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Is bigger better?
Longer Atlantic salmon smolts return as adults

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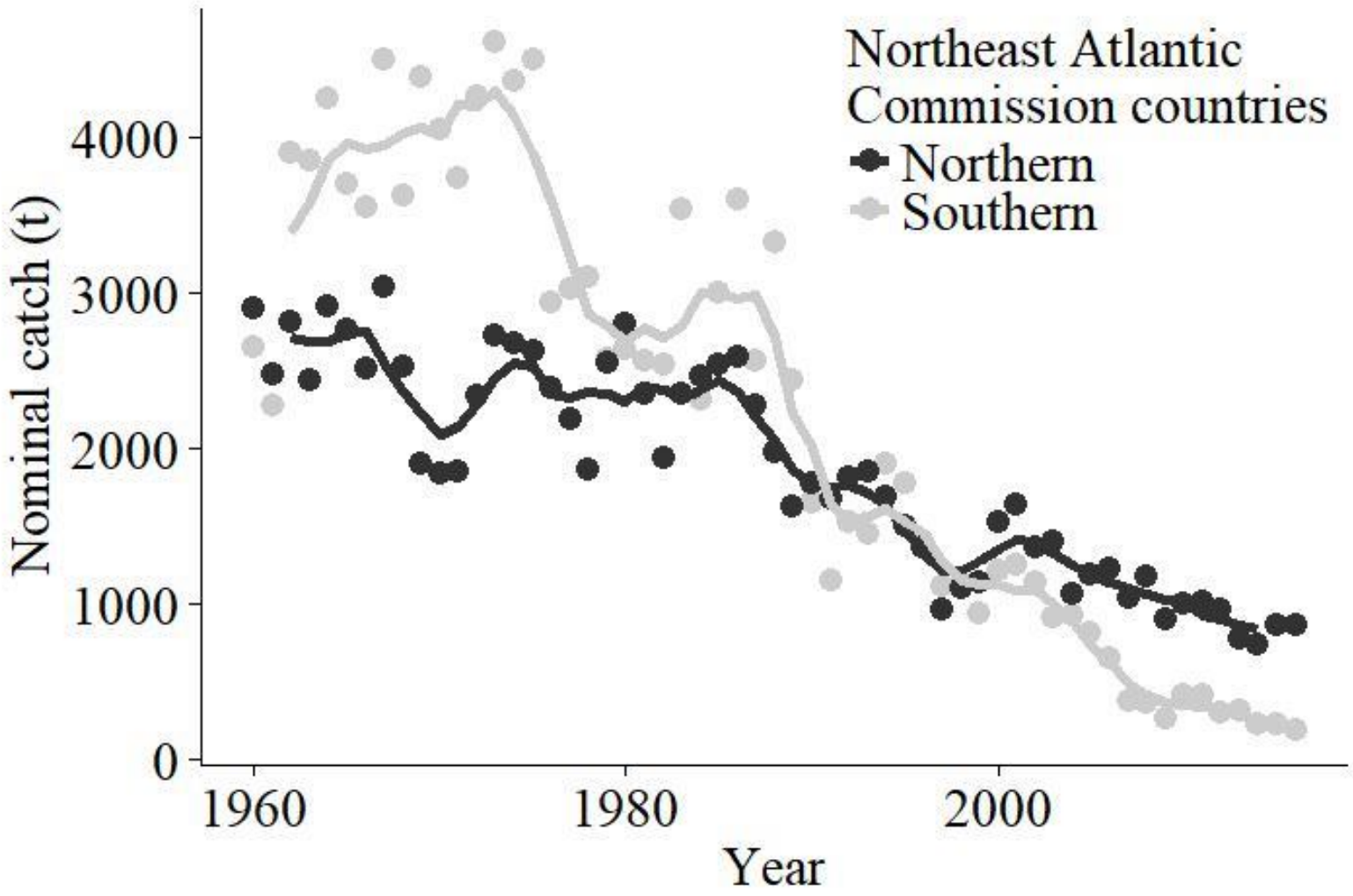
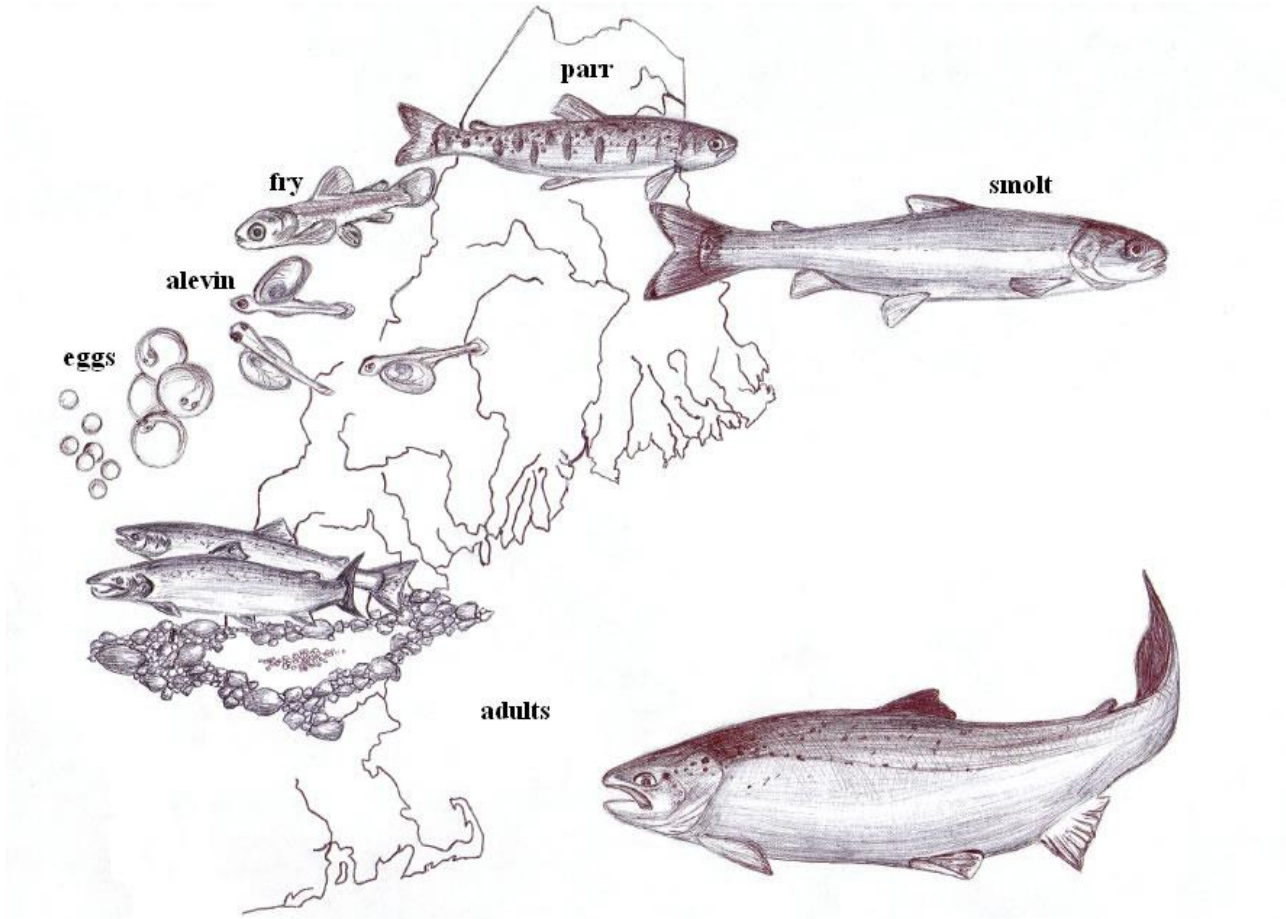
State of salmon



State of salmon



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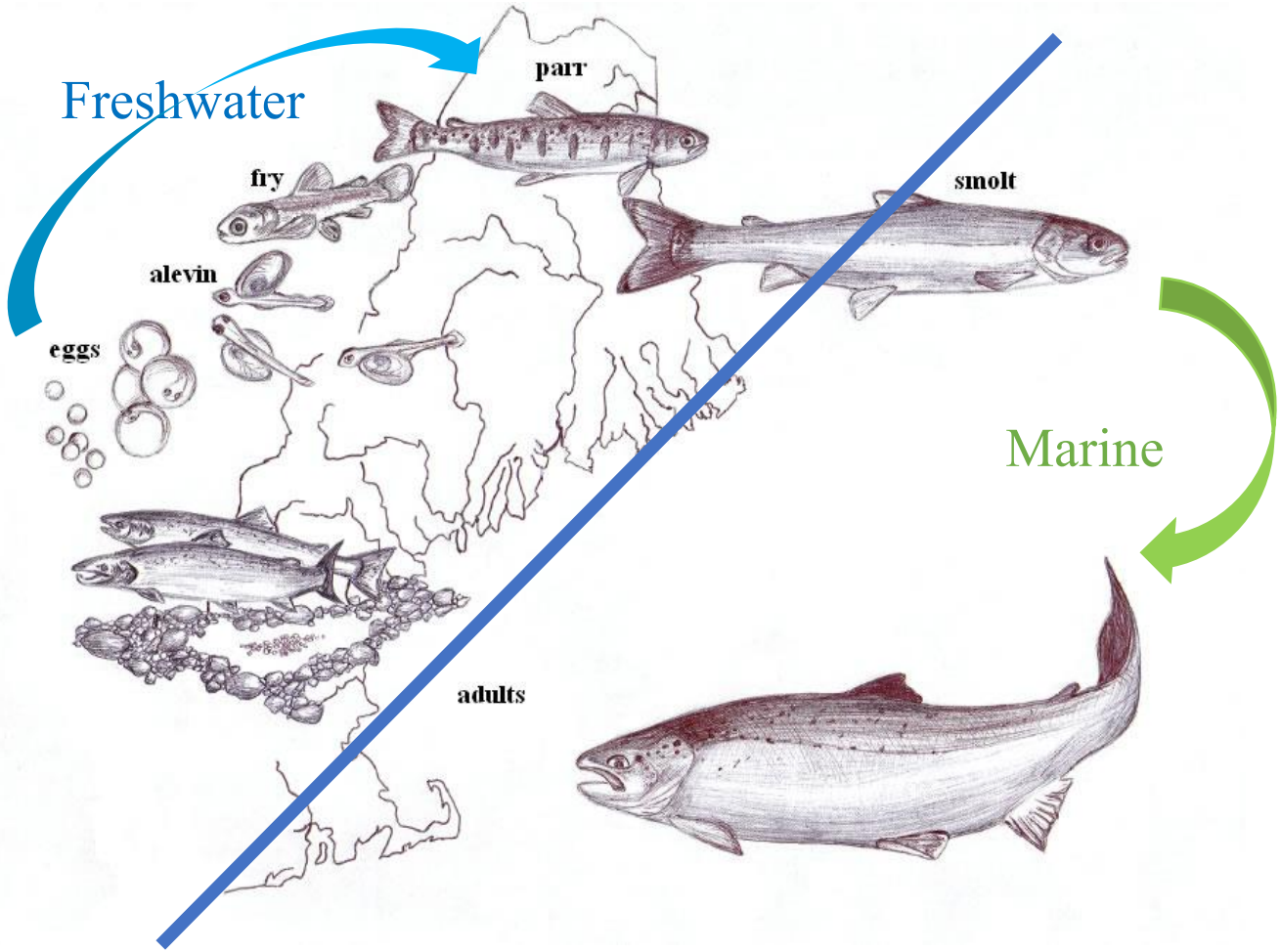
State of salmon

- **Anadromous**
  - Freshwater
  - Marine



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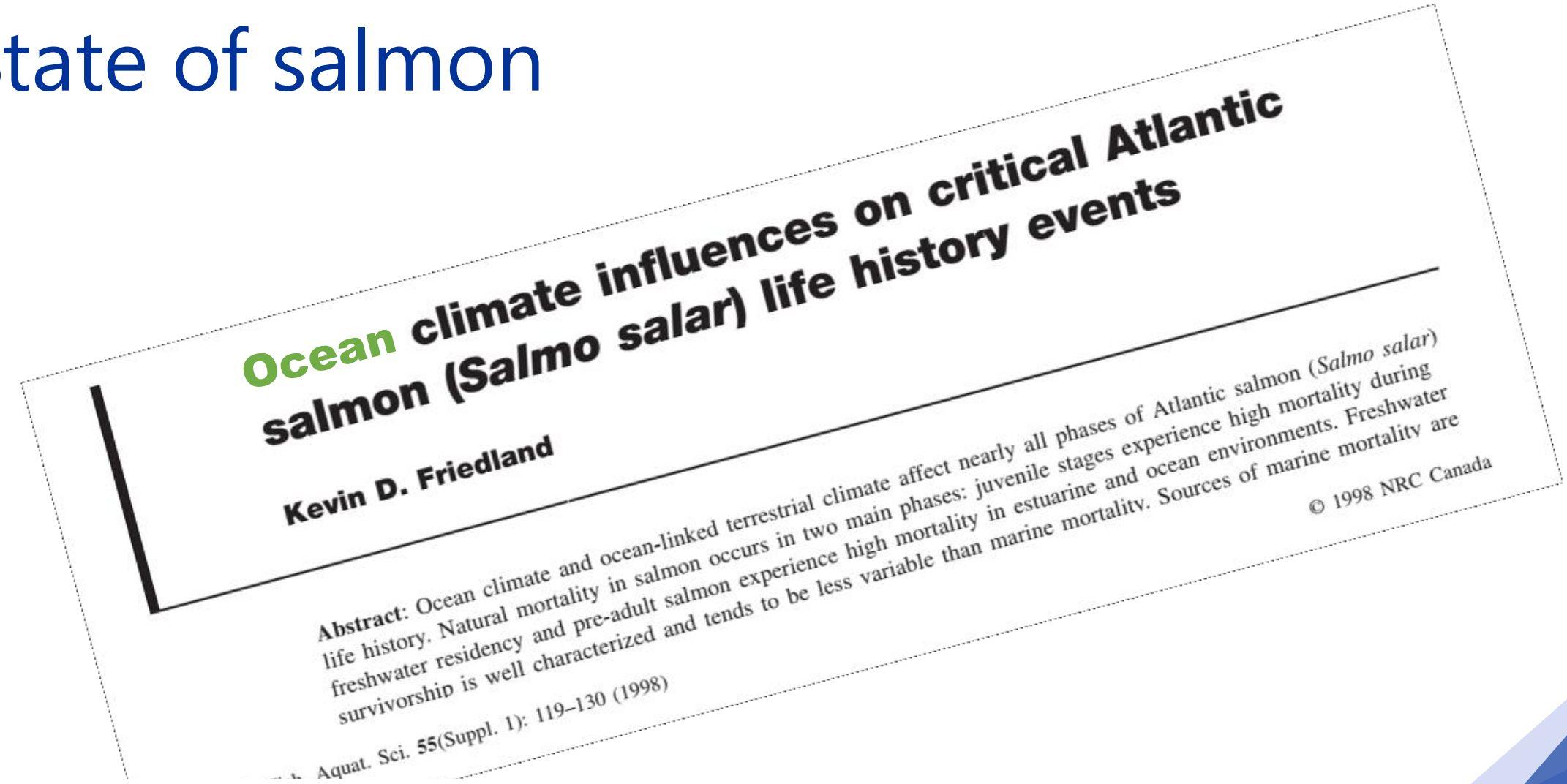
State of salmon



Ocean climate influences on critical Atlantic salmon (*Salmo salar*) life history events

Kevin D. Friedland

Abstract: Ocean climate and ocean-linked terrestrial climate affect nearly all phases of Atlantic salmon (*Salmo salar*) life history. Natural mortality in salmon occurs in two main phases: juvenile stages experience high mortality during freshwater residency and pre-adult salmon experience high mortality in estuarine and ocean environments. Freshwater survivorship is well characterized and tends to be less variable than marine mortality. Sources of marine mortality are

Aquat. Sci. **55**(Suppl. 1): 119–130 (1998)

Imon

ICES Journal of Marine Science (2012), 69(9), 1538–1548. doi:10.1093/icesjms/fss013

Overview of the status of Atlantic salmon (*Salmo salar*) in the North Atlantic and trends in marine mortality

Gérald Chaput

Fisheries and Oceans Canada, PO Box 5030, Moncton, New Brunswick, Canada E1C 9B6; tel: +1 506 851 2022; fax: +1 506 851 2620;

Chaput, G. 2012. Overview of the status of Atlantic salmon (*Salmo salar*) in the North Atlantic and trends in marine mortality. – ICES Journal of Marine Science, 69: 1538–1548.

Received 9 September 2011; accepted 3 January 2012; advance access publication 19 April 2012.

Since the early 1980s, the ICES Working Group on North Atlantic Salmon has collated and interpreted catch data, exchanged information on research initiatives, and provided advice to managers in support of conservation efforts for Atlantic salmon. During the past

critical Atlantic events

life h…

freshwater …

survivorship is …

Can. J. Fish. Aquat. Sci. 55(Suppl. 1): 119–…

ICES Journal of Marine Science; doi:10.1093/icesjms/fsr208

The influence of the freshwater environment and the biological characteristics of Atlantic salmon smolts on their subsequent marine survival

Ian C. Russell[1]*, Miran W. Aprahamian[2], Jon Barry[1], Ian C. Davidson[3], Peder Fiske[4], Anton T. Ibbotson[5], Richard J. Kennedy[6], Julian C. Maclean[7], Andrew Moore[1], Jaime Otero[8], Ted (E. C. E.) Potter[1], and Christopher D. Todd[9]

[1]*Cefas, Pakefield Road, Lowestoft, Suffolk NR33 0HT, UK*
[2]*Environment Agency, Richard Fairclough House, Knutsford Road, Warrington WA4 1HG, UK*
[3]*Environment Agency, Chester Road, Buckley, Flintshire CH7 3AJ, UK*
[4]*Norwegian Institute for Nature Research, PO Box 5685, Sluppen, Trondheim 7485, Norway*
[5]*Game and Wildlife Conservation Trust, Salmon and Trout Research Centre, The River Laboratory, East Stoke, Wareham, Dorset BH20 6BB, UK*

Stock decline causes

- **Extrinsic factors**
  - Climate change sea surface temperature
  - Environmental change phytoplankton blooms

- **Intrinsic factors**
  - Behaviours migration phenology
  - Individual characteristics body size

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Body size

"fish mortality is inversely related to their body size"

Ricker's (1976) *inverse-weight hypothesis*

Empirical evidence

Reviewed in Gregory et al. (2018)

Journal of FISH BIOLOGY

fsbi An International Society for Fish Biology

Journal of Fish Biology (2018) **92**, 579–592
doi:10.1111/jfb.13550, available online at wileyonlinelibrary.com

Is bigger really better? Towards improved models for testing how Atlantic salmon *Salmo salar* smolt size affects marine survival

S. D. GREGORY*†, J. D. ARMSTRONG‡ AND J. R. BRITTON§

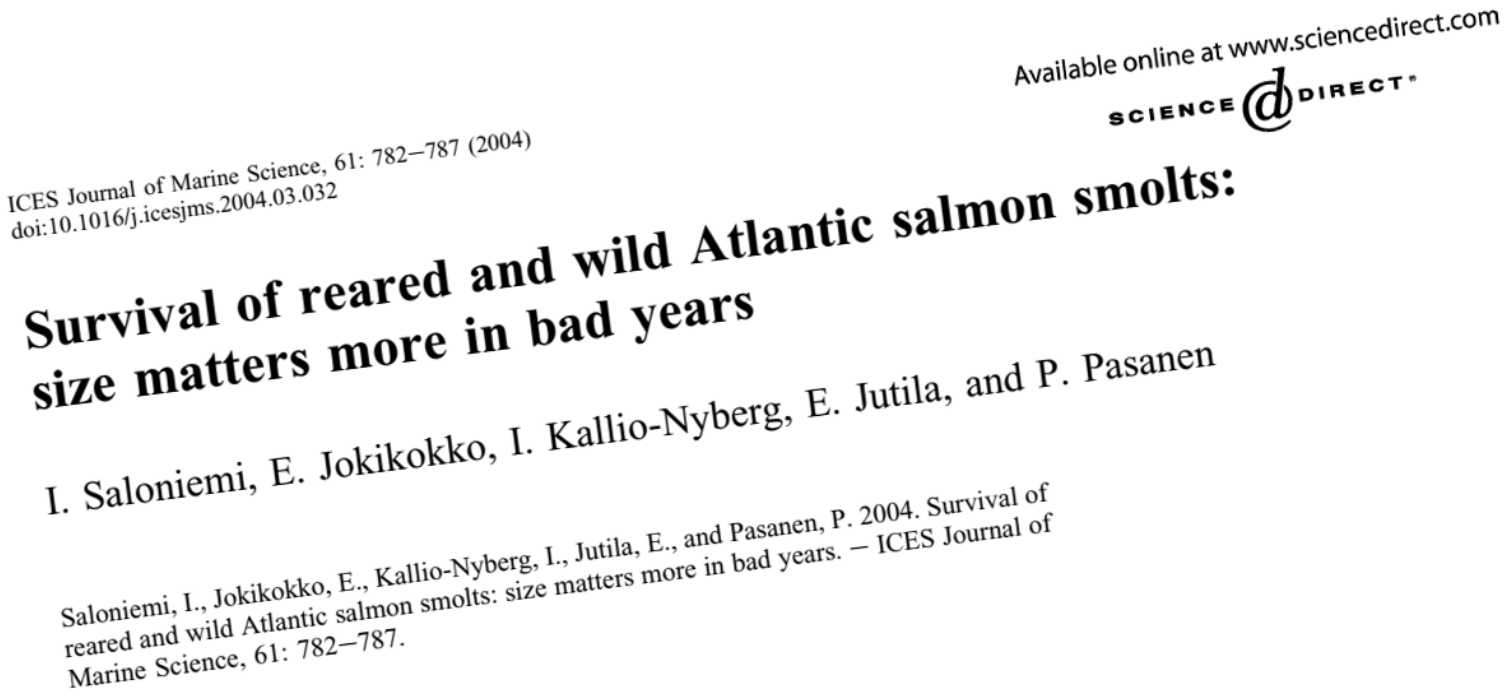
**Salmon & Trout Research Centre, Game and Wildlife Conservation Trust, FBA River Laboratory, Wareham, BH20 6BB, U.K., ‡Freshwater Fisheries Laboratory, Marine Scotland Science, Faskally, Pitlochry, Perthshire, PH16 5LB, U.K. and §Centre for Conservation Ecology and Environmental Sciences, Faculty of Science and Technology, Bournemouth University, Poole, Dorset, BH12 5BB, U.K.*

"assessed over several studies, the influence of smolt length on marine survival appears equivocal (Table I)."

Gregory et al. (2018) doi:10.1111/jfb.13550

Empirical evidence

Saloniemi et al. (2004)



ICES Journal of Marine Science, 61: 782–787 (2004)
doi:10.1016/j.icesjms.2004.03.032

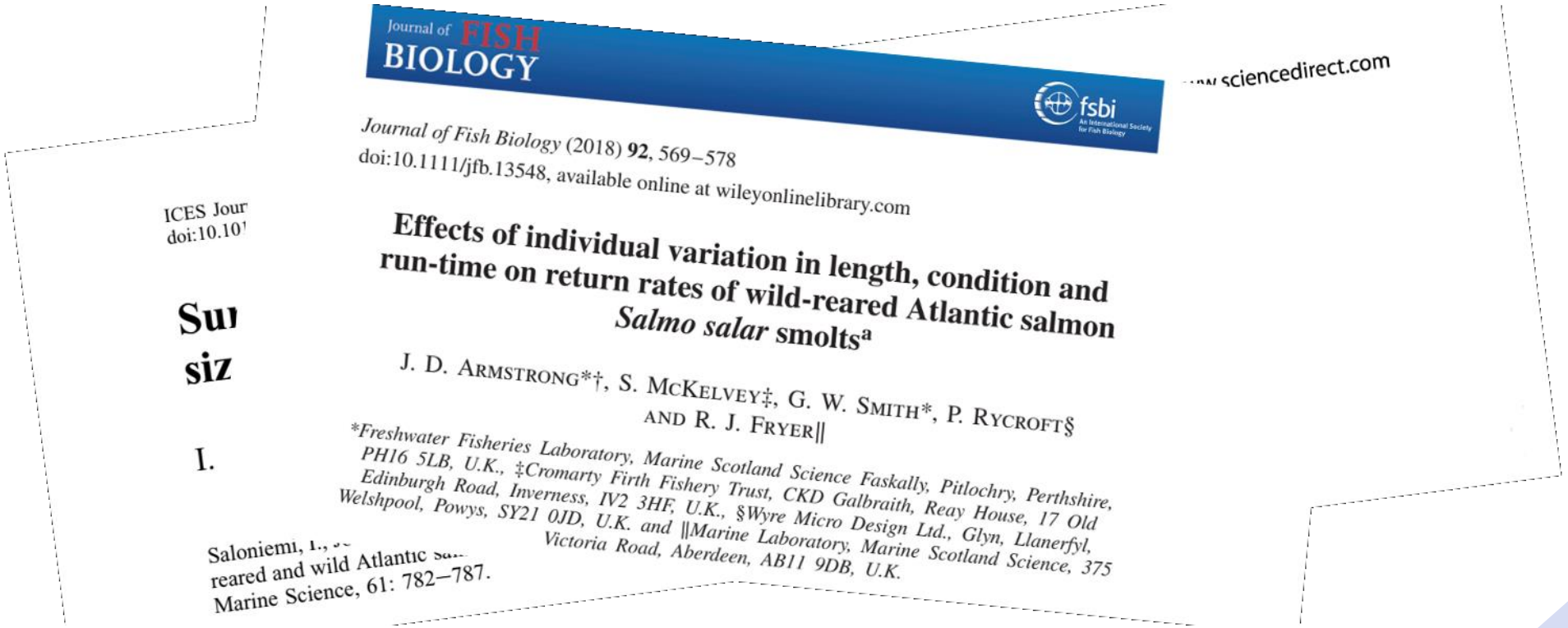
Survival of reared and wild Atlantic salmon smolts: size matters more in bad years

I. Saloniemi, E. Jokikokko, I. Kallio-Nyberg, E. Jutila, and P. Pasanen

Saloniemi, I., Jokikokko, E., Kallio-Nyberg, I., Jutila, E., and Pasanen, P. 2004. Survival of reared and wild Atlantic salmon smolts: size matters more in bad years. – ICES Journal of Marine Science, 61: 782–787.

Empirical evidence

Saloniemi et al. (2004) and Armstrong et al. (2018)



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doi:10.10

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Marine Science, 61: 782–787.

sciencedirect.com

Journal of FISH BIOLOGY

fsbi An International Society for Fish Biology

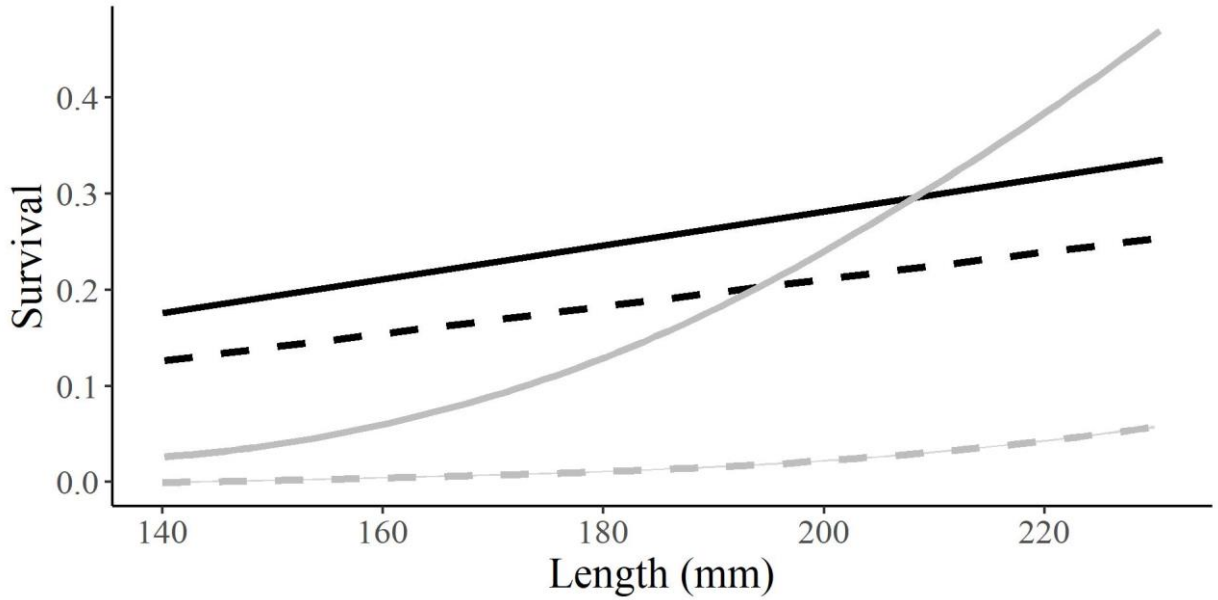
Journal of Fish Biology (2018) **92**, 569–578
doi:10.1111/jfb.13548, available online at wileyonlinelibrary.com

Effects of individual variation in length, condition and run-time on return rates of wild-reared Atlantic salmon *Salmo salar* smolts[a]

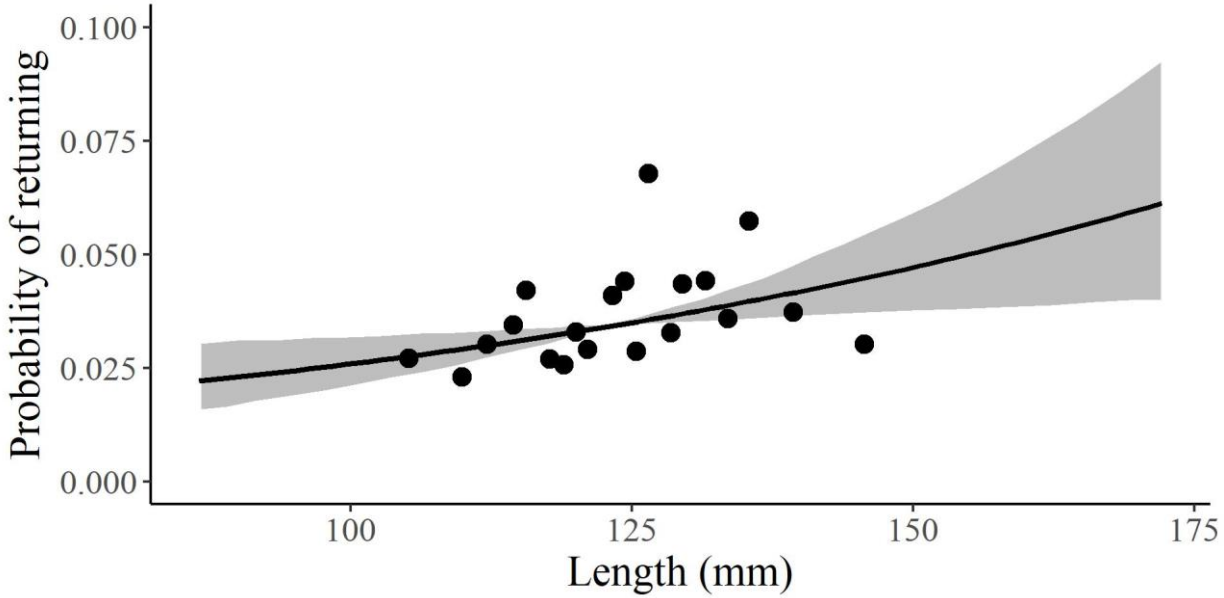
J. D. ARMSTRONG*†, S. MCKELVEY‡, G. W. SMITH*, P. RYCROFT§ AND R. J. FRYER‖

*Freshwater Fisheries Laboratory, Marine Scotland Science Faskally, Pitlochry, Perthshire, PH16 5LB, U.K., ‡Cromarty Firth Fishery Trust, CKD Galbraith, Reay House, 17 Old Edinburgh Road, Inverness, IV2 3HF, U.K., §Wyre Micro Design Ltd., Glyn, Llanerfyl, Welshpool, Powys, SY21 0JD, U.K. and ‖Marine Laboratory, Marine Scotland Science, 375 Victoria Road, Aberdeen, AB11 9DB, U.K.

Saloniemi et al. (2004)



Armstrong et al. (2018)



A state-space model approach

- An SSM including:
  - multiple states juvenile, adult and dead
  - mark-recapture model detected and not detected
  - individual- and group-level covariates body size or release year

European dipper (Gimenez et al., 2007) & sea lamprey (Holbrook et al., 2014)

OIKOS

Research

Individual heterogeneity and capture–recapture models: what, why and how?

Olivier Gimenez, Emmanuelle Cam and Jean-Michel Gaillard

O. Gimenez (http://orcid.org/0000-0001-7001-5142) (olivier.gimenez@cefe.cnrs.fr), CEFE UMR 5175, CNRS, Univ. de Montpellier, Univ. Paul-Valéry Montpellier, EPHE, 1919 Route de Mende, FR-34293 Montpellier Cedex 5, France. – E. Cam, Evolution et Diversité Biologique, UMR 5174, CNRS-ENSFEA-IRD, Univ. Toulouse, Toulouse, France. – J.-M. Gaillard, Laboratoire de Biométrie et Biologie Evolutive, UMR 5558, Univ. de Lyon, Villeurbanne, France.

Oikos
127: 664–686, 2018
doi: 10.1111/oik.04532

Variation between and within individuals in life history traits is ubiquitous in natural populations. When affecting fitness-related traits such as survival or reproduction, individual heterogeneity plays a key role in population dynamics and life history

A state-space model approach

SSM separates the observation $y_{i,o}$ of individual i at occasion o from its state $z_{i,o}$ according to

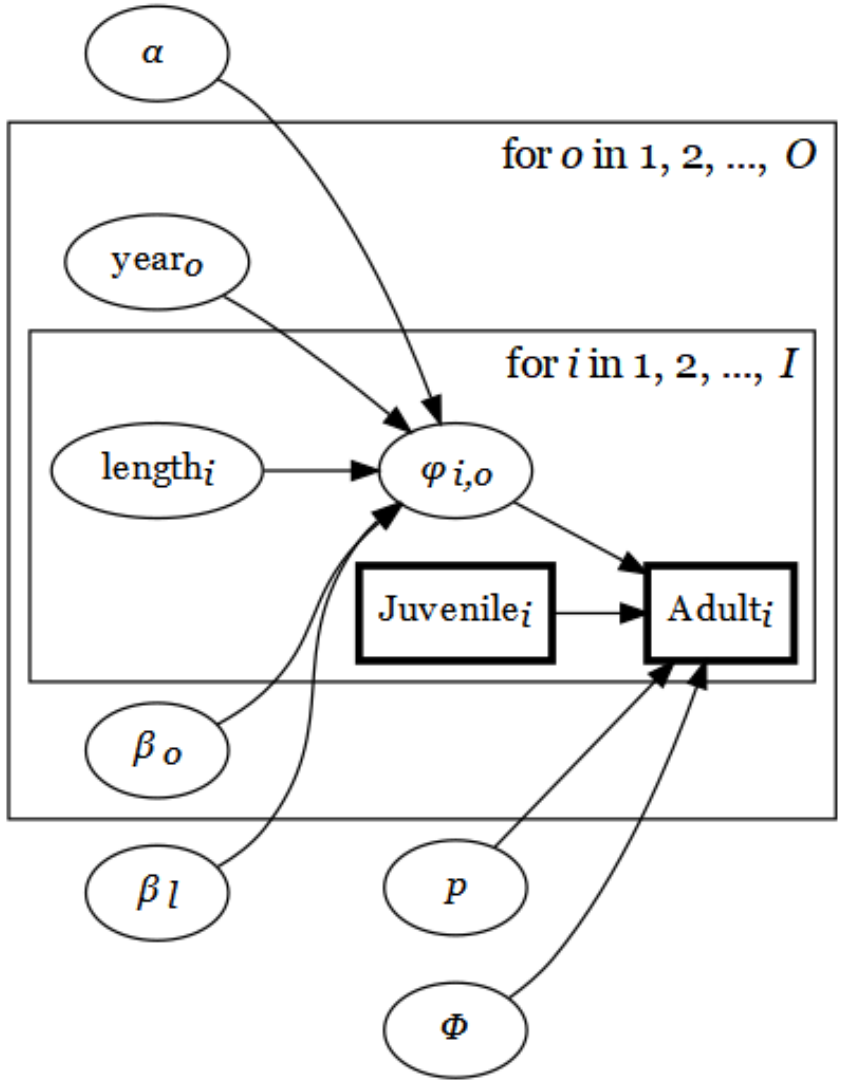
$$y_{i,o}|z_{i,o} \sim Bernoulli(z_{i,o}p)$$
$$z_{i,o+1}|z_{i,o} \sim Bernoulli(z_{i,o}\varphi_{i,o})$$

where p is the probability of detecting an individual and $\varphi_{i,o}$ is the survival of individual i from state z_{o-1} to state z_o, which can be specified as a function of individual length $length_i$

$$logit(\varphi_{i,o}) = \alpha + \beta_1 year_o + \beta_2 length_i$$

where α, β_1 and β_2 are constants to be estimated.

A state-space model approach

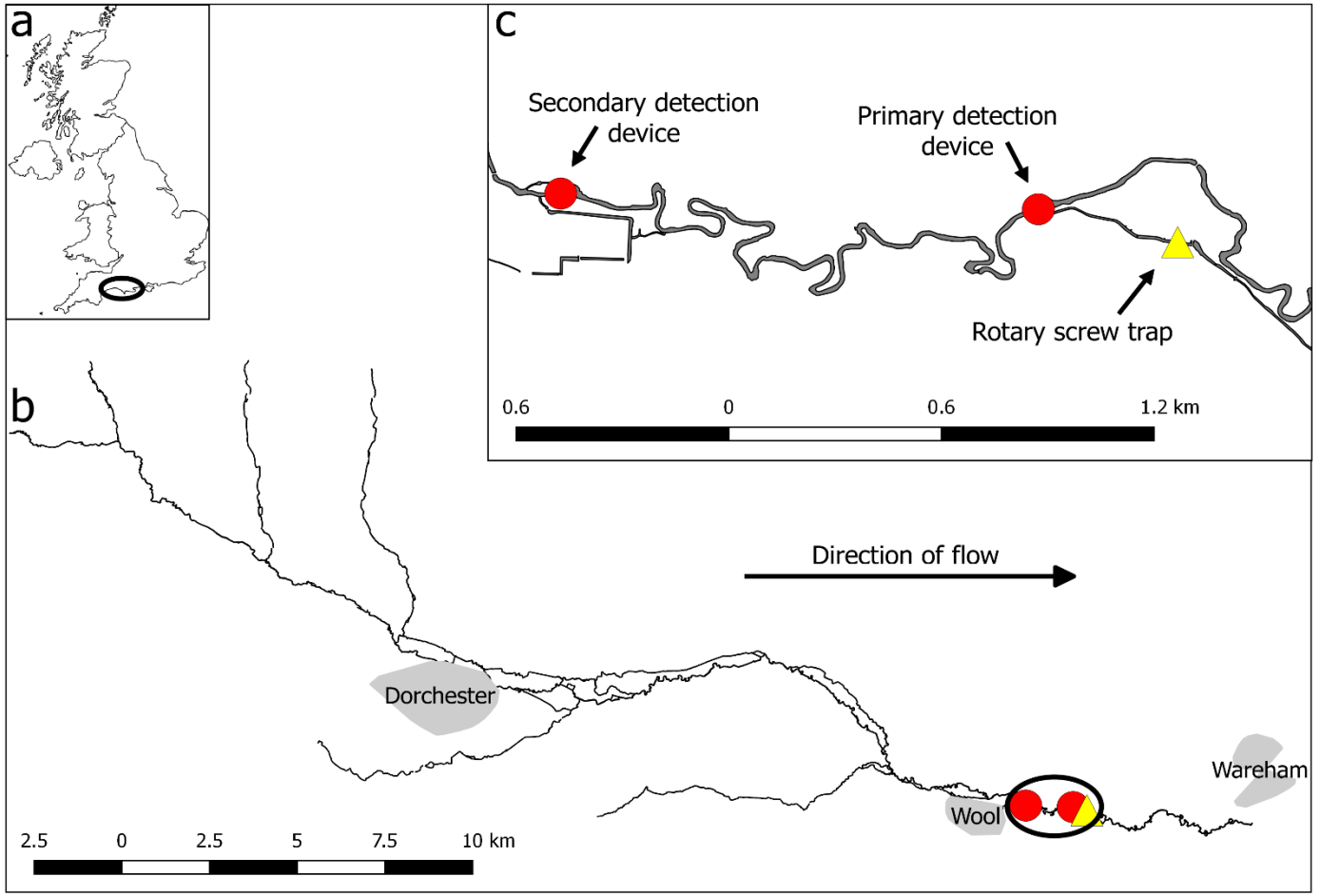


Salmon monitoring on the Frome, Dorset

1) Approx. 10,000 juvenile salmon marked each September
2) Following spring, a rotary screw trap collects smolts
3) Smolts identified, measured and released
4) Returning adults detected by PIT antennae

*All protocols done under UK Home Office license

Salmon monitoring on the Frome, Dorset



A map showing (a) the location of the river Frome in the UK, the locations of the detection devices and the trap (b) in the catchment and (c) on the river.

Parameter estimation and model selection

Parameters estimated for 3 SSMs written in Stan:

Null model no effect of year or individual length

Year model separate year effects but no effect of individual length

Length model effects of separate years and individual length

3 parallel chains run via R package rstan for 2000 iterations after a 1000 iteration burnin. Priors were weakly informative.

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Results

Variable	Null	Year	Length
$\phi_{i,o}$	0.034 (0.025 - 0.048)	0.029 (0.013 - 0.067)	0.026 (0.011 - 0.06)
ψ	0.73 (0.526 - 0.953)	0.717 (0.524 - 0.934)	0.725 (0.512 - 0.944)
p	0.714 (0.53 - 0.862)	0.72 (0.537 - 0.863)	0.721 (0.542 - 0.852)
α		-3.501 (-4.366 - -2.632)	-3.606 (-4.465 - -2.743)
β_{length}			0.449 (0.117 - 0.792)
IC_{loo}	505.007	501.517	496.127
SE	60.655	60.988	60.477

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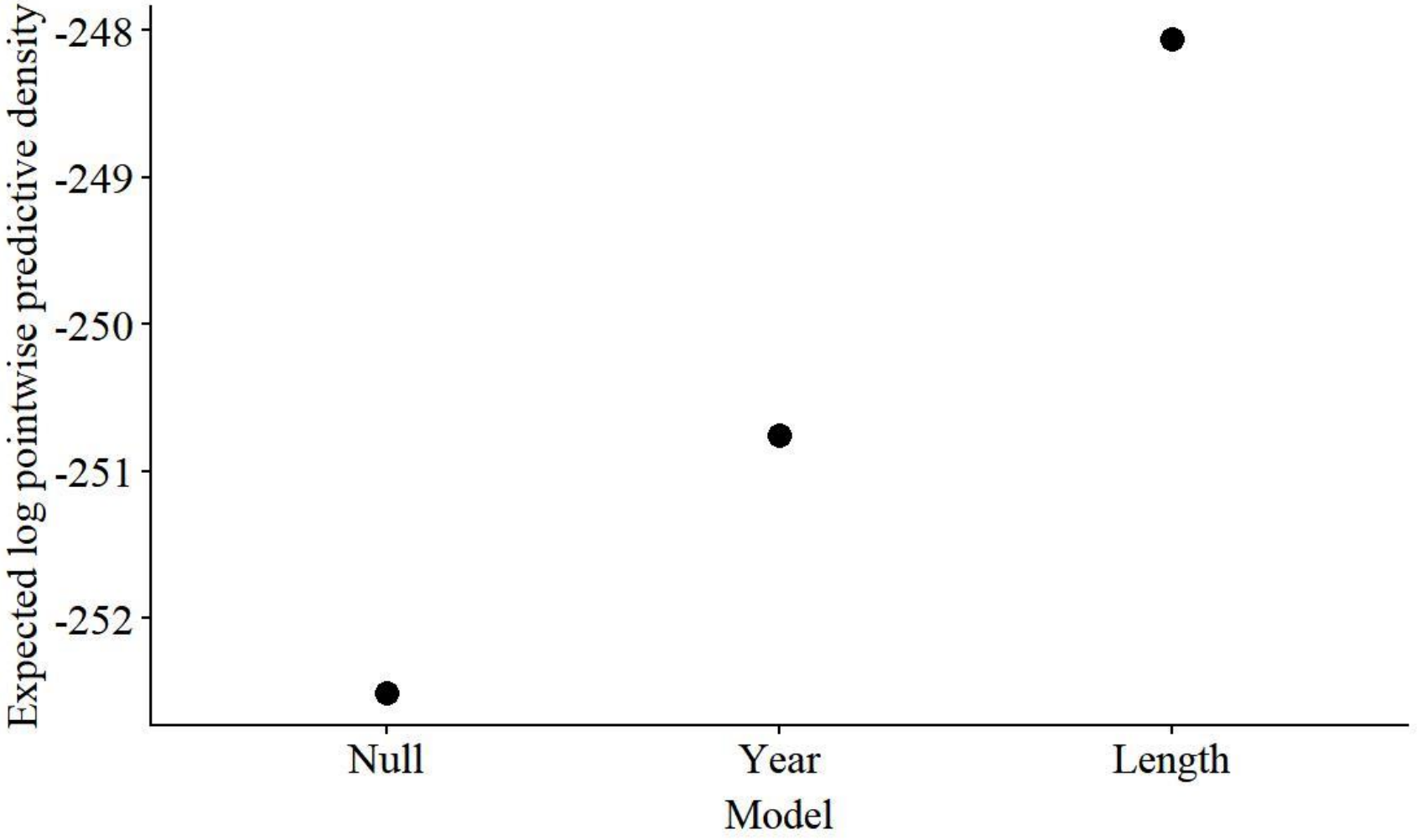
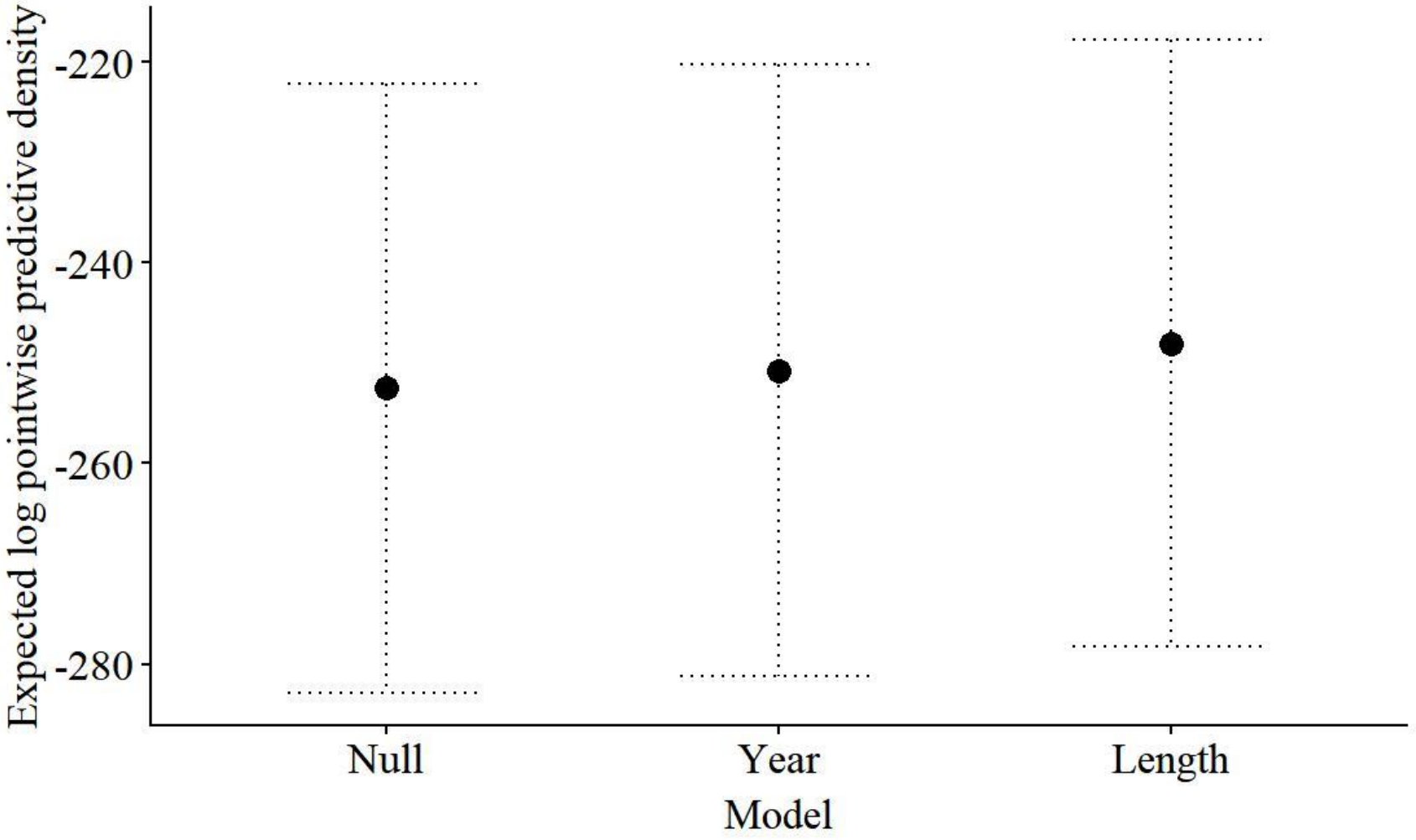
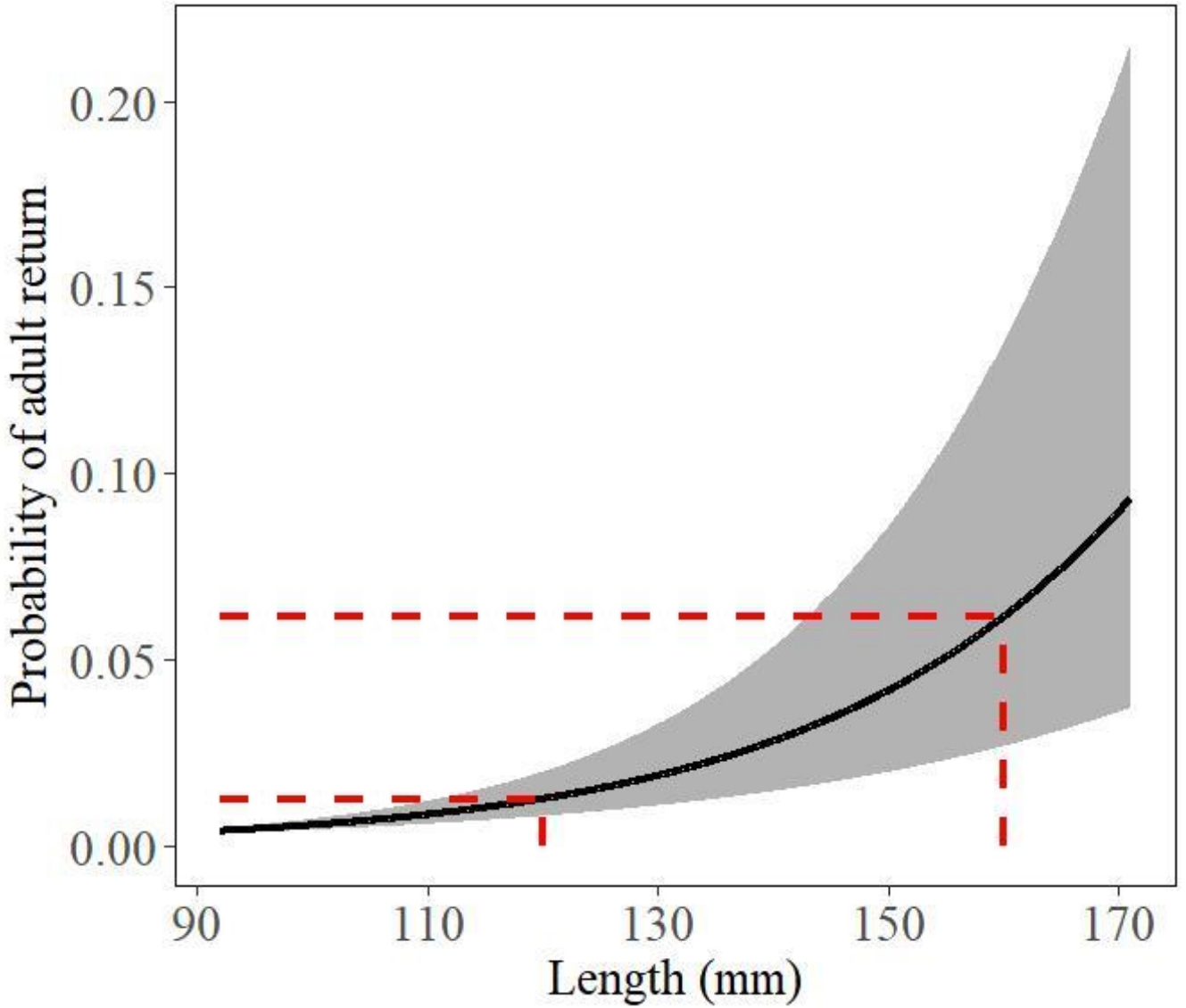

Expected log pointwise predictive density
-248
-249
-250
-251
-252
Null
Year
Length
Model

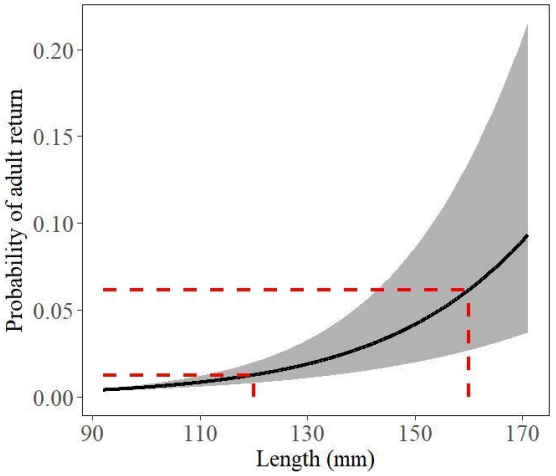
Results


Expected log pointwise predictive density
-220
-240
-260
-280
Null
Year
Length
Model

Results


Probability of adult return
0.20
0.15
0.10
0.05
0.00
90
110
130
150
170
Length (mm)

Discussion



- Smolt length related to probability to return as an adult

- Effect is not small:
    - 16cm smolt 3-4x more likely to return *cf*. 12cm smolt

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Management

Current ICES advice:

- maximise production

This study:

- maximise *quality* production

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Next Steps

- Refine model selection for these data
  - 45 adults from 1556 juveniles; (<3%)
  - LOO appropriate?
- Generalise to 1SW and MSW salmon life histories
- Alternative factors, other river systems…

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Thanks

sgregory@gwct.org.uk

http://stephendavidgregory.github.io/

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