared fish may, however, present a risk to the natural stocks, as the long-term effects of rearing are difficult to estimate (Fraser et al., 2010; Araki and Schmid, 2010). Reared and released fish are in most cases genetically and phenotypically different from the wild fish population in the recipient water area, even if they originally came from the same common genetic stocks (Koljonen et al., 2002; Saloniemi et al., 2004; Kallio-Nyberg et al., 2011). The goal of supportive stockings is to increase the density of juveniles in the river, and ultimately to increase the number of spawners in the wild. The attainment of these goals may be uncertain. Reared fish may be adapted to the hatchery conditions and show non-adaptive variation in life-history traits and behaviour (Houde et al., 2010; Milot et al., 2012; Hyvärinen and Rodewald, 2013). The phenotypically reared fish may also reduce the fitness of the wild fish population (Hindar et al., 1991; Fraser et al., 2008). There is, however, evidence that fish populations may re-adapt in the wild over some generations (Hendry et al., 2000; Koskinen et al., 2002).

* Corresponding author. Tel.: +358 295 327 678.
E-mail address: irma.kallio-nyberg@luke.fi (I. Kallio-Nyberg).

http://dx.doi.org/10.1016/j.fishres.2014.12.022
0165-7836/

To benefit the population, the reared and released fish should be adapted to the natural conditions and should not diverge phenotypically from the wild fish (Svåsand et al., 1998). However, many studies have documented that reared fish are different from wild fish in the natural environment. Besides their lower marine survival (Jokikokko and Jutila, 2009; Jonsson et al., 1991a, 2003; Saloniemi et al., 2004; Thorstad et al., 2011), hatchery-reared fish often have a younger sea age at maturity (Kallio-Nyberg et al., 2011) and a different sea and return migration pattern (Jonsson et al., 1990; Jutila et al., 2003b; Kallio-Nyberg et al., 2011) or lower lifetime success (Fleming et al., 1997, 2002; McGinnity et al., 2007) compared to wild fish. The divergence of reared fish from wild ones usually increases as a function of the time under rearing (Fleming et al., 1994; Jokikokko et al., 2006; Kallio-Nyberg et al., 2013).

The status of salmon in the Baltic Sea declined from the 1950s to the 1980s, mainly as a consequence of overexploitation and the damming of salmon rivers (Lindroth, 1984; Eriksson and Eriksson, 1993). Due to damming, reared parr and smolts have been released either to entirely compensate for natural reproduction or to support the stock over the period when the natural spawning stock is weakest (Salminen et al., 1995, 2007; Kallio-Nyberg et al., 2006; ICES, 2011). Several stocks have died out in the Baltic Sea and the population size of the remaining natural stocks is often far below the potential level (Romakkaniemi et al., 2003; ICES, 2011).

The aim of this study was to compare the phenotypic diversity in two wild Atlantic salmon stocks of the northern Baltic Sea (Tornionjoki and Simojoki salmon stocks) and their respective reared strains. Both of the stocks were supported by stocking with young salmon of their own genetic origin from the 1980s to the 2000s (Jutila and Pruuki, 1988; Jutila et al., 2003b; Romakkaniemi et al., 2003; Jokikokko and Jutila, 2009). Adaptive phenotypic variation between the wild stocks and differences between the wild and reared stocks were investigated by estimating marine survival, the sea migration pattern and the sea age at maturity. The analyses were based on the tagging and recapture of wild and reared smolts. Previous studies (Säisä et al., 2005) have demonstrated that the wild salmon of the Tornionjoki and Simojoki Rivers genetically differ, even though they are geographically close to each other (Fig. 1).

The impact of the releases of hatchery-reared parr and smolts has been documented through tagging experiments (Romakkaniemi et al., 2003; Jutila et al., 2003a; Jutila and Jokikokko, 2008). In this study, we compared wild and reared smolt groups marked in 1999–2008. The reared smolts were individually tagged in the hatchery before release into the river. In both rivers, wild smolts were tagged in the same years at smolt traps during their seaward migration (Haikonen et al., 2006; Jutila and Jokikokko, 2008).

We assumed that genetically different salmon stocks differ in phenotypic life-history traits and that rearing has caused deviations between wild and reared stocks within the studied rivers. The present wild stocks are likely to display adaptive variation between the stocks, and the variation caused by stocking may be less adaptive. Both stocks have now partly recovered and they no longer require supportive releases (Jutila et al., 2003a; Romakkaniemi, 2008; Kallio-Nyberg et al., 2013). The importance and effect of the releases on the recovery of the stocks is discussed.

2. Materials and methods

2.1. Salmon stocks

The Tornionjoki River (mouth 65°51.0′N, 24°09.5′E) is the largest unregulated Baltic river and flows along the border between Sweden and Finland into the Bothnian Bay, the northernmost part of the Baltic Sea (Romakkaniemi, 2008) (Fig. 1). The estuary of the Simojoki River (65°38′N, 25°00′E) is located about 50 km to the southeast of the Tornionjoki River estuary.

The decline in the natural salmon stocks of these rivers began in the 1950s and 1960s. The status was weakest in the late 1980s, when the Tornionjoki annually produced 50,000–100,000 wild smolts and the Simojoki only a few thousand smolts (Jutila et al., 2003a; Romakkaniemi et al., 2003). Thus, the natural salmon stock, especially in the Simojoki River, was close to extinction (Jutila et al., 2003a). Regular supportive stocking of reared salmon juveniles began in 1979 in the Tornionjoki and in 1984 in the Simojoki River. Presently, the Tornionjoki River produces 1–1.5 million smolts/year and Simojoki 30,000–40,000 smolts/year (ICES, 2013).

The main reason for the decline in natural production was overfishing in the sea and the consequent lack of spawners in the rivers (Jutila and Pruuki, 1988). Because the regulation of salmon fishing was not effective enough to prevent the decline in the natural salmon stocks, it became necessary to produce reared parr and smolts for release (Jutila and Pruuki, 1988; Romakkaniemi, 2008). Together with supportive stocking, habitat restoration and fishing regulation improved the status of stocks, and large-scale supportive stocking was ended in both rivers during the first years of the 2000s. Since then, only small-scale stocking has been continued to monitor tagged smolts.

Bothnian Bay salmon migrate southwards to feed (Carlin, 1969; Kallio-Nyberg et al., 1999; Jutila et al., 2003b). The post-smolts first reach the nearest feeding area, the Bothnian Sea, in the late summer (Ikonen, 2006; Jutila et al., 2009). From there, most of the salmon continue their migration to the Main Basin of the Baltic Sea. When salmon mature one to several years later, they migrate back along the coastal waters of the Gulf of Bothnia to their home river (Siira et al., 2006). Adult salmon caught in the Bothnian Bay during the spawning migration from spring to autumn are returning salmon (Jutila et al., 2003b; Kallio-Nyberg et al., 2013). Over 85% of returning salmon are undergoing their first spawning migration (Romakkaniemi et al., 2003; Jokikokko and Jutila, 2005).

Altogether, 13,624 wild Simojoki and 43,697 wild Tornionjoki smolts were tagged during 1999–2008 (Table 1). The wild smolts were marked with individual Carlin tags at the smolt traps in May and June during the seaward migration (Jutila and Jokikokko, 2008). The smolt length of tagged fish was concurrently measured. In the same years, a total of 15,893 Simojoki and 26,862 Tornionjoki hatchery-reared salmon smolts were individually tagged with Carlin tags and released into the rivers (Table 1). The reared smolts were tagged at the hatcheries and the smolt length and weight were concurrently recorded. The measured smolt length at tagging was approximately the same as the release length, because smolts do not grow in the winter and spring months, when the water temperature is close to 0 °C.

The reared smolts were produced using wild parents caught from the natural environment or the parents of the hatchery-maintained broodstocks. Because information on the parental background was not available for the all reared smolts, the parental background was not taken into account in the analysis. The tags were mainly returned to the Tagging Office of Finnish Game and Fisheries Research Institute by professional fishermen operating at sea, but a minor proportion were from fish captured in river fishing. Together with the tag, information on the recapture time (date, year), recapture site (ICES subdivision) and fish catch size was usually obtained.

2.2. Statistical methods

The mean smolt length and size at capture were calculated from individual recapture data and the differences were tested using the *t*-test (SAS TTEST; SAS Institute, 2012) after checking for outliers and normality. Here and in other analyses we followed