Fisheries Research 102 (2010) 69–79

Contents lists available at ScienceDirect

Fisheries Research

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

Research article

Can the lost migratory *Salmo trutta* stocks be compensated with resident trout stocks in coastal rivers?

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ARTICLE INFO

Article history:
Received 3 July 2009
Received in revised form 16 October 2009
Accepted 19 October 2009

Keywords:
Salmo trutta
Baltic Sea
Migration pattern
Stocking
Recapture rate
Genetic diversity

ABSTRACT

The migration patterns and recapture rates of migratory and resident trout stocks (*Salmo trutta*) were compared by tagging and releasing hatchery-reared smolts of both migratory types in the same coastal rivers, Merikarvianjoki (river A) and Viantienjoki (river B), flowing into the Gulf of Bothnia, the Baltic Sea. There is no longer native trout production in these open rivers. The resident trout stocks originated from closed streams. The resident Karvianjoki ($R1_{-A}$) trout released in river A remained resident more often (70%) than the migratory Isojoki trout ($M1_{-A}$) (16%) ($P < 0.001$). In contrast, the migration behaviour of the resident Ohtaoja trout ($R2_{-B}$) and migratory Iijoki trout ($M2_{-B}$) and their crossed offspring, released in river B, did not differ; about 30% of the recaptures from each genetic group were caught in the river and the rest in the sea. A few fish from both migratory types had a long feeding migration into the main basin of the Baltic Sea. The growth rate to catch size did not differ between the resident and migratory trout ($R1_{-A}/M1_{-A}$ or $R2_{-B}/M2_{-B}$). The migratory M1 trout had somewhat better survival and gave a higher catch than the resident R1 trout ($P < 0.001$). The crossed trout had better survival (2.2%) than fish from the pure trout stocks (1.1%) ($P < 0.05$). According to their genetic distances, the sampled stocks were grouped into three groups corresponding to the river systems from which they originated rather than according to their life history type or migration behaviour. In both stock pairs the migratory type had a somewhat greater genetic diversity (R2/M2 richness: 4.8/5.5 and R1/M1 richness: 3.8/4.4), which indicates larger effective population sizes for the migratory stocks. The experiments with the resident trout stocks were promising from the enhancement point of view, as some of the resident trout migrated to feed in the sea, like the migratory trout. The compensation of lost migratory trout stocks is a case-specific and long process, but if possible it might be useful to exploit the resident trout still living in the upper reaches and headwaters of coastal rivers.

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1. Introduction

The brown trout (*Salmo trutta* L.) uses a large ecological niche (Klemetsen et al., 2003). It spawns in running water, feeds as a resident fish in its home stream or leaves the stream and undergoes a feeding migration in the sea or in freshwater before returning to its home site to spawn (Skrochowska, 1969; Jonsson, 1989; Jonsson et al., 2001). These migratory, sea-run (*S. trutta m. trutta*) and resident (*S. trutta m. fario*) morphs, forms or life history types may live in the same water system and they can be genetically isolated or belong to the same population (Jonsson, 1985; Hansen and Mensberg, 1998; Skaala and Nævdal, 1989; Jutila et al., 1998; Pettersson et al., 2001). In brown trout, the migratory and resident types often coexist in the same population. The trout may mature as resident fish or they can leave freshwater and migrate to the sea (Jonsson, 1985; Dellefors and Faremo, 1988; Jonsson and Jonsson, 2006). Among individuals, the decision to migrate is controlled by both genetic and environmental factors (Jonsson, 1982; Giger et al., 2006; Olsson et al., 2006; Wysujack et al., 2009). Due to homing to the natal site for reproduction, the geographical distance between spawning sites within a stream may maintain genetic differentiation among trout stocks (Hindar et al., 1991; Cross et al., 1992).

In the Baltic Sea area, trout stocks commonly occur in nearly all of its drainage basins (Christensen and Larsson, 1979; Kangur and Paaver, 1988; Hansen and Mensberg, 1998; Koljonen and Kallio-Nyberg, 1991). However, many trout stocks have been lost and the present stocks are threatened because of human-induced environmental changes in streams, such as the damming of rapids, damage to nursery areas or overexploitation (Jutila et al.,

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doi:10.1016/j.fishres.2009.10.011

2006; Was and Wenne, 2002; Heinimaa et al., 2007). For example, the migratory stocks in Finnish coastal rivers have largely been lost. Earlier, Finnish rivers supported at least 47 migratory trout stocks (Toivonen and Ikonen, 1980), but less than 10 declining or endangered native migratory trout stocks currently remain, which are assumed to be indigenous (Kaukoranta et al., 2000; Kallio-Nyberg et al., 2003). Five of these sea trout stocks are maintained as hatchery stocks in brood-stock breeding. At least two of them have been raised from rather few parents captured over 30 years ago without any later supplementation from natural spawning. Thus, their effective population sizes are not very large and they may have lost some of their adaptive genetic potential. However, about 30 rivers flowing into the Baltic Sea in Finland still support resident trout stocks in the upper reaches or in the headwaters (Kaukoranta et al., 2000).

During the last few decades, several fishways have been constructed in Finnish rivers, once again allowing migration between the sea and the upper reaches in many of the former sea trout rivers. Implementation of the EU Water Framework Directive will probably continue to increase the pressure to improve migration possibilities within river systems, such as by building new fishways. Therefore, there is a need to consider how existing resident trout populations could be utilised in the rehabilitation of empty coastal rivers.

In the management of coastal rivers, migratory trout are commonly rated as more preferable targets for fishing due to their fast growth rate and potentially larger catch size than resident forms. Because the resident and migratory stocks may coexist in the same water course, they are often also found to be genetically similar, or nearly similar, when measured with neutral markers (Hansen and Mensberg, 1998). As trout have a large behavioural plasticity (Walker, 2006), it is possible that migratory trout could evolve from resident trout or vice versa. At least new sea trout and Atlantic salmon stocks have arisen as a consequence of recolonization (Knutsen et al., 2001; Vasemägi et al., 2001). The growth rate of trout is known to largely depend on environmental conditions, as shown in a transplantation experiment with resident and anadromous fish (Jonsson et al., 1995).

Earlier studies have demonstrated that non-migratory trout have the potential to evolve into migratory trout in a new environment (Skrochowska, 1969; Jonsson et al., 1995). Based on this our aim was to compare the success of resident and migratory trout when stocked in the same empty coastal rivers in order to determine whether the native resident trout stocks might have potential to evolve into fast-growing migratory trout. In the present study the migration behaviour and growth of resident and migratory trout stocks were compared in two rivers flowing into the Gulf of Bothnia, the northern part of the Baltic Sea. These rivers were the Merikarvianjoki (river A) (native resident Karvianjoki trout ($R1_{-A}$) and transplanted, migratory Isojoki trout ($M1_{-A}$)) and the Viantienjoki (river B) (transplanted, non-native resident Ohtaoja ($R2_{-B}$) and non-native migratory Iijoki stock ($M2_{-B}$)). Hatchery-tagged groups of migratory and resident trout were released at the same site into the river with a free migration route to the sea. The ultimate goal was to identify new migratory trout stocks for empty coastal rivers. If resident trout released into the lower part of the river would also show the ability to migrate, they might be better suited for enhancement stocking than the few present migratory trout stocks. The genetic variation and isolation of these four trout stocks were additionally examined. Stocking experiments were also used to assess whether the migration patterns are primarily determined by genetic or environmental factors. In addition, the possibilities and consequences of transplantation and hybridization are discussed.

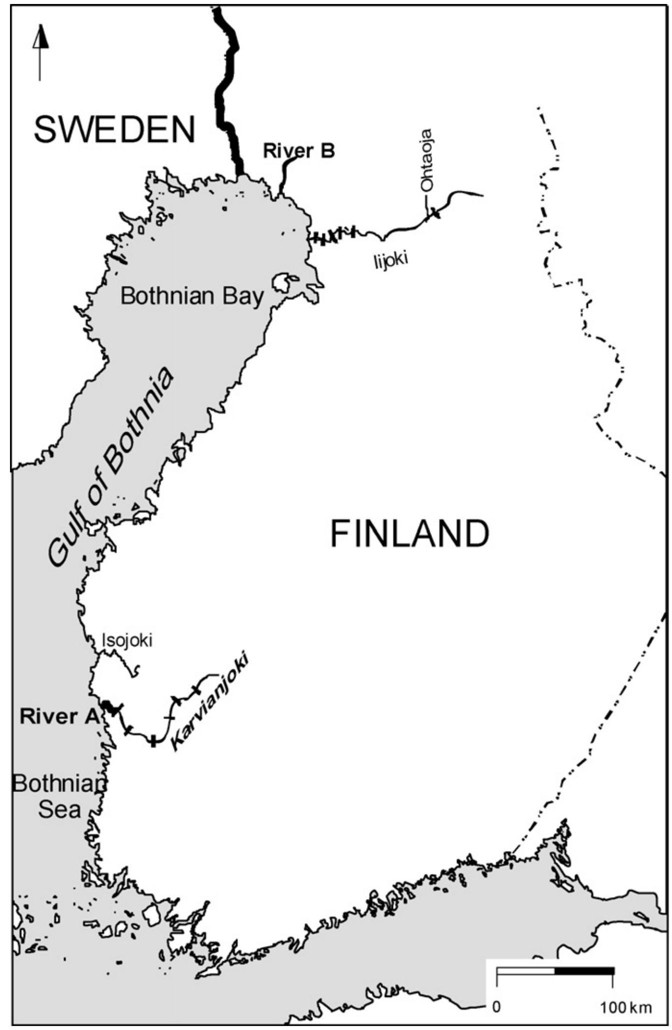

Fig. 1. The Gulf of Bothnia of the Baltic Sea and the location of some rivers. The trout were stocked in rivers A (Merikarvianjoki) and B (Viantienjoki). The migratory trout originated from the Iijoki and Isojoki rivers and the resident trout from the Karvianjoki and Ohtaoja (a tributary of the Iijoki) rivers. The dams in the Karvianjoki and Iijoki rivers are indicated.

2. Materials and methods

2.1. Tagged trout groups

Two resident and two migratory brown trout stocks were separately compared in the Merikarvianjoki (river A, 61°50′N, 21°30′E) and Viantienjoki (river B, 65°40′N, 24°54′E) (Fig. 1). Hatchery-reared groups of resident Karvianjoki trout ($R1_{-A}$) originating from the headwater streams of river A and migratory Isojoki trout ($M1_{-A}$) from the neighbouring river were stocked in river A in 2001–2002. Similarly, resident Ohtaoja ($R2_{-B}$) and migratory Iijoki trout ($M2_{-B}$), both originating from the Iijoki river system, were stocked in river B in 2004–2005. In addition, some earlier and later tagging experiments with the R2 (1986–1988) and M1 trout (2003–2006) were included in the analysis (Table 1). All trout groups were tagged under anaesthesia (MS-222) in the hatchery in spring within one or two months before release and none of them were intentionally handled in different way.

River A (Merikarvianjoki, length 26 km, width about 30 m, mean discharge 15.5 $m^3 s^{-1}$), flowing into the southern part of the Gulf of Bothnia in the Bothnian Sea, is a former sea trout river (Hurme, 1962), and it has still been rated as a potential river for migratory trout (Kallio-Nyberg et al., 2003). River A is the largest of the three

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