Interreg
EUROPEAN UNION
France ( Channel Manche ) England
SAMARCH
SAlmonid MAnagement Round the CHannel
European Regional Development Fund

# Producing the next generation

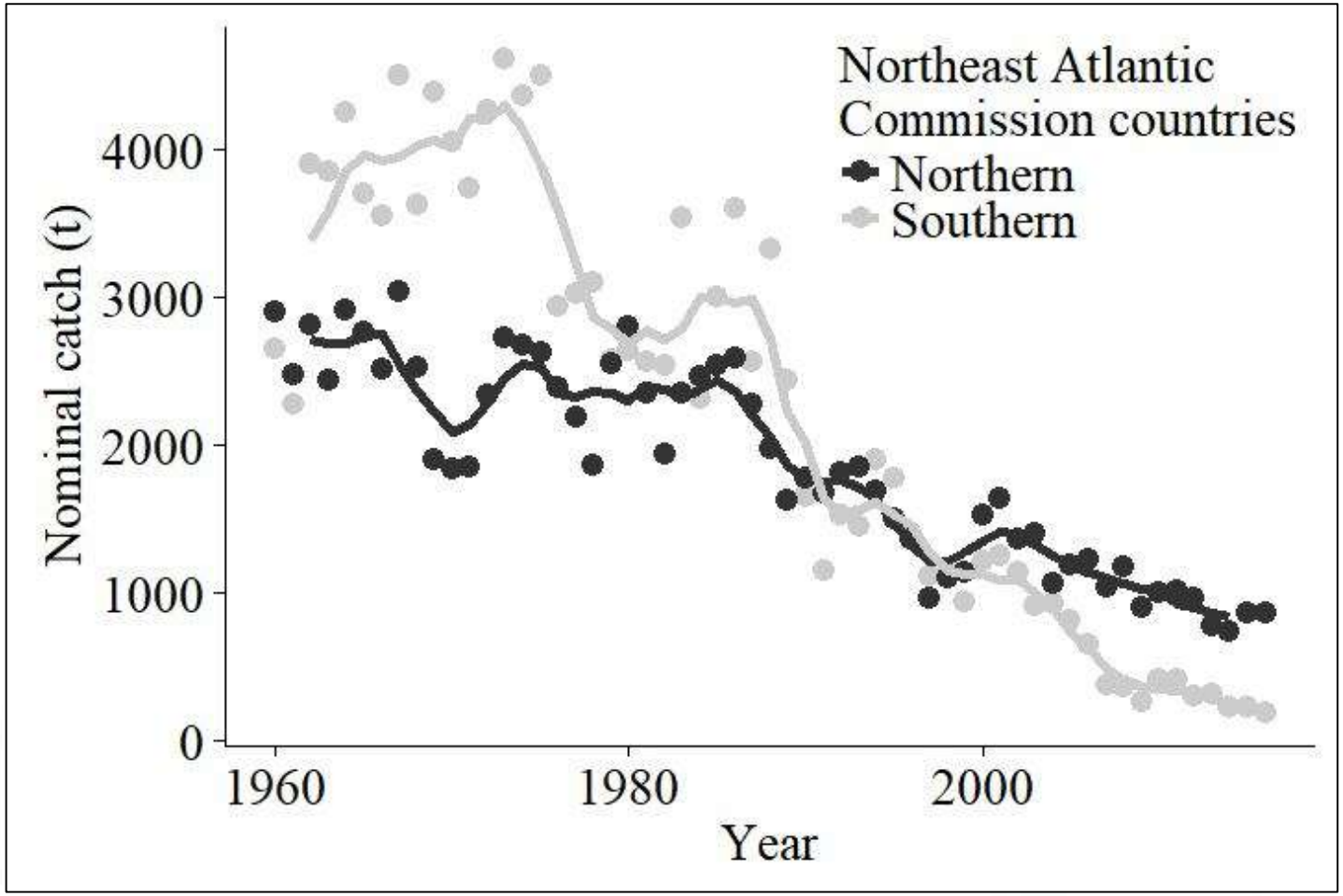
## Improving smolt output with examples from the R. Frome

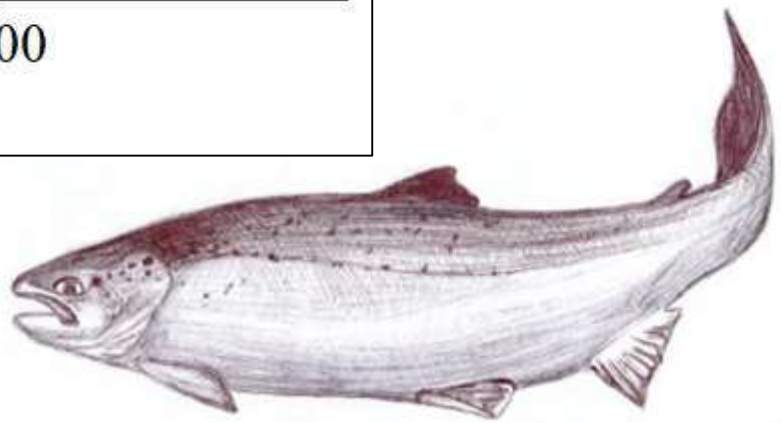
Stephen D. Gregory, Céline Artero, Jessica E. Marsh & Olivia M. Simmons

ifm Institute of Fisheries Management

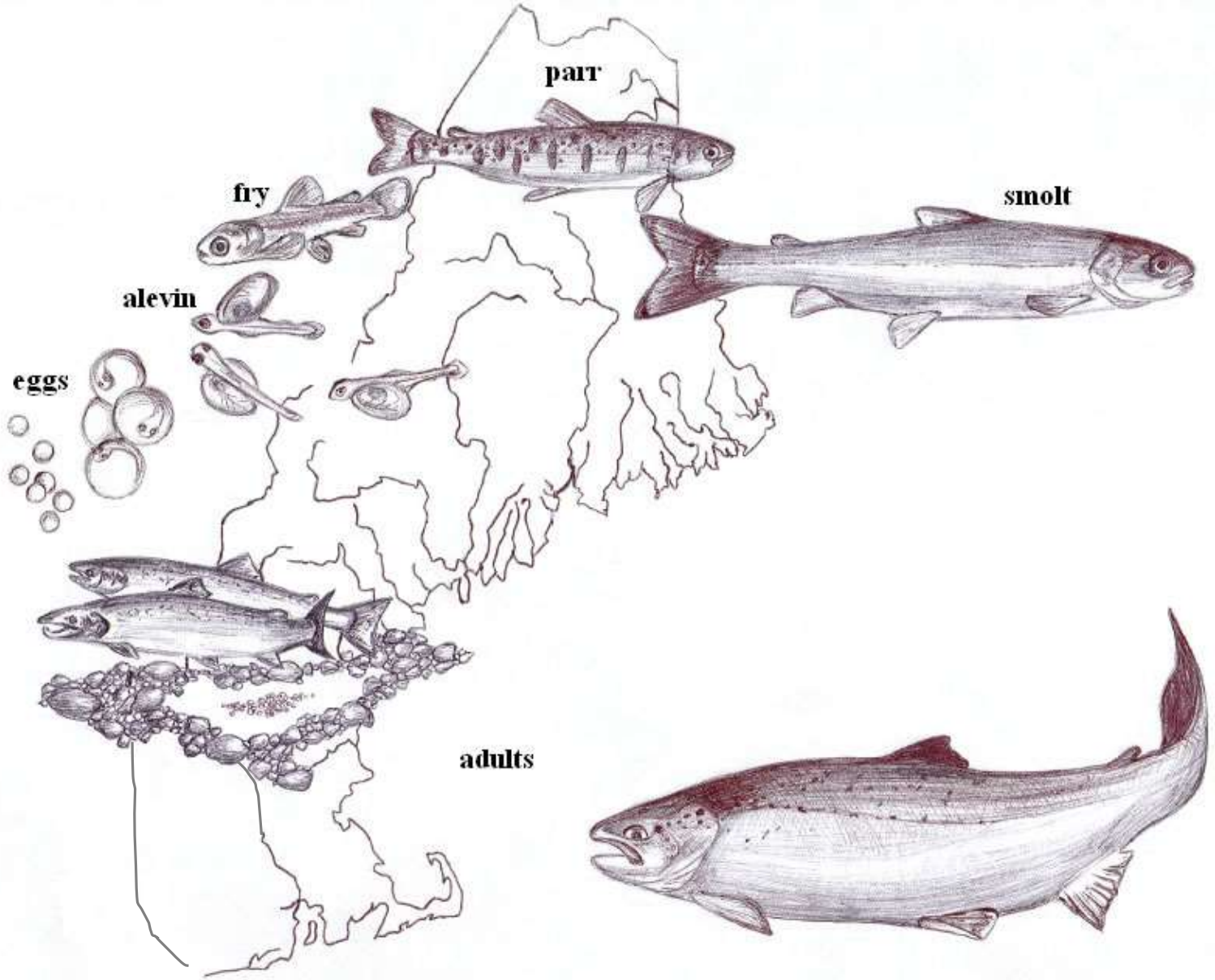
Festival of Fisheries

Atlantic Salmon Conservation

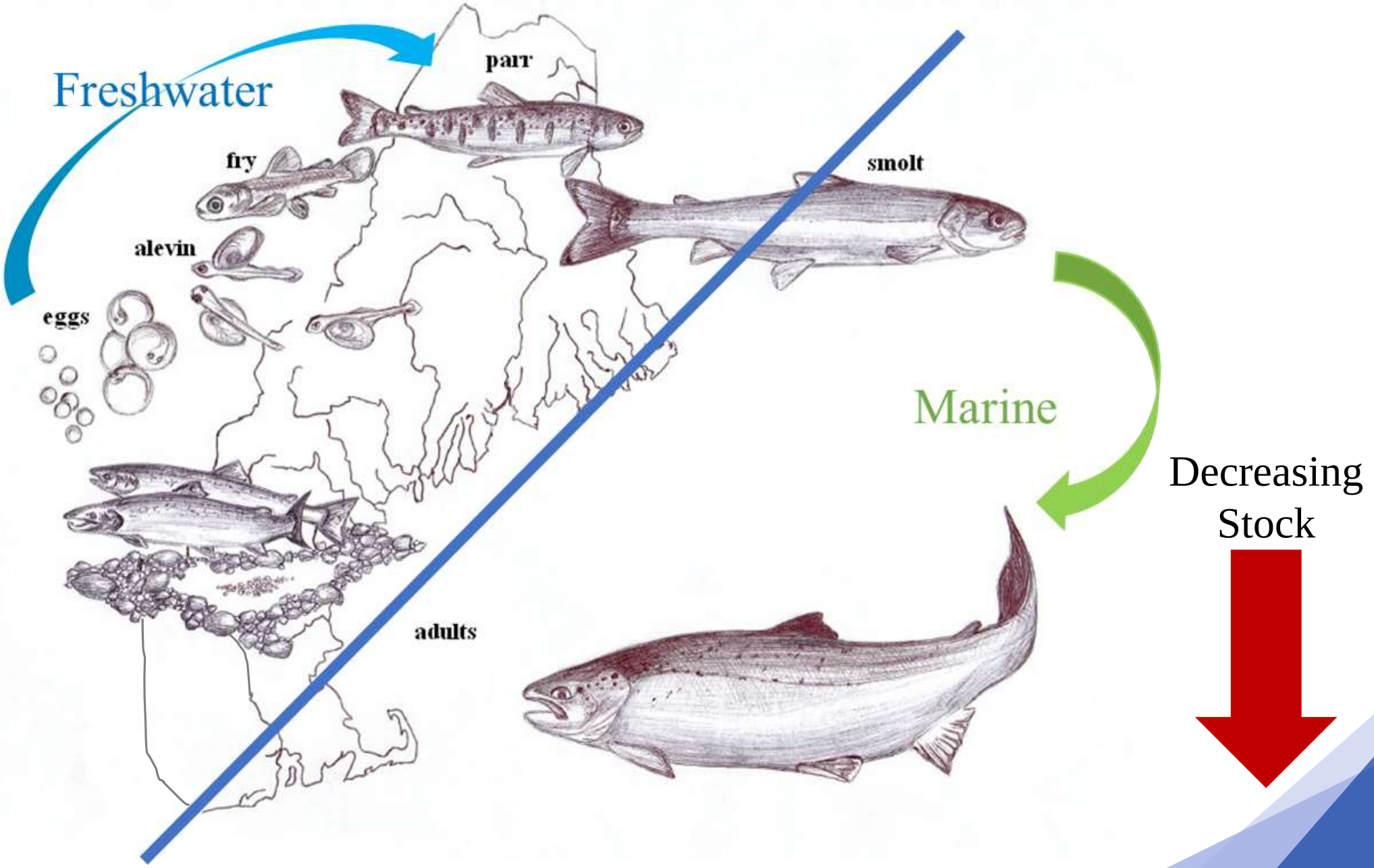


Decreasing
Stock

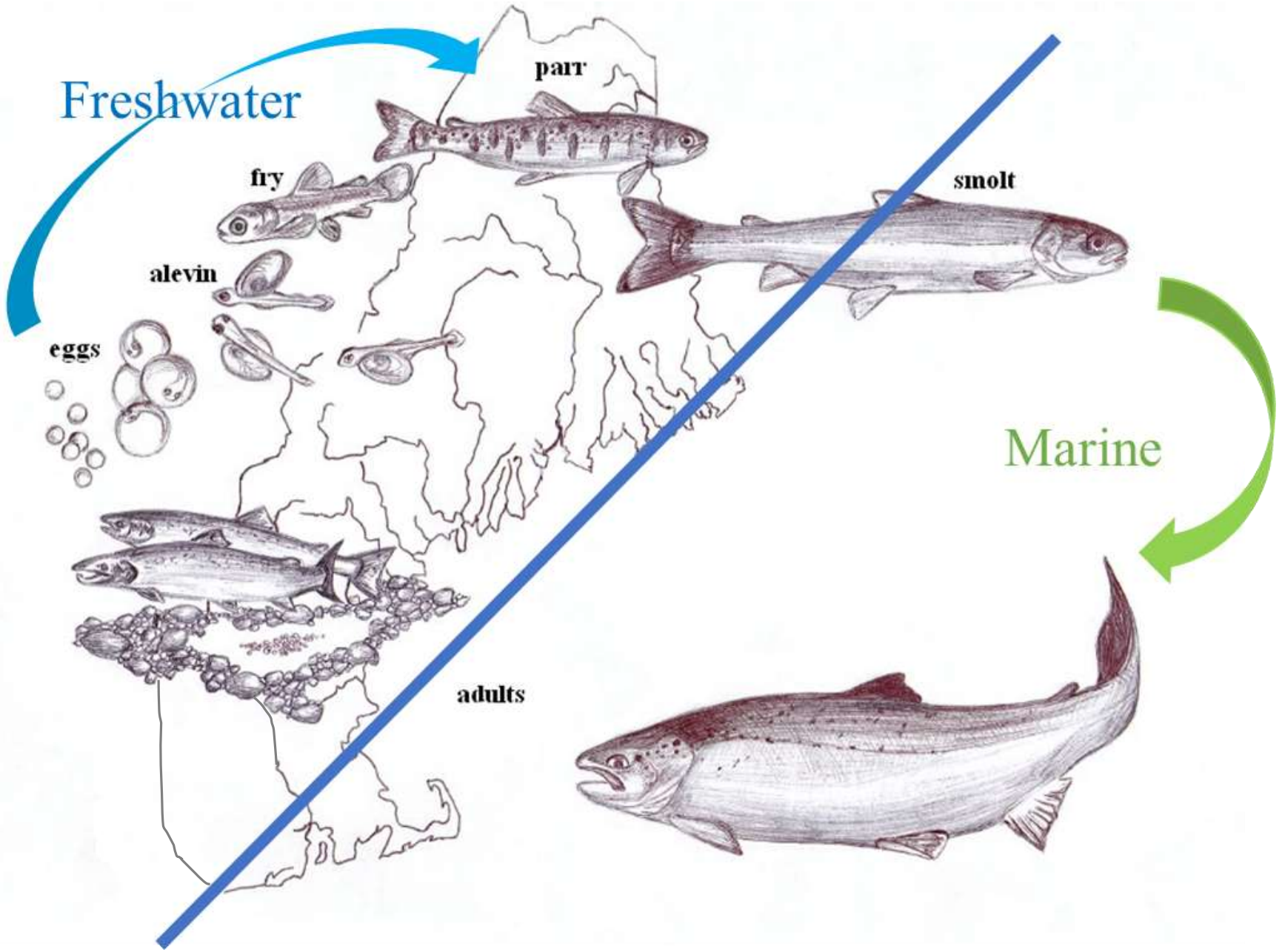



Decreasing Stock


Freshwater
parr
fry
alevin
eggs
smolt
Marine
adults
Decreasing
Stock

?

?




Decreasing Stock

# Decline causes

## 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)

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.

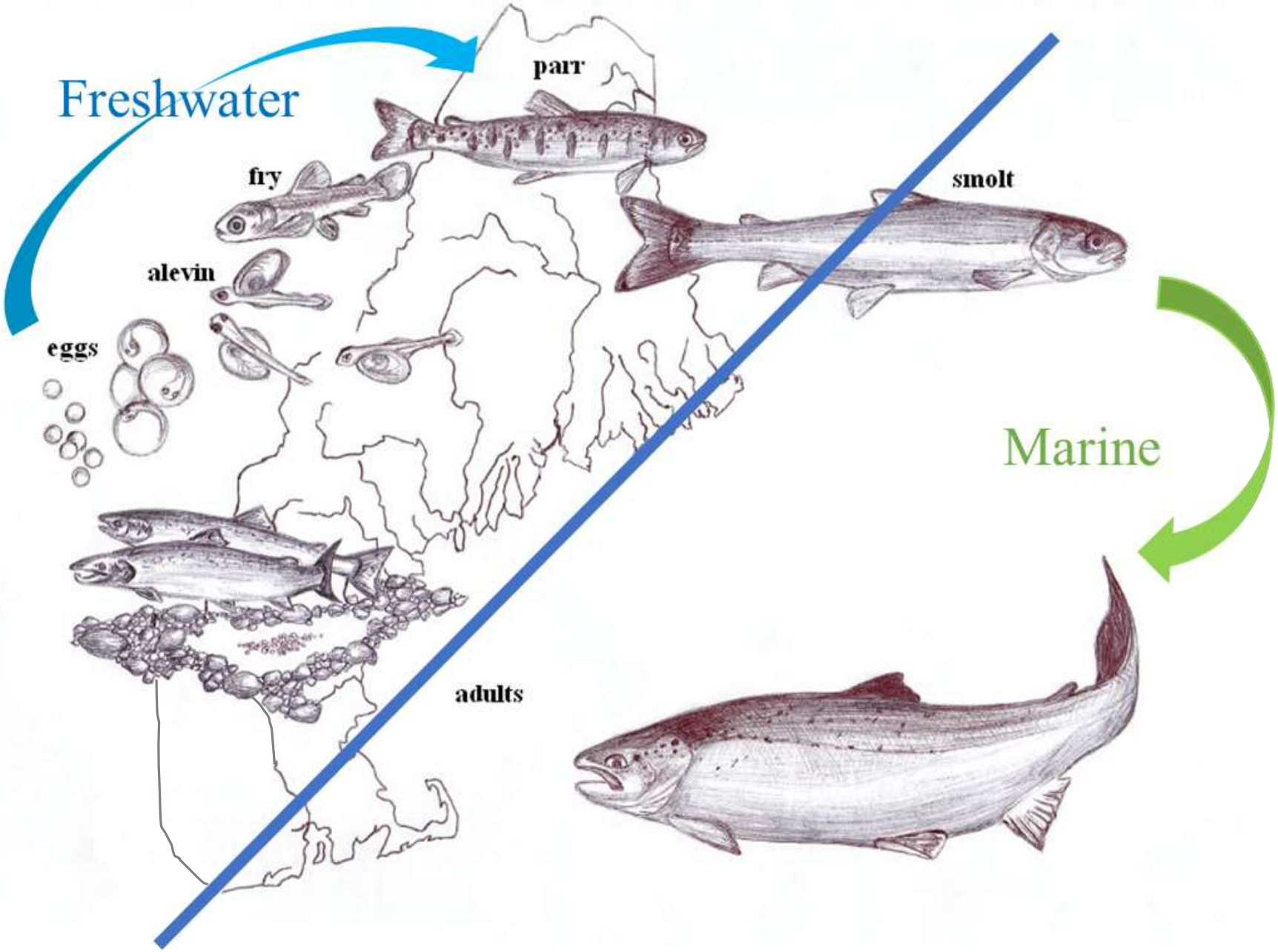
Since the early 1980s, the ICES Working Group on North Atlantic Salmon has collated and interpreted catch data, exchanged information on research initiatives, and provided advice to managers in support of conservation efforts for Atlantic salmon. During the past

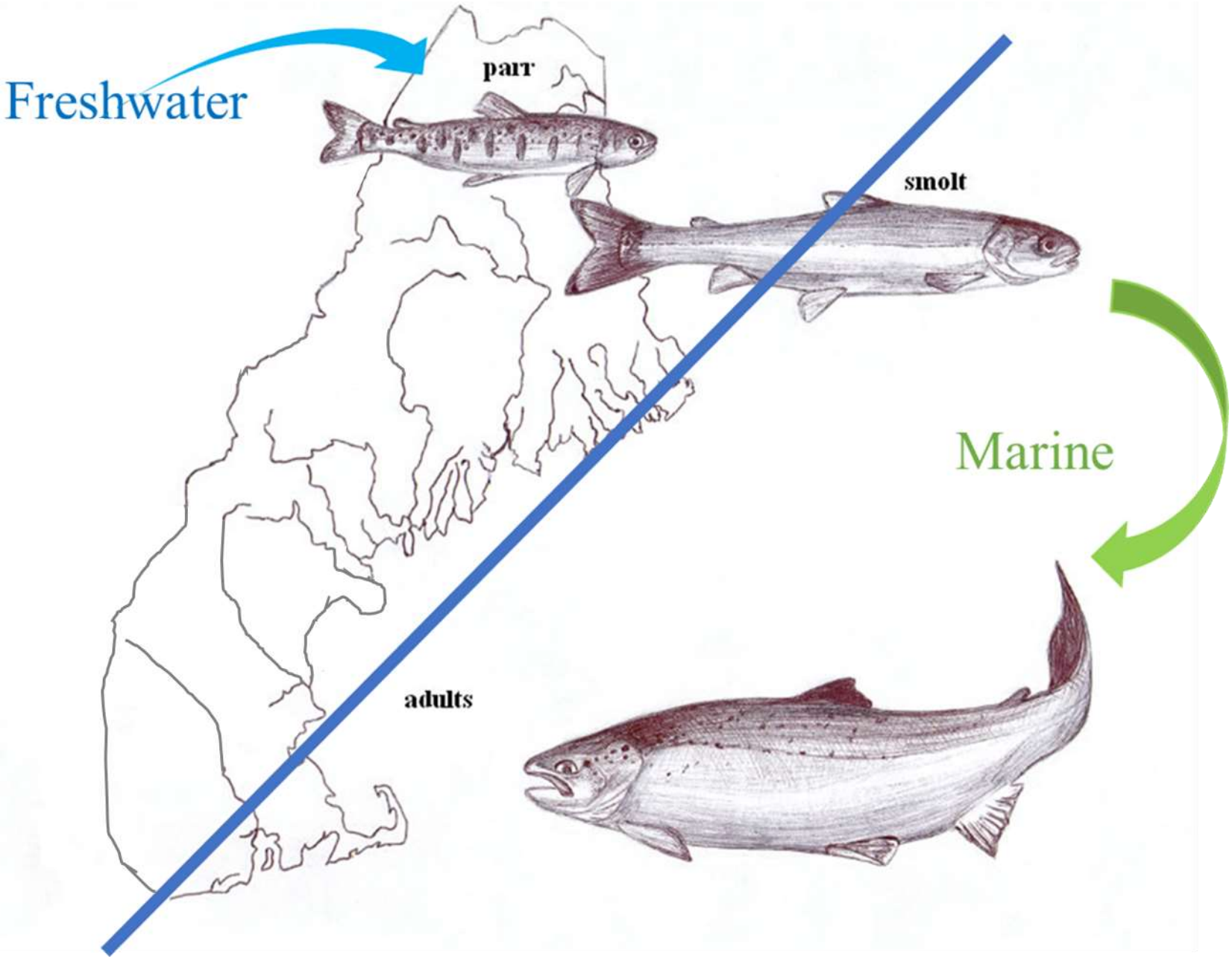
ICES Journal of Marine Science; doi:10.1093/icesjms/fsr208

# 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*


Freshwater
parr
fry
alevin
eggs
smolt
Marine
adults


Freshwater
parr
smolt
Marine
adults

Juvenile habitat

Jessica Marsh
jmarsh@gwct.org.uk

Juvenile growth & migration

Olivia Simmons
osimmons@gwct.org.uk

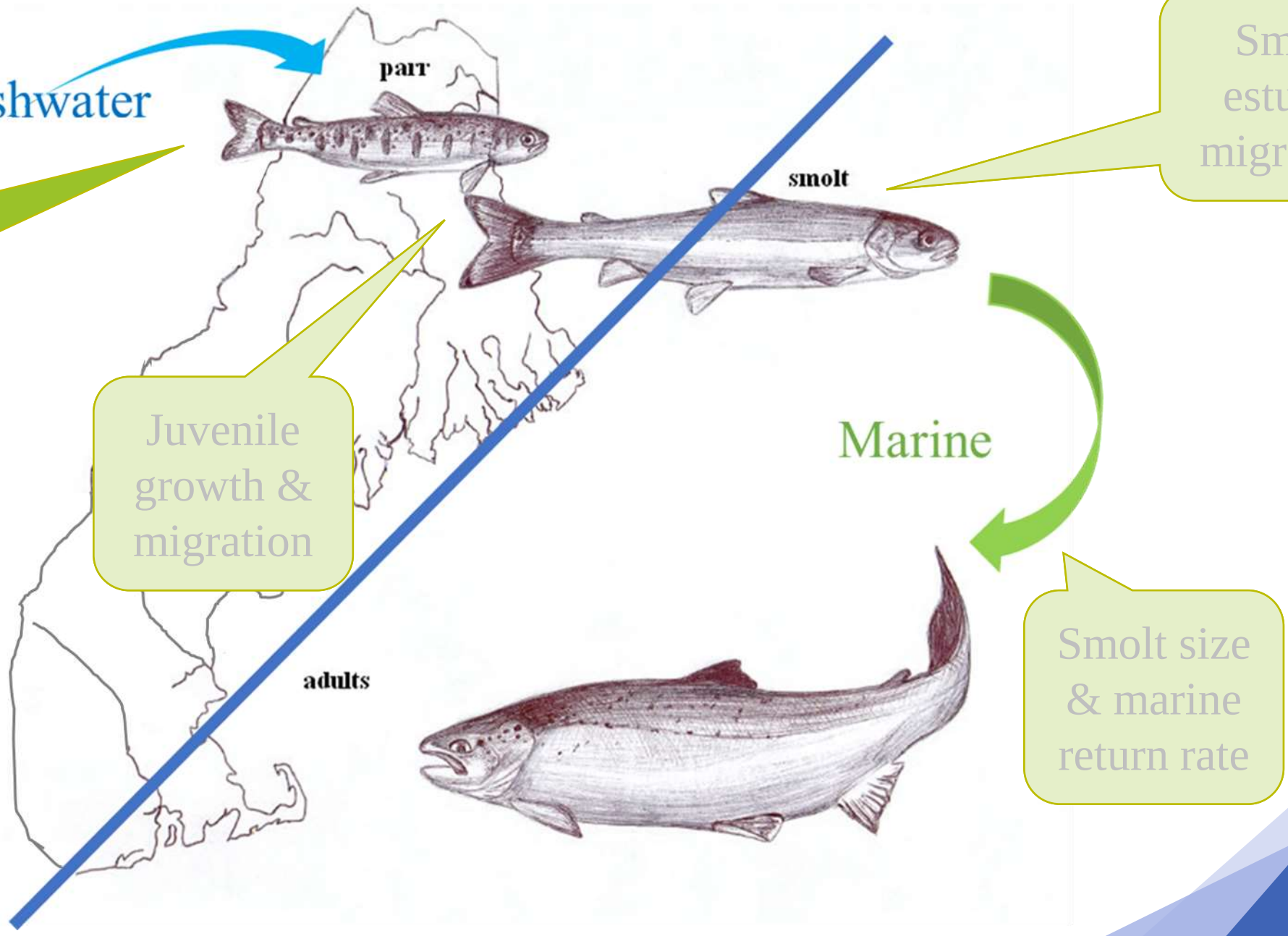



Smolt estuary migration

Céline Artero
cartero@gwct.org.uk

Smolt size & marine return rate

Stephen Gregory
sgregory@gwct.org.uk




**Juvenile habitat**

Smolt estuary migration

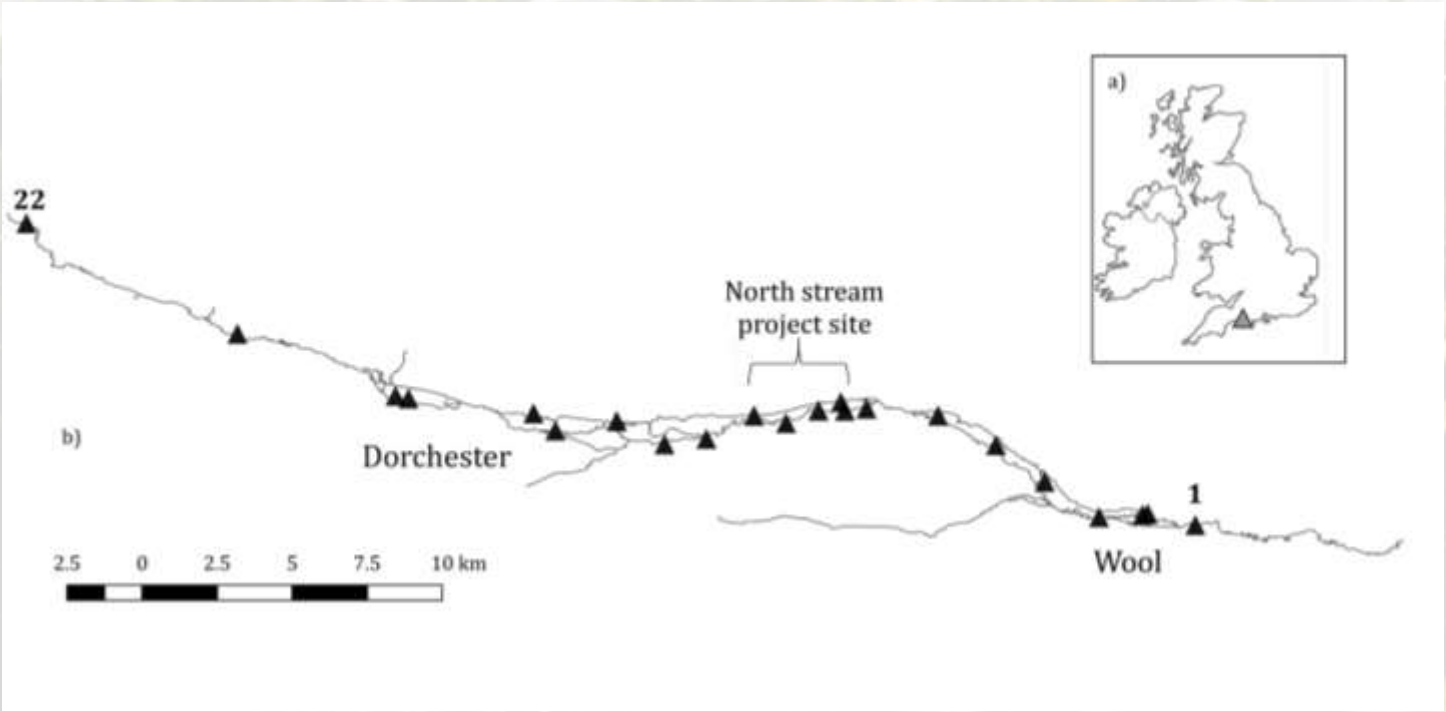
Juvenile growth & migration

Smolt size & marine return rate

Jessica Marsh
jmarsh@gwct.org.uk


Juvenile habitat

# Correlation study

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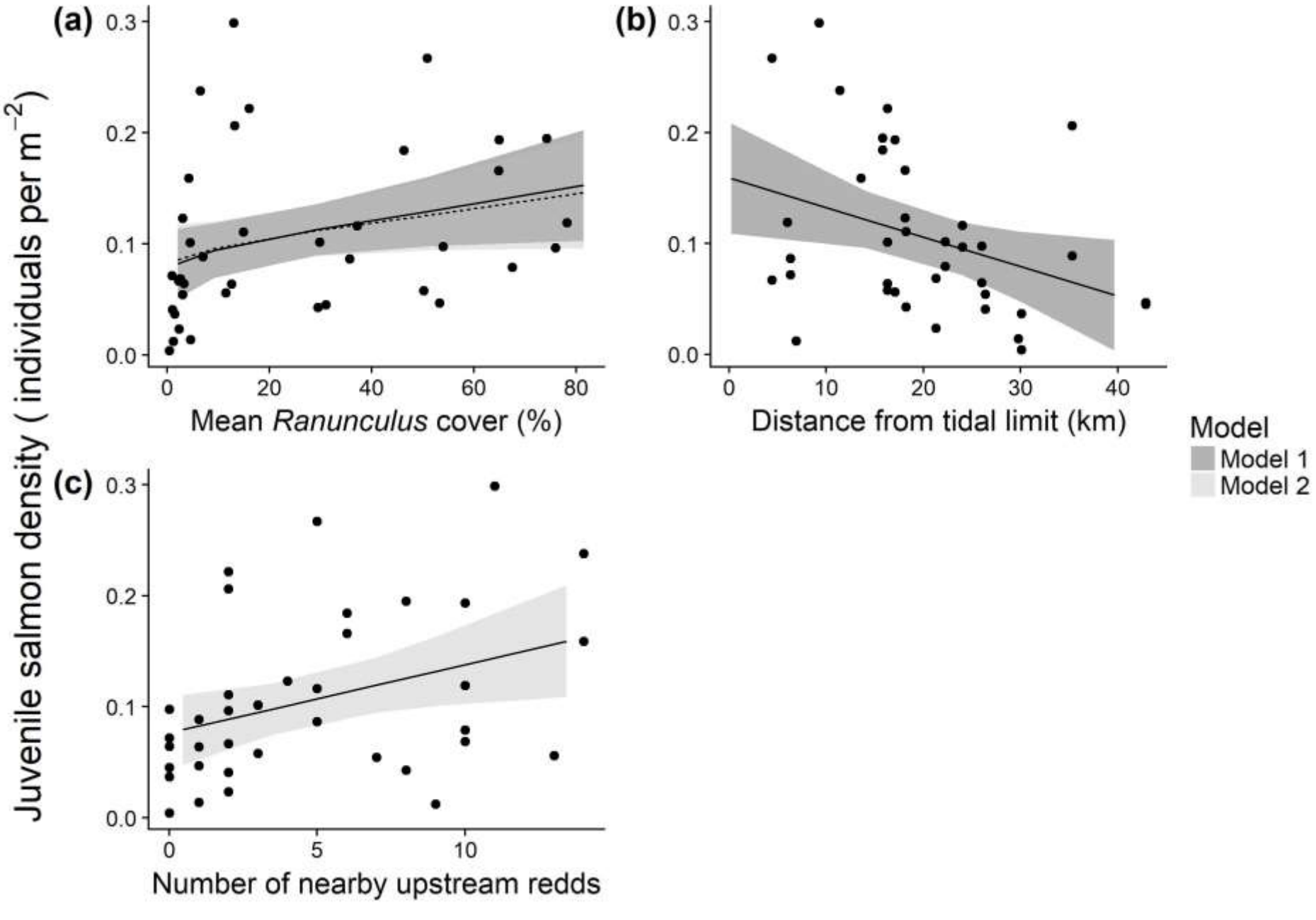

(a)
(b)
(c)
Juvenile salmon density ( individuals per m$^{-2}$)
Mean *Ranunculus* cover (%)
Distance from tidal limit (km)
Number of nearby upstream redds
Model
Model 1
Model 2


Received: 7 October 2019 | Revised: 22 November 2019 | Accepted: 27 November 2019

DOI: 10.1111/eff.12529

ORIGINAL ARTICLE

Ecology of FRESHWATER FISH WILEY

# Above parr: Lowland river habitat characteristics associated with higher juvenile Atlantic salmon (*Salmo salar*) and brown trout (*S. trutta*) densities

Jessica E. Marsh[1,2] | Rasmus B. Lauridsen[2] | Stephen D. Gregory[2] | William R. C. Beaumont[2] | Luke J. Scott[2] | Pavel Kratina[1] | J. Iwan Jones[1]

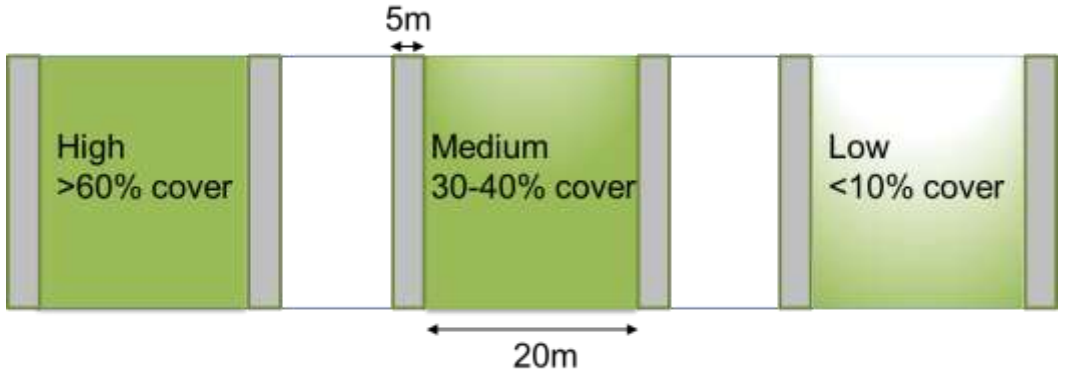
[1]School of Biological and Chemical Sciences, Queen Mary University of London, London, UK

[2]Salmon and Trout Research Centre, Game & Wildlife Conservation Trust, The River Laboratory, Wareham, UK

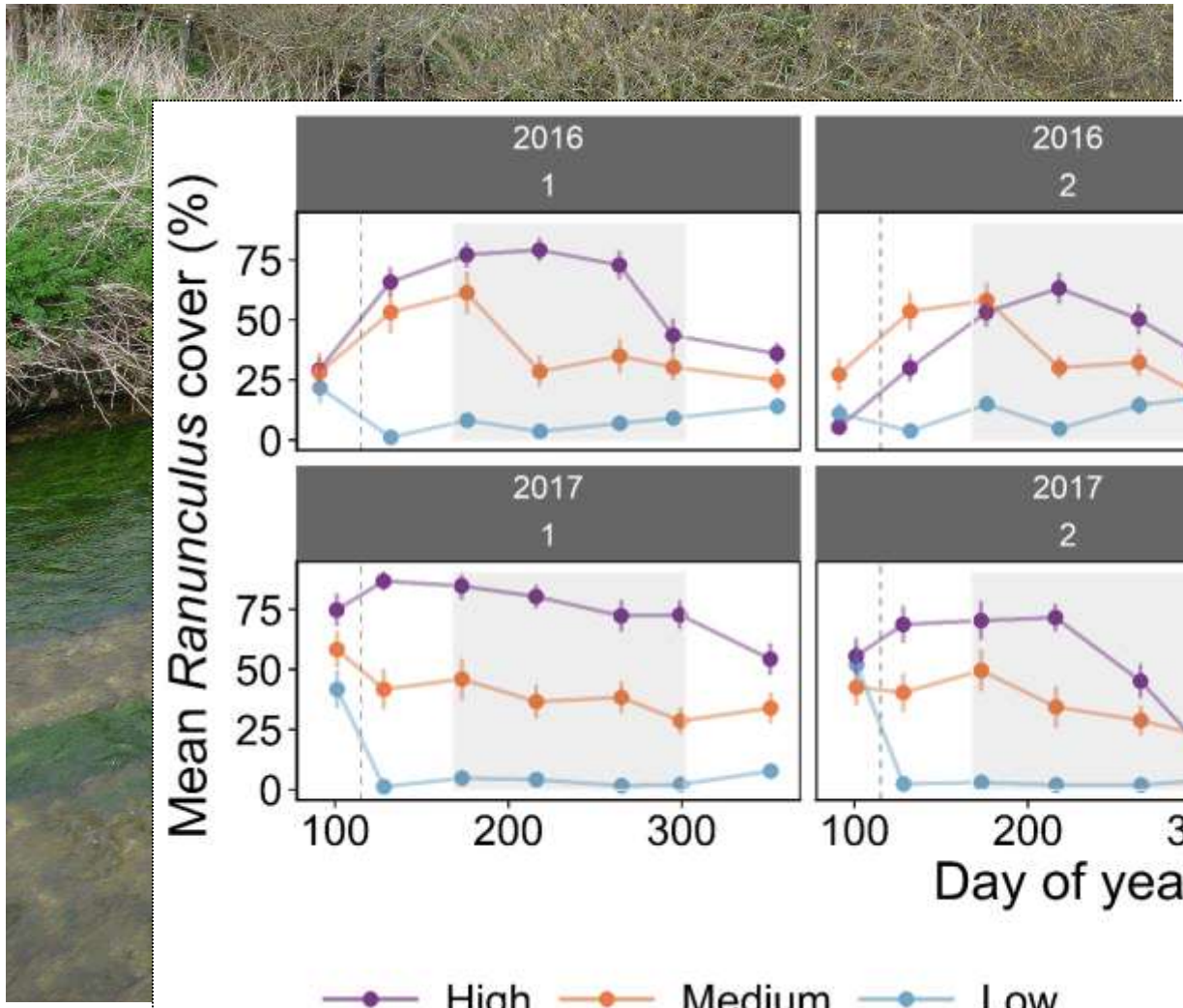
**Abstract**

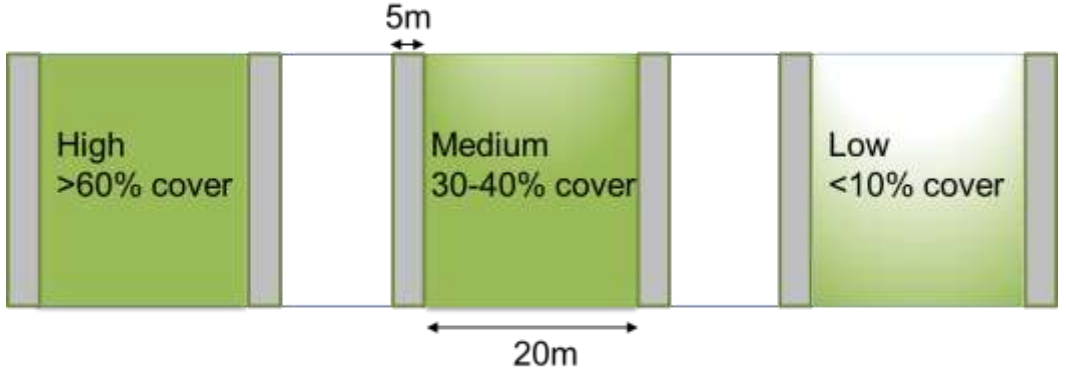
Understanding juvenile salmonid habitat requirements is critical for their effective management, but little is known about these requirements in lowland rivers, which include important but unique salmonid habitats. We compared the relative influence of in-stream *Ranunculus* cover, water depth, prey abundance, distance upstream and

# Manipulation study



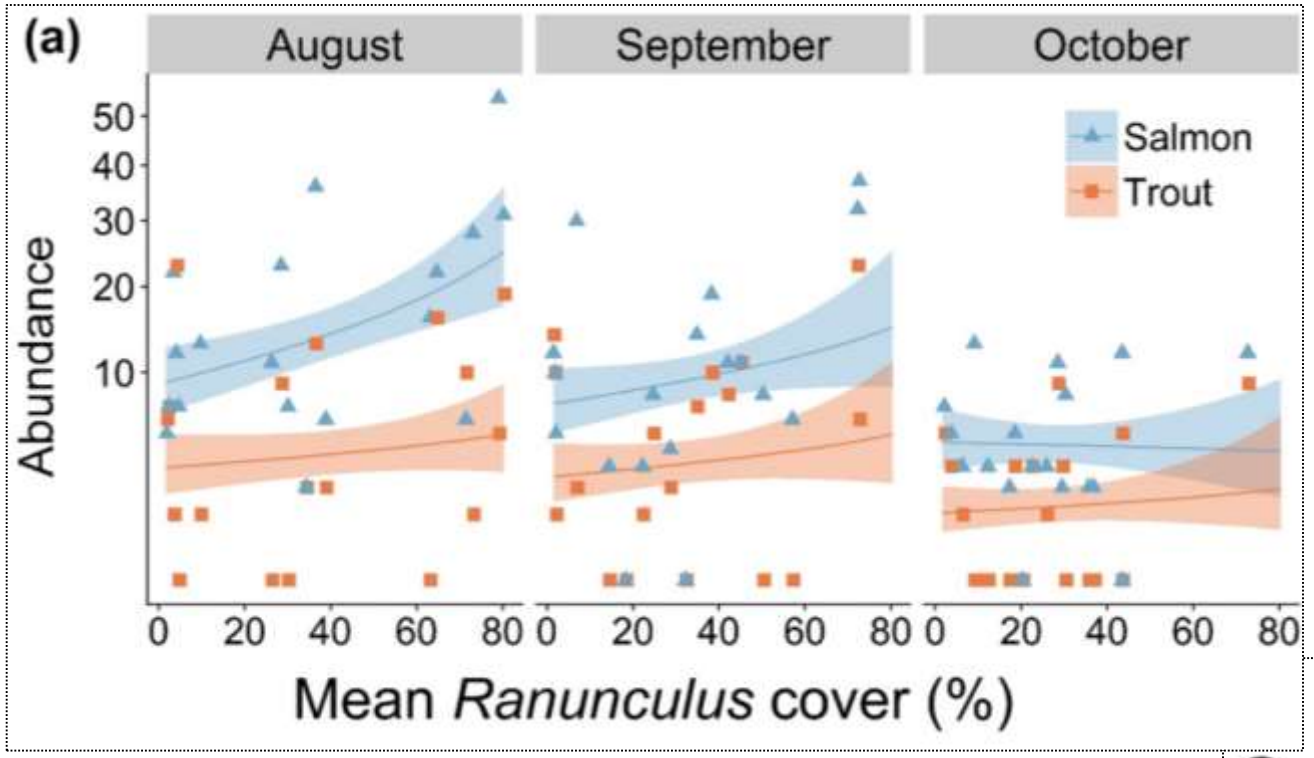

# Manipulation study



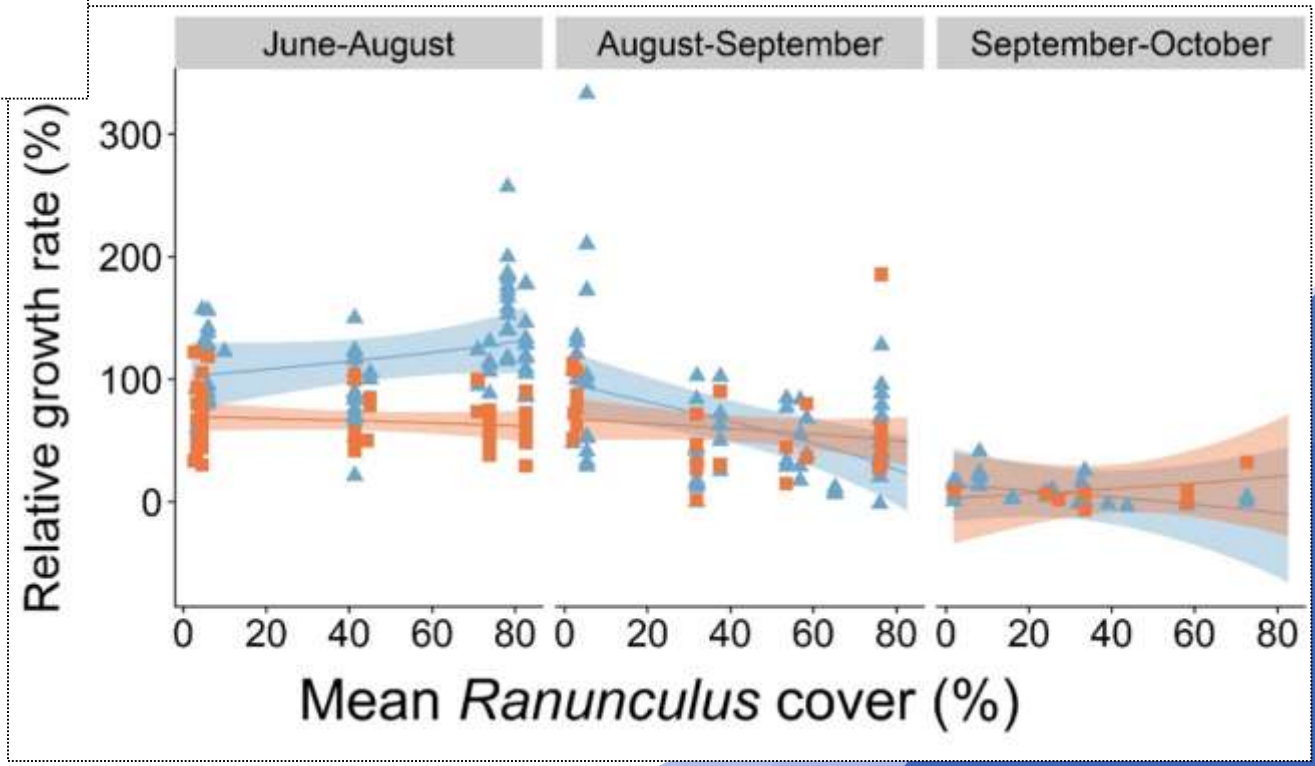









More *Ranunculus*
-> More & bigger juveniles

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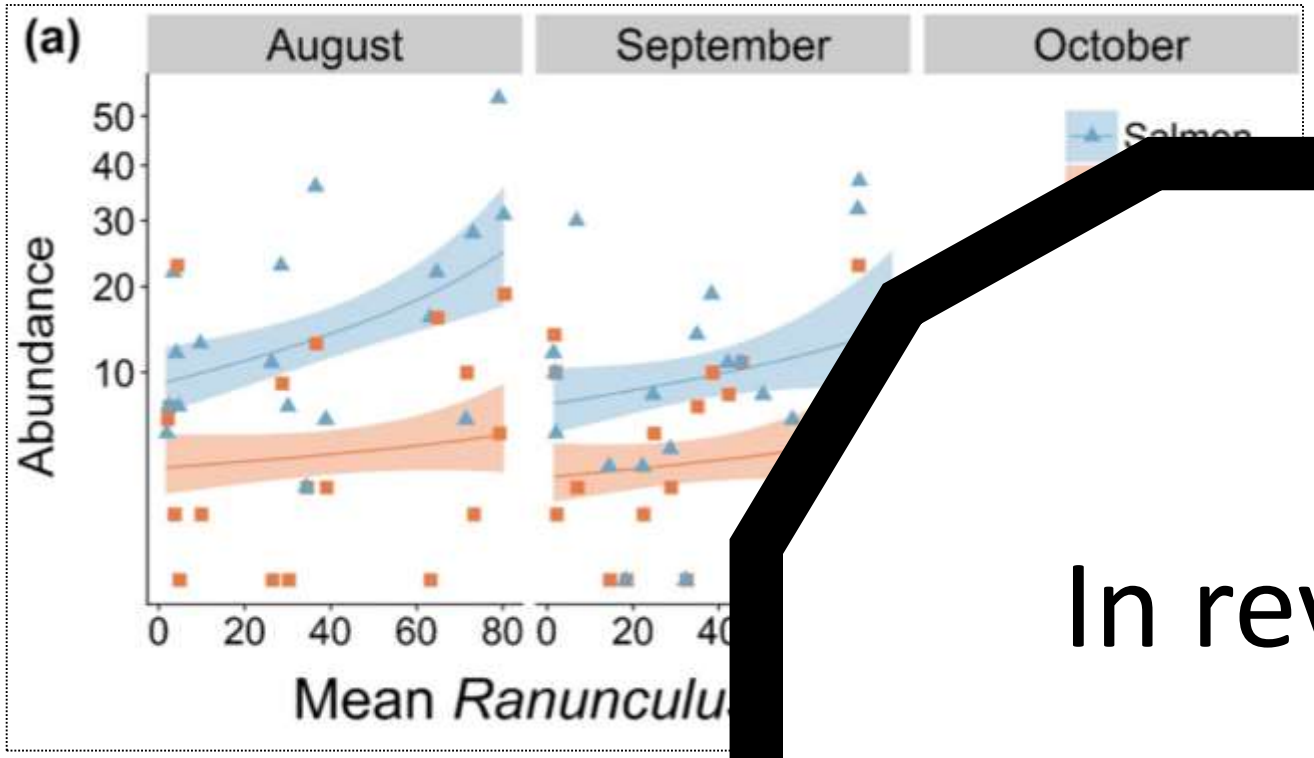
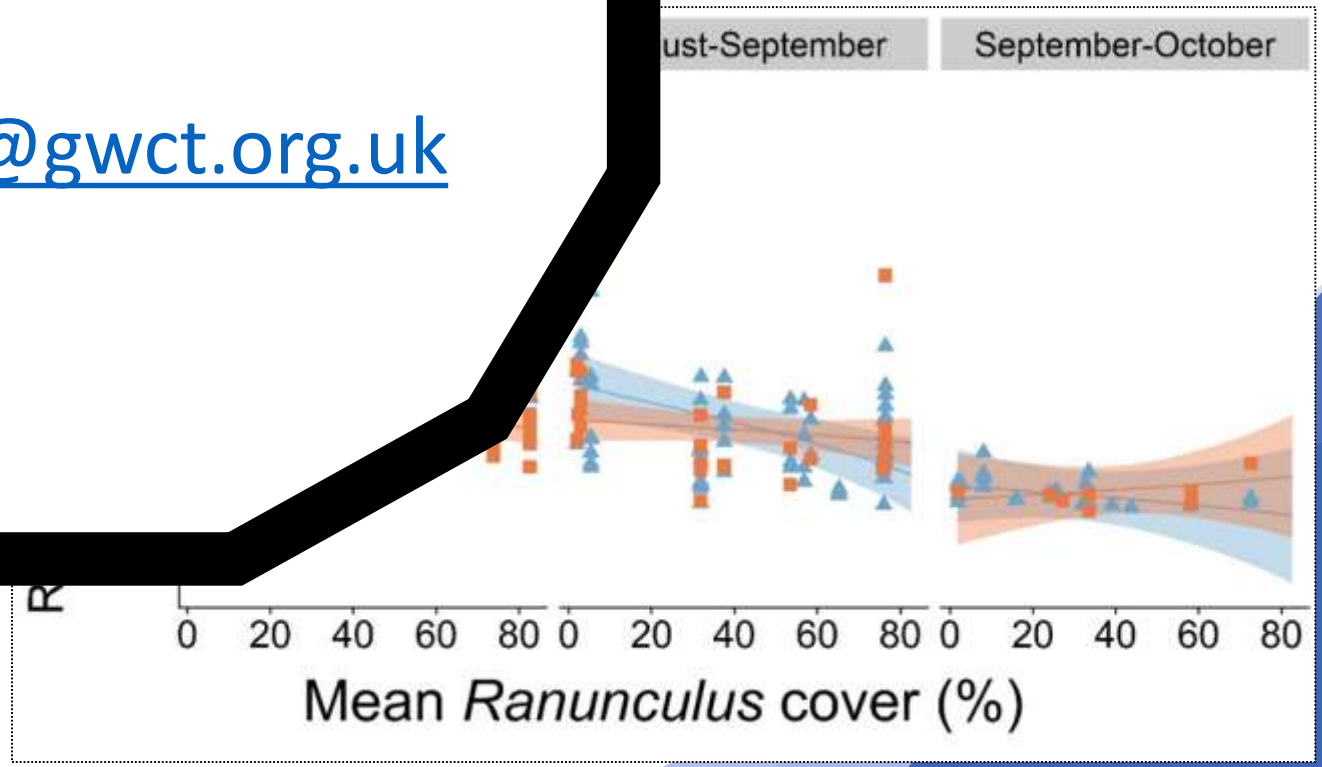



*unculus*

re & bigger juveniles

In review

jmarsh@gwct.org.uk

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Freshwater

parr

smolt

Marine

adults

Juvenile habitat

**Juvenile growth & migration**

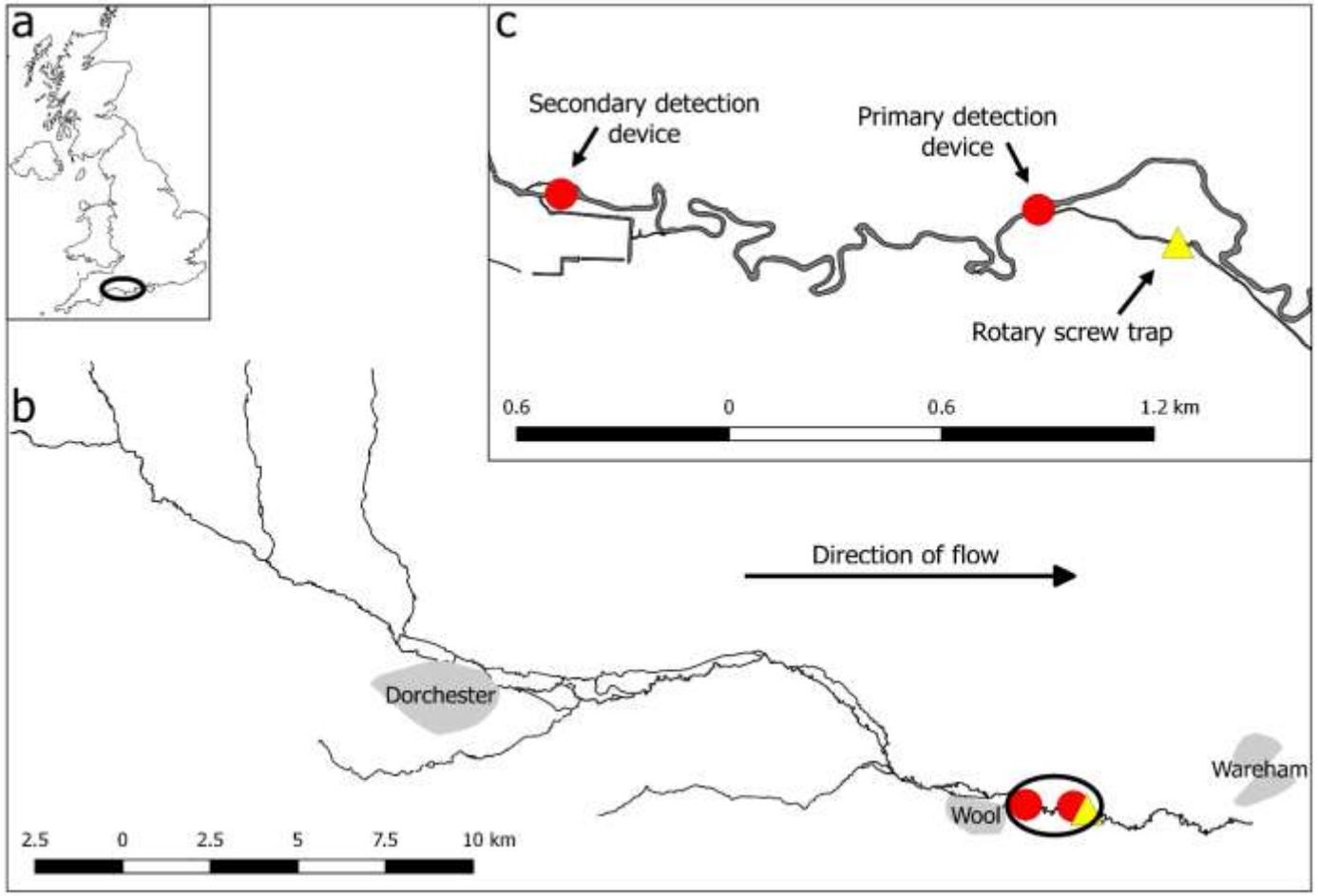
Smolt estuary migration

Smolt size & marine return rate

Olivia Simmons
osimmons@gwct.org.uk


Juvenile growth

# Smolt monitoring on the R. 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.

Bournemouth University

Game & Wildlife Conservation Trust

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# Overwinter juvenile growth on R. Frome

**TABLE 3** Total number of PIT-tagged smolts caught in the RST each spring

| Year | Number of Smolts caught in RST |
|---|---|
| 2006 | 316 |
| 2007 | 609 |
| 2008 | 389 |
| 2009 | 419 |
| 2010 | 356 |
| 2011 | 224 |
| 2012 | 223 |
| 2013 | 330 |
| 2014 | 303 |
| 2015 | 220 |
| 2016 | 233 |
| 2017 | 141 |
| 2018 | 136 |

# Overwinter juvenile growth on R. Frome

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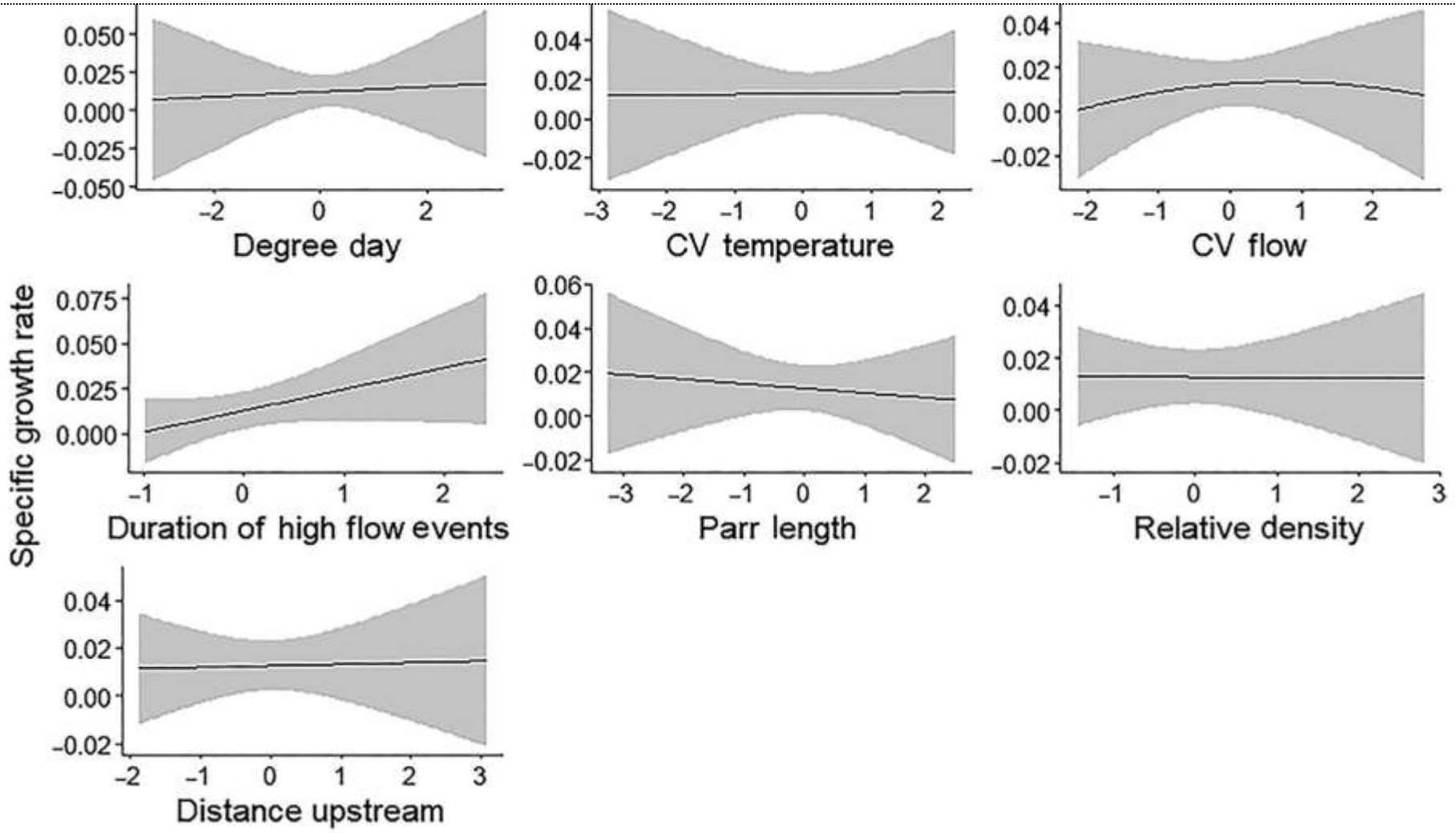


**FIGURE 5** Marginal effects plots of each standardised explanatory variable. The shaded areas represent the 95% confidence interval

# O… …n P. Frome

Received: 19 November 2019 | Revised: 14 February 2020 | Accepted: 18 February 2020
DOI: 10.1111/eff.12542

ORIGINAL ARTICLE

Ecology of FRESHWATER FISH WILEY

Check for updates

# Influence of environmental and biological factors on the overwinter growth rate of Atlantic salmon *Salmo salar* parr in a UK chalk stream

Olivia M. Simmons[1,2] | John Robert Britton[1] | Phillipa K. Gillingham[1] | Stephen D. Gregory[2]

[1]Department of Life and Environmental Sciences, Faculty of Science and Technology, Bournemouth University, Poole, UK
[2]Salmon & Trout Research Centre, Game and Wildlife Conservation Trust, FBA River Laboratory, Wareham, UK

**Abstract**

Smolt lengths are increasingly recognised as an important determinant of salmonid marine survival rates. Overwintering growth rates could thus strongly influence adult return rates. In Atlantic salmon *Salmo salar*, most overwintering studies focus on riv-

TABLE 3 … each sprin…

| Year | |
|---|---|
| 2006 | |
| 2007 | |
| 2008 | |
| 2009 | |
| 2010 | |
| 201… | |
| 201… | |
| 201… | |
| 20… | |
| 2015 | |
| 2016 | 233 |
| 2017 | 141 |
| 2018 | 136 |


FIGURE 5 Marginal effects plots of each standardised explanatory variable. The shaded … …fidence interval

# Smolt in-river migration

# R. Frome smolt run

| Year | Detections | Captures |
|---|---|---|
| 2006 | 710 | 320 |
| 2007 | 1063 | 610 |
| 2008 | 986 | 400 |
| 2009 | 896 | 442 |
| 2010 | 741 | 356 |
| 2011 | 595 | 234 |
| 2012 | 387 | 235 |
| 2013 | 856 | 341 |
| 2014 | 698 | 309 |
| 2015 | 545 | 228 |
| 2016 | 553 | 238 |
| 2017 | 433 | 147 |
| 2018 | 434 | 138 |
| 2019 | 415 | 130 |
| 2020 | 406 | 181 |

Bournemouth University

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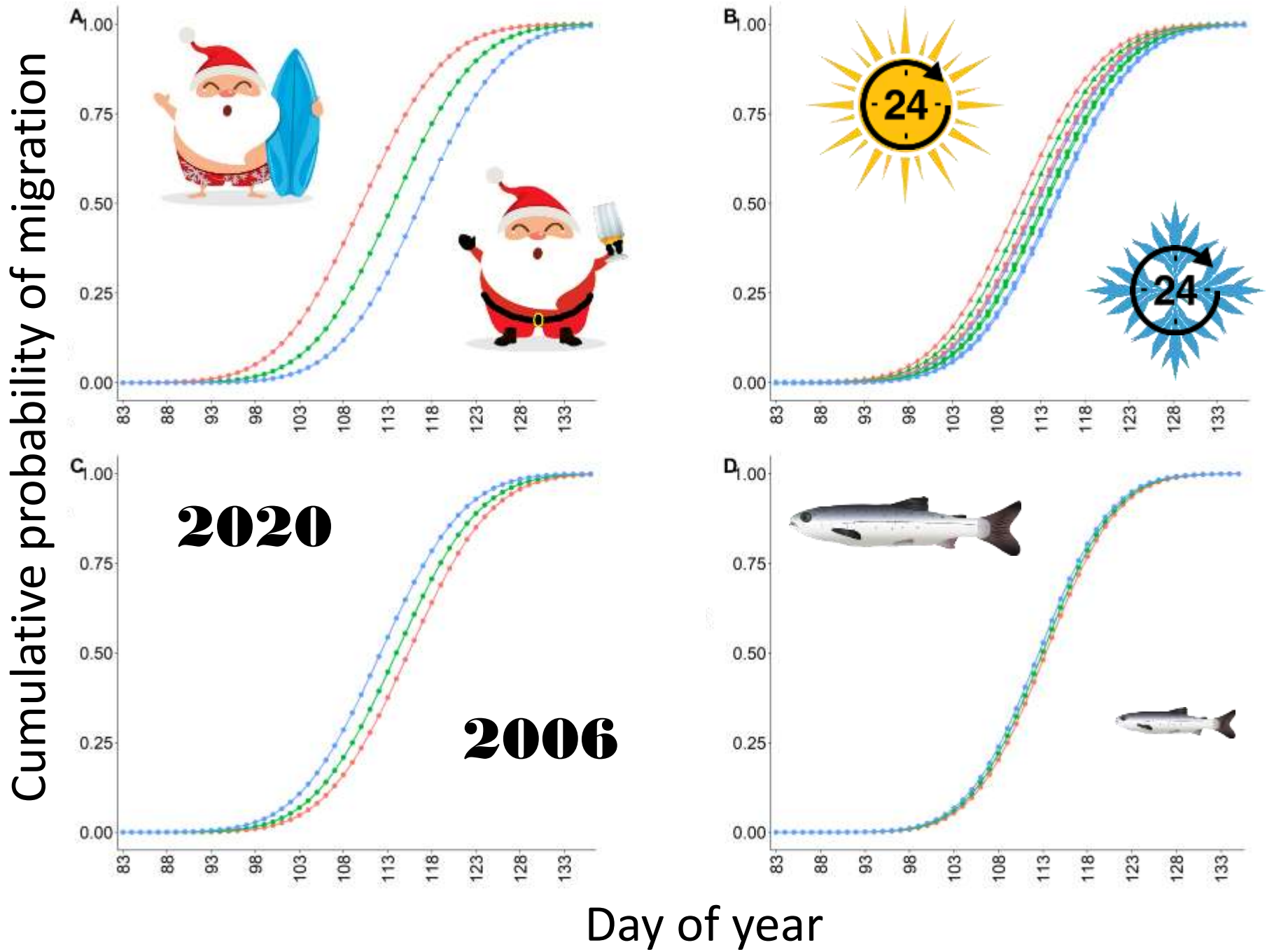
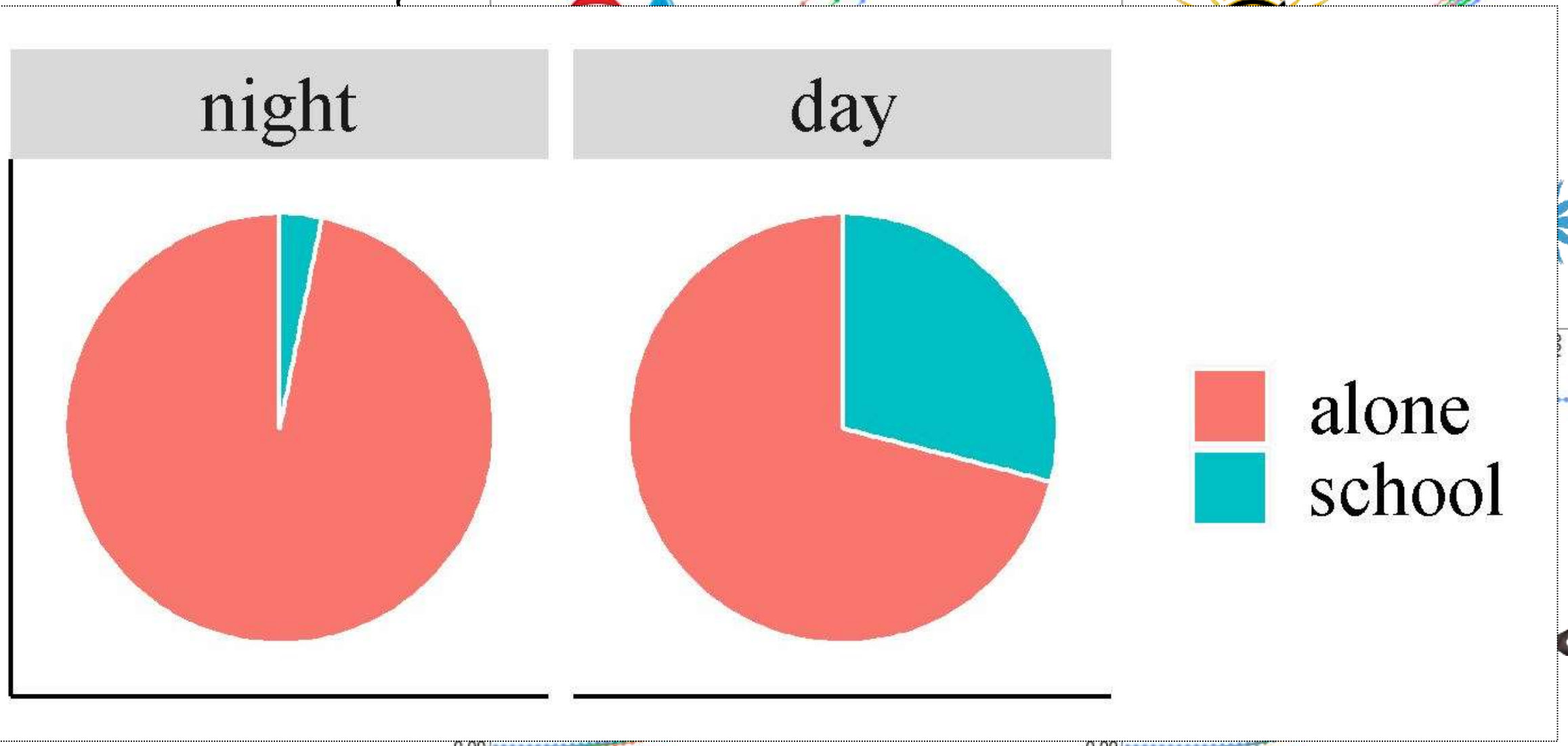
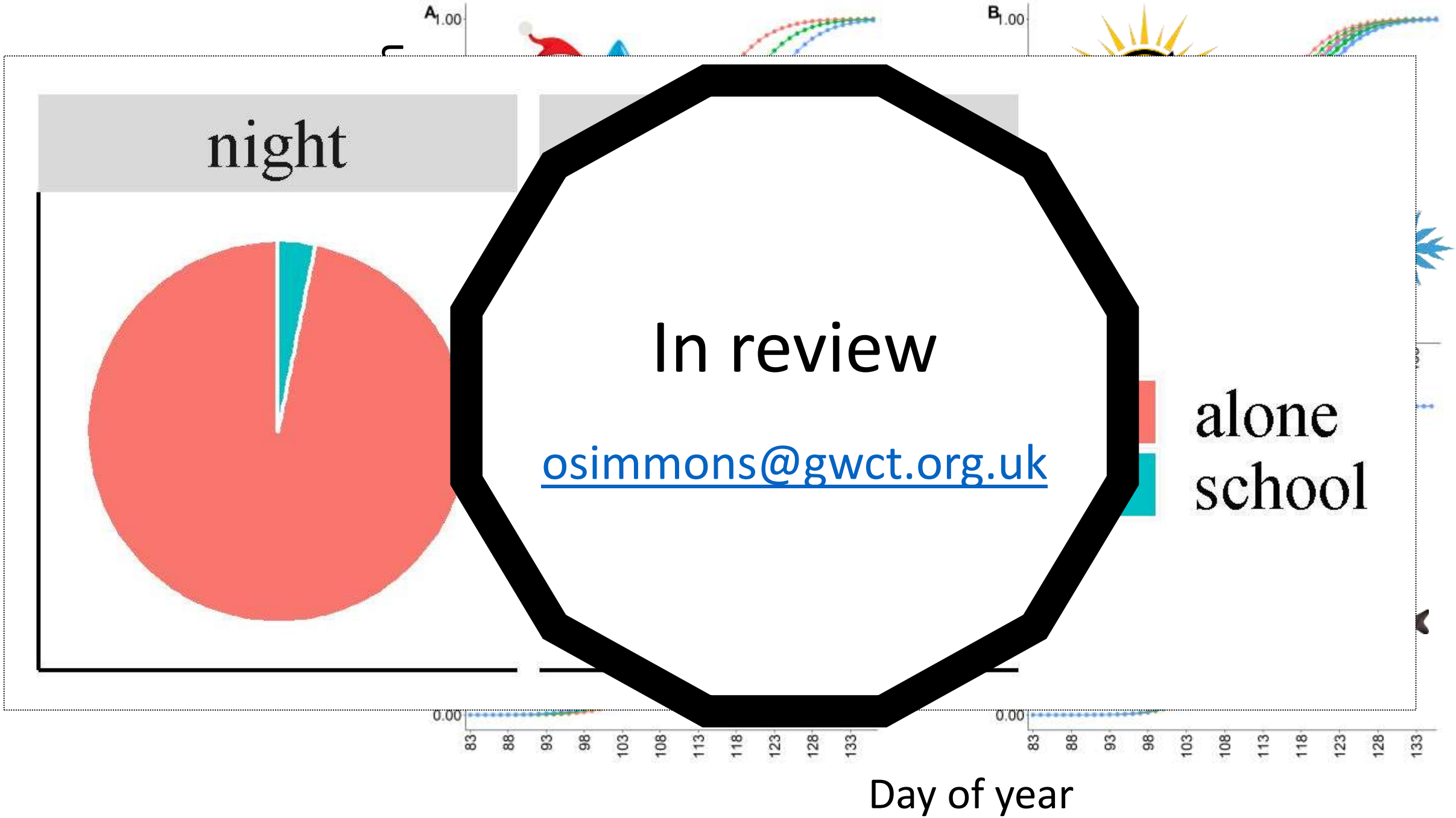

A
B
C
D
1.00
0.75
0.50
0.25
0.00
83
88
93
98
103
108
113
118
123
128
133
24
24
2020
2006
Cumulative probability of migration
Day of year

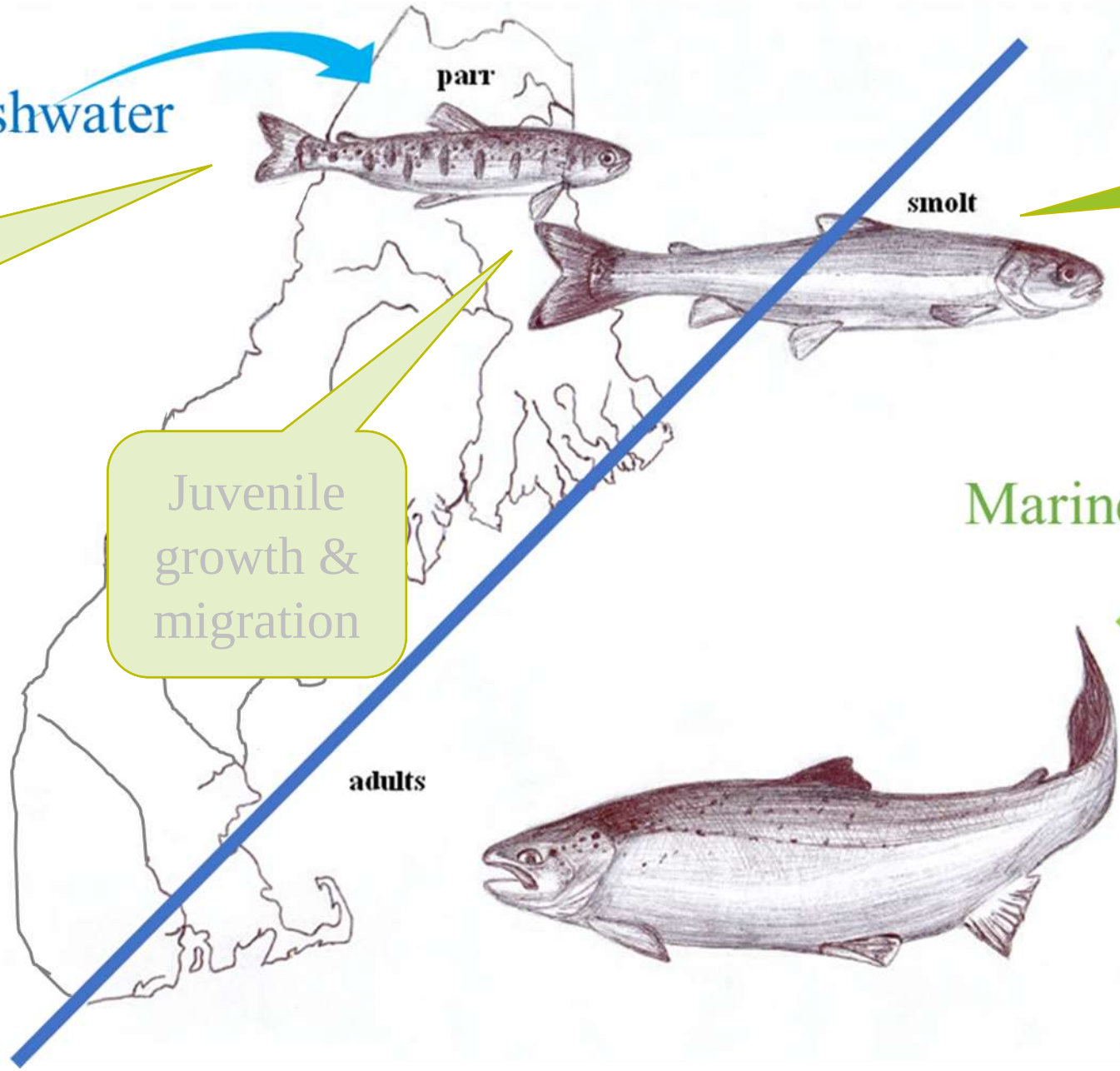



Day of year




# In review

osimmons@gwct.org.uk




Juvenile habitat

Juvenile growth & migration

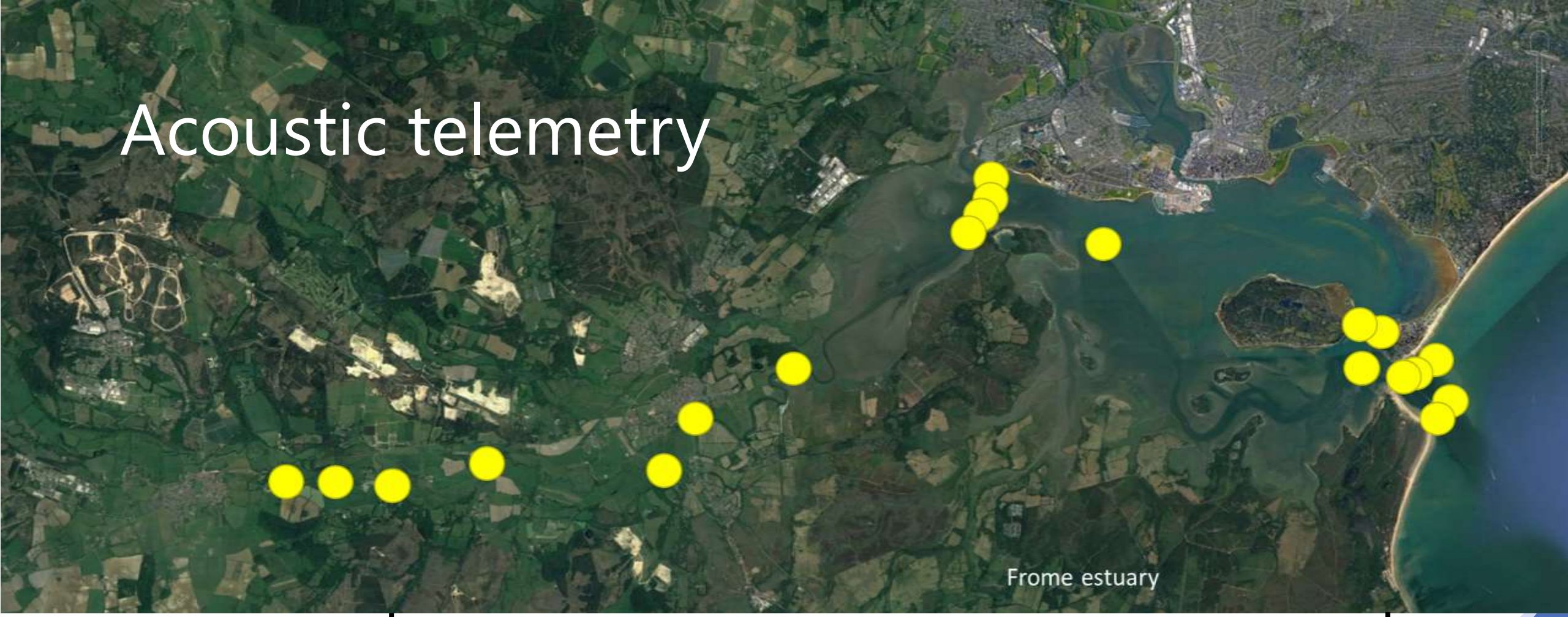
**Smolt estuary migration**

Smolt size & marine return rate

Céline Artero
cartero@gwct.org.uk

# Smolt estuary migration

# Acoustic telemetry




River | Estuary | Coast

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SAMARCH

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European Regional Development Fund

# Tag detections

| Year | No. smolts tagged |
|---|---|
| 2018 | 35 |
| 2019 | 85 |
| Total | 120 |

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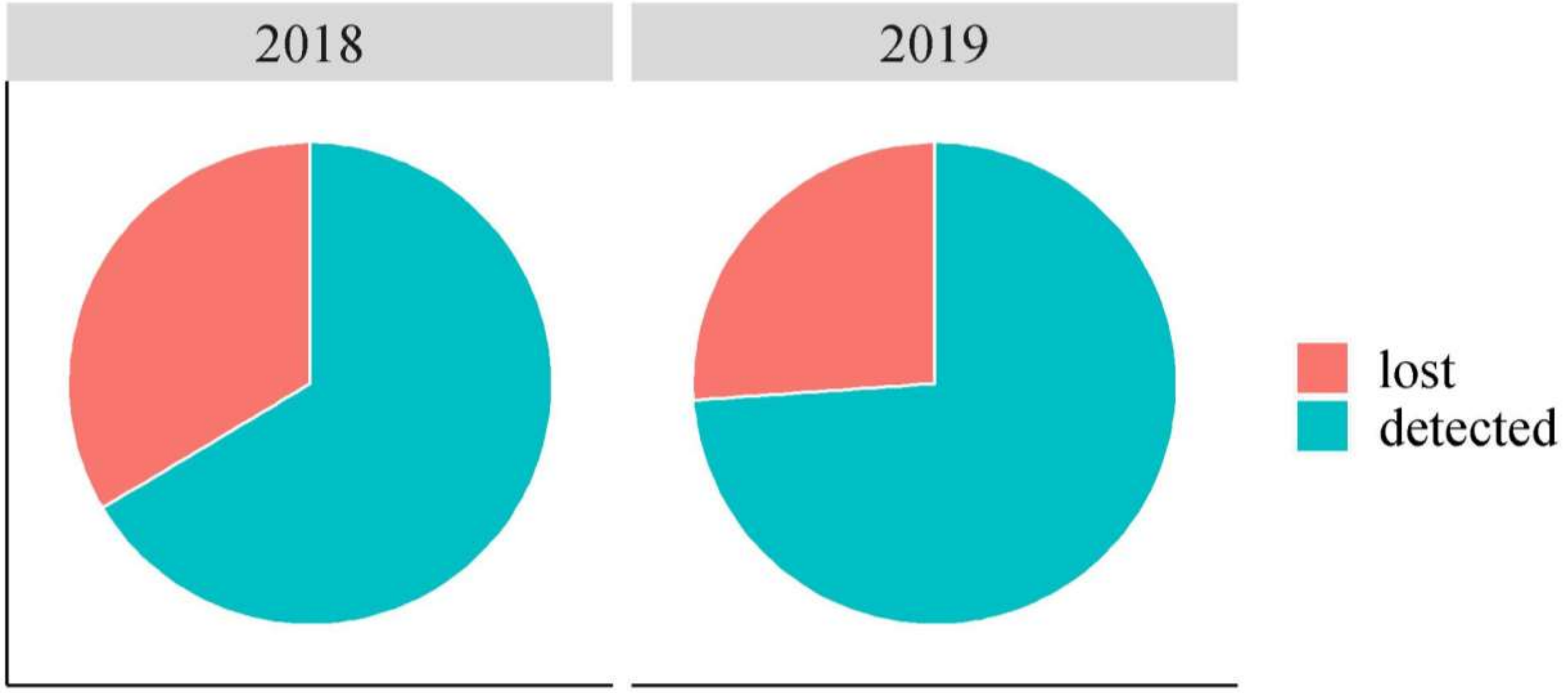
SAMARCH

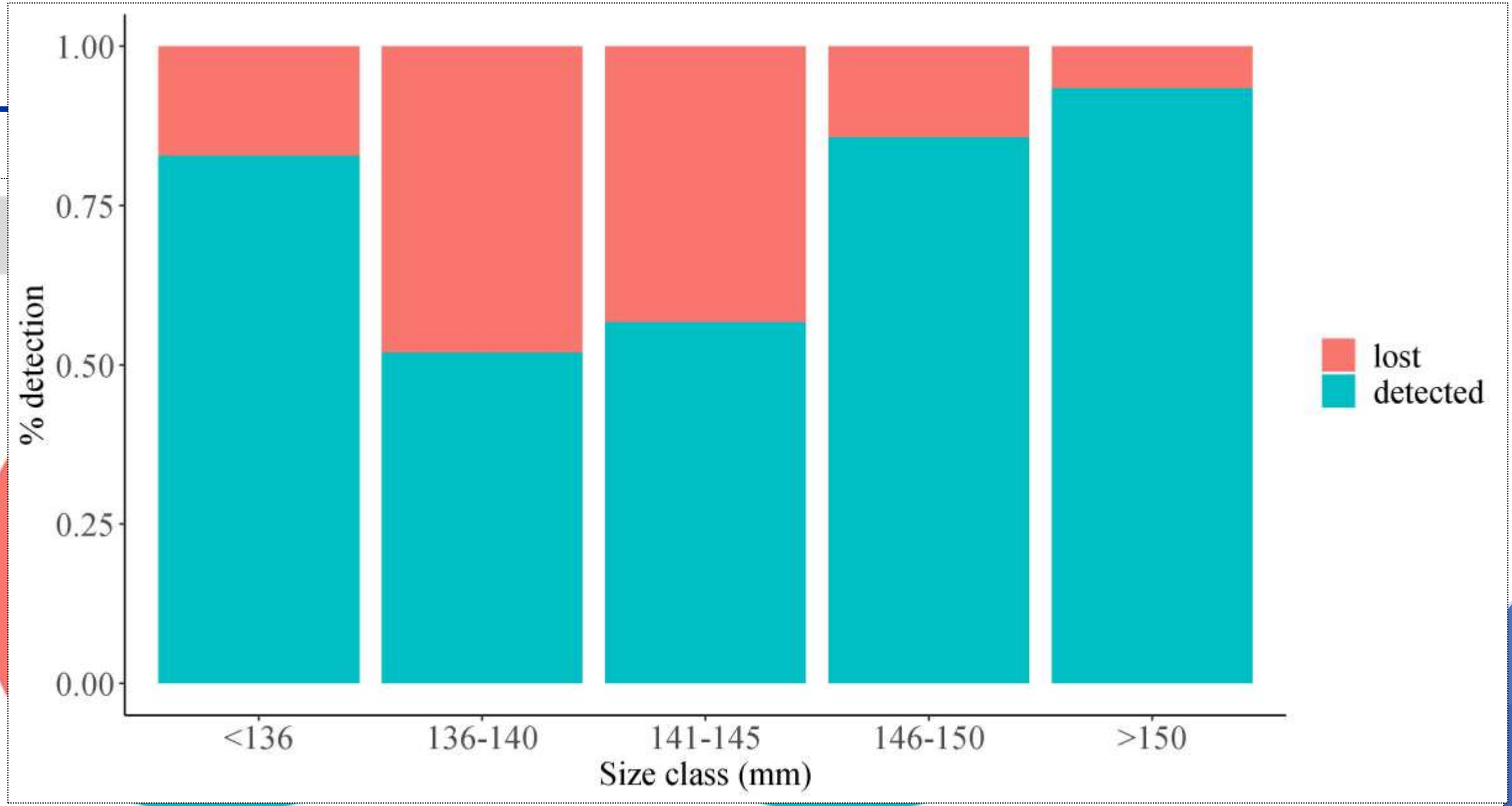
SAlmonid MAnagement Round the CHannel

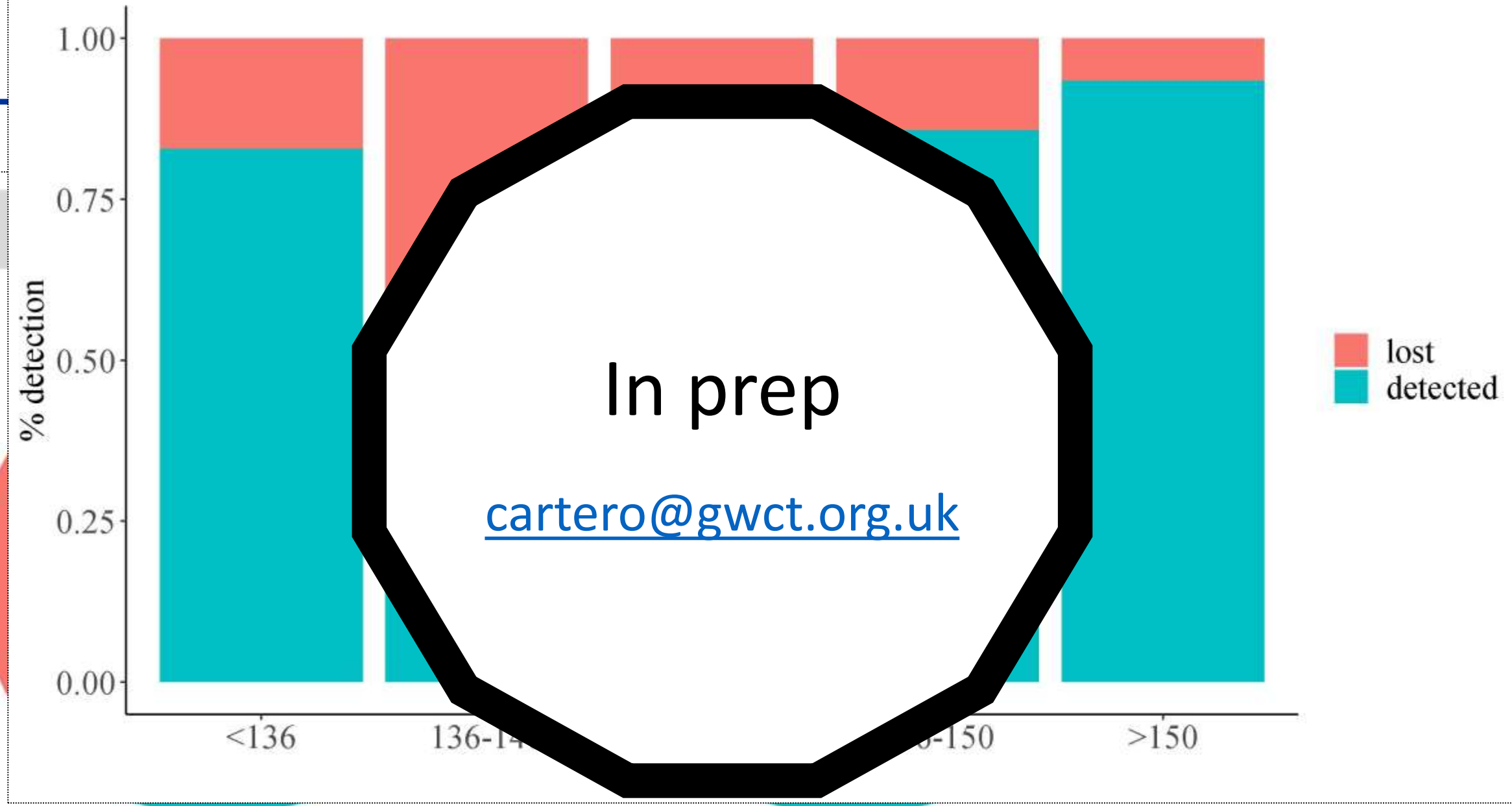
European Regional Development Fund

# Tag detections

| Year | No. smolts tagged |
|---|---|
| 2018 | 35 |

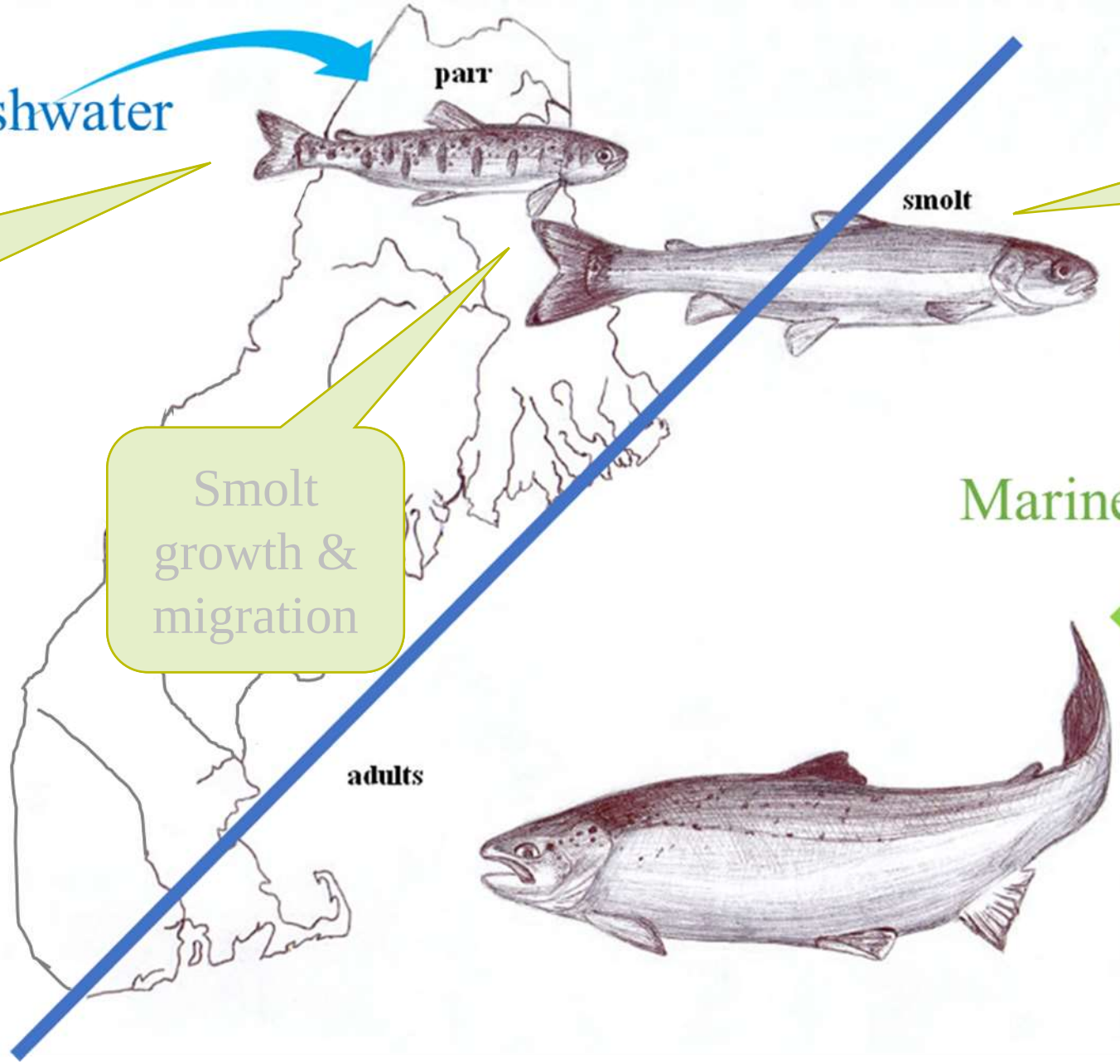



1.00
0.75
0.50
0.25
0.00
% detection
<136
136-140
141-145
146-150
>150
Size class (mm)
lost
detected




# In prep

cartero@gwct.org.uk




Juvenile habitat

Smolt growth & migration

Smolt estuary migration

**Smolt size & marine return rate**

Stephen Gregory
sgregory@gwct.org.uk

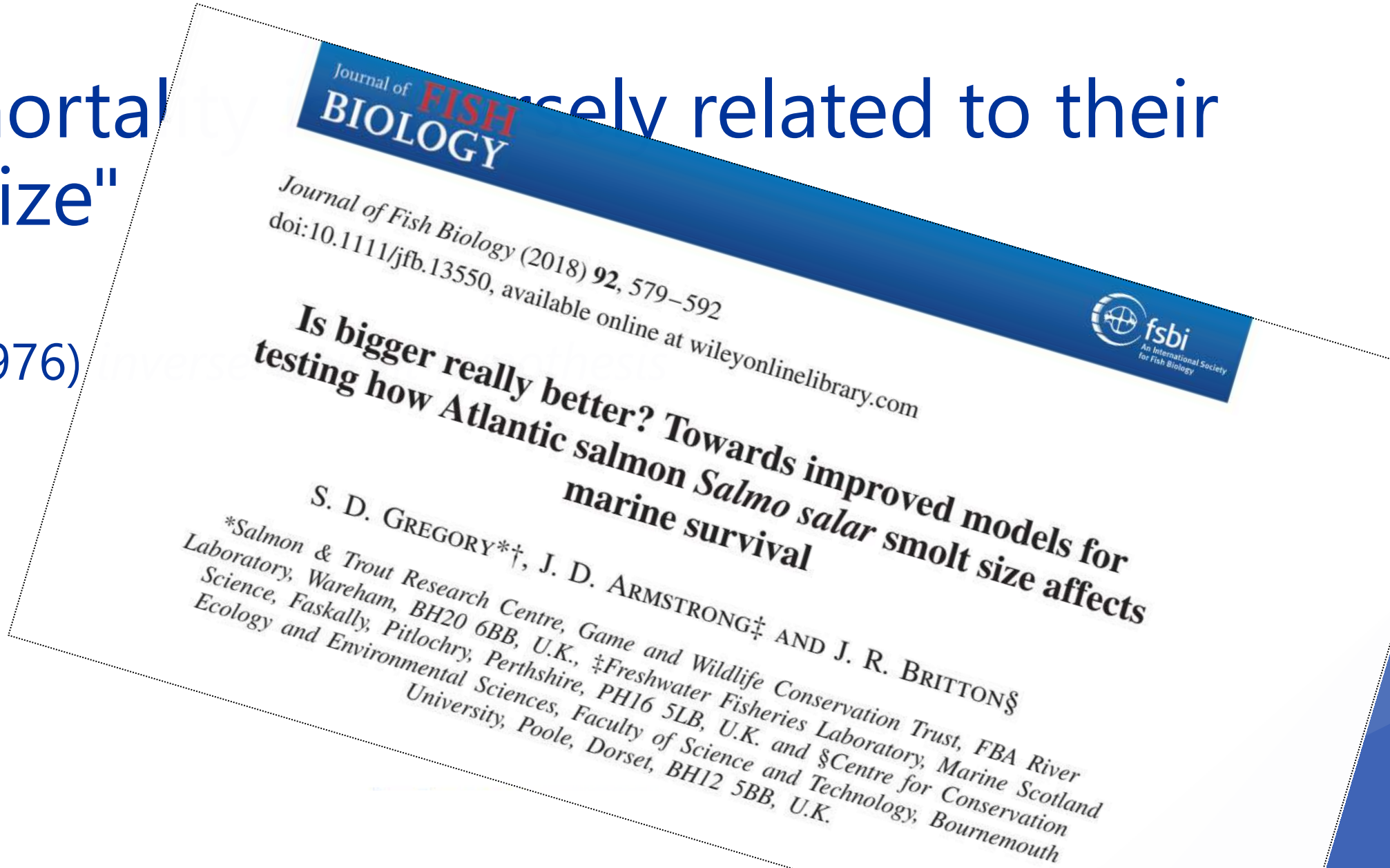
# Smolt size & marine return rate

# "fish mortality is inversely related to their body size"

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

# "fish mortality [illegible]rsely related to their body size"

Ricker's (1976) [illegible]



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.

# "fish mortality ~ body size"

Ricker's (1976) inverse

Journal of FISH BIOLOGY

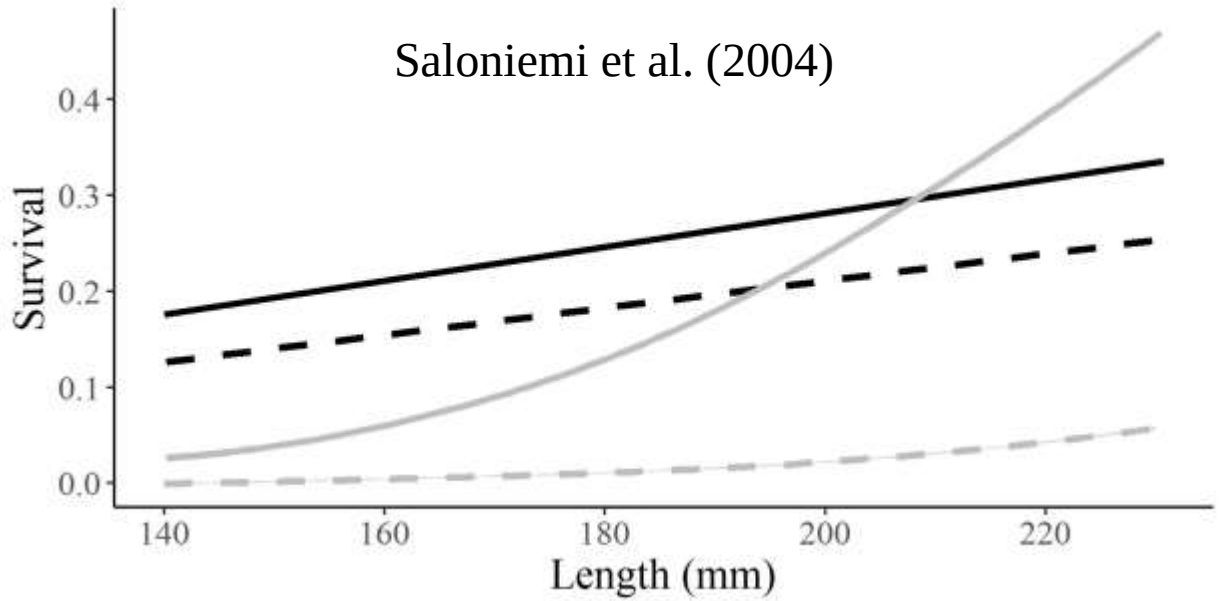
Journal of Fish Bio

doi:10.1111/jfb.135

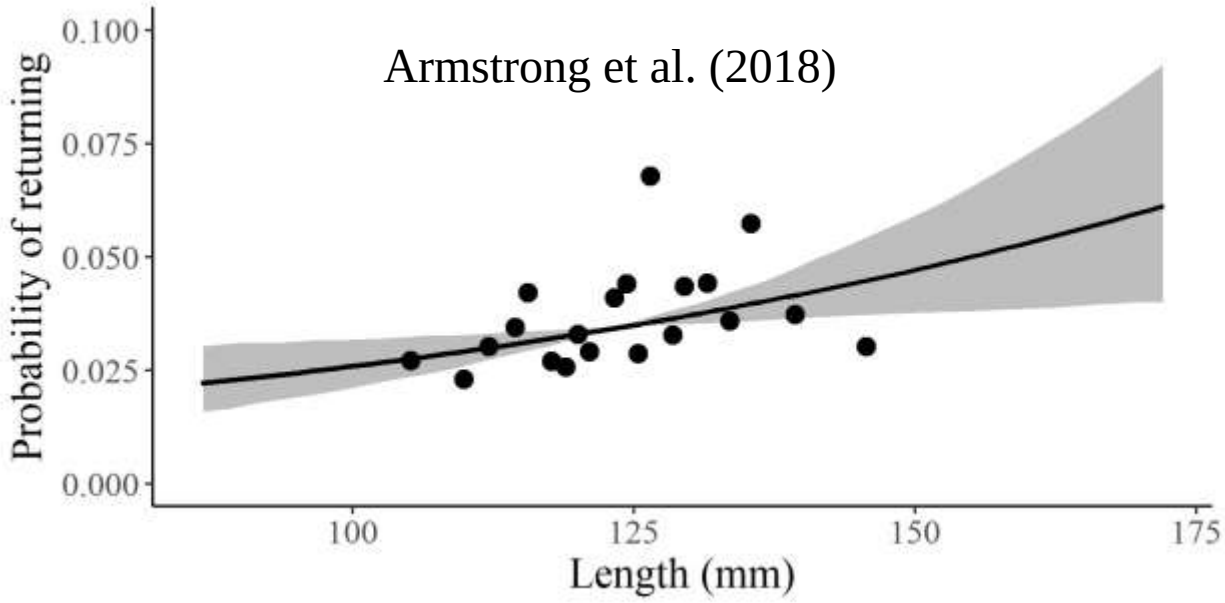
**Is bigger re**

**testing how A**

Saloniemi et al. (2004)




Armstrong et al. (2018)




**rds improved models for**

**almon *Salmo salar* smolt size affects**

**marine survival**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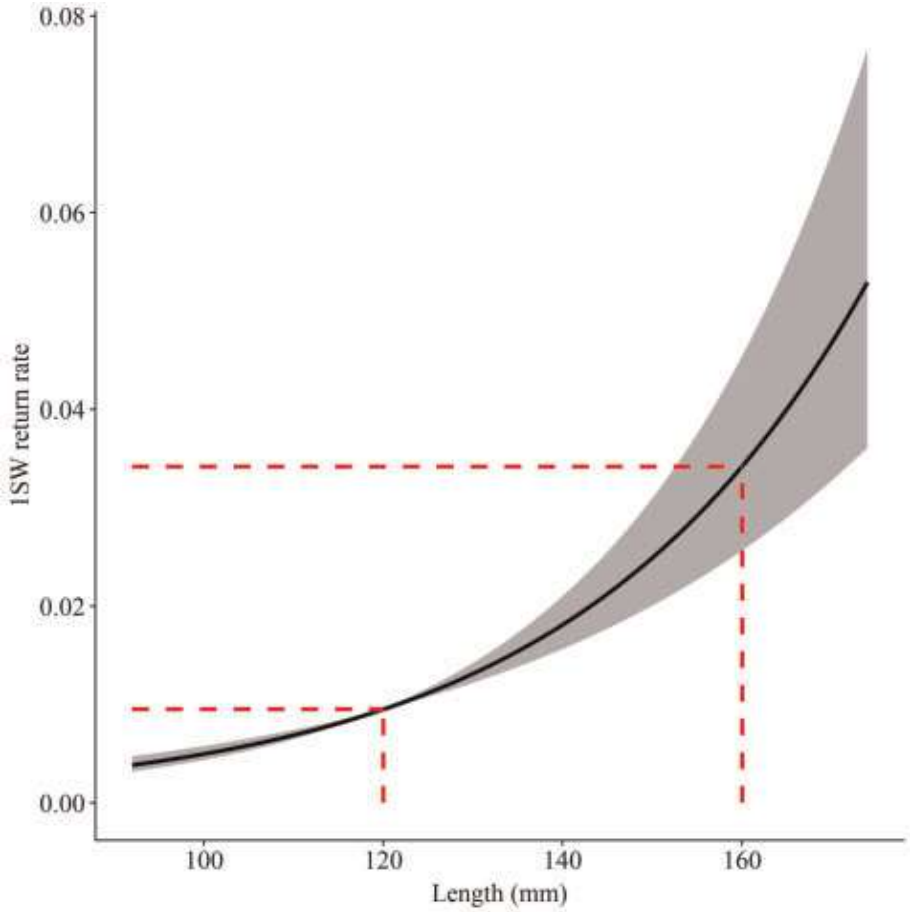
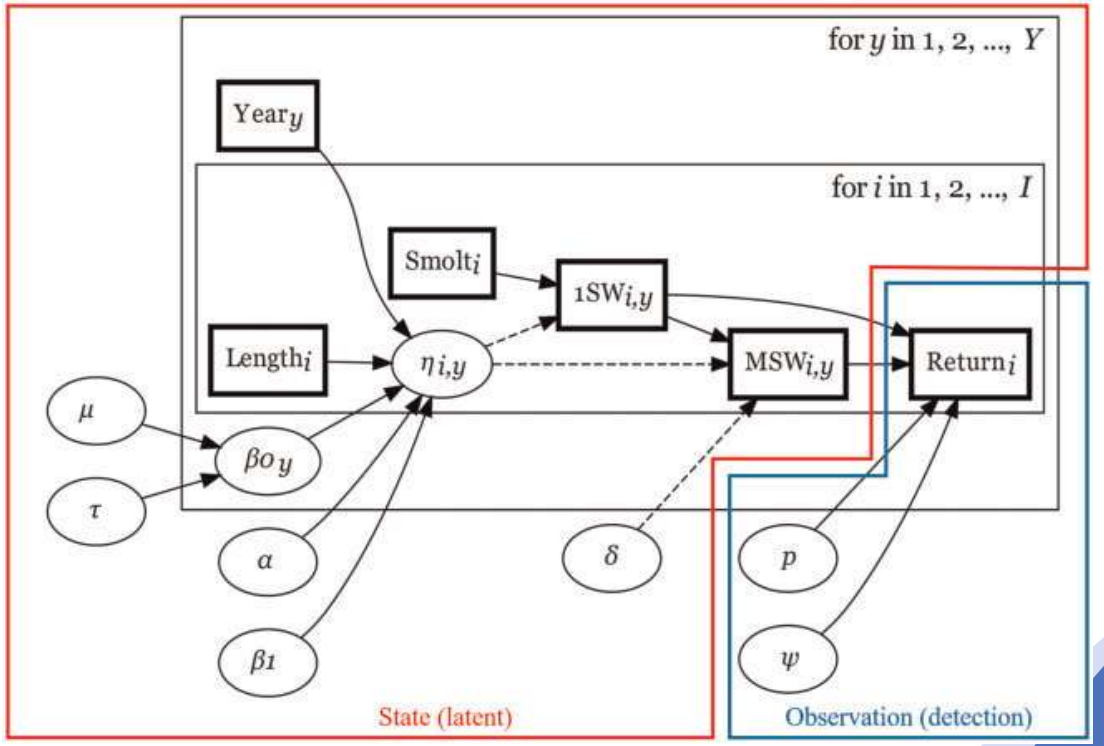
*ire, PH16 5LB, U.K. and §Centre for Conservation*

*, Faculty of Science and Technology, Bournemouth*

*le, Dorset, BH12 5BB, U.K.*

# R. Frome smolt length & marine return rate

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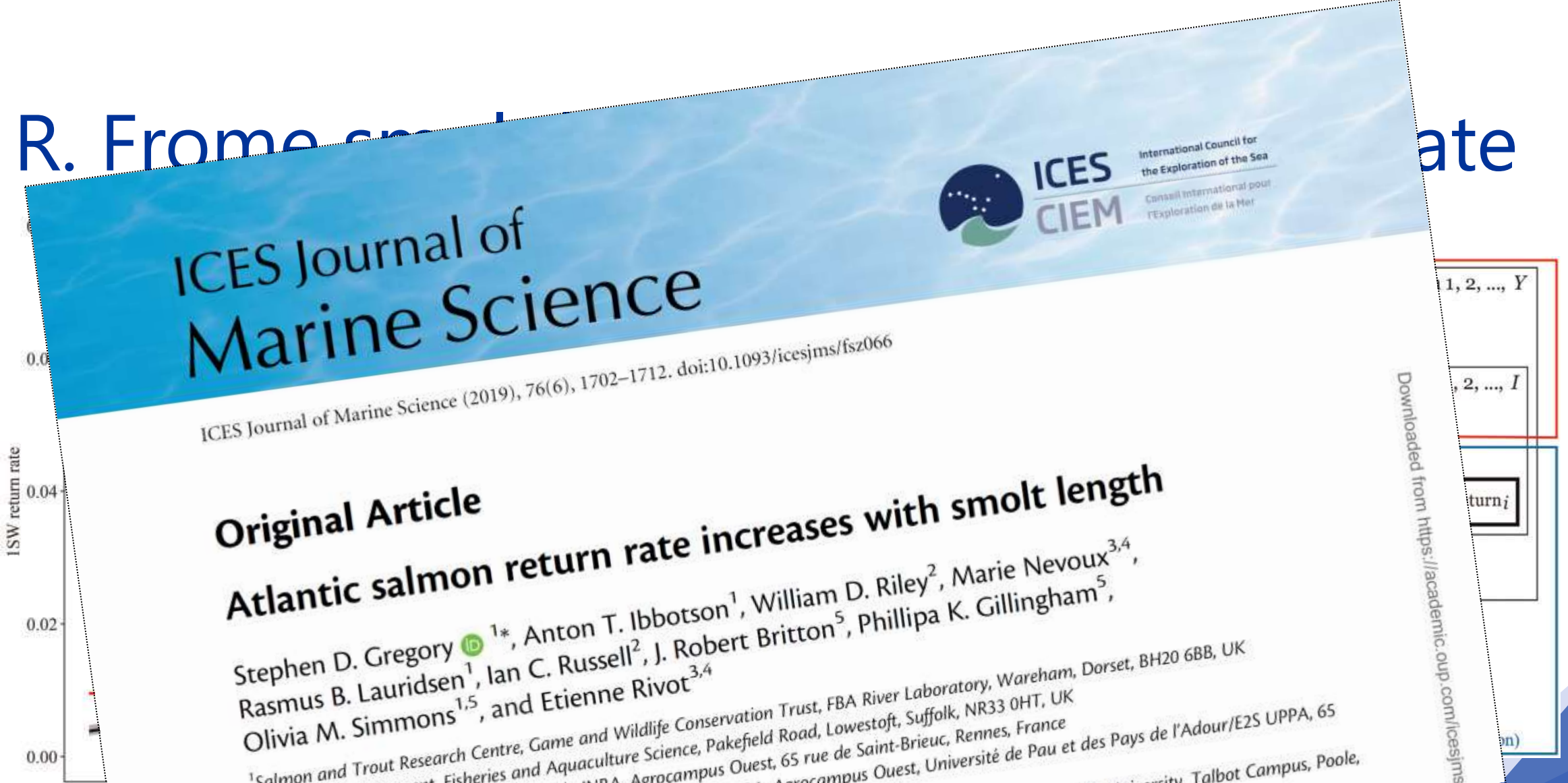
# R. Frome sm… …ate




ICES Journal of Marine Science

ICES International Council for the Exploration of the Sea
CIEM Conseil International pour l'Exploration de la Mer

ICES Journal of Marine Science (2019), 76(6), 1702–1712. doi:10.1093/icesjms/fsz066

Original Article

## Atlantic salmon return rate increases with smolt length

Stephen D. Gregory [1]*, Anton T. Ibbotson[1], William D. Riley[2], Marie Nevoux[3,4], Rasmus B. Lauridsen[1], Ian C. Russell[2], J. Robert Britton[5], Phillipa K. Gillingham[5], Olivia M. Simmons[1,5], and Etienne Rivot[3,4]

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[3]UMR ESE, Ecology and Ecosystems Health, INRA, Agrocampus Ouest, 65 rue de Saint-Brieuc, Rennes, France
[4]Management of Diadromous Fish in their Environment, AFB, INRA, Agrocampus Ouest, Université de Pau et des Pays de l'Adour/E2S UPPA, 65 rue de Saint-Brieuc, Rennes, France
[5]Centre for Conservation Ecology and Environmental Sciences, Faculty of Science and Technology, Bournemouth University, Talbot Campus, Poole, Dorset, BH12 5BB, UK



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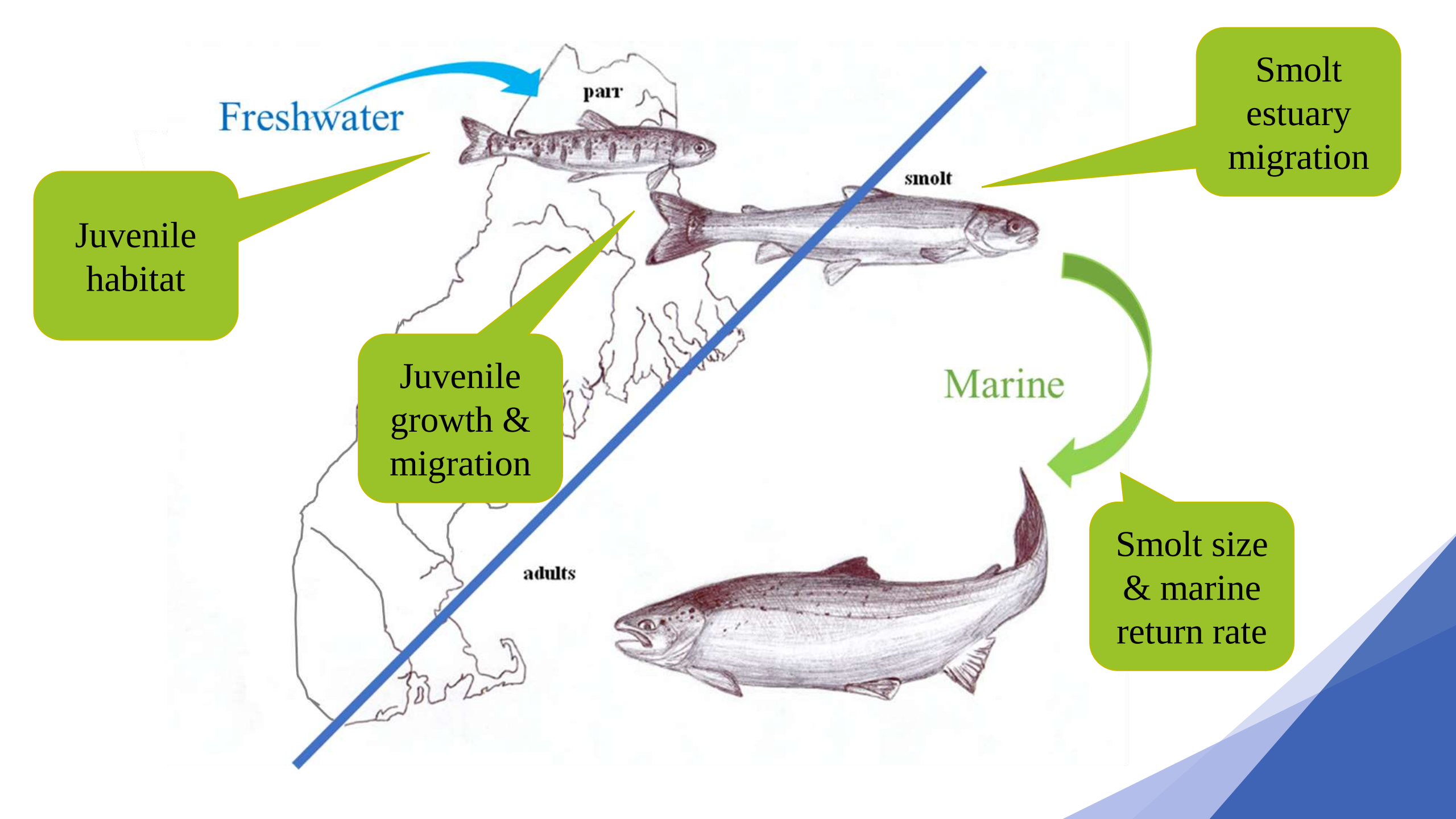
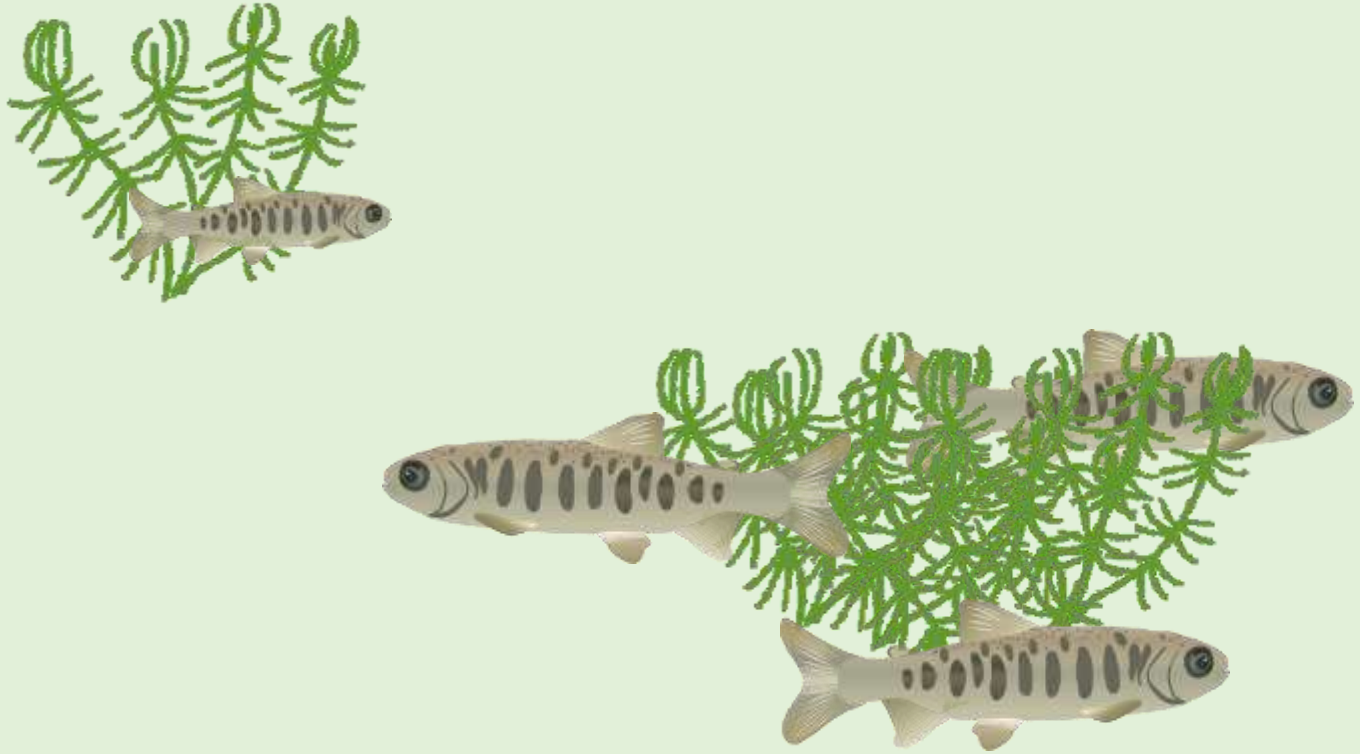
# Putting it all together


Freshwater
parr
smolt
Marine
adults
Juvenile habitat
Juvenile growth & migration
Smolt estuary migration
Smolt size & marine return rate

Fres

**Juvenil**
**habita**

More juvenile habitat >> More & larger juveniles



Smolt estuary migration

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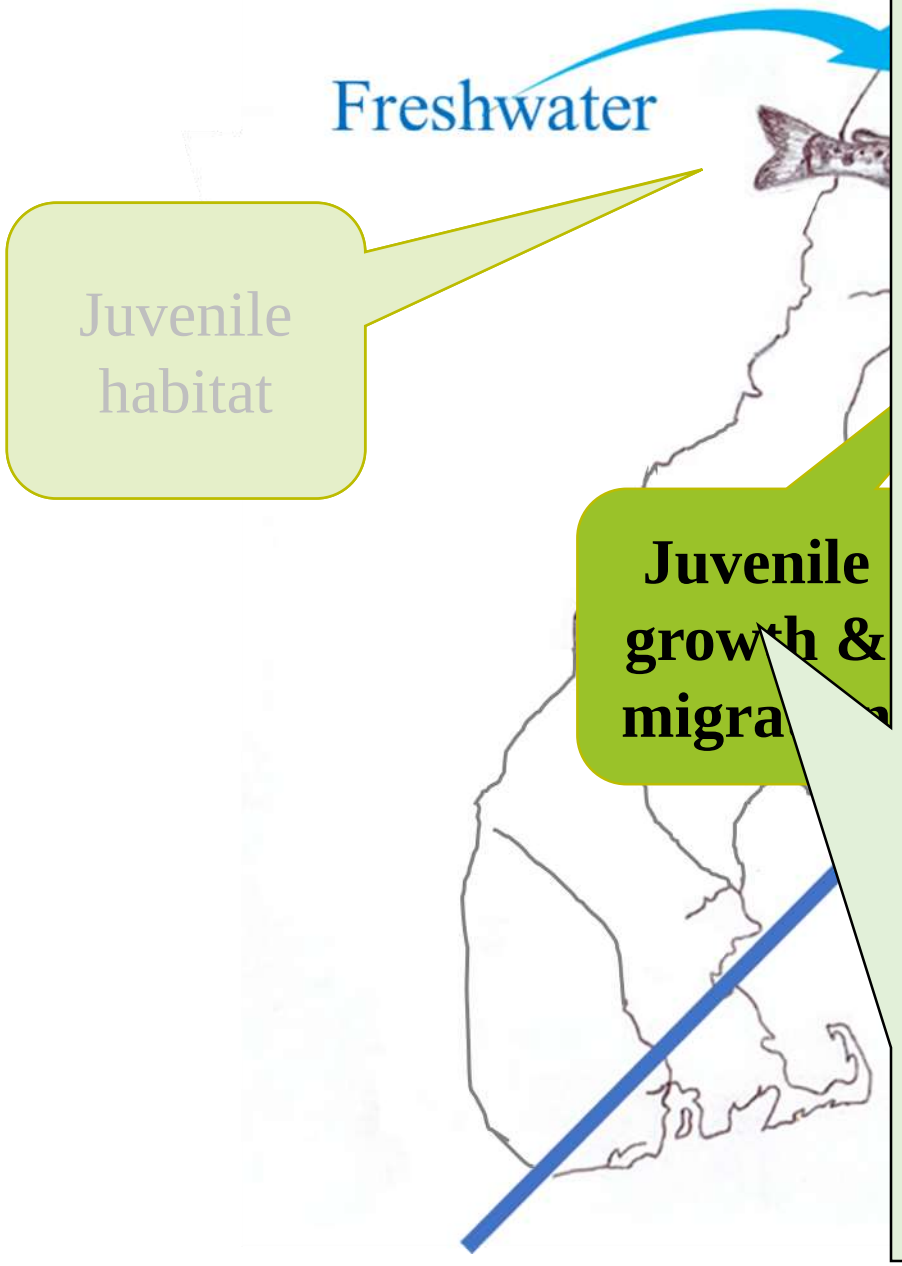
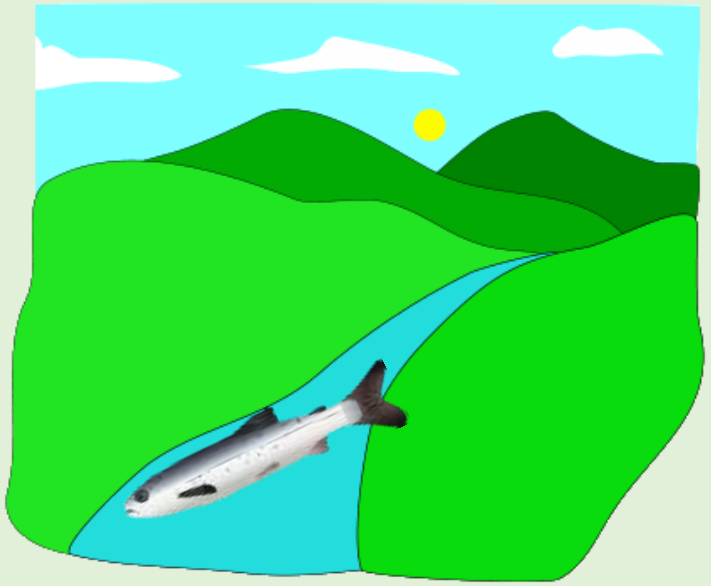



Warmer & wetter winters >> Larger & earlier migrating smolts



Some evidence that larger smolts >> Higher survival through estuaries?


**Smolt estuary migration**

Smolt size & marine return rate

Larger smolts are 3-4x >> More likely to survive their first year at sea

Smolt estuary migration

Marine

**Smolt size & marine return rate**

# Freshwater influences marine*

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]

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[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

* at least for the R. Frome

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- Juvenile habitat – Jess jmarsh@gwct.org.uk
- Juvenile growth & migration – Olivia osimmons@gwct.org.uk
- Smolt estuary migration – Céline cartero@gwct.org.uk
- Smolt size & marine return rate – Stephen sgregory@gwct.org.uk

Marsh et al. 2020

Simmons et al. 2020

Gregory et al. 2018

Gregory et al. 2019