Spatial State-Space Survey Based Assessment Model for the Grand Banks American Plaice

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October 4, 2018
CAPAM workshop on spatial stock assessment models

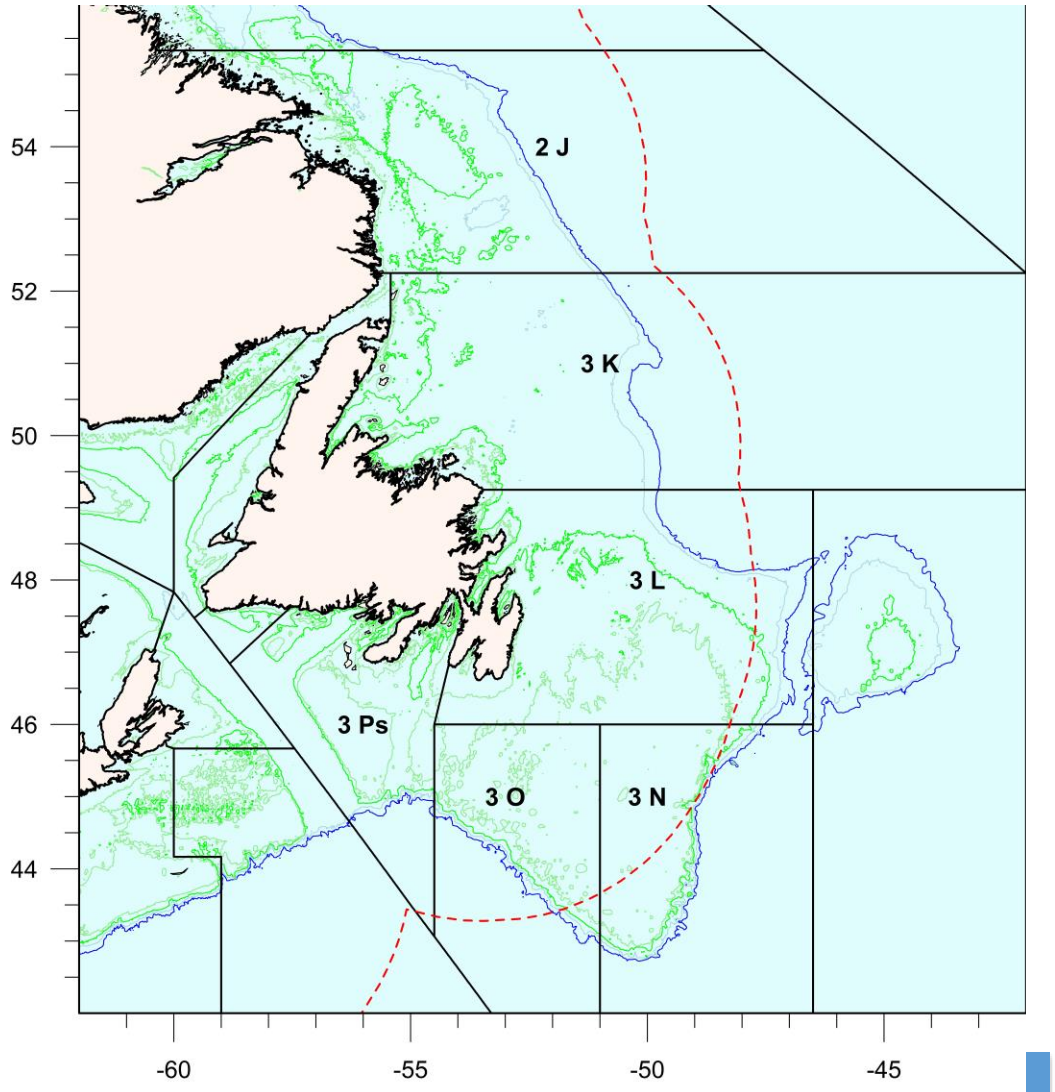
Outline

- Introduction
- Methods
- Model selection
- Results from the best model

Introduction

- American Plaice is a demersal marine flatfish
  - Once considered to be the most abundant flatfish in Newfoundland and Labrador (NL) waters
  - Under moratorium since 1995

- NL population of American plaice is managed as 3 stocks:
  - 2GHJ3K (Labrador and the northeast coast of Newfoundland stock),
  - 3LNO (the Grand Bank stock), and
  - 3Ps (St. Pierre Bank stock)

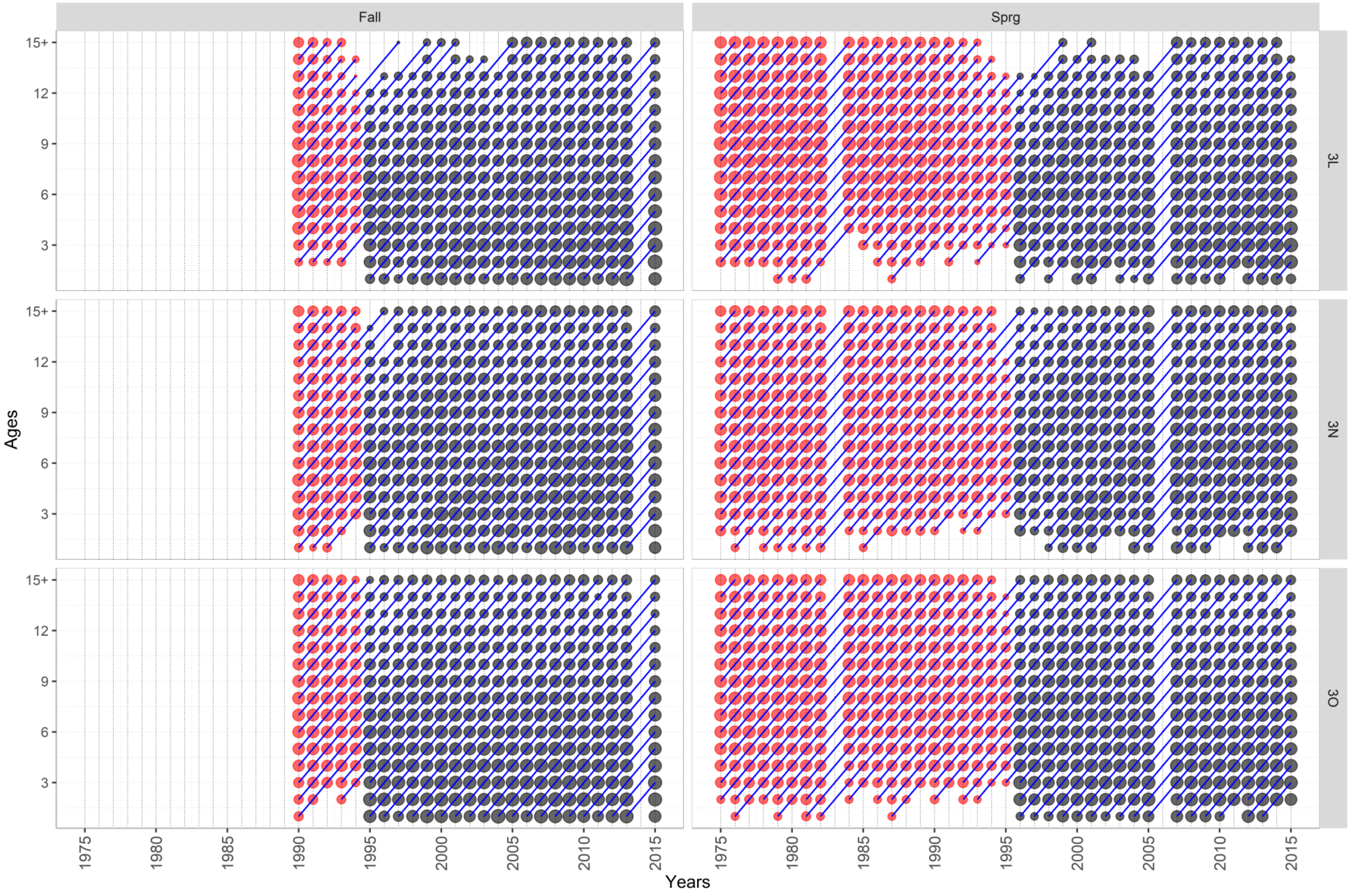


Introduction

- Survey-based assessment model(SURBA):
  - is useful when catch information is not available OR not reliable
  - gives estimate of F and Z, and relative stock size and cohort strength
  - can also provide some idea about catch, which can be compared with reported catch trend
- Spatial SURBA:
  - Accounts for spatial differences in the stock

Survey data

- Abundance indices from Canadian RV surveys
- 1995 (Fall)-2015: smaller meshed Campelen trawl conducts survey
- Engel , a larger-meshed, trawl was used in earlier years



Methods

- Abundance (N) at age (a), year (y) in a given division (D) is equal to cohort size*cumulative mortality (Z)
  - $N_{a+1,y+1,D} = N_{a,y,D} * \exp(-Z_{a,y,D}) * \exp(\delta_{a+1,y+1,D})$
    - Process errors correlated: $\delta \sim MVN_D(0, \Sigma)$

$$\begin{pmatrix} \delta_{a,y,3L} \\ \delta_{a,y,3N} \\ \delta_{a,y,3O} \end{pmatrix} \sim N\left(\begin{bmatrix} 0 \\ 0 \\ 0 \end{bmatrix}, \begin{bmatrix} \tau_{3L}^2 & r_{3LN}\tau_{3L}\tau_{3N} & r_{3LO}\tau_{3L}\tau_{3O} \\ r_{3LN}\tau_{3L}\tau_{3N} & \tau_{3N}^2 & r_{3NO}\tau_{3N}\tau_{3O} \\ r_{3LO}\tau_{3L}\tau_{3O} & r_{3NO}\tau_{3N}\tau_{3O} & \tau_{3O}^2 \end{bmatrix} \right)$$

$where, \tau = st.dev; r = divisional\ corr.coef\ of\ process\ error$

  - $Z_{a,y,D} = F_{a,y,D} + M_{a,y,D}$
  - F is separable into age effect (S_a) and year effect (f_y)
    - $F_{a,y,D} = s_a * f_{y,D}$

Methods: Lorenzen M

- M is calculated using Lorenzen's equation
  - M is related to body weight (W) of fish.
    - $M_a = M_\infty * (W_a / W_\infty)^{-0.305}$
- The equation was reformulated in terms of growth parameters (vonB and L-W)
  - $M_{a,y,D} = M_\infty * \left(1 - \exp\left(-k_{c=y-a,D} * \left(a - a_{o_D}\right)\right)\right)^{-0.305 * b_D}$
    - M_∞ (M of a very old fish) is a scaling factor. We assumed it 0.1
    - $k_{y-a,D}$ and a_{o_D} were estimated using weighted likelihood approach (Zheng et al. 2018)
    - Allometric exponent b of L-W was estimated separately for each division using individual data

Zheng,N.,Cadigan,N.,and Morgan,JM.(in prep).A Spatiotemporal Von Bertalanffy Growth Model and Its Estimation When Data are Collected Through Length-Stratified Sampling, With Application to American Plaice Data

Methods: Observation model

Abundance index (I) for age (a), year (y) and divisions D is given by

- $I_{a,y,D} = \frac{q_{a,y,D} * N_{a,y,D} * \exp(-Z_{a,y,D} * sf)}{Swept\ area\ ratio\ (\psi)} * \exp(\epsilon)$
  - $\epsilon \sim \begin{cases} N(0, \sigma_1)\ if\ a \leq 5 \\ N(0, \sigma_2)\ if\ a > 5 \end{cases}$
  - Swept area ratio of Engel/Campelen =1.83; therefore,
    - $\psi = \begin{cases} 1.83\ if\ \ gear\ is\ Engel\ |\ y \leq 1995\ Spring \\ 1.0\ if\ \ gear\ is\ Campelan\ |\ y \geq 1995\ Fall \end{cases}$

Methods: Catchability in the observation model

- Catchability (q) is modelled as the function of fish length
- Camplen catchability (q_c) is assumed to follows logistic function of fish length
  - $q_c = f\left(L_{a,s,y-a,D}\right)$ [where s is survey, a=age, y=year, D =Division]
    - $f = \frac{\exp(\beta_0+\beta_1*L)}{1+\exp(\beta_0+\beta_1*L)}$
    - $\beta_1 = \frac{\log(19)}{L_{95}-L_{50}}$
    - $\beta_0 = -\beta_1 * L_{50}$
    - L_{95} and L_{50} were estimated as parameters

Cont..

Methods: Catchability in the observation model

- Engel catchability (q_e) is estimated from Campelen catchability and length-based conversion factors (CF) derived from the experimental fishing (Morgan et al 1998)

  - $q_e = q_c / CF$
    - $$CF = \begin{cases} \lambda \; if \; L \leq 23cm \\ \exp\left(39.96 + 0.36 * \left(L - 41 * log(L)\right)\right) if \; 23 < L < 40 \\ 1 \; if \; L \geq 40cm \end{cases}$$
    - λ was estimated as a parameter

- Therefore, catchability (q) in the observation model is:

  - $$q = \begin{cases} q_{e,} \; if \; y \leq 1995 \; Spring \\ q_{c,} \; if \; y \geq 1995 \; Fall \end{cases}$$

M.J. Morgan, W.B. Brodie, W.R. Bowering, D. Maddock Parsons and D.C. Orr (1998). Results of Data Conversions for American Plaice in Div. 3LNO from Comparative Fishing Trials Between the Engel Otter Trawl and the Campelen 1800 Shrimp Trawl. NAFO SCR Doc. 98/70

Model fitting

- Fitted in log-scale, Used TMB
- $F_{a,y,D} = s_a * f_{y,D}$
  - Random walk model for age effect (sa)
    - Assumed constant age-effect between the divisions
    - Estimated independent variances for younger ages 1-9 (sa1) and fully selected ages >=10 (sa2)
  - Random walk model for year-effect ($f_{y,D}$)
    - Estimated independently for each division, but has a common variance
- PEs are random with correlated MVN
- Recruitment is estimated with Auto-regressive model of order 1 (AR1)

Cont..

Model fitting: Autoregressive model (AR1) for recruitment

- Spatio-temporal Correlation in the recruitment (R_y) of the Divisions (D) were implemented through stationary AR(1) model with multivariate normal error

  - AR1 process:
    - $\log(R_{y,D}) = c_D + \phi_D * \log(R_{y-1,D}) + e_{y,D}$

  - The deviations from the AR1 process are correlated and follow multivariate normal distribution in the Divisions (D) 3LNO:
    - $$\begin{pmatrix} e_{y,3L} \\ e_{y,3N} \\ e_{y,3O} \end{pmatrix} \sim N\left(\begin{bmatrix} 0 \\ 0 \\ 0 \end{bmatrix}, \begin{bmatrix} \omega_{3L}^2 & \rho_{3LN}\omega_{3L}\omega_{3N} & \rho_{3LO}\omega_{3L}\omega_{3O} \\ \rho_{3LN}\omega_{3L}\omega_{3N} & \omega_{3N}^2 & \rho_{3NO}\omega_{3N}\omega_{3O} \\ \rho_{3LO}\omega_{3L}\omega_{3O} & \rho_{3NO}\omega_{3N}\omega_{3O} & \omega_{3O}^2 \end{bmatrix}\right)$$

    $where, \omega = st.dev; \rho = divisional\ corr.coef\ of\ deviations\ (errors)$

Cont..

Autoregressive model (AR1) for recruitment

- Marginal distribution of *log($R_{y,D}$)* under the stationary assumption of AR1 is:
  - $\log(R_{y,D}) \sim N(\mu_D, \Psi_\mathrm{D})$

    where, $\mu_D = c_D(1-\phi_D)$ and $\Psi = \frac{\omega_D}{\sqrt{1-\phi_D^2}}$

  - The marginal correlation in the recruitment between any two divisions is given by
    - $corr(\log(R_{y,d_1}), \log(R_{y,d_2})) = \varrho_{d_1 d_2} = \rho_{d_1 d_2} \frac{\sqrt{1-\phi_{d_1}^2}\sqrt{1-\phi_{d_2}^2}}{1-\phi_{d_1}\phi_{d_2}}$

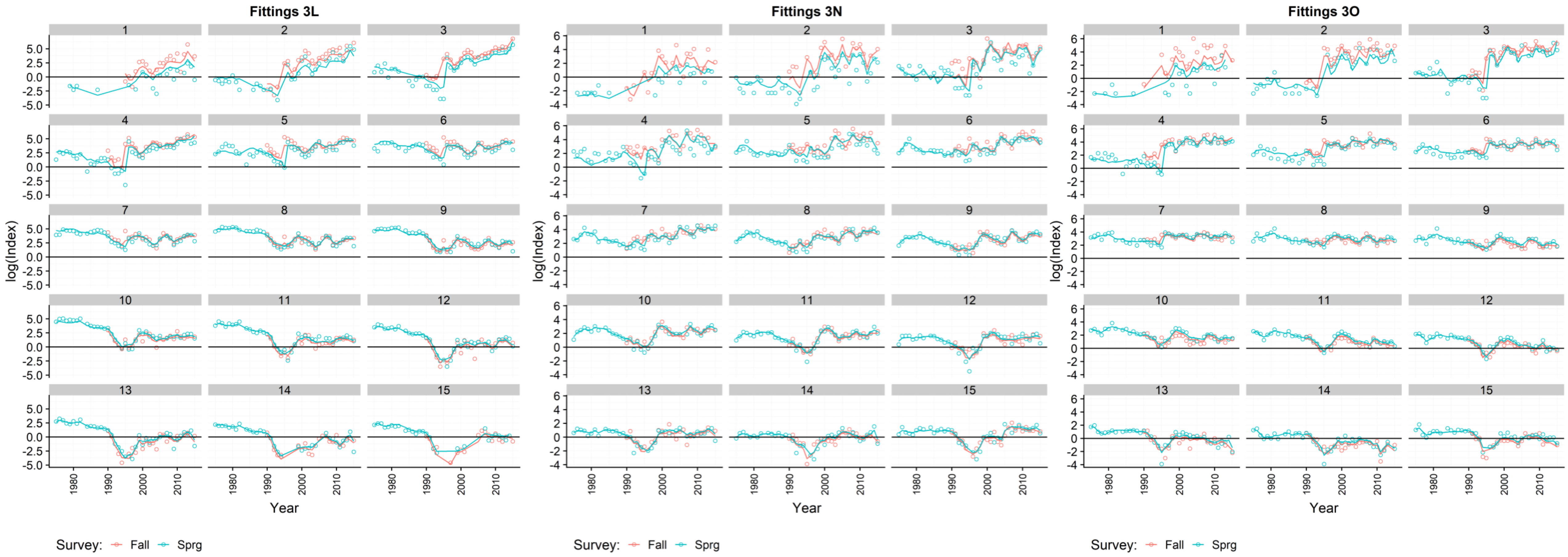
  - Therefore, the marginal joint distribution of the recruitments is
    - $\begin{pmatrix} \log(R_{y,3L}) \\ \log(R_{y,3N}) \\ \log(R_{y,3O}) \end{pmatrix} \sim N\left(\begin{bmatrix} \log(R_{y-1,3L}) \\ \log(R_{y-1,3N}) \\ \log(R_{y-1,3O}) \end{bmatrix}, \begin{bmatrix} \Psi_{3L}^2 & \varrho_{3LN}\Psi_{3L}\Psi_{3N} & \varrho_{3LO}\Psi_{3L}\Psi_{3O} \\ \varrho_{3LN}\Psi_{3L}\Psi_{3N} & \Psi_{3N}^2 & \varrho_{3NO}\Psi_{3N}\Psi_{3O} \\ \varrho_{3LO}\Psi_{3L}\Psi_{3O} & \varrho_{3NO}\Psi_{3N}\Psi_{3O} & \Psi_{3O}^2 \end{bmatrix}\right)$

Model comparison

Models	nll	Dev	N of fixed parms	AIC	BIC	convergence
No PE	3079.704	6159.407	62	6283.407	6650.475	YES
Common PE	2976.099	5952.197	63	6078.197	6451.185	YES
Division-wise correlated PE	2945.013	5890.027	68	6026.027	6428.617	YES

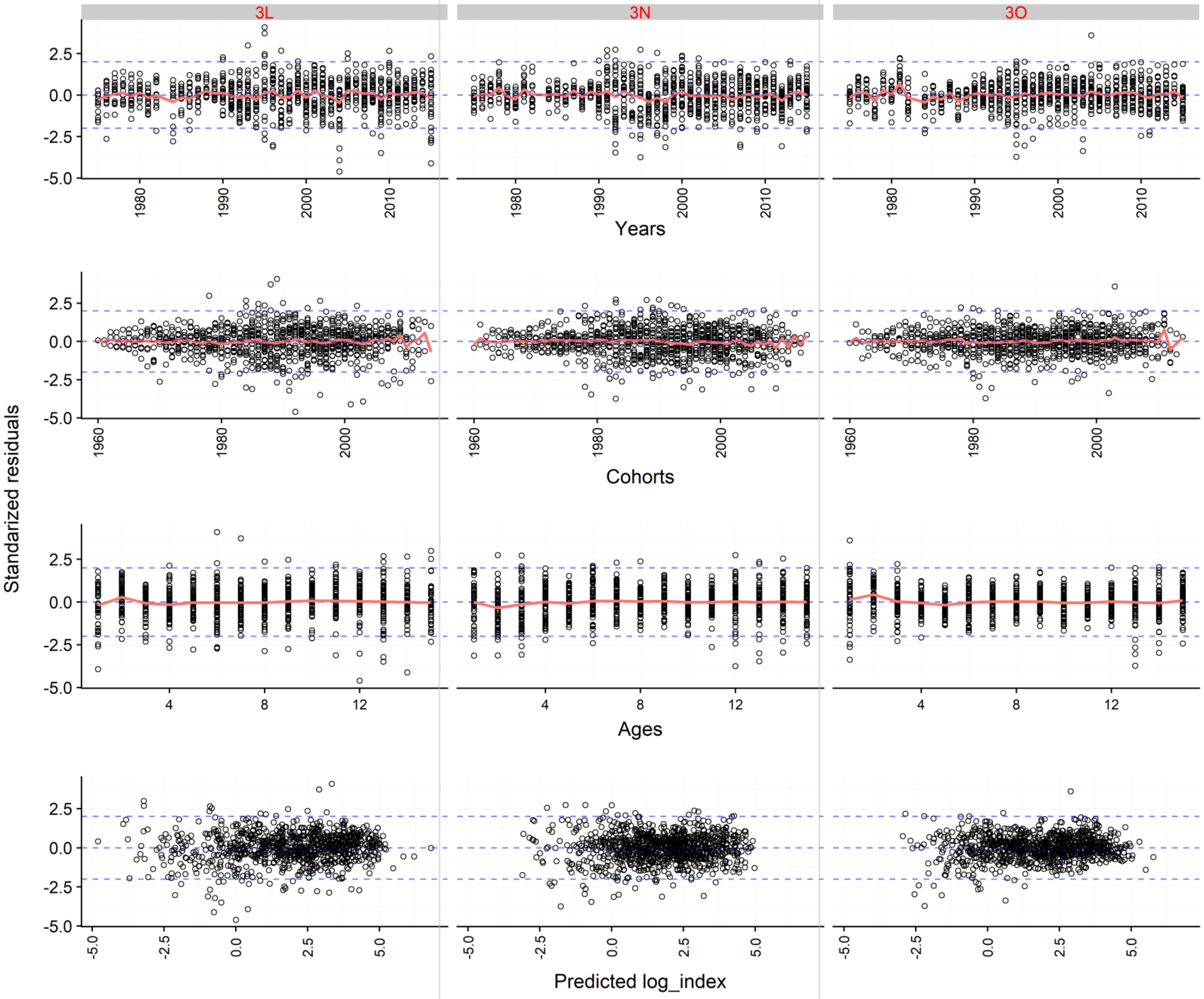
- Based on lowest AIC, the model with division-wise correlated PE is selected
- Results presented in the following slides are based on this model

Results: model fitting

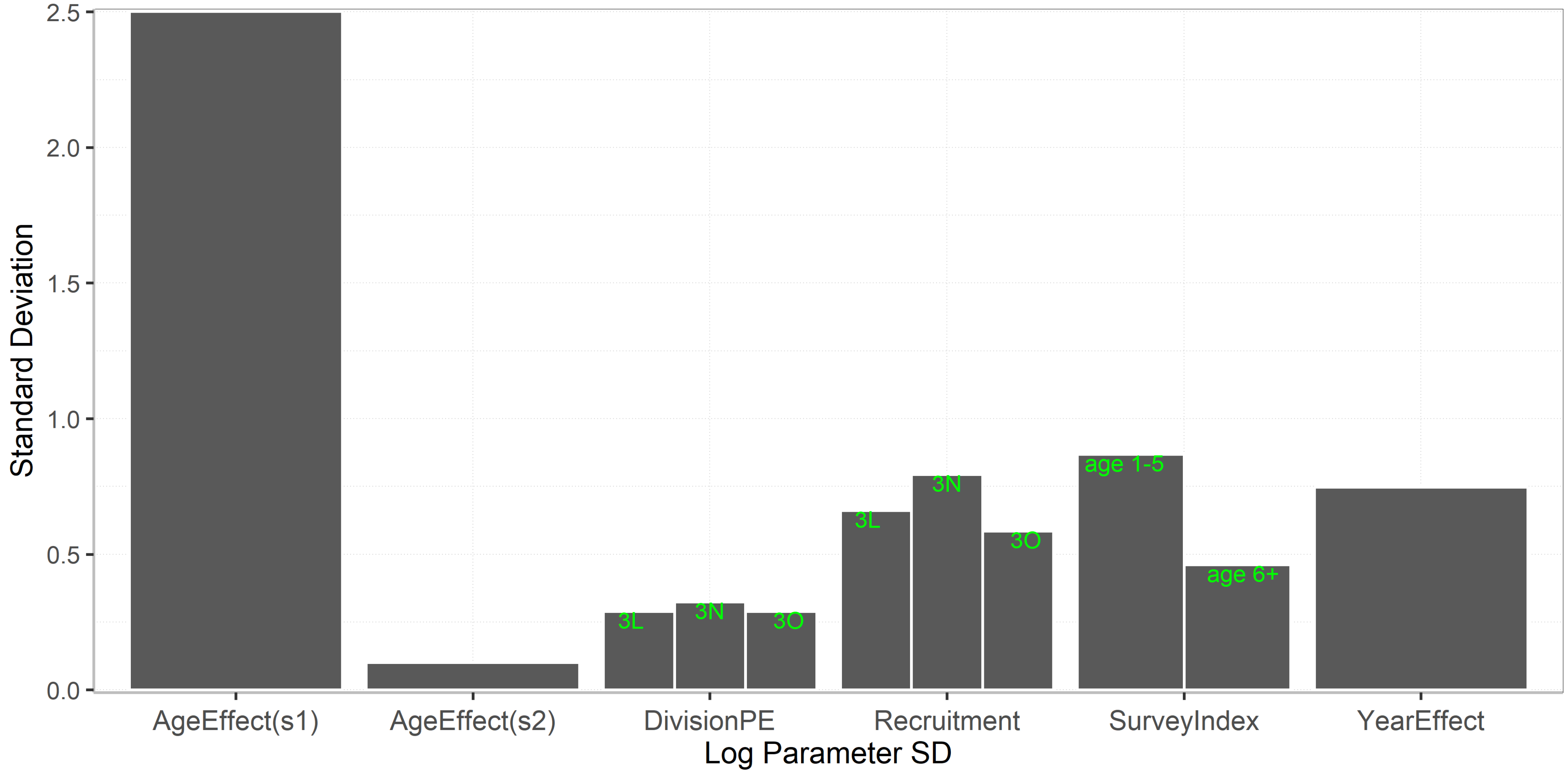


Results: residuals

- Residual patterns against years, cohort, ages, or predicted index do not show any obvious patterns

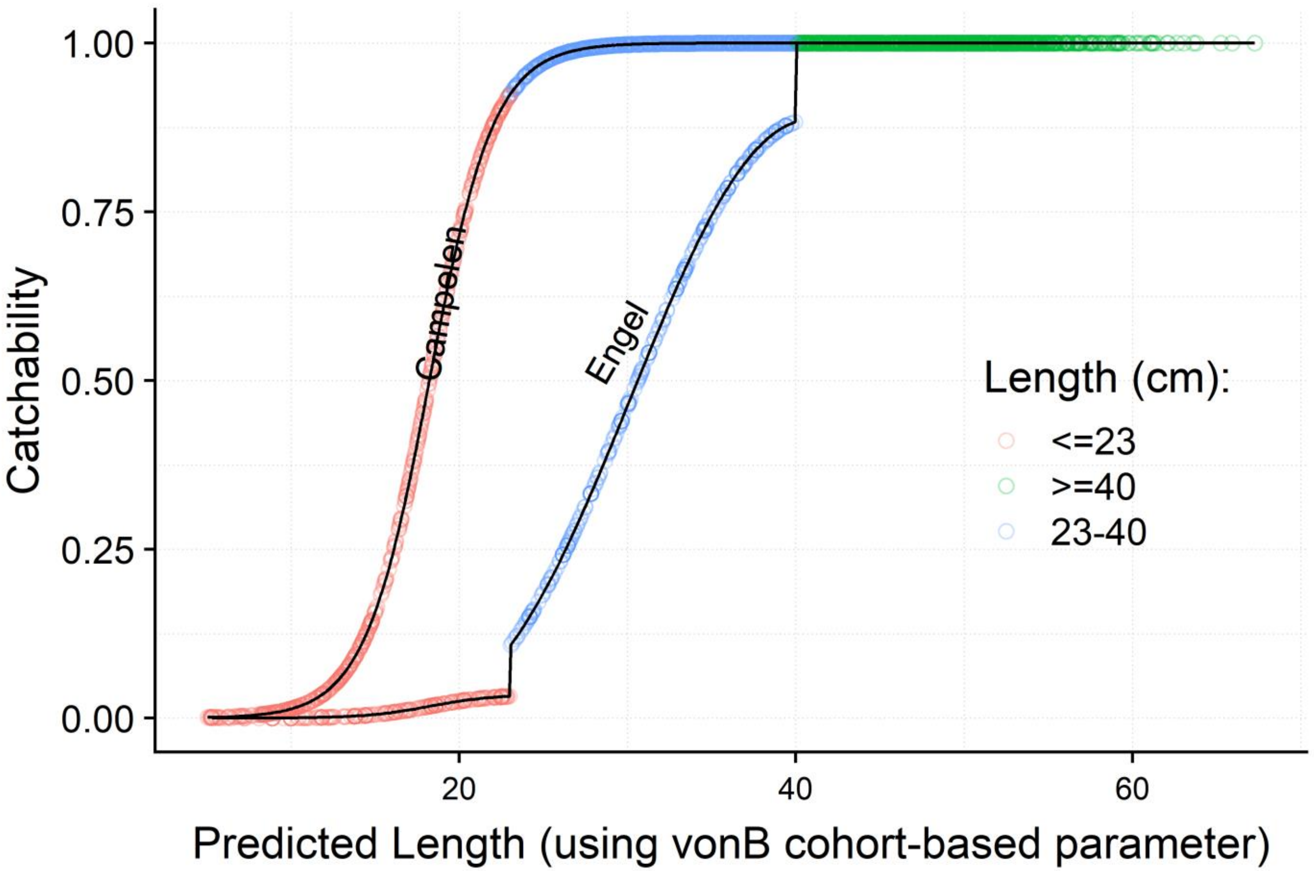


Results: all variances

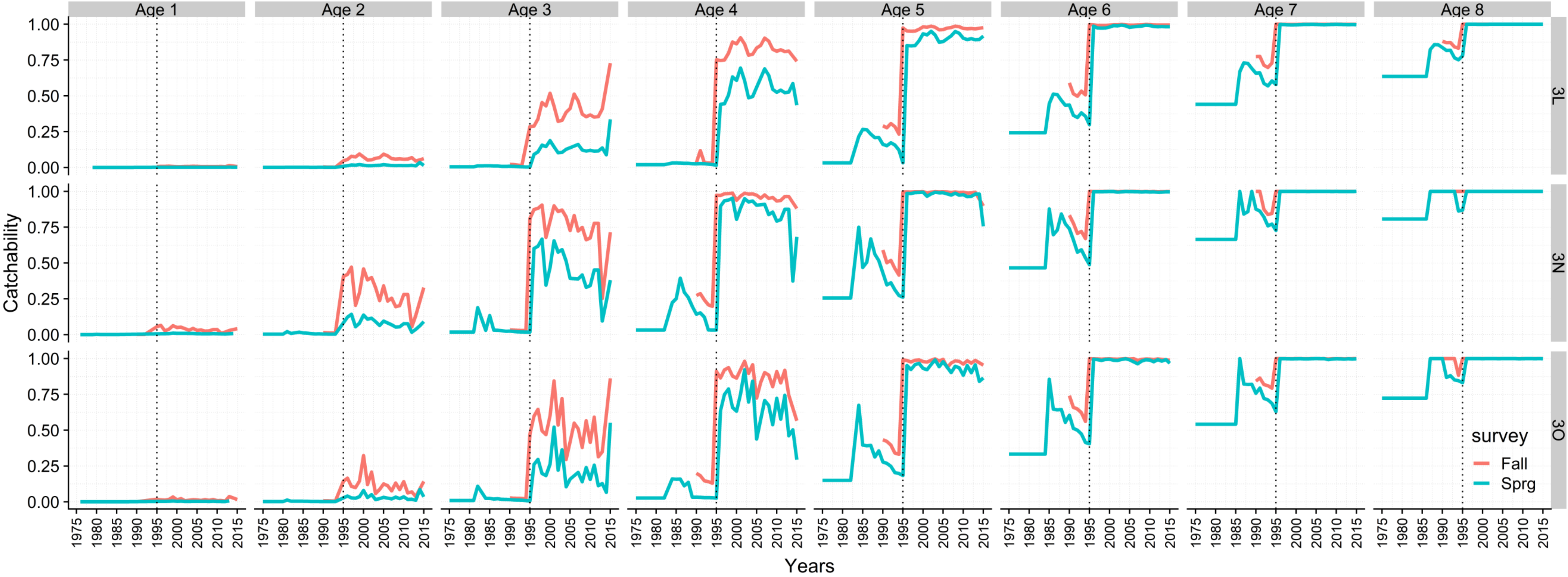


Results: catchability at length

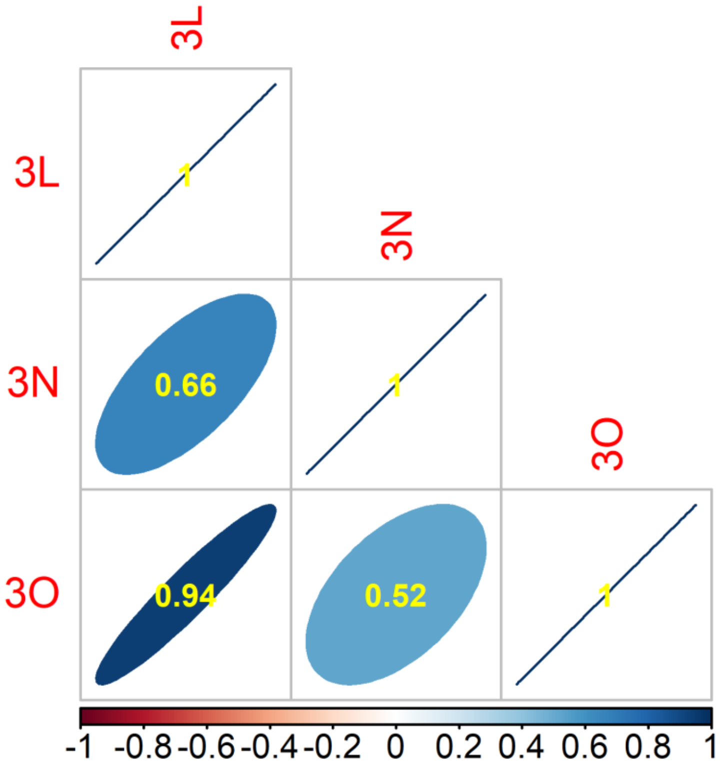
q parameters	value
L50	17.87
L95	23.46
CF1 (λ)	32.27



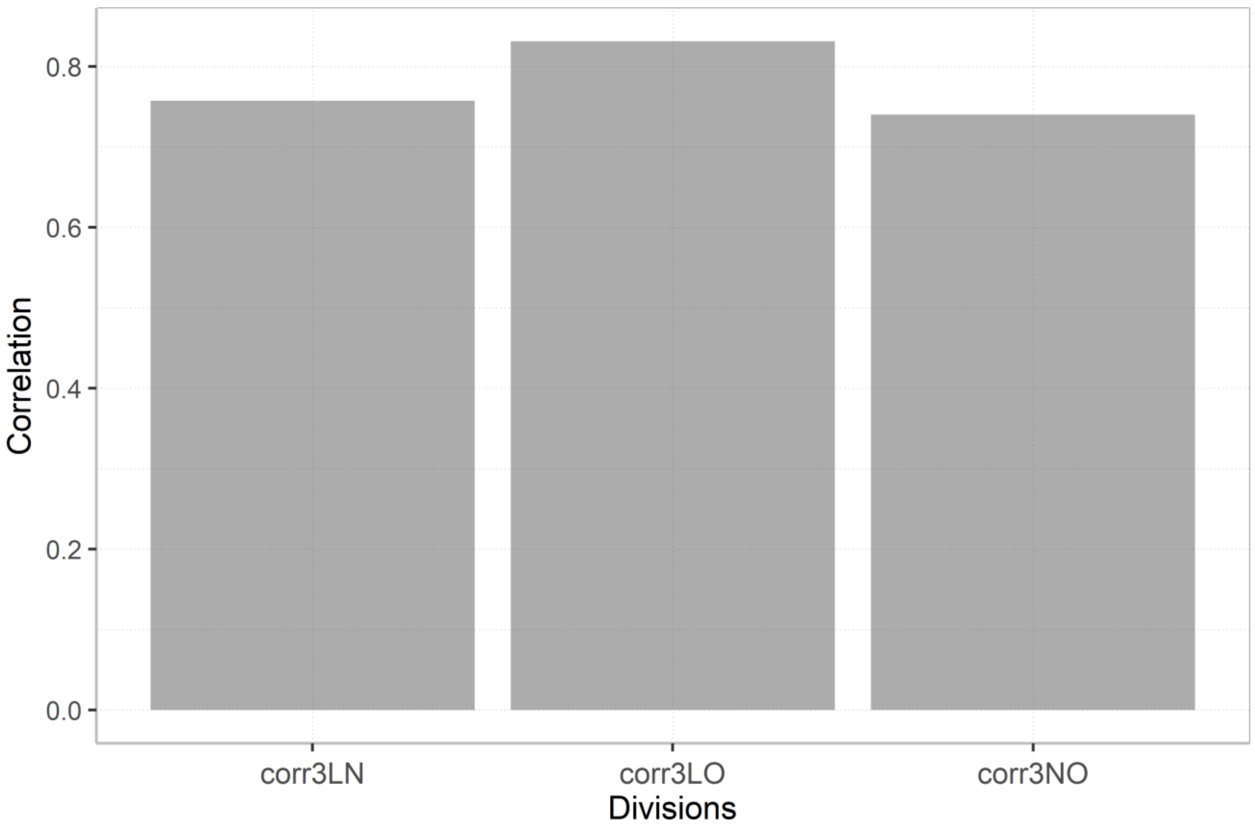
Results: changes in catchabilities

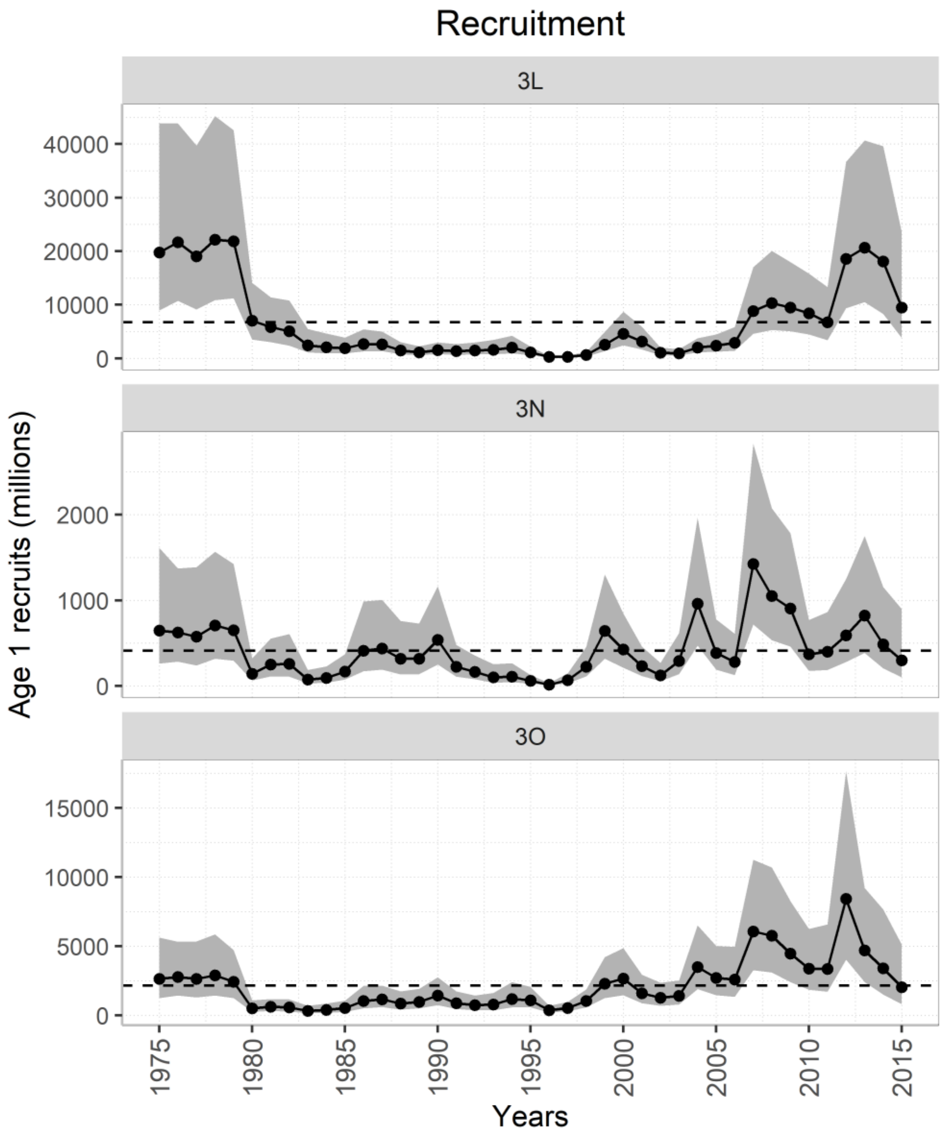


Results: process errors

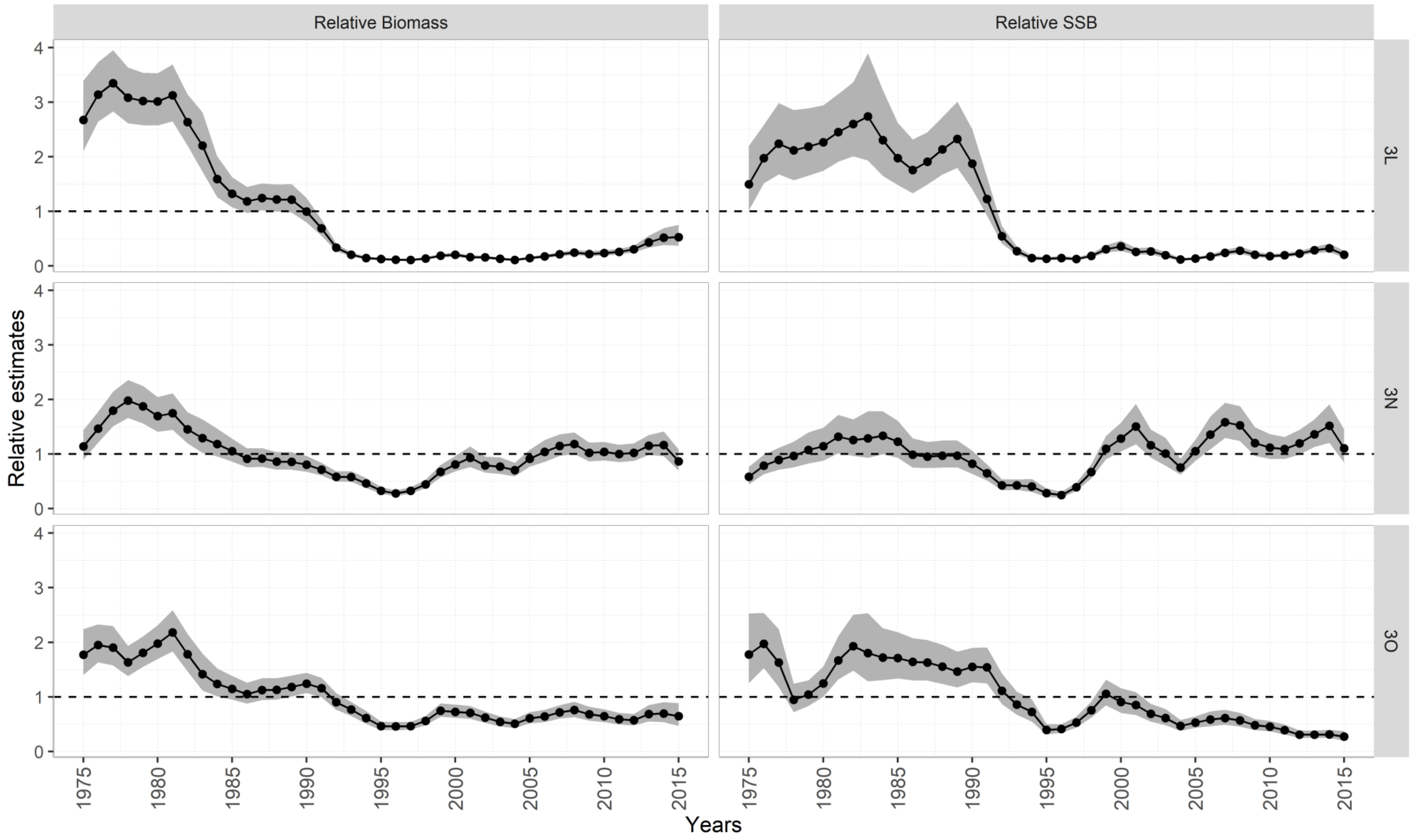


Results: recruitment series and their correlation

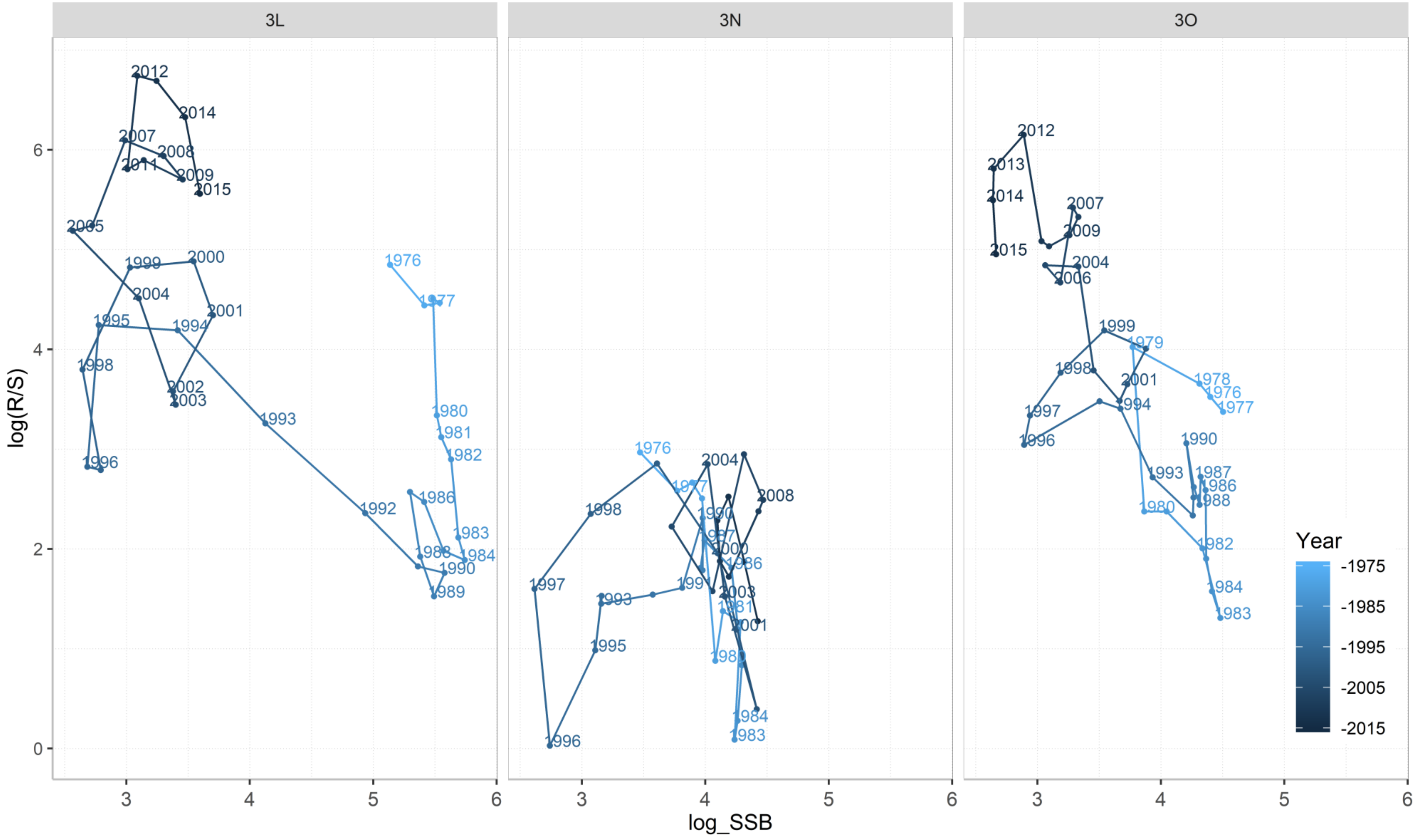




Results: relative biomass and SSB

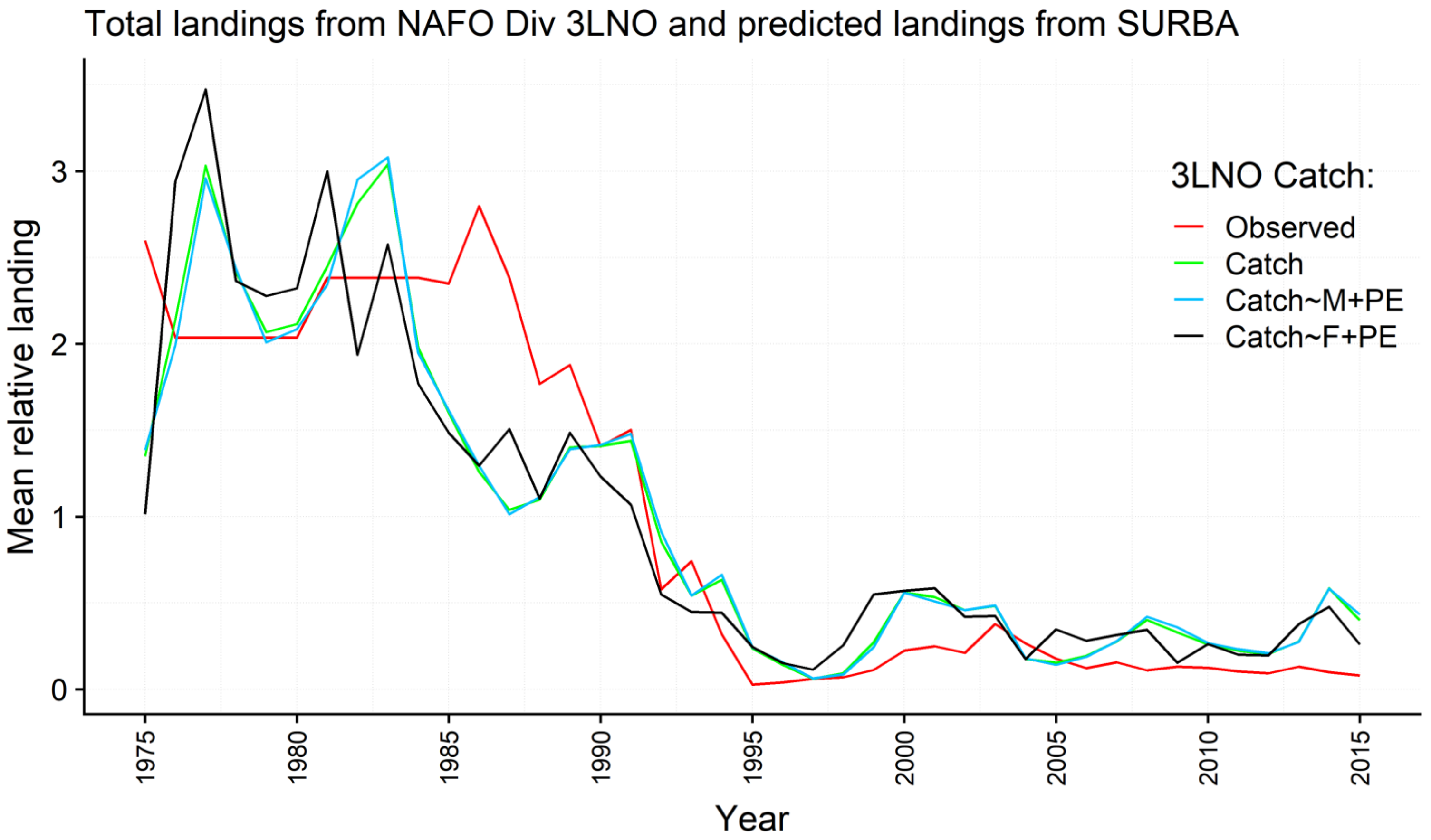


Results: recruits per spawner



Results: comparison of catch with reported trends in landings

- Shows similarity in trends



Source: NAFO SCS Doc. 16/30

Conclusion

- The spatial model shows that stock status estimates for the divisions are substantially different from each other

- Recruitment in 3LNO shows moderate to strong correlation

- Productivity above average in recent years

THANK YOU

Comments and Questions?