

Bayesian hierarchical modelling

Bayesian modelling of capture-mark-recapture experiments to estimate the smolts and adults runs

Based on

Rivot E. and Prevost E. 2002. Hierarchical Bayesian Analysis of Capture-Mark-Recapture Data. Canadian Journal of Fisheries and Aquatic Sciences, 59: 1768-1784

November 2025

Etienne RIVOT

L'Institut Agro, Département Ecologie, UP Ecologie Halieutique

UMR DECOD Ecosystem Dynamic and Sustainability

etienne.rivot@institut-agro.fr

Hierarchical models

- **A wide class of models**

Key tools in all field of modern **statistical modelling**

Statistical hierarchical models

Multi-level stochastic models

Statistical models with latent (hidden) variables

Models with random effects

Models with latent (hidden) variables

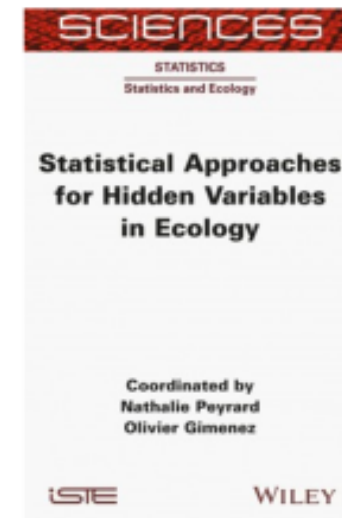
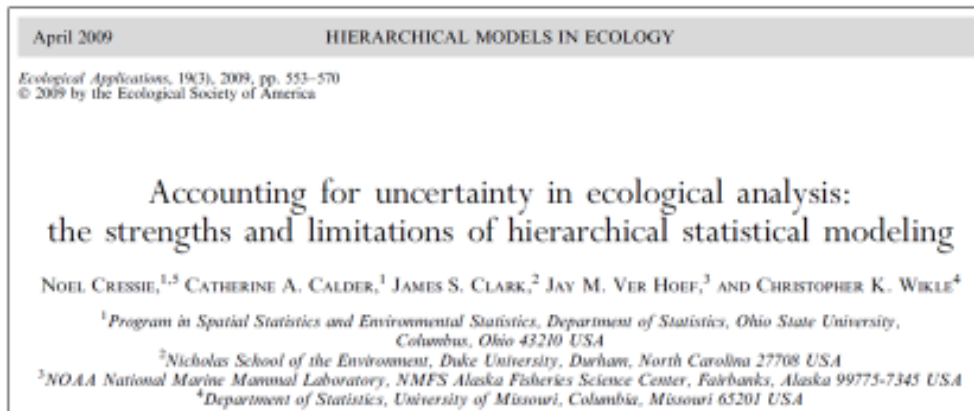
(Hierarchical models / Multi-level stochastic models)

- **A wide class of models**

Key tools in all field of modern **statistical modelling**

Key tools in modern **statistical ecology** with multiple applications

- **Inferences in Bayesian or “Classical” framework**



Methodological challenges



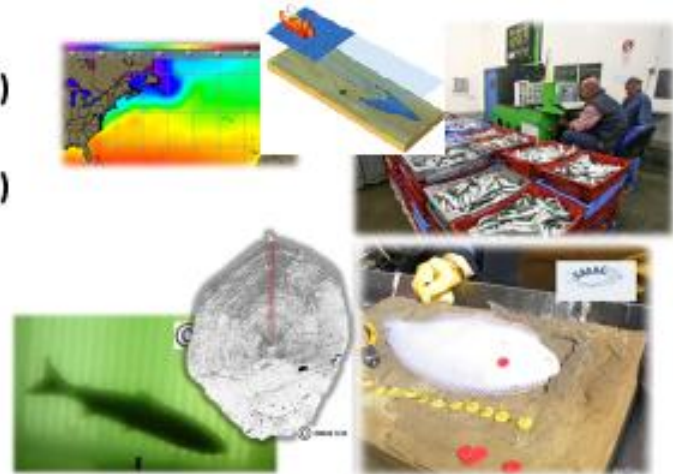
■ Model

- Multiple form of dependencies (time, space, groups ...)
- Variability and stochasticity (demographic, environmental)
- **Hidden process and variables**



■ Data

- Various scales (individuals, populations, ecosystems ...)
- From controlled sampling scheme or opportunistic
- Various scales (individuals, populations, ecosystems ...)
- Hierarchical structure
- Correlated in time and/or space
- Noisy, incomplete (missing data)
- **Not directly related to the process of interest**



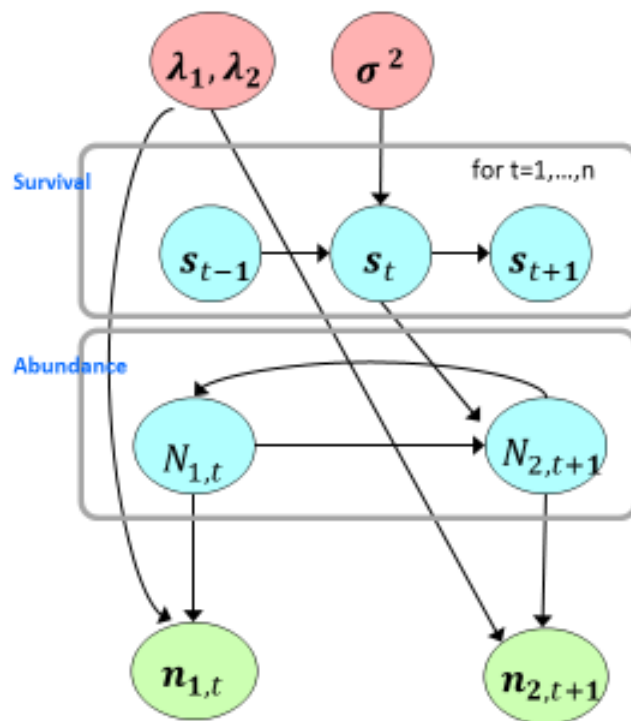
Population dynamics

Statistical Science
2007, Vol. 22, No. 1, 44–58
DOI: 10.1214/088342306000000673
© Institute of Mathematical Statistics, 2007

Embedding Population Dynamics Models in Inference

Stephen T. Buckland, Ken B. Newman, Carmen Fernández, Len Thomas and John Harwood

Toy example



Parameters

States

$P(\text{States} \mid \text{Parameters})$

$$s_{t+1} = s_t + \varepsilon_t \sim N(0, \sigma^2)$$

$$N_{2,t+1} \sim \text{Binom}(N_{1,t}, s_t)$$

Observations

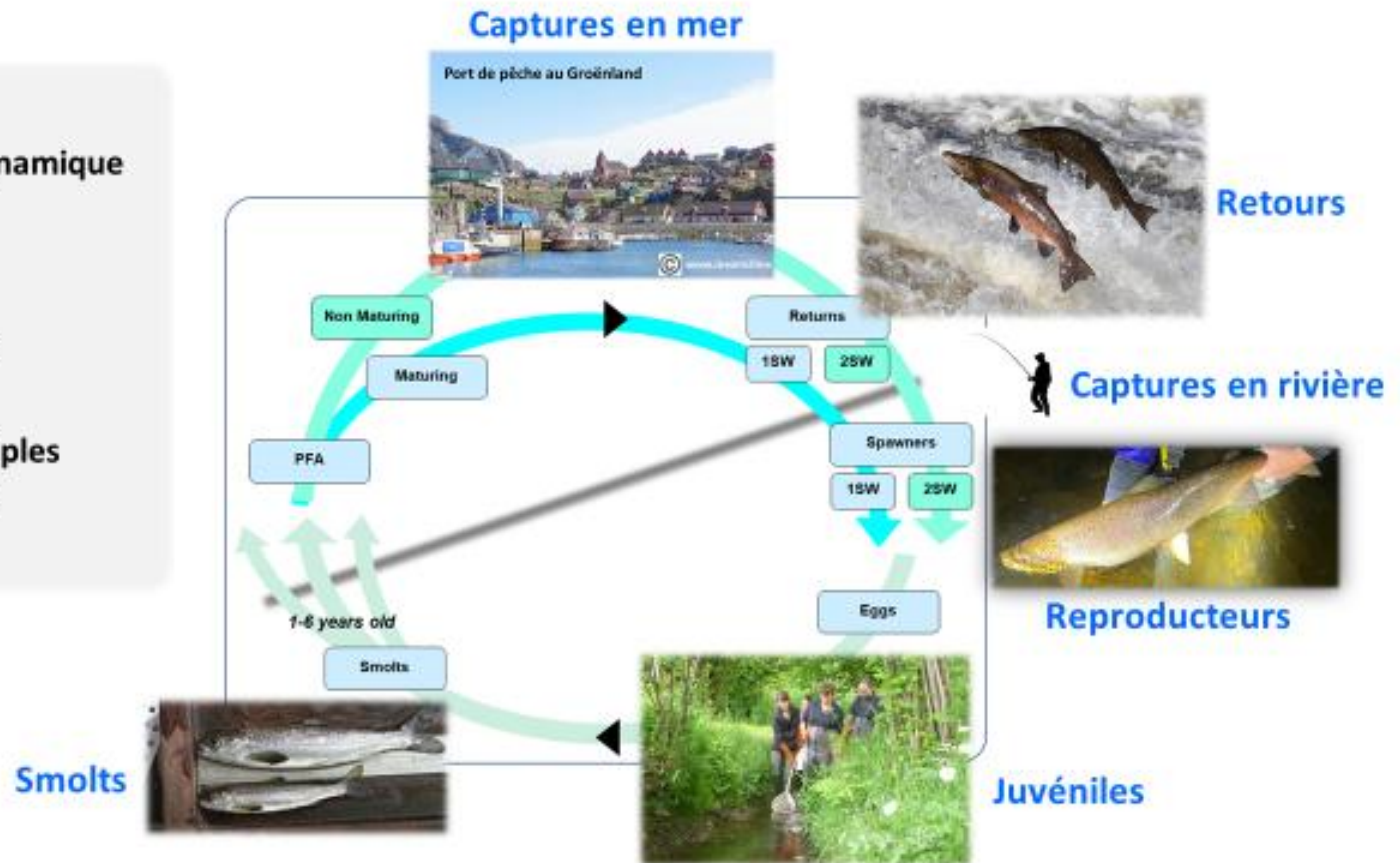
$P(\text{Observations} \mid \text{States}, \text{Param.})$

$$n_{1,t} \sim \text{Pois}(N_{1,t} \cdot \lambda_1)$$

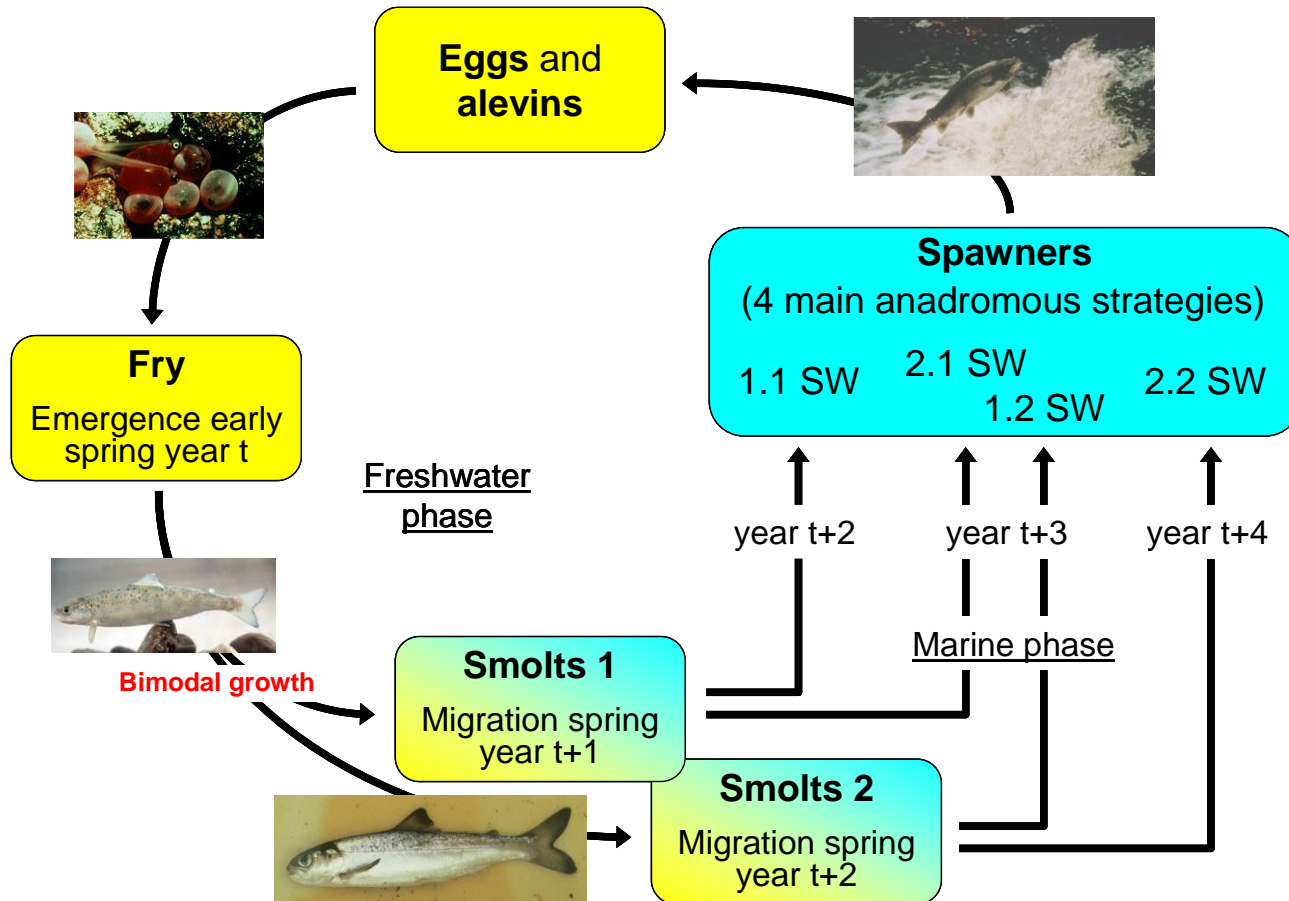
$$n_{2,t+1} \sim \text{Pois}(N_{2,t+1} \cdot \lambda_2)$$

Un modèle intégré à variables latentes

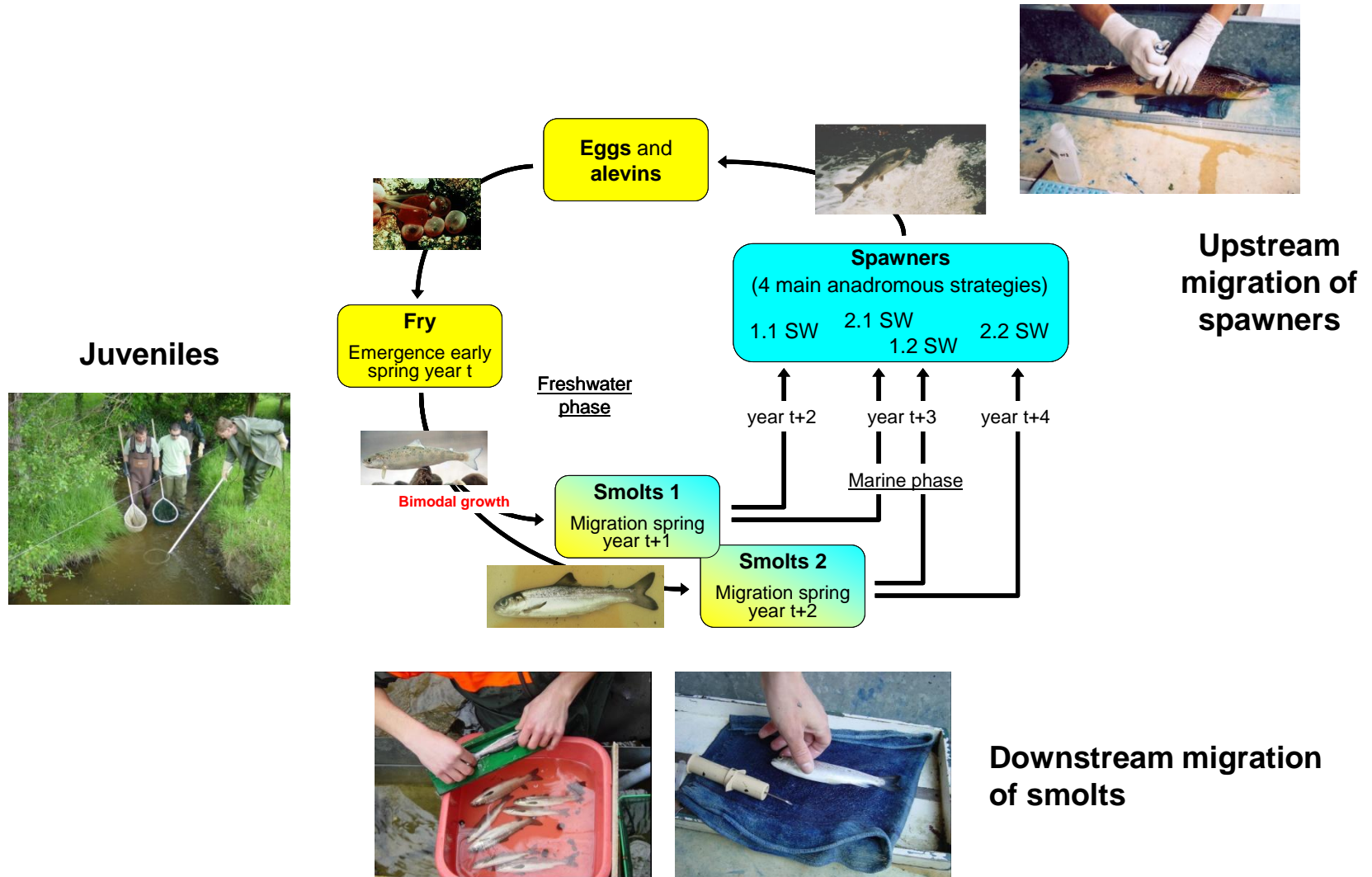
- Inférences sur la dynamique de population
 - Abondance
 - Taux de transition démographiques
- Intégration de multiples sources de données



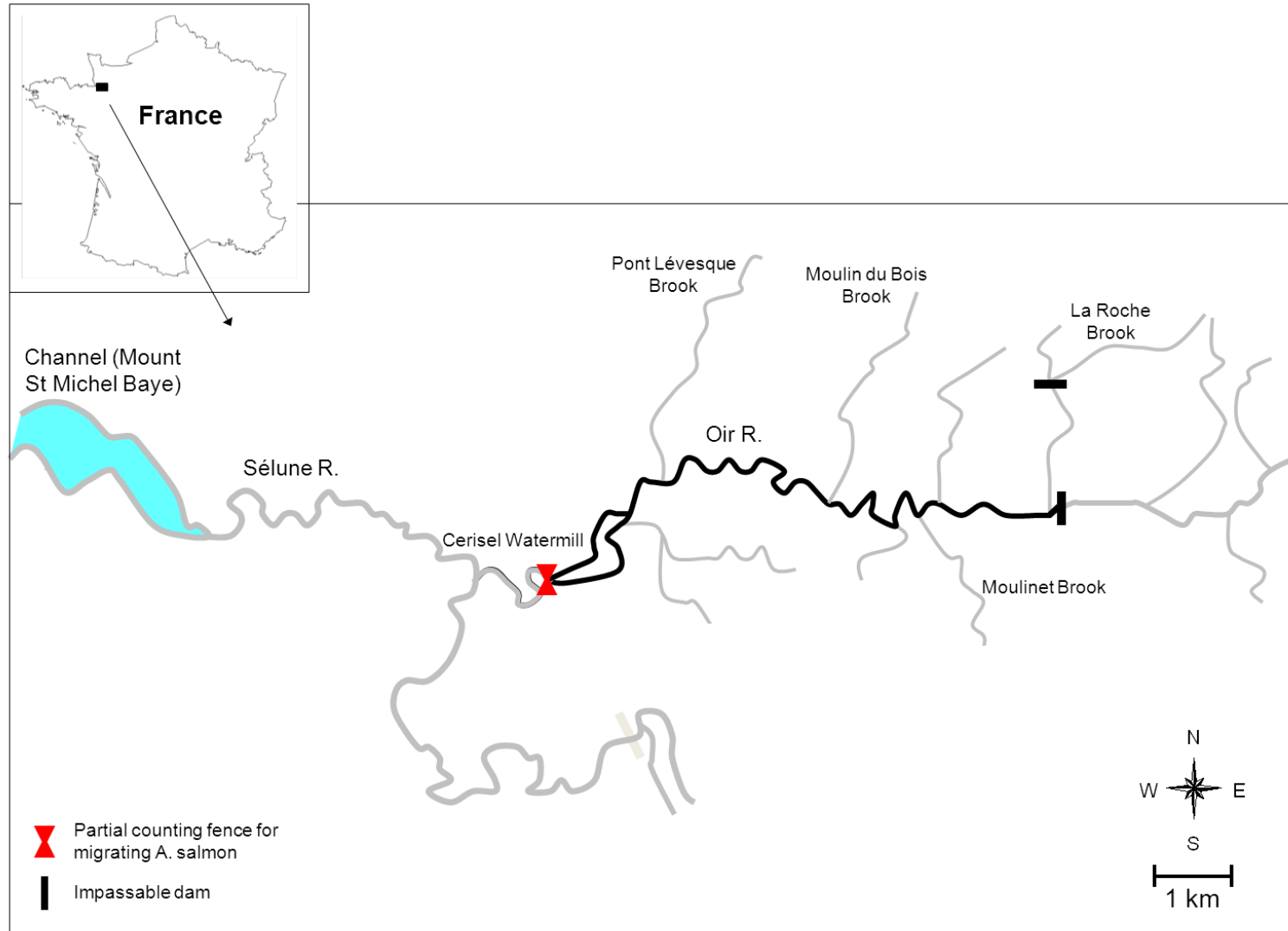
Atlantic salmon life cycle (In France)



Field surveys



The Oir river



Observation errors in SR analysis

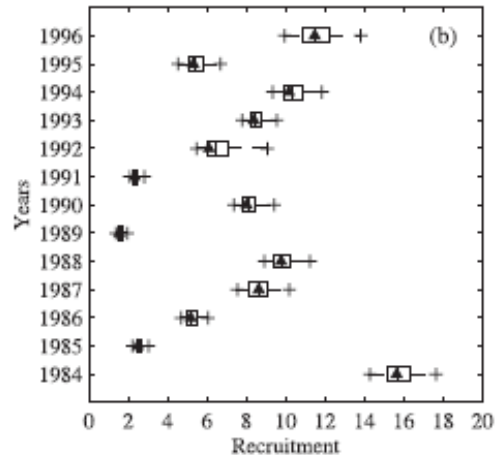
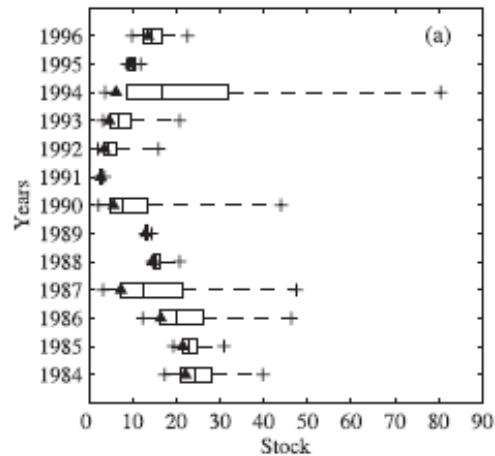
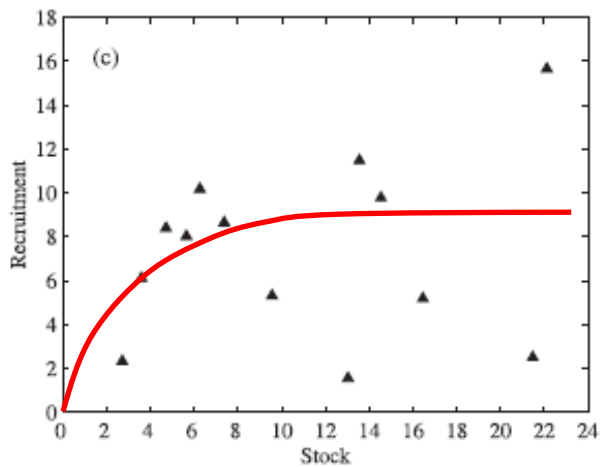
Rivot et al., 2001

Can. J. Fish. Aquat. Sci. 58: 2284–2297 (2001)

DOI: 10.1139/cjfas-58-11-2284

Observation errors on Stock and recruitment

Point estimates



Observation errors in SR analysis

Rivot et al., 2001

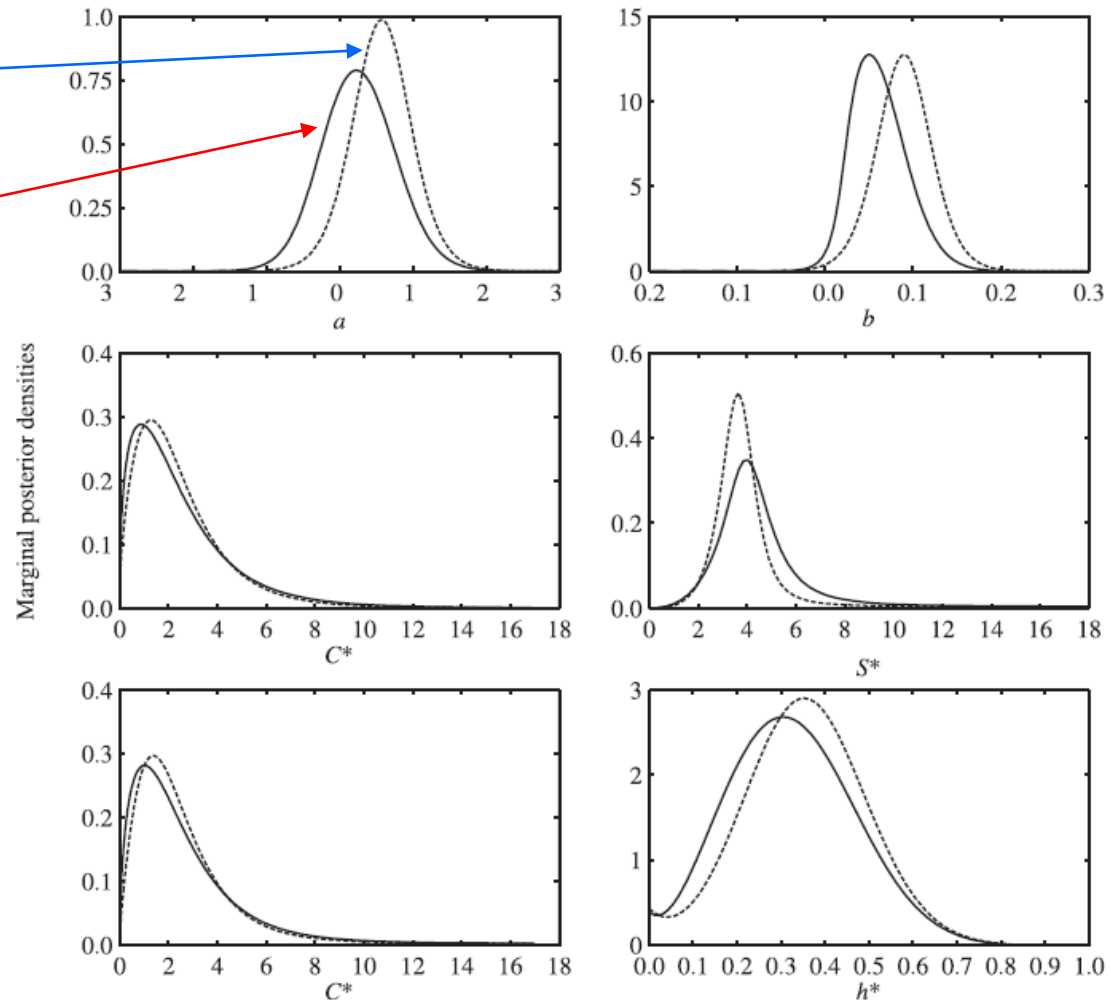
Can. J. Fish. Aquat. Sci. 58: 2284–2297 (2001)

DOI: 10.1139/cjfas-58-11-2284

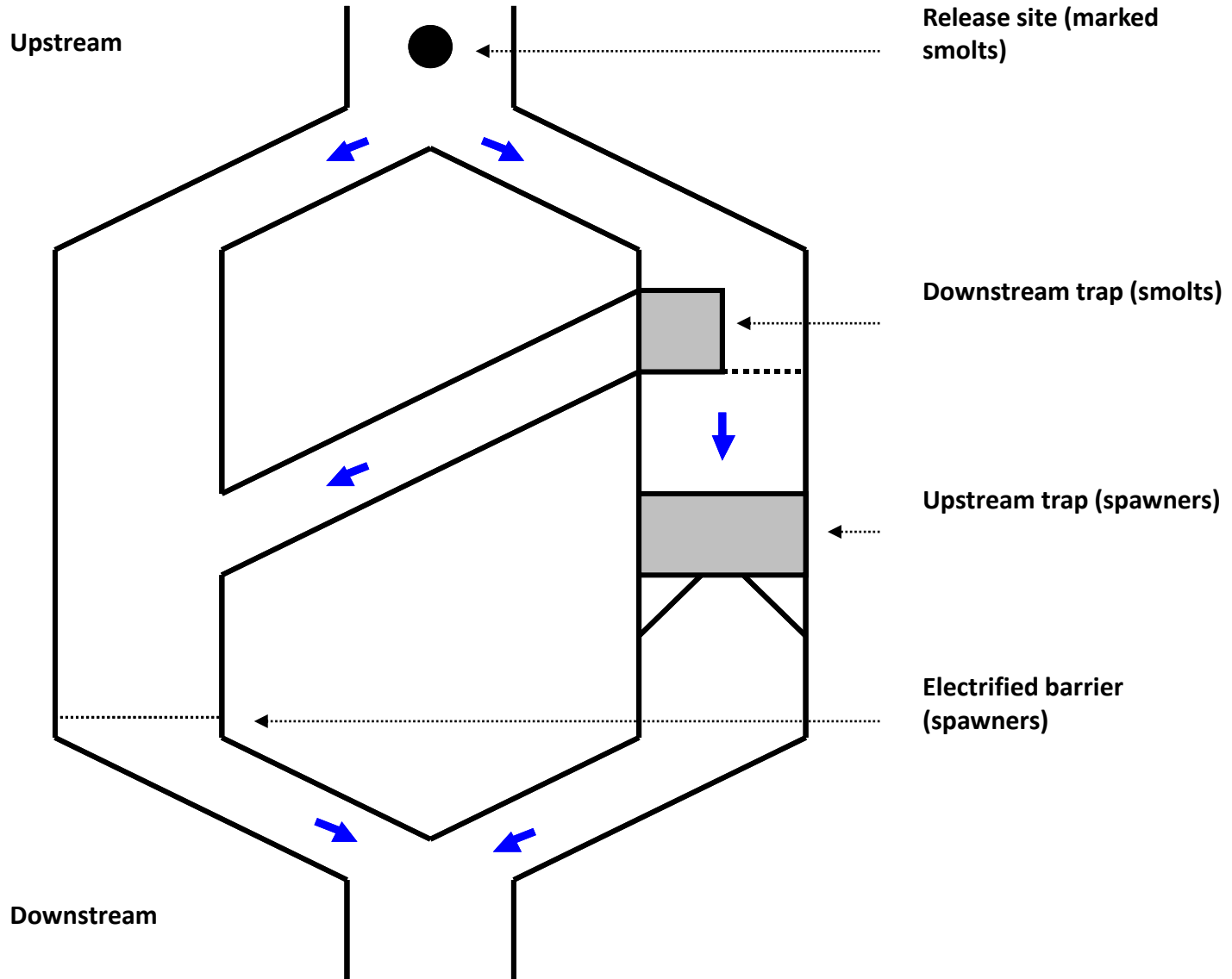
Fig. 3. Marginal posterior density profiles corresponding to joint posterior density of (a, b) (top), (C^*, S^*) (middle), and (C^*, h^*) (bottom) obtained accounting for process errors only (broken line) or for both process and measurement errors (solid line). All are obtained with uniform priors on the three parameter couples and with a noninformative prior for σ ($q = 1$).

Process error
only

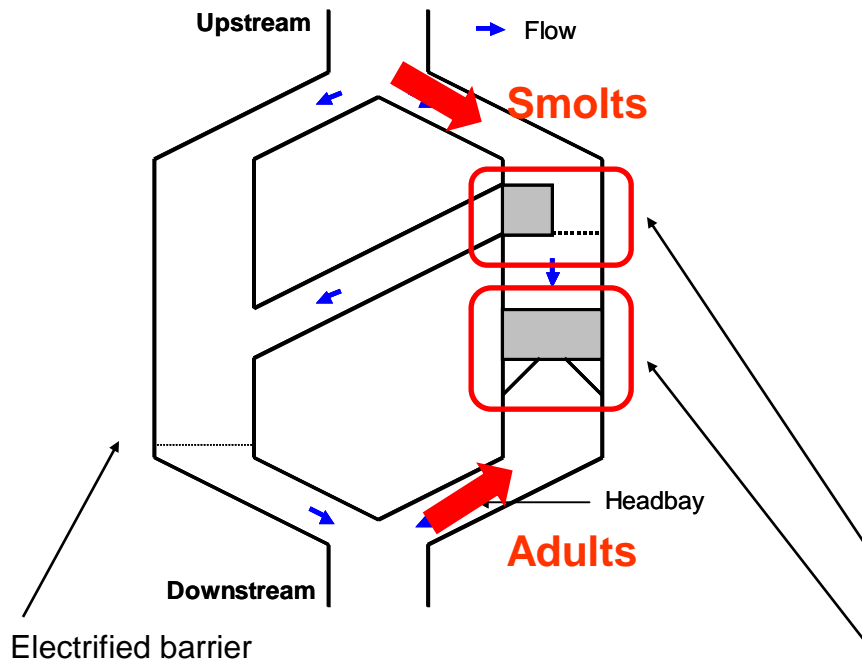
Process +
observation
errors



The trapping facility

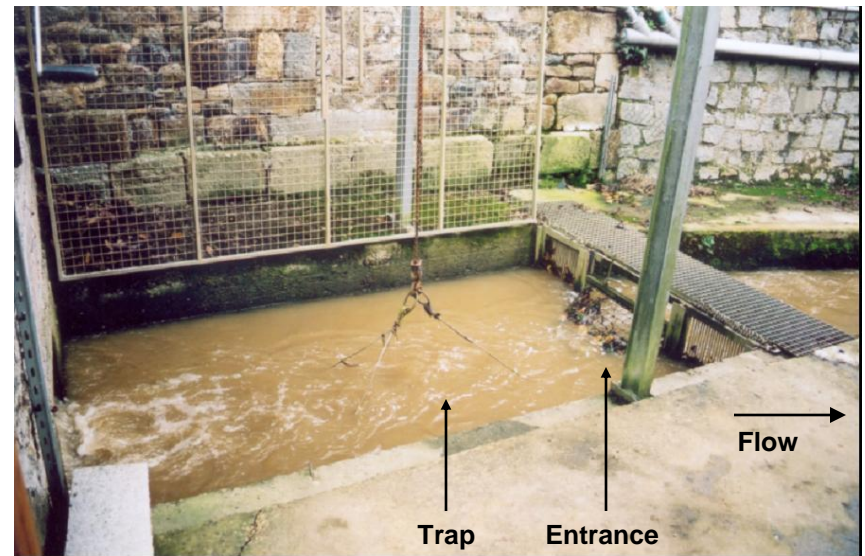


The double partial trapping facility (Cerisel trap, Oir R.)



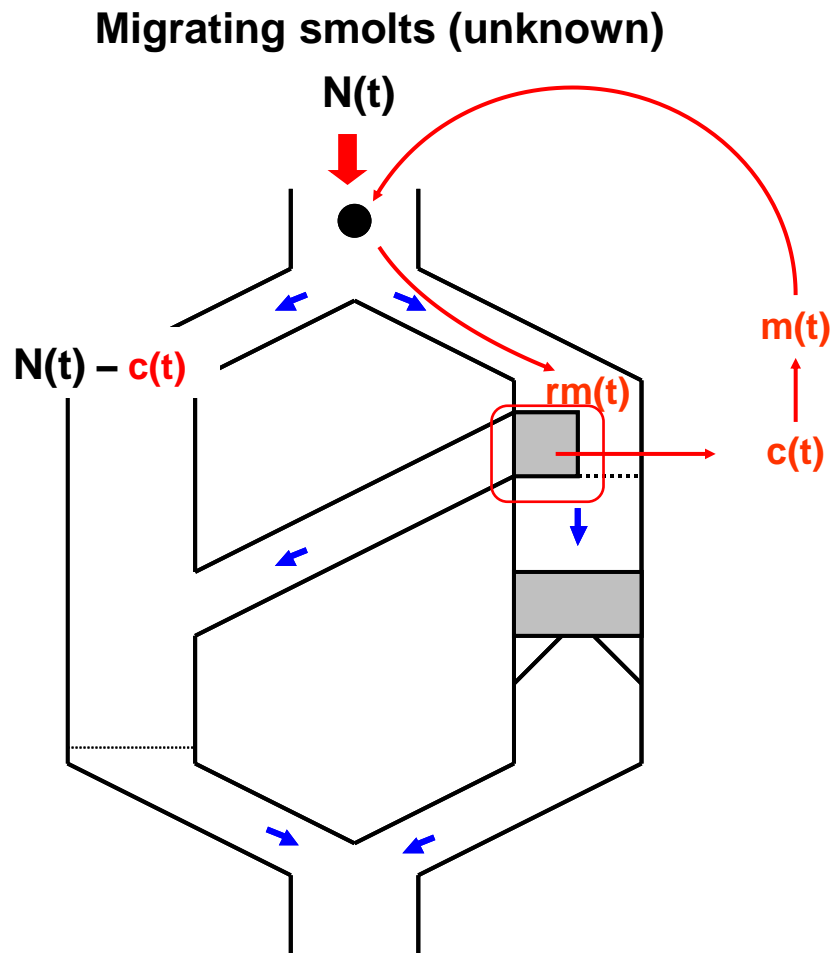
Downstream trap (SMOLTS)

Upstream trap (SPAWNERS)



S1

CMR for downstream migrating smolts



S2

Data

Exp	year	c	m	rm	Q	pSm1	Nb_juv0_previous_year
1	1986	887	135	91	6.18	0.956	3326
2	1987	283	31	24	4.19	0.516	1801
3	1988	307	59	43	3.12	0.917	856
4	1989	553	65	43	4.13	0.895	2799
5	1990	746	38	35	1.81	0.949	3170
6	1991	151	35	27	5.45	0.669	NA
7	1992	580	50	43	1.68	0.984	2383
8	1993	209	26	24	3.25	0.818	567
9	1994	329	17	10	4.77	0.982	1154
10	1995	618	63	NA	3.17	0.875	586
11	1996	767	76	NA	3.38	0.892	2307
12	1997	205	63	31	5.29	0.907	1604
13	1998	511	91	44	6.43	0.857	3652
14	1999	195	59	45	3.40	0.221	264
15	2000	1849	300	232	5.04	0.992	3497
16	2001	688	264	123	7.86	0.924	4657
17	2002	1919	442	352	2.71	0.833	6184
18	2003	844	326	222	4.42	0.581	1325

A vous de jouer !