Understanding smolt migration in large regulated rivers: A case study from River Klarälven, Sweden

John J. Piccolo, Larry Greenberg, and Eva Bergman , Karlstad University, Sweden
Bror Jonsson, Norwegian Institute for Nature Research, Norway

Introduction

Wild salmon populations worldwide have declined drastically over the past two centuries, and countless locally-adapted stocks have been extirpated. Today most wild salmon populations in large regulated rivers are at only a fraction of their historic sizes and vast efforts are expended to conserve remaining stocks. Management strategies for complex social-ecological salmonid systems require life-stage specific knowledge of fish populations – smolt production is a key metric of habitat quality and long-term population viability.

Our objective is to develop the first estimate of wild salmon smolt production for Klarälven, Scandinavia's longest river. Klarälven is home to one of the few remaining wild landlocked salmon populations in Europe. Habitat loss, damming, and overfishing had reduced annual wild salmon returns from over 25,000 to below 100 spawners by the 1980s (Piccolo et al. 2012). Today, spawners are collected at the lower-most dam and taken by truck past 8 dams to spawn naturally (Hagelin et al. 2014). Smolt must migrate downstream past all 8 dams through either the turbines or spillgates (Norrgård et al. 2013). Conservation efforts have resulted in increases in wild spawners to over 1200 in recent years. Currently, however, almost nothing is known about the quantity and quality of rearing habitat, with no estimates of wild smolt production. This makes it impossible to assess population trends or to partition mortality between lake and river life stages. We combined a smolt-trapping project with a life-history based model to estimate smolt production and propose simple population viability analyses for various management scenarios.

Materials and methods

Smolt trapping: We trápped smolt from 2012-2014 using a smolt fyke net system of Finnish design, anchored to the river bottom with 4-m long iron poles (Fig 1). The nylon mesh leader arms were 40 m long x 4 m deep on either side, giving broad coverage. These could be raised as needed from the bottom to adjust for increasing discharge. We used streamer tags to conduct mark-recapture estimates of the number of smolt passing the trap

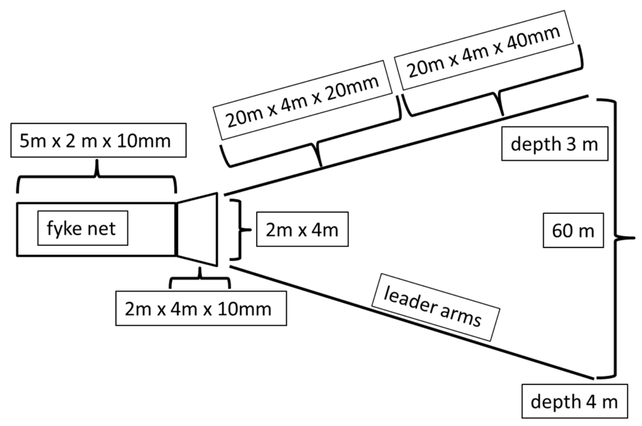


Figure 1. Top-view diagram of the smolt fyke net.

Life-history modeling: We used site-specific data and literature values to model 50-year prognoses of salmon populations and to corroborate smolt production estimates We used to model to investigate potential effects of changes in fish passage efficiencies and habitat restoration measures.

Results

Smolt trapping

The fyke net had very high average capture efficiencies (~10-20%) which is particularly important for Atlantic salmon because run sizes are typically much smaller than are those for Pacific salmon. We were able to clearly demark the duration of the prolonged run period from 1 May-31 July 2013 and 2014 (Fig. 2). We needed to stop fishing during peak discharge, and likely missed important portions of the run during this time. Thus, we estimate the minimum number of smolt for these years. We use these estimates to calibrate the life history model below. Actual run sizes are likely to be considerably higher if large numbers of smolt migrate with peak discharge.

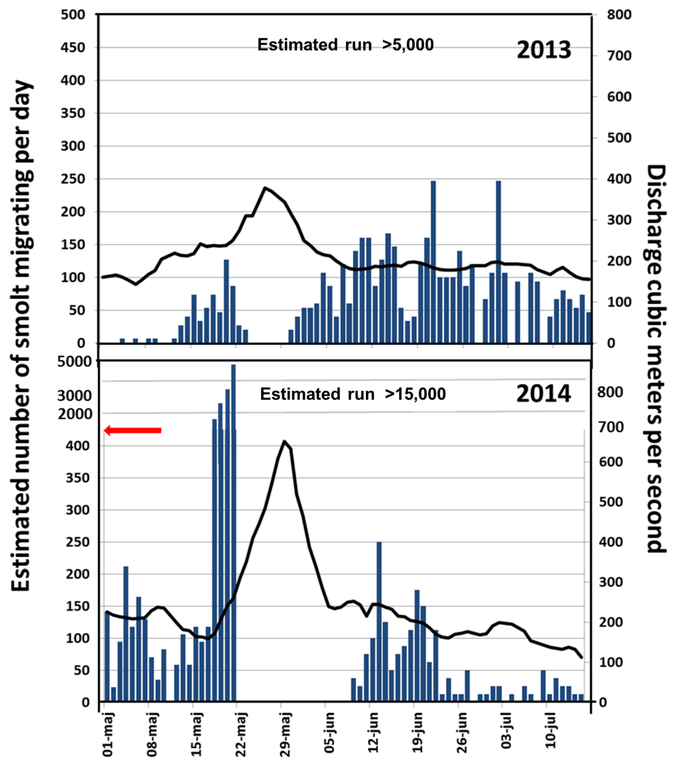
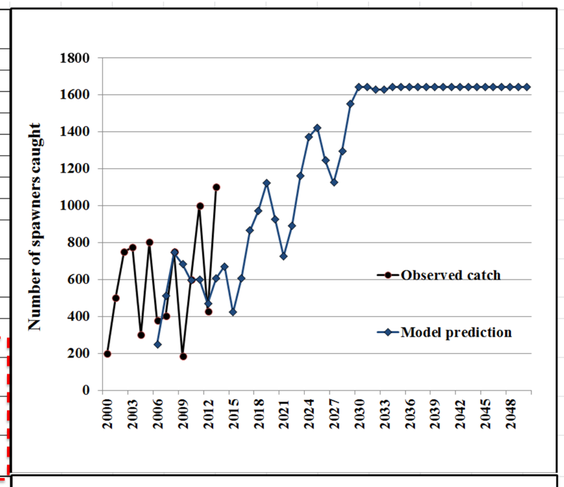


Figure 2. Estimated daily smolt migration 2013 and 2014. The open space in May of both years are days when we were unable to fish because of discharge (black line)

Parameter	Value
Mean weight female	3,7
Number of eggs per kg	1350
Survival egg to fry	0,1
Survial 0+ to 1+	0,66
Survial 1+ to 2+	0,66
Percent 2+ smolt	0,5
Survival 2+ to 3+	0,66
Max. smolt production	114000
Smolt migration survival	0,3
Smolt-adult survival	0,3
Adult trap efficiency	0,8
Number of smolt 2013 (model)	22059
Nmber of smolt 2013 (trap estimate)	>5000
Number of smolt 2014 (model)	62000
Number of smolt 2014 (trap estimate)	>15000



Parameter	Value
Mean weight female	3,7
Number of eggs per kg	1350
Survival egg to fry	0,05
Survial 0+ to 1+	0,66
Survial 1+ to 2+	0,66
Percent 2+ smolt	0,5
Survival 2+ to 3+	0,66
Max. smolt production	114000
Smolt migration survival	0,7
Smolt-adult survival	0,3
Adult trap efficiency	0,8
Number of smolt 2013 (model)	11030
Nmber of smolt 2013 (trap estimate)	>5000
Number of smolt 2014 (model)	31000
Number of smolt 2014 (trap estimate)	>15000

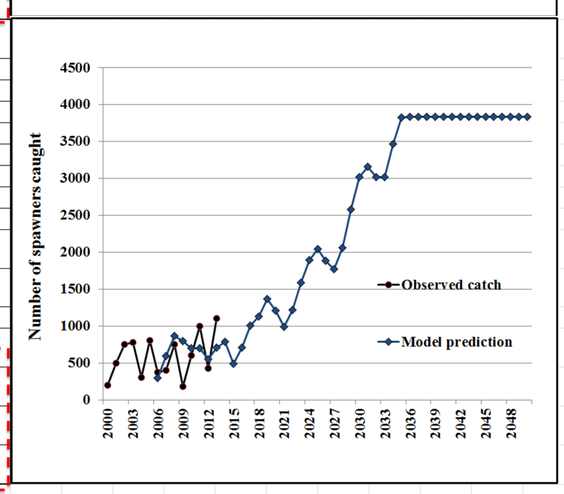


Figure 3. Two life-history modelling scenarios in which the predicted number of spawners fit the observed return data. The lower panel dispays the more realistic projected smolt numbers resulting from lower egg-smolt survival but higher smolt migration survival.

Modeling

For this poster we modelled two scenarios, both of which allowed reasonable fits for the observed data (Fig. 3). We used high egg-fry/low smolt migration survival (top panel) and low egg-fry/high smolt migration survival (bottom panel) scenarios to compare the modeled number of smolts produced to those estimated from the fyke net trapping (see red boxes, Fig. 3). Both models fit the observed spawner data, but the high smolt survival model made more realistic predictions of smolt production, based on the trapping estimates

Conclusions

We documented for the first time substantial production of wild smolt in Klarälven, a recovering population of wild landlocked salmon. With continued development our research could lead to robust estimates of smolt production, an important component of sustainable fisheries management. Modifications in the fyke net should allow it to be fished at higher discharges. Ideally, floating traps could be used in conjunction with the fyke net for complete sampling during higher flows. In addition to estimate production biological sampling has also allowed us to monitor age and growth and genetics. These can be used as baseline data for monitoring effects of stressors such as climate change or hydropower operations.

Combining the smolt trapping with a life-history model enables us to assess management alternatives, for example improvements in fish passage or rearing habitat. The most biologically-realistic model at present suggests that downstream survival of smolt is relatively high, probably because they migrate during high-spill periods. During periods of low discharge when they must migrate through turbines at up to eight dams, cumulative losses are known to be substantial (Norrgård et al. 2013). Given that turbine capacity in Klarälven is typically exceeded at high discharge, further population recovery might therefore be limited more by spawning habitat and egg-smolt survival. This will require habitat improvement and access to the vast historic spawning and rearing grounds in the Norwegian side of the river. These are currently inaccessible.

We documented recovery of wild smolt production in a heavily-regulated river. Population modelling, however, suggests that the number of returning spawners (~5,000) might grow to only 10-20% of historic levels (>25,000) over the next 50 years even in the best-case scenario. Thus, conservation of this unique, endemic landlocked salmon stock will require continued vigilance that will need to include a broad socio-ecological perspective.

References

Hagelin, A., et al. 2015 Spawning migration of wild and supplementary stocked landlocked Atlantic salmon *River Res. Applic* doi: 10.1002/rra.2870

Norrgård, J.R. et al. . 2013. Multiplicative loss of landlocked Atlantic salmon *Salmo salar* L. smolts during downstream passage through multiple dams. *River Research and Applications*. **29**:1306–1317

Piccolo, J.J., et al. 2012. Conservation of endemic migratory salmonids in regulated rivers: A case study from Lake Vänern, Sweden. *Fish and Fisheries*. **13**:418–433.

Naturresurs rinnande vatten

Biologi – Karlstads universitet

For more information on the smolt trap or model contact: john.piccolo@kau.se
See us at Karlstad University at: http://www.kau.se/en/biology Visit our blog at: http://www.nrrv.se/.

Acknowledgements: Thomas Hasselborg led development of the fyke net. Special thanks to P Gustafsson, M Hedenskog and T Qvenild for leading the EU-funded Interreg project 21177 Vänerlaxen Fria Gång. Thanks to J Ainegren, O Askling, A Björkman, O Carlsson, T Collin, L Dahlström, R Gow, J Norrgård, J Greenberg, A Romakkaniemi T Stenlund, residents of Edebäck, Sweden and employees of Fortum AB.