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# Spatial and temporal migration of wild Atlantic salmon smolts determined from a video camera array in the sub-Arctic River Tana

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**Abstract**

Spatial and temporal migratory behaviour of wild Atlantic salmon smolt (*Salmo salar* L.) was investigated at the River Utsjoki, a tributary of the sub-Arctic River Tana, using submerged video cameras that covered the entire water column across the river. The matrix of cameras provided information on the exact time, position in water column, and swimming direction of individual smolts. The smolt migration started in the beginning of June and ended in the middle of July, i.e. during the period of midnight sun. In contrast to most other studies, smolts migrated all day, with a peak from 07:00 to 10:00 h. Hours of sunshine and change in water level explained 55% of day-to-day variation in numbers of migrating smolts. Most smolts migrated actively (head first) in lower part of the water column with only 4% observed in the upper 30 cm surface water layer.


*Keywords:* Atlantic salmon smolt; Migratory behaviour; Sub-Arctic; Tana river

## 1. Introduction

The anadromous Atlantic salmon, *Salmo salar* L., is widespread in the North Atlantic (Mills, 1979, 1989; Crisp, 2000). Throughout its distribution, salmon displays considerable plasticity in various life history traits including variability in migration characteristics and run timing (e.g. see Klemetsen et al., 2003). Recent research has indicated that the smolt migration in Arctic systems differs from those in more studied temperate areas (Veselov et al., 1998). Midnight sun and hence bright nights are characteristic of the Arctic summer and may influence the behaviour of smolts during their seaward migration.

Timing of smoltification and sea migration are environmentally controlled by specific geographical

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and hydrological characters (Heggberget et al., 1993; Veselov et al., 1998) of which water discharge and temperature have been identified as several of the most important although the proximate factors triggering migration may vary between streams (Mills, 1964; Österdahl, 1969; Solomon, 1978b; Jonsson and Ruud-Hansen, 1985; Jonsson, 1991; Hvidsten et al., 1995; McCormick et al., 1998). Smoltification is followed by a seaward feeding migration. Synchrony of ocean temperatures and feeding opportunities with the timing of smolt migration from rivers is crucial (Power, 1969; Hvidsten et al., 1995; Hansen, 2000) such that smolt attempt to match their sea migration with ocean conditions to ensure optimal chance for survival. The peak smolt migration in Norwegian rivers corresponds with the seawater temperatures reaching 8 °C in spring and early summer, with migration time later in more northern latitudes (Hvidsten et al., 1998).

During the seaward migration predation on smolts from piscivorous fish and birds is a constant threat and predation pressure is expected to have a strong selective effect on the behaviour of migrating smolts (Reitan et al., 1987; Wood, 1987; Feltham, 1995; Spicer et al., 1995; Mather, 1998). Nocturnal migration of smolts is often reported in temperate areas, where the nights are dark (Thorpe and Morgan, 1978; Solomon, 1982; Youngson et al., 1983; Hansen and Jonsson, 1985; Hvidsten et al., 1995; Aarestrup et al., 2002), and might be a strategy to prevent or minimize predation by sight-feeding predators (Solomon, 1982). In some Arctic rivers, however, diurnal (daytime) migration has also been reported (Veselov et al., 1998; Carlsen et al., 2004). Based on experimental studies, it has been shown that juvenile Atlantic salmon change from migrating at night to moving during the daytime, when water temperatures exceed 8 °C (Fraser et al., 1993). The latter authors suggest that rising water temperatures may increase the ability of smolts to avoid endothermic predators such as birds, and that diurnal migration increases at high water temperatures.

In the present study the spatial and temporal migratory behaviour of wild Atlantic salmon smolts from the River Utsjoki, a tributary to the sub-Arctic River Tana, was examined. By use of an array of submerged video cameras, the exact time, position in water column, and swimming direction of each individual smolt were observed without directly influencing the behaviour of the smolts. Observations were examined in relation to water level, water temperature, light intensity and potential predatory influences, and discussed in the context of results from previous investigations.

## 2. Materials and methods

### 2.1. Study area

The sub-Arctic River Tana (70°N, 28°E), drains into Tana Fjord and hence to the Barents Sea in northern Europe. It is one of the northernmost Atlantic salmon rivers in the world and forms the border between the northernmost part of Finnish Lapland and Northern Norway (Fig. 1). It is a seventh order river with catchment area of 16.386 km$^2$ (Erkinaro, 1997) and about 1000 km of different stretches of the system are accessible to ascending salmon (Niemelä et al., 2000). The watercourse probably supports the largest wild Atlantic salmon populations in the world, with annual in-river catches between 80 and 250 tonnes (Niemelä, 2004). Smolt ages vary between 2 and 7 years, but most migrate at 3–5 years of age (Erkinaro, 1997).

The River Utsjoki (length 66 km, a sixth order river, drainage area 1652 km$^2$) is the largest tributary on the Finnish side of the River Tana (Erkinaro, 1995) (Fig. 1). The distance from the mouth of the River Utsjoki to the Tana estuary is 106 km (Mansikkaniemi, 1973). The oligotrophic River Utsjoki (Traaen and Huru, 1994) flows through a deep mountain valley and is characterised by its heterogeneous habitat with alternating river stretches, pools and a large number (>15) of accessible lakes for salmon. Salmon can migrate about 40 km upstream in the Utsjoki main stem (Erkinaro, 1997). The bottom varies from sand and gravel, to cobble (7–25 cm). Spring ice break-up is normally in the middle of May and the river usually freezes in October. In 2002, the river was open by 29 April.

The fish fauna in the running waters of the river Utsjoki is diverse. In addition to Atlantic salmon which dominates the fluvial habitats (Niemelä et al., 1999) 10 fish species are present (Pihlaja et al., 1998). The goosander (*Mergus merganser* L.) and the red-breasted merganser (*Mergus serrator* L.), both reported to be effective predators on salmon smolt (Wood, 1987; Feltham, 1995), nest along the River Tana system (Aass, 1956; Svenning et al., 2005). In the River Utsjoki, goosanders were observed hunting the smolts by