



Does smolt length influence the size of return adult 1SW salmon?

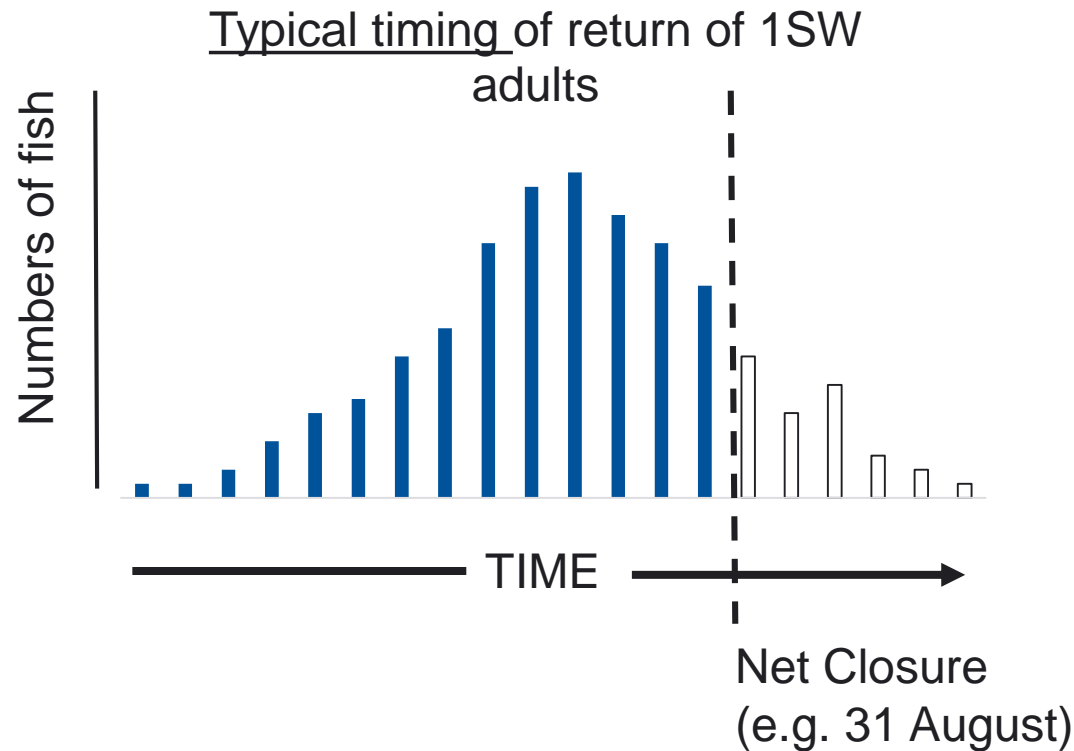
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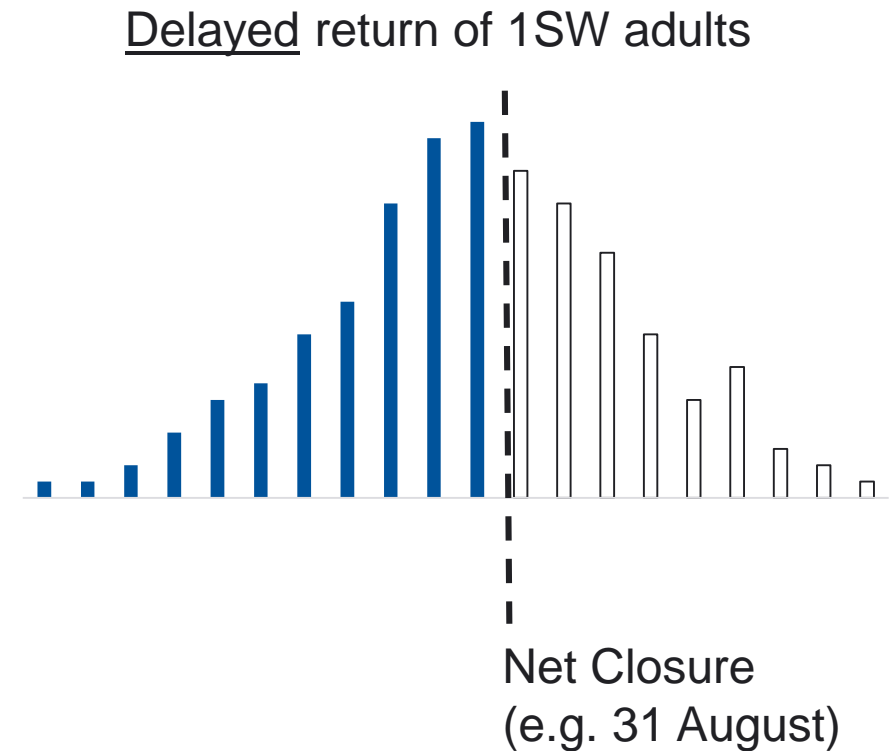
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PROBLEM 1: Entire 1SW cohort never sampled by MSS because of net season closure. **PROBLEM 2:** Differing run-timing influences the observed cohort proportion and size of adults.



TRUE average weight = 3.02 kg

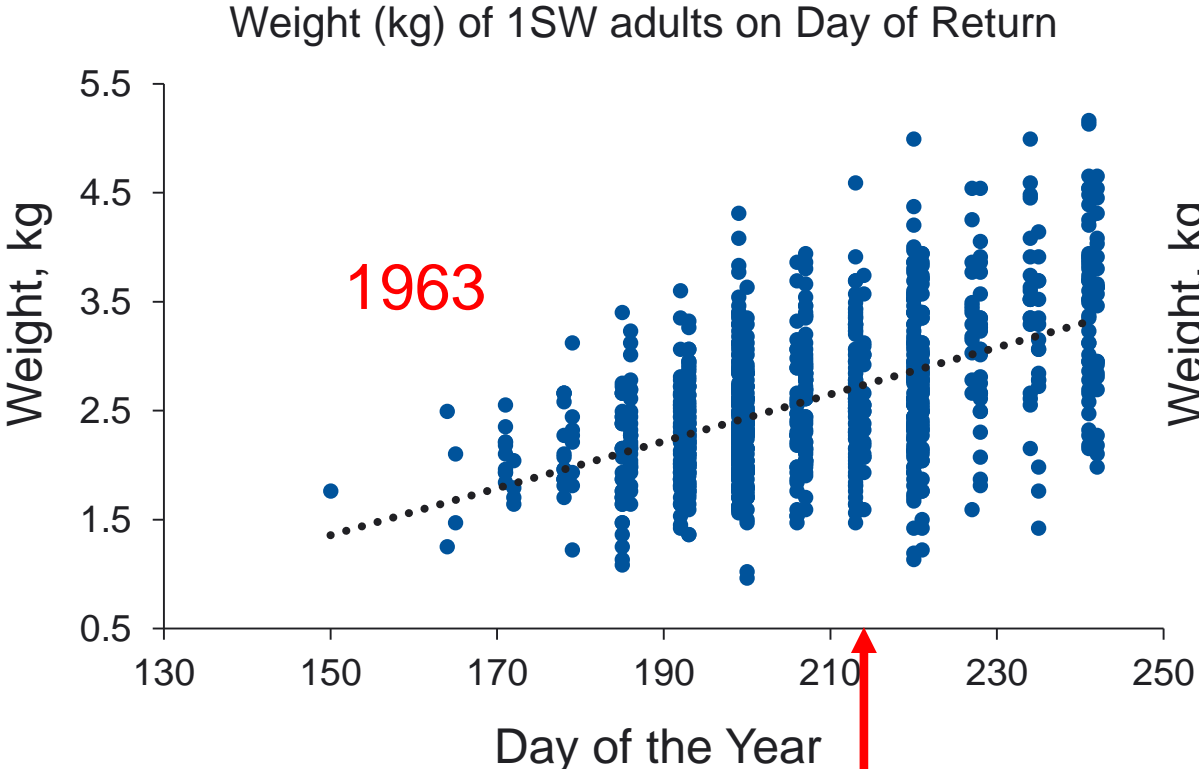
“OBSERVED” average weight = 2.76 kg



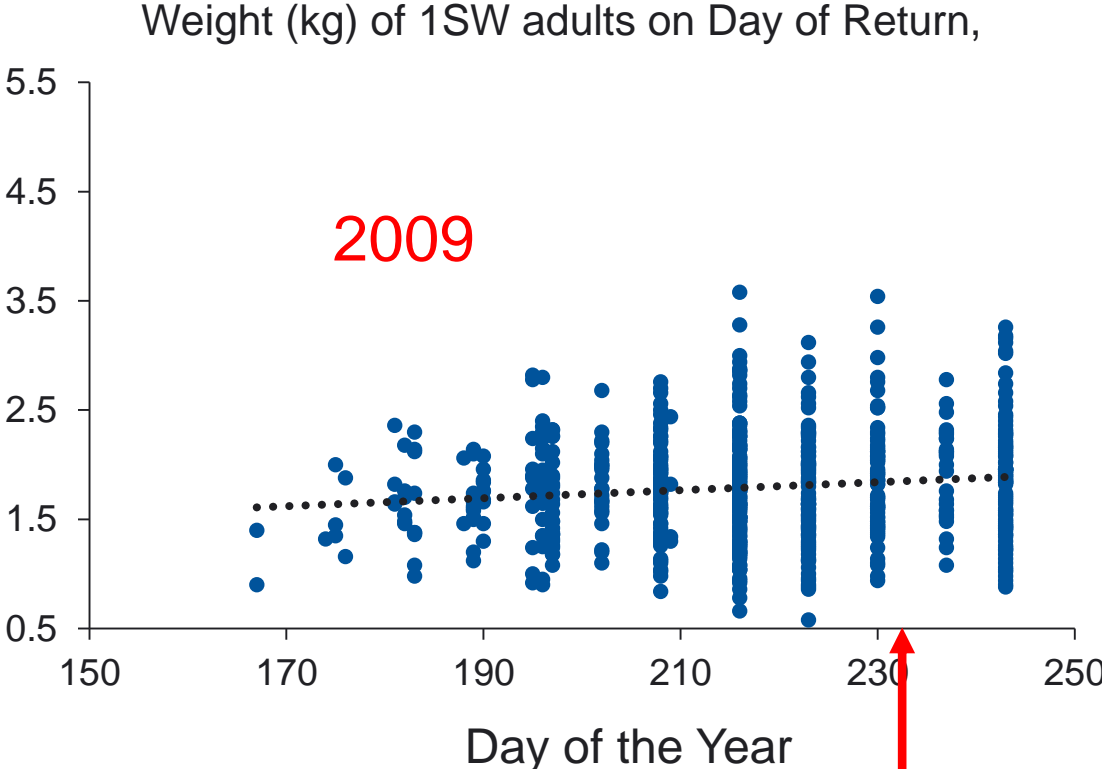
TRUE average weight = 3.02 kg

“OBSERVED” average weight = 1.83 kg

NORTH ESK – 1SW ADULTS, 1963 AND 2009. PROBLEM 3: Average size of return adults tends to increase as the summer progresses.



Modal Date of Migratory Return = Day 213 (1 August)



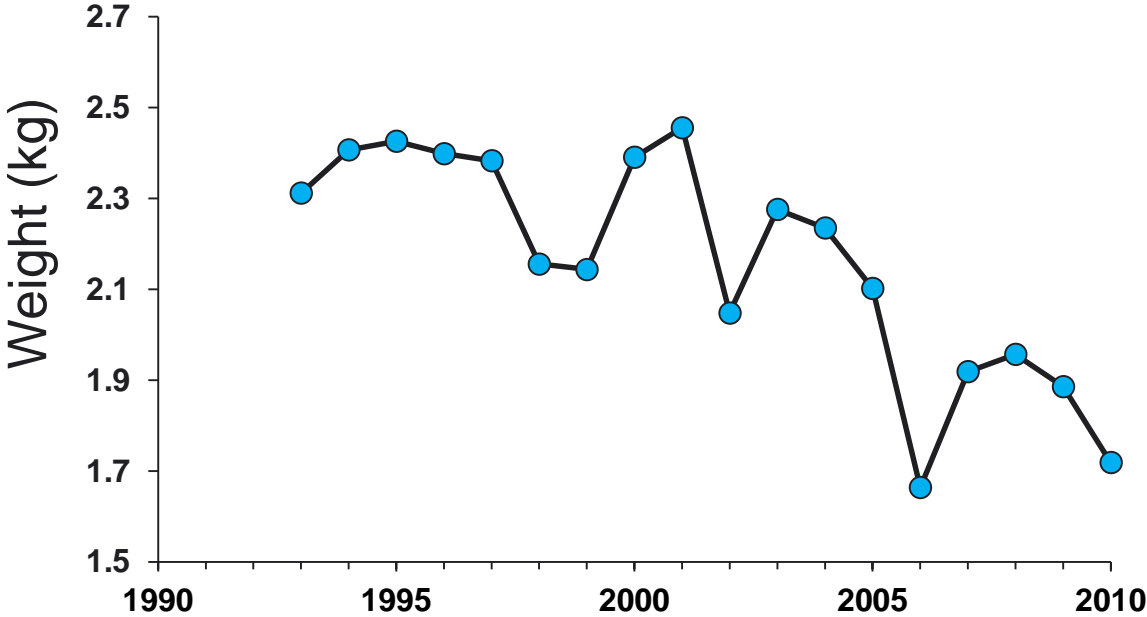
Modal Date of Migratory Return = Day 232 (20 August)

DATA (Marine Scotland Science): 1SW adults, North Esk.

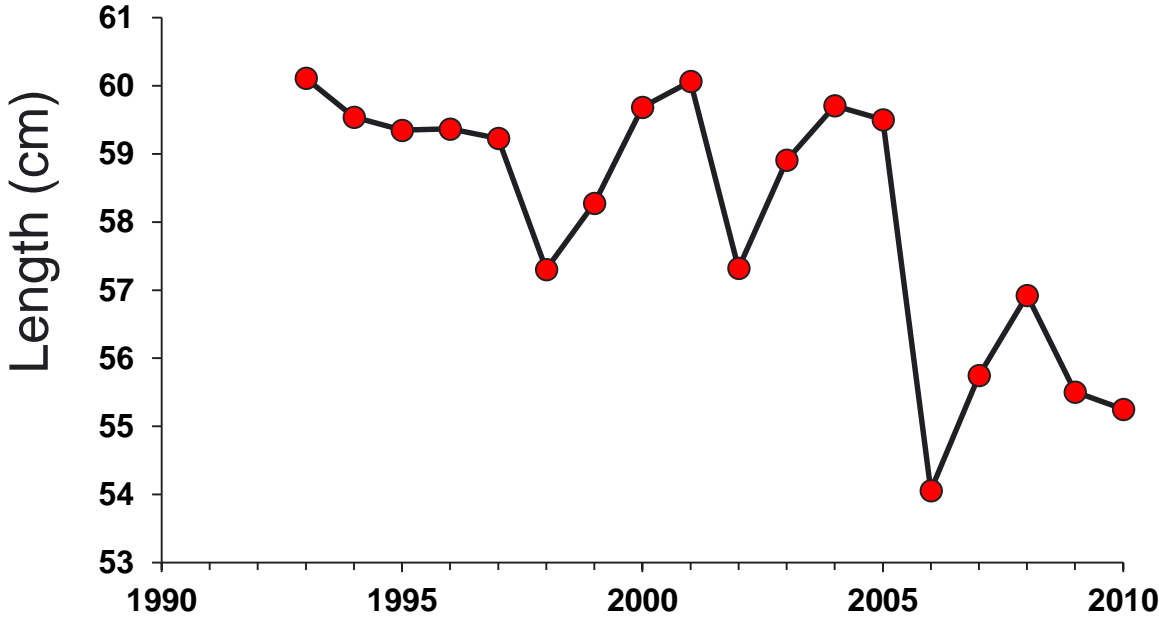
- ~100 individual 1SW adults weighed and measured each year, 1993-2010
- Adult scale samples measured; **smolt lengths estimated** from Dahl-Lea back-calculation, with “length correction” according to Hanson *et al.* (2019) *J. Fish Biol.*, **94**: 183-186
- **Modal Date of Migratory Return** for 1SW adult cohort each year estimated by Todd *et al.* (2012) *ICES J. Mar. Sci.*, **69**: 1686-1698
- **Residual weight** (kg) of each fish [i.e. departure from mean weight on the given Day of Capture] plotted against estimated smolt length

NORTH ESK, 1SW ADULTS. Average size (kg, cm) at Modal Date of Migratory Return, 1993-2010

North Esk, 1SW Adults. Average Weight (kg) on Modal Date of Migratory Return

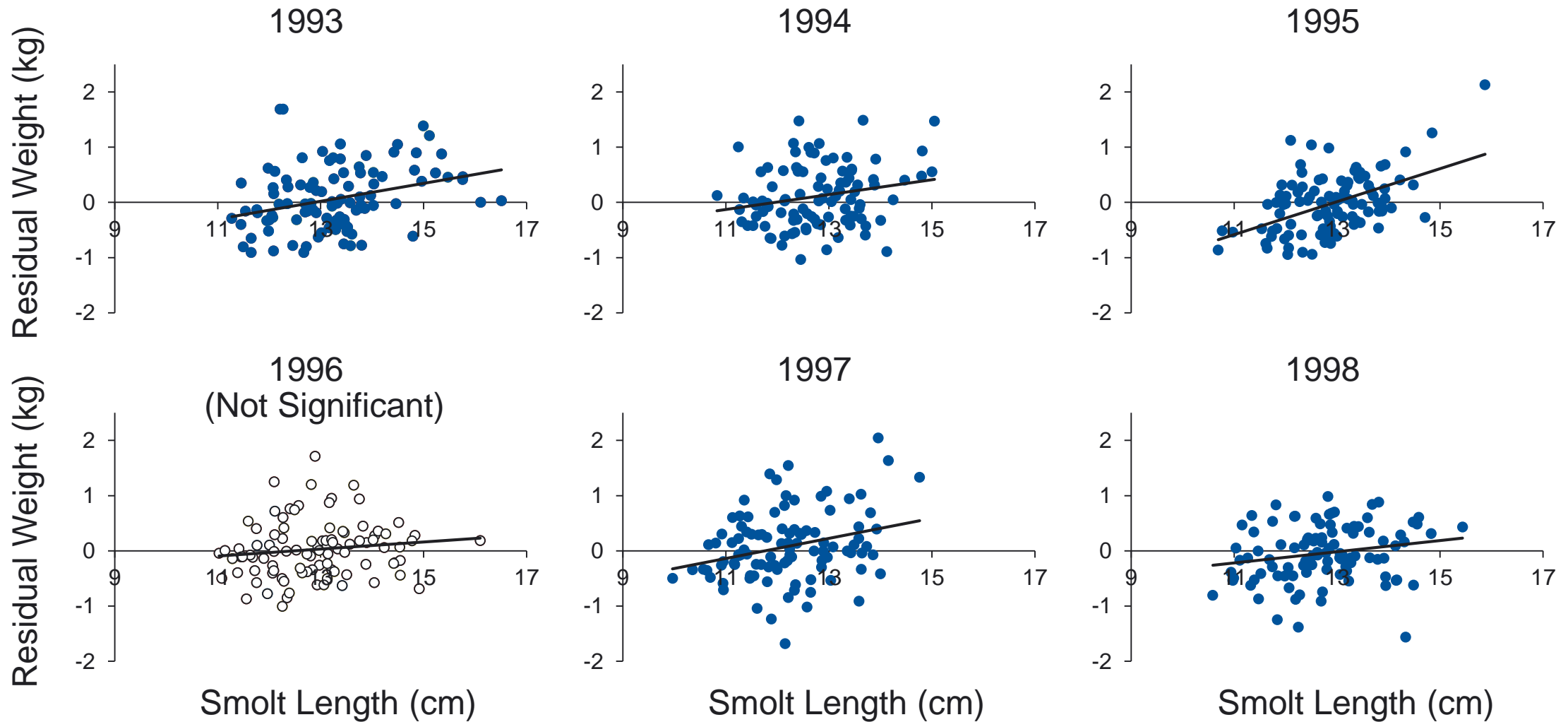


North Esk, 1SW Adults. Average Length (cm) on Modal Date of Migratory Return

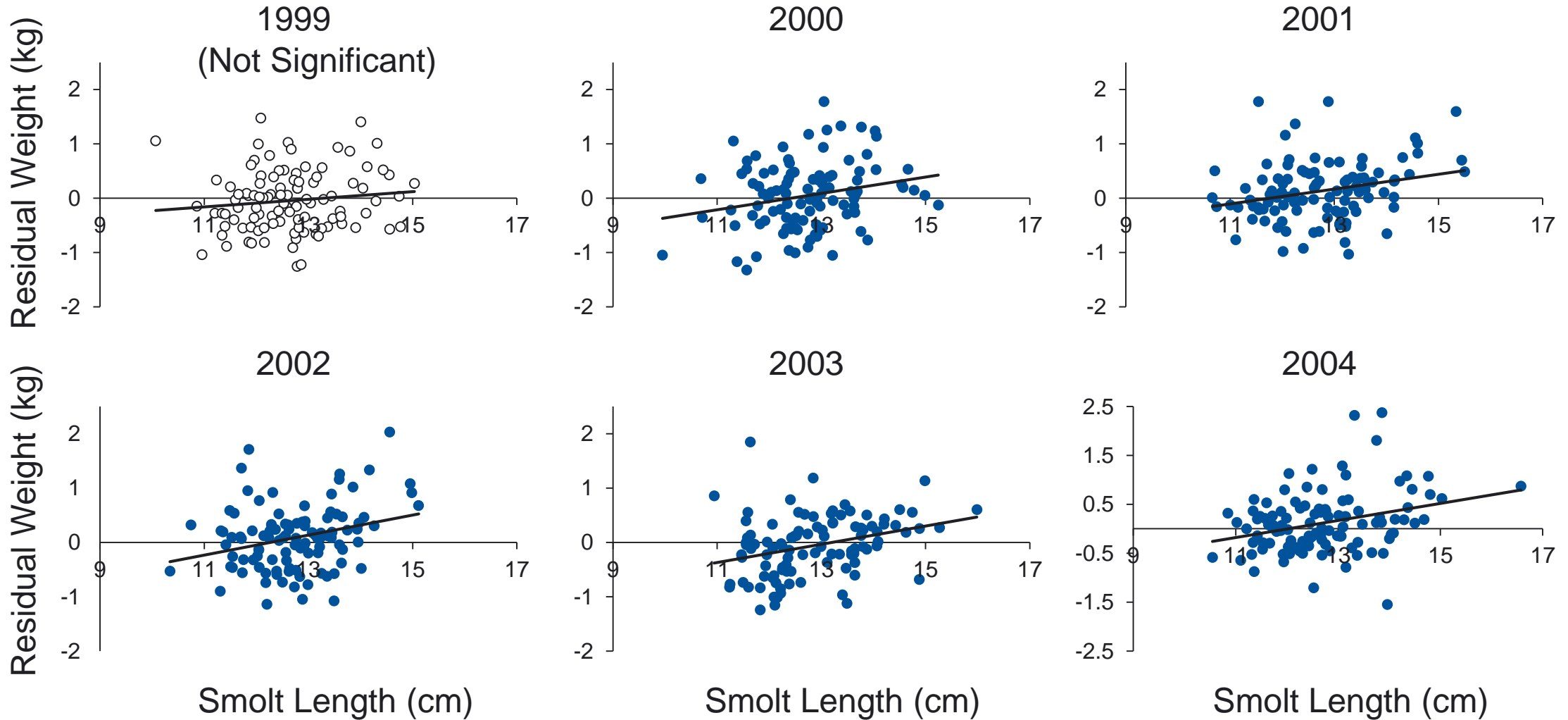


Here, allowance has been made for changes in run-timing. Grilse runs have tended to delay in recent years.

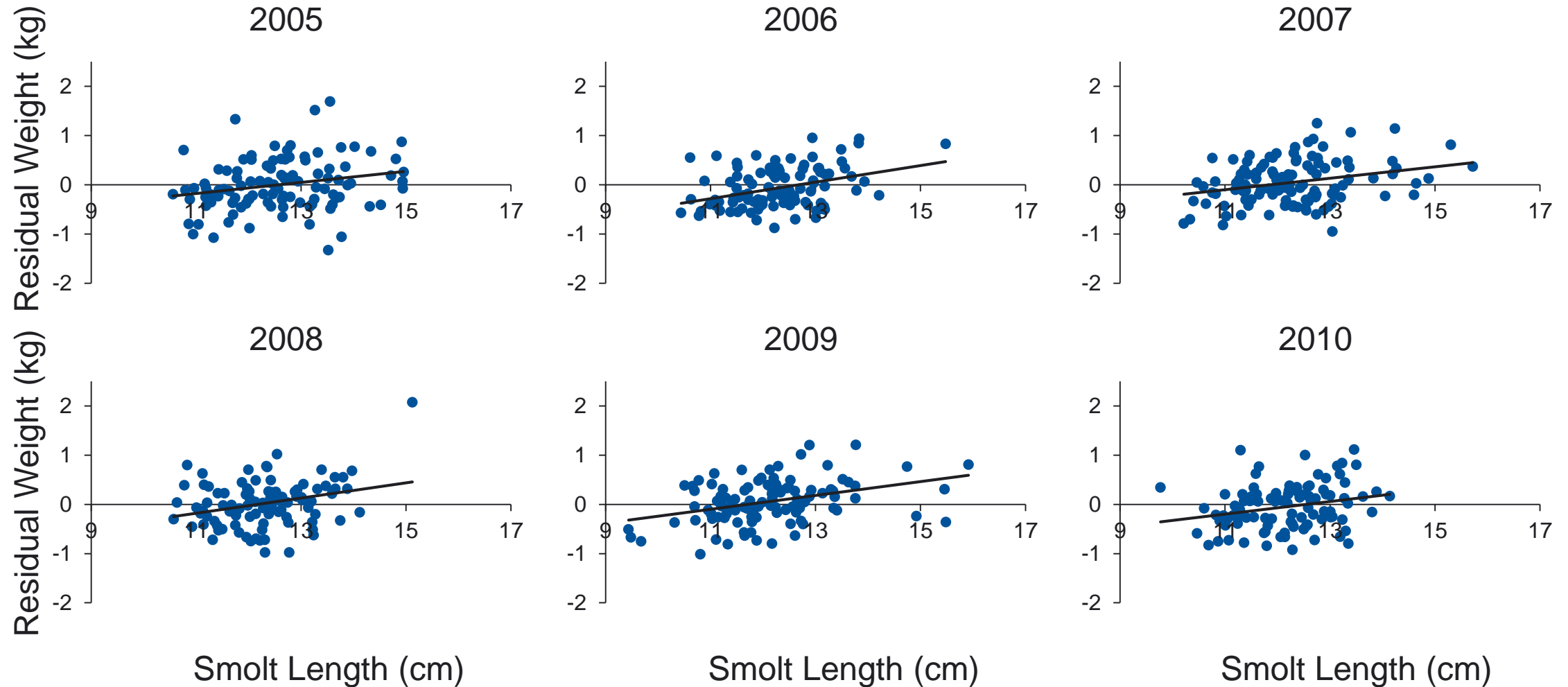
Residual Weight (kg) of individuals (N ~ 100 per year) in relation to emigrant smolt length (cm). Separate calculations of residuals for S1, S2 and S3/S4 smolts



Residual Weight (kg) of individuals (N ~ 100 per year) in relation to emigrant smolt length (cm)

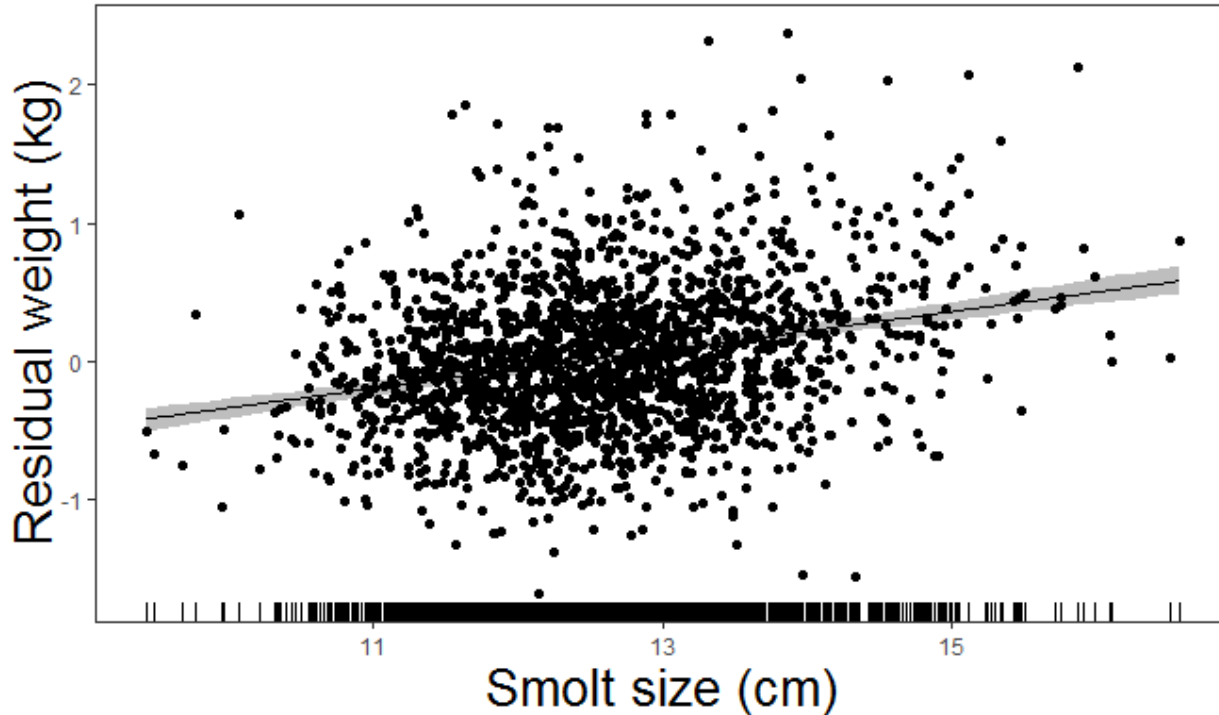


Residual Weight (kg) of individuals (N ~ 100 per year) in relation to emigrant smolt length (cm)



Residual Weight (kg) of individuals (N = 1823) in relation to emigrant smolt length (cm)

OVERALL 1993-2010



| Random effect: | SD | | | | |
|----------------|--------------|---------|---------|----------|-----------|
| 1 year | 0.0499 | | | | |
| Residual | 0.5128 | | | | |
| Fixed-effects | Estimate | SE | t-value | 2.5%c.i. | 97.5%c.i. |
| Intercept | -1.72 | 0.149 | -11.51 | -2.202 | -1.428 |
| Smolt size | 0.139 | 0.01182 | 11.77 | 0.115 | 0.162 |

SD – Standard Deviation; SE – Standard Error; ci – Confidence Interval

Final adult weight of 1SW individuals is very variable. BUT, smolt length alone explains 7% of the variation in adult weight.

An “extra” cm of smolt length results in 0.14 kg increase in return adult weight residual

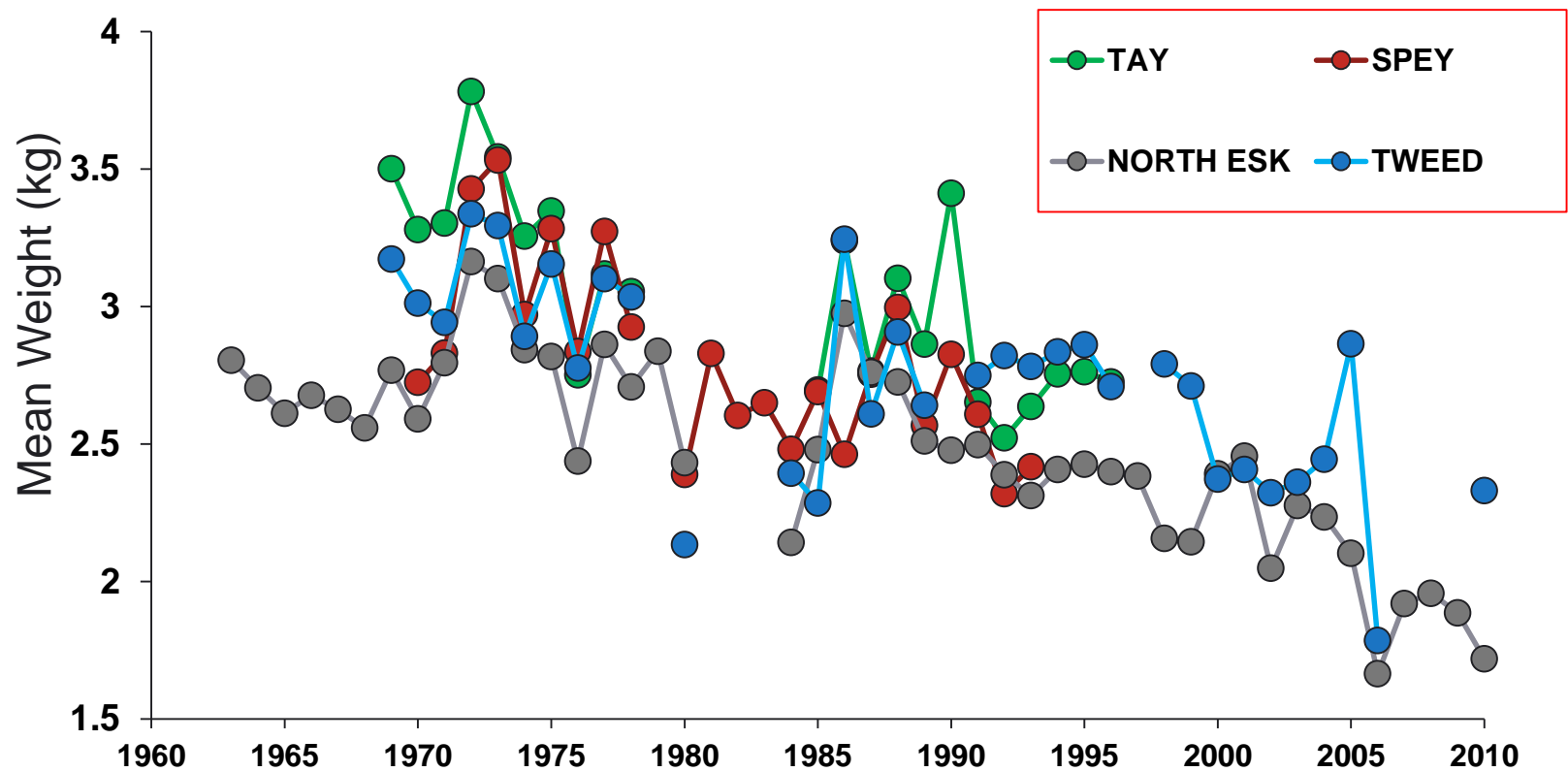
| | Adult Weight Increase per cm Smolt Length | Average Weight 1SW Adult | * Percent Increase in Weight of Average Adult per cm Smolt Length |
|------|--|-----------------------------|---|
| 1993 | 0.162 kg/cm | 2.312 kg | 7 % |
| 1994 | 0.135 | 2.407 | 6 % |
| 1995 | 0.311 | 2.426 | 13 % |
| 1996 | 0.063 | 2.399 | 3 % |
| 1997 | 0.182 | 2.383 | 8 % |
| 1998 | 0.102 | 2.156 | 5 % |
| 1999 | 0.071 | 2.144 | 3 % |
| 2000 | 0.150 | 2.391 | 6 % |
| 2001 | 0.136 | 2.456 | 6 % |
| 2002 | 0.185 | 2.048 | 9 % |
| 2003 | 0.168 | 2.276 | 7 % |
| 2004 | 0.175 | 2.235 | 8 % |
| 2005 | 0.113 | 2.102 | 5 % |
| 2006 | 0.168 | 1.664 | 10 % |
| 2007 | 0.126 | 1.919 | 7 % |
| 2008 | 0.155 | 1.957 | 8 % |
| 2009 | 0.141 | 1.886 | 7 % |
| 2010 | 0.128 | 1.719 | 7 % |

* Percent Increase here shows the predicted increase for an Average 1SW adult if smolt length were 1 cm longer

CONCLUSIONS

- MSS monitoring of return adults to the North Esk, Spey, Tay, Tweed dates back to the 1960s
- Average size of return adult 1SW salmon has decreased significantly since the early 1970s. Primarily a consequence of ocean warming and its impacts on prey availability to salmon at sea. BUT average length of North Esk S2 smolts has fallen slightly in recent years [Todd *et al.* (2012) *ICES J. Mar. Sci.*, **69**: 1686-1698].

Mean weight (kg) * for 1SW adults returning to rivers TAY, SPEY, NORTH ESK and TWEED



* Mean weight here is that predicted for 1SW grilse on the peak day of migratory return – i.e., allowance has been made for annual changes in run-timing.

The grilse run has typically shown marked delay, by up to one month, in recent years

CONCLUSIONS

- MSS have monitored return adults to the North Esk, Spey, Tay, Tweed since the 1960s
- Average size of return adult 1SW salmon has decreased significantly since the early 1970s. A consequence of ocean warming and its impacts on prey availability to salmon at sea.
- For North Esk, an increase in emigrant smolt length of just 1 cm – e.g. from the average of 12 cm to 13 cm – results in a predicted average increase in adult weight of 7 %
- Consequences for female fecundity and implications for management of the riparian environment ?

ACKNOWLEDGEMENTS

- Marine Science Scotland (MSS), for access to their data and scale archives
- Nora Hanson, Gordon Smith, Julian MacLean, John Armstrong at MSS
- Tania Mendo at University of St Andrews