Migrating together improves Atlantic salmon (*Salmo salar*) smolt survival

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Introduction

- Despite high mortality risk, juvenile *S. salar*, termed smolts, migrate from freshwater to sea.
- Smolts typically migrate in spring[1] and move at night[2], but their movements may also be more intricately synchronised[2,3].
- As collective behaviour reduces predation risk[4], synchronisation may improve survival[5], but this is untested in wild *S. salar*.

Aims: 1) Are smolt movements nocturnal? 2) Do smolts move in clusters? 3) Does synchronisation improve survival?

Methods

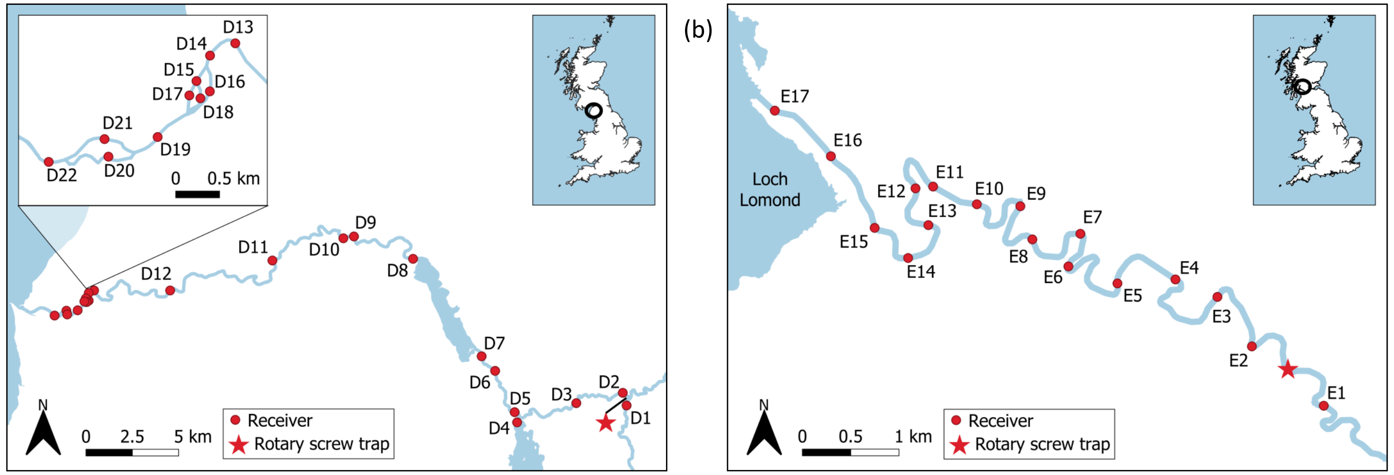

Figure 1 - (a) Derwent and (b) Endrick study sites. Apart from 57 smolts released at D10, tagged smolts were released at the rotary screw traps.

- Across two sites (Fig. 1), 248 acoustic-tagged (Innovasea V7) *S. salar* smolts were tracked with 39 hydrophone receivers.

1) At every receiver that detected fish (n = 38), the null hypothesis of uniform diel movement times was tested with a Rayleigh test, and movements were classed as nocturnal if their mean time was later than the receiver's sunset time.
2) At 17 receivers that detected > 30 fish, time intervals between smolts were compared with those calculated from 1000 Monte Carlo simulations[2]. Randomisations within days and hours respectively tested for loose and tight clusters.
3) At each site, survival was modelled (binomial GLM) as a function of four co-migrant density proxies (see results), fork length and tagging date. Fish detected at or below D7 (66 survived/93 released at trap) or E17 (75/98) were survivors.

Results

1) Movements were nocturnal (Rayleigh test, $p < 0.05$) at 63% of receivers (Fig. 2).
2) Intervals between moving smolts were shorter (1st or 10th percentile, < 5% sim. < obs.) or less even (H regularity index[2], < 5% sim. < obs.) than expected at 82% of receivers when movements were randomised within days, and at 12% when randomised within hours.
3) In the Derwent, for a unit increase in rotary screw trap catch the day after tagging, the odds of survival to D7 increased by 0.3% (LRT: $\chi^2 = 6.071$, df = 1, $p = 0.014$). No other co-migrant density proxy (trap catch day before tagging, day of tagging and five day rolling average catch) affected survival.

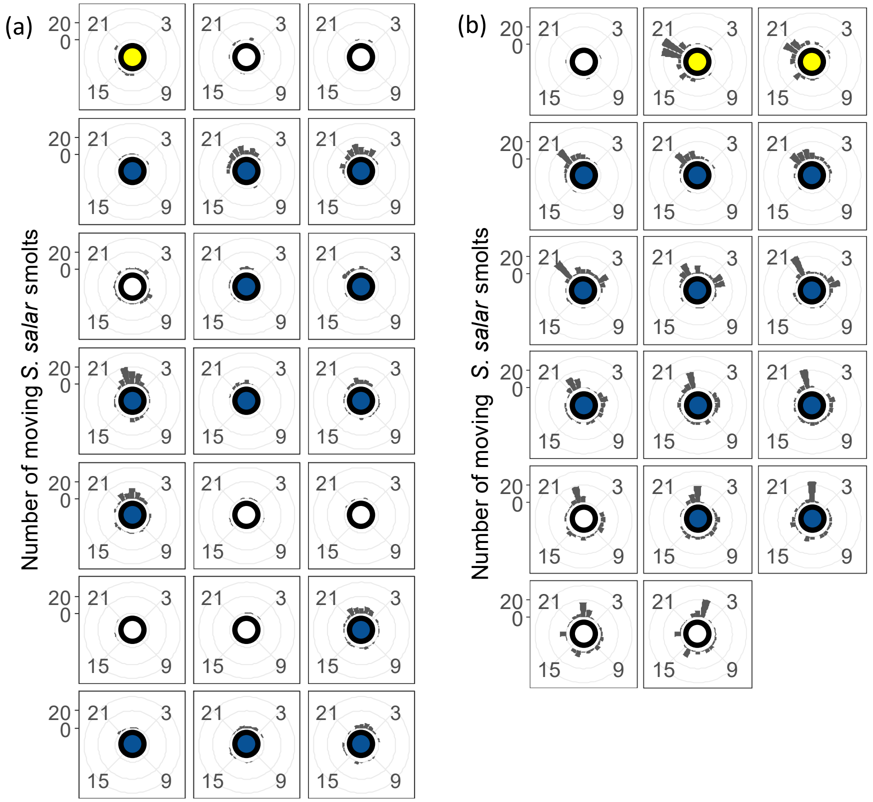

Figure 2 (right) - (a) Derwent and (b) Endrick diel timing. Panels are receivers in downstream order from top left. Bars are hourly moving smolt frequencies (3 = 3am, 15 = 3pm). Blue, yellow and white dots are nocturnal, diurnal and uniformly-distributed movements.

Conclusions

- The strong evidence of nocturnal movement reflects the likely anti-predator benefit of moving in darkness[2].
- Significant clustering within days but not within hours indicates tagged smolts were loosely but not tightly clustered. However, the maximum number of intervals (ni) was 89, and ni > 300 may be needed to identify tighter clustering[2].
- The positive effect of co-migrant density on survival supports the hypothesis that synchronised migration is adaptive.

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References

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