Migratory behaviour and survival rates of wild northern Atlantic salmon (*Salmo salar*) post-smolts: effects of environmental factors

J. G. Davidsen[1]*, A. H. Rikardsen[1], E. Halttunen[1], E. B. Thorstad[2], F. Økland[2], B.H. Letcher[3], J. Skarðhamar[1] and T. F. Næsje[2]

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Introduction

Overall, there is a lack of information on the early ocean migration of Atlantic salmon (*S. salar* L.). This is especially true for northern *S. salar* populations which do not have experienced the same reduction, as the more southern populations. Given the potential importance of the initial life-history stage of post-smolts at sea to overall marine survival, the focus of this study was to examine the survival and migratory speeds of northern smolts and post-smolts during i) final within-river migration, ii) sea entry, and iii) fjord migration. The observed fish behaviour was correlated with the tidal cycle, day and night periods, fjord currents and wind speeds and directions.

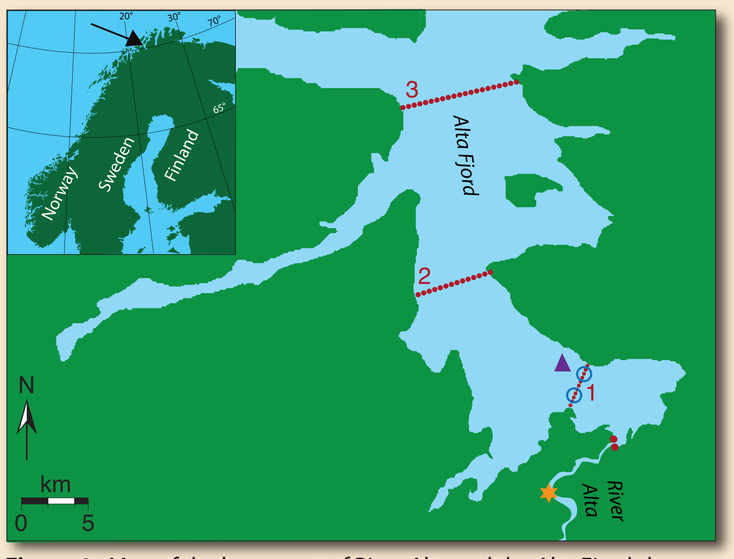
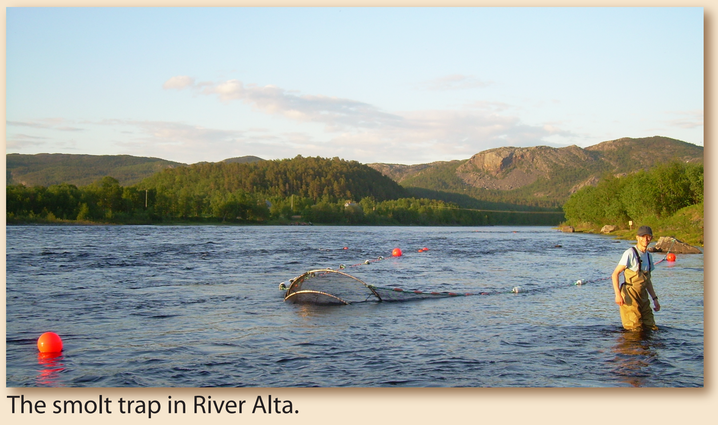


Figure 1. Map of the lower part of River Alta and the Alta Fjord showing the release site (✸), the two ALSs in the river mouth (•), the three ALS arrays in the fjord (••••), the two current meters in the first ALS array (○) and the weather station (▲).

Material and methods

In 2007, 120 wild smolts were caught in a smolt trap 11 km upstream the Alta River, northern Norway, and tagged with individually coded acoustic transmitters (Thelma AS, Norway, model LP-7.3). Two automatic listening stations (ALS) (Vemco INC, Canada, model VR2) were deployed in the river mouth. Three ALS arrays were deployed across the fjord at 4 km, 17 km and 31 km from the river mouth (Fig. 1). Environmental variables (temperature, salinity, tidal cycle, light intensity, water current and wind speed and direction) were recorded in the fjord.



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Results

Survival:

- 75% (95% CL: 63–89%) of the post-smolts were estimated to survive during the first 17 km of the fjord migration (Fig. 2).
- Survival rates did not differ in the different parts of the fjord.
- Post-smolts entering the sea at low tide (91%) had a higher survival rate than post-smolts entering at high tide (67%).

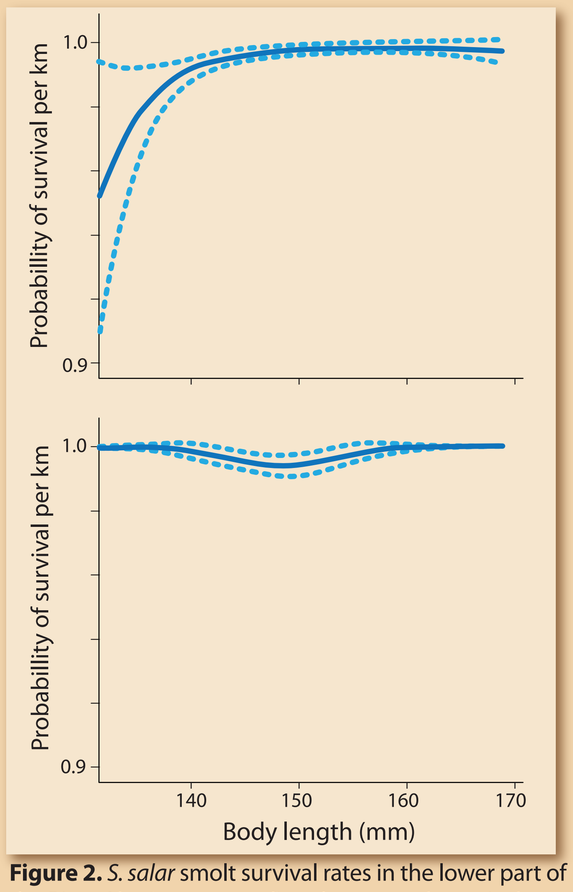

Figure 2. *S. salar* smolt survival rates in the lower part of the River Alta (upper panel) and post-smolt survival rates in the Alta Fjord (lower panel) as a function of body length. Dotted lines show 95% confidence intervals.

Migratory speed:

- Mean migration time from the river mouth to the last array 31 km along the fjord was 36 h (range: 11–165 h, S.D. = 32).
- Migratory speed was slower from the river mouth to the first array (1.8 bl sec^{-1}) than from the first to the second array (3.0 bl sec^{-1}) (*t*-test, $n = 59$, $P = 0.005$).
- There was no difference in migratory speed from the first to the second (3.0 bl sec^{-1}) and from the second to the third array (3.1 bl sec^{-1}) (*t*-test, $n = 48$, $P = 0.90$).

Effects of environmental factors on the migration patterns:

- 70% of the post-smolts entered the sea at high or ebbing tide. However, the post-smolts did not seem to continue following an outgoing tidal current at the time they passed the first ALS array four km from the river mouth, since more post-smolts passed the array on ingoing currents (Fig. 3).
- More smolts entered the fjord from the river by night (66%, 2000–0800 hours). There was no diurnal variation in the timing of migration in the catches in the smolt trap in the river, nor in the time of arrival at the three ALS arrays in the fjord.
- There was a significant relationship between wind direction and horizontal distribution of the post-smolts in the second ALS array.

Figure 3. Water current velocity at 3 m depth at the north-eastern (upper panel) and south-western (lower panel) side of the Alta Fjord at the first ALS array. The current velocity components were computed for the dominating current directions. Positive values are the velocity components towards the fjord head and negative values are towards the fjord mouth. ● indicates time at post-smolt passage.

Discussion

Survival rates

The estimated post-smolt survival rate of 75% over the first 17 km through the estuary and fjord indicates that post-smolts in the northern Alta Fjord had a relatively high mortality during the first days after sea entry. Therefore, these results provide further support for the general belief that the period of first migration to sea is critical in the overall survival of salmon at sea.

Migratory speed

The migratory speed out of the fjord was slightly higher than in studies from more southern areas. There was a large individual variation in migratory speeds, which may indicate that the individuals encountered different current speeds and directions at sea entry. Alternatively, this may be an indication of individual behaviour. The fact that the mean migratory speed was always higher than the measured current velocities indicates that the post-smolts had an active swimming behaviour.

Effects of environmental factors on the migration

Swimming in outgoing tide currents speeds up the migration during the first hours through the estuary. However, the complex current system in the inner part of the Alta Fjord may complicate the post-smolts outward migration, so they only were able to take advantage of an outgoing tidal current during a short period after sea entry. It may, therefore, be that the reason for the observed higher survival rate of post-smolts entering the sea at low tide (91%) than at high tide (67%) was that post-smolts entering the sea at high tide in this case had no, or only an initial, advantage by doing so.

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The significant relationship between wind direction and horizontal distribution of the post-smolts in the second ALS array shows that the migration routes in this part of the fjord were influenced by the wind-induced surface currents.

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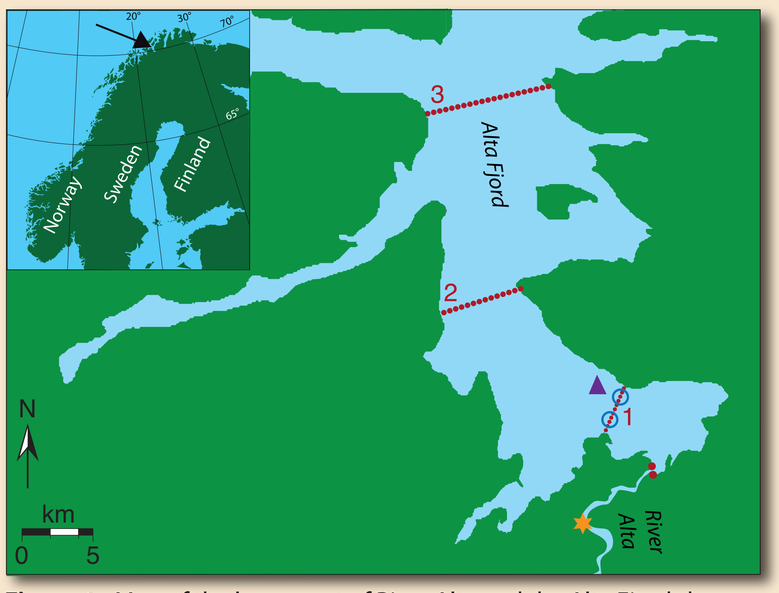

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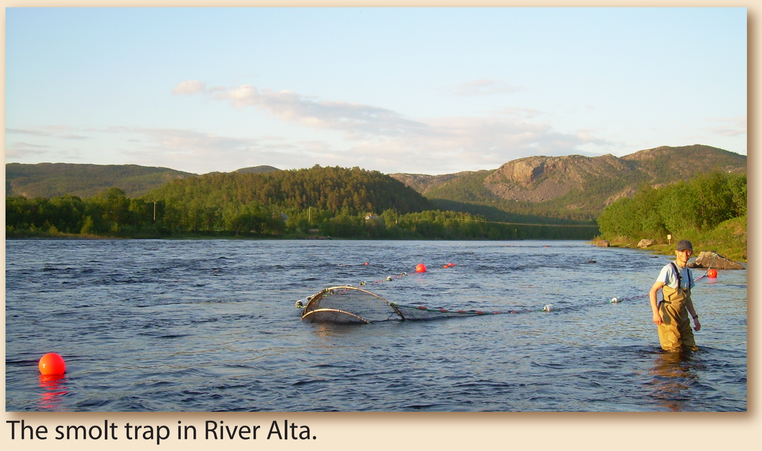

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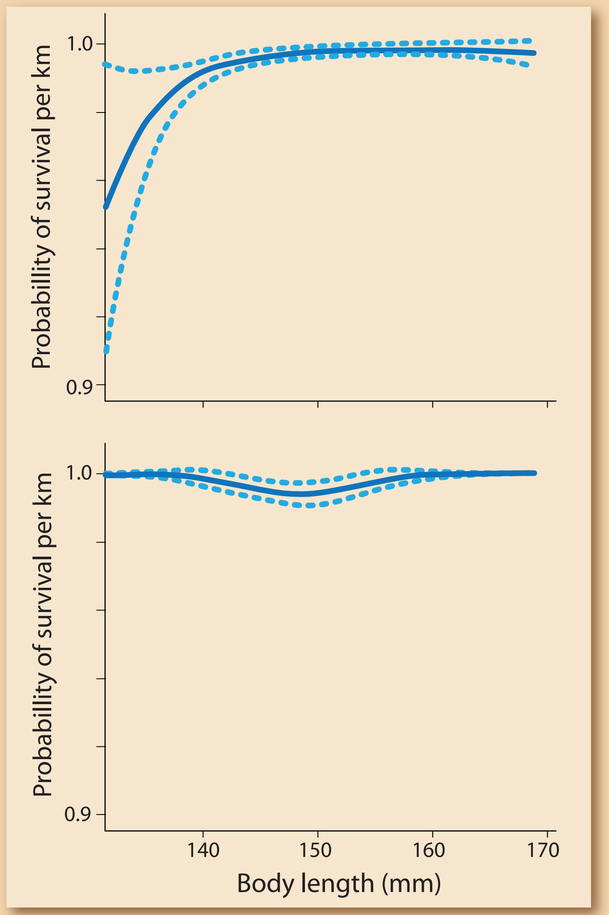

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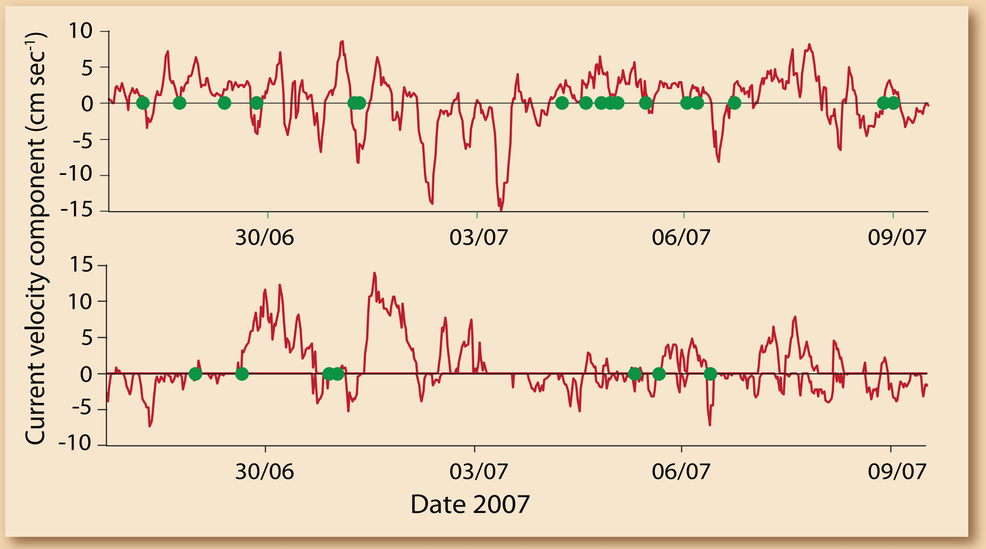

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Layout: Freyste Strand, UoT