

Life Cycle Model for Atlantic salmon stock assessment

Retrospective analysis using Mohn's ρ statistics

*Etienne Rivot and Gaspard Dubost
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Method

Retrospective patterns allow to detect any systematic inconsistency in an estimate in stock assessment models, and are typically applied for spawning stock biomass (SSB) or fishing mortality, in recent years of an assessment (Mohn, 1999; Legault, 2020; Breivik et al., 2023). Such inconsistencies indicate model misspecification. In particular, they may indicate that parameters have been systematically over- or underestimated in some consecutive years.

We tested for the existence of retrospective pattern in estimates of key quantities estimated from the model, i.e., estimates of PFA (maturing, non-maturing, and total), smolt-to-PFA marine survival, and estimates of proportion of maturing PFA.

We used the common version of Mohn's ρ (Mohn, 1999) calculated for any derived quantity X:

$$\rho_X = \frac{1}{K} \sum_{k=1}^K \frac{\hat{X}_{n-k,n-k} - \hat{X}_{n-k,n}}{\hat{X}_{n-k,n}}$$

where K is the number of years removed (peeled) from the terminal year (n), $\hat{X}_{n-k,n}$ is the estimate of the derived quantity X in year $n - k$ using the entire time series of data through year n , and $\hat{X}_{n-k,n-k}$ is the estimate of the derived quantity X in year $n - k$ using the time series of data through year $n - k$ (k years peeled).

Because our estimates are Bayesian, posterior medians of marginal posterior distributions were used as point estimates of all quantities \hat{X} .

In this study, a 5-year peel was used and all Mohn's rho estimates reported here are for 5-years peels. The model was fitted to the data set consolidated during the benchmark (ICES, 2023), that is the time series from 1971 through year 2022.

We calculated the Mohn's ρ for five key quantities in the model: Pre Fishery Abundance (PFA maturing, PFA non-maturing, and total PFA), the smolt-to-PFA marine survival, and the proportion of maturing PFA, and independently for the 25 Stock Units in the model.

Results

Results revealed that the estimates of the five quantities are very stable when peeling the data series (Figs. 1,2,3,4,5; see also the additional Figures with the entire time series in Sup Mat 1). Consistently, most of the Mohn's ρ values are below 0.05 (Table 1).

This "overstability" is a direct consequence of the capacity of the model to capture the temporal variability, especially in the smolt-to-PFA survival and the proportion of maturing PFA. As outlined during the benchmark workshops, further development should assess the tradeoff between retrospective stability and predictive performance by investigating alternative modeling assumptions, especially modelling assumptions on the times series of post-smolt survival and proportion maturing (e.g., a higher level autoregressive process).

References

Breivik, O. N., Aldrin, M., Fuglebakk, E., & Nielsen, A. (2023). Detecting significant retrospective patterns in state space fish stock assessment. *Canadian Journal of Fisheries and Aquatic Sciences*, 80(9), 1509-1518.
<https://doi.org/10.1139/cjfas-2022-0250>

- ICES (2023). Benchmark Workshop on Atlantic salmon in the North Atlantic (WKBSALMON). ICES Scientific Reports. 5:112. 85 pp. <https://doi.org/10.17895/ices.pub.24752079>
- Legault, C. M. (2020). Rose vs. Rho : A comparison of two approaches to address retrospective patterns in stock assessments. ICES Journal of Marine Science, 77(7-8), 3016-3030. <https://doi.org/10.1093/icesjms/fsaa184>
- Mohn, R. (1999). The retrospective problem in sequential population analysis : An investigation using cod fishery and simulated data. ICES Journal of Marine Science, 56(4), 473-488. <https://doi.org/10.1006/jmsc.1999.0481>

Stock units	Total PFA	Maturing PFA	Non-maturing PFA	Post-smolt survival	Prob. of maturing as 1SW
LB	0.0819	0.1073	0.0104	0.1397	0.0220
NF	-0.0062	-0.0140	0.0073	-0.0626	-0.0084
QC	0.0008	0.0006	0.0014	0.0091	-0.0009
GF	0.0061	-0.0030	0.0076	-0.0035	-0.0089
SF	-0.0002	-0.0009	-0.0010	-0.1168	-0.0004
US	-0.0016	-0.0011	-0.0023	-0.0902	0.0009
FR	0.0468	0.0818	-0.0058	0.0779	0.0356
EW	0.0060	0.0800	-0.0238	0.0245	0.0787
IR	-0.0162	-0.0166	-0.0178	-0.0478	-0,00009
NI_FO	0.1607	0.1718	0.0474	0.3026	0.0094
NI_FB	-0.0001	-0,0005	0.0004	0.0070	-0.0004
SC_WE	0.0028	-0.0143	0.0203	-0.0189	-0.0116
SC_EA	0.0088	-0.0076	0.0168	0.0023	-0.0147
IC_SW	0.0081	0.0074	0.0021	0.0745	-0,0001
IC_NE	0.0088	0.0021	0.0201	0.0291	-0.0061
SW	-0.0046	-0.0020	-0.0067	-0.0313	0.0029
NO_SE	0.0089	0.0015	0.0120	0.0256	-0.0071
NO_SW	0.0072	0.0357	-0.0055	0.0710	0.0304
NO_MI	0.0084	0.0067	0.0066	0.0708	-0.0023
NO_NO	0.0166	-0.0099	0.0354	0.1204	-0.0266
FI	0.0052	0.0070	-0.0035	0.0567	0.0033
RU_KB	-0.0168	-0.0284	-0.0137	-0.0652	-0.0111
RU_KW	0.0587	0.0597	-0.0009	0.0562	-0.0002
RU_AK	0.0050	-0.0011	-0.0009	0.0322	-0.0053
RU_RP	-0.0021	-0,00001	-0.0023	-0.0227	0.0019

Table 1. Mohn's ρ diagnostics calculated for estimates of PFA (maturing, non-maturing, and total), smolt-to-PFA marine survival, and proportion of maturing PFA. Mohn's ρ diagnostics were calculated independently for all SU, for 5-years peels. Medians of the marginal Bayesian posterior distributions were used as point estimates.

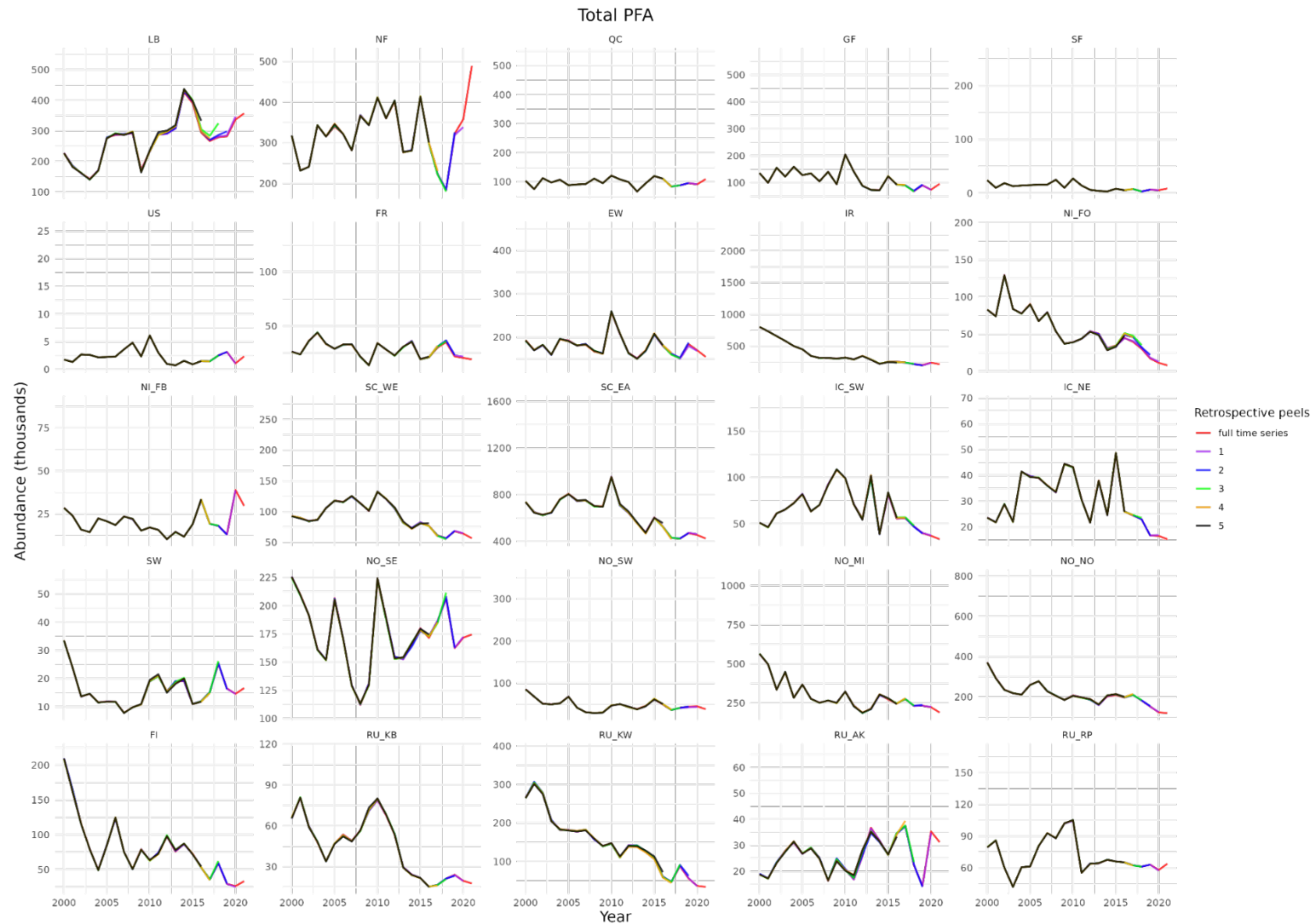


Figure 1. Retrospective patterns for PFA. The lines in each panel show the medians of the Bayesian posterior distributions of PFA (mature + non mature PFA), obtained by using the full time series of data (1971-2022) and five retrospective peels (1 to 5 years of data removed from the full data set). Note the graph is cut after year 1990 to increase resolution. The full time series are visible in Sup Mat 1.

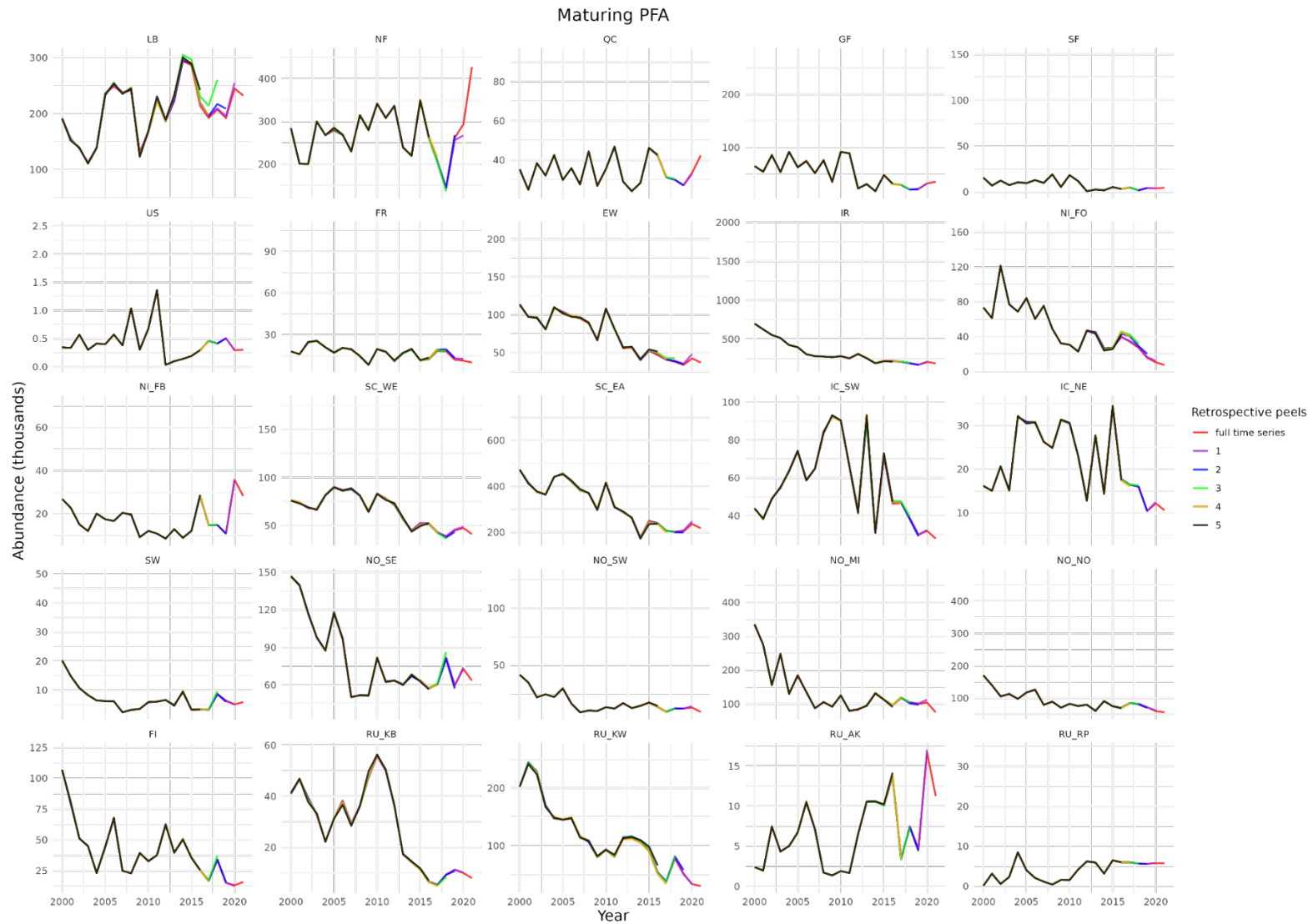


Figure 2. Retrospective patterns for maturing PFA. The lines in each panel show the medians of the Bayesian posterior distributions of maturing PFA, obtained by using the full time series of data (1971-2022) and five retrospective peels (1 to 5 years of data removed from the full data set). Note the graph is cut after year 1990 to increase resolution. The full time series are visible in Sup Mat 1.

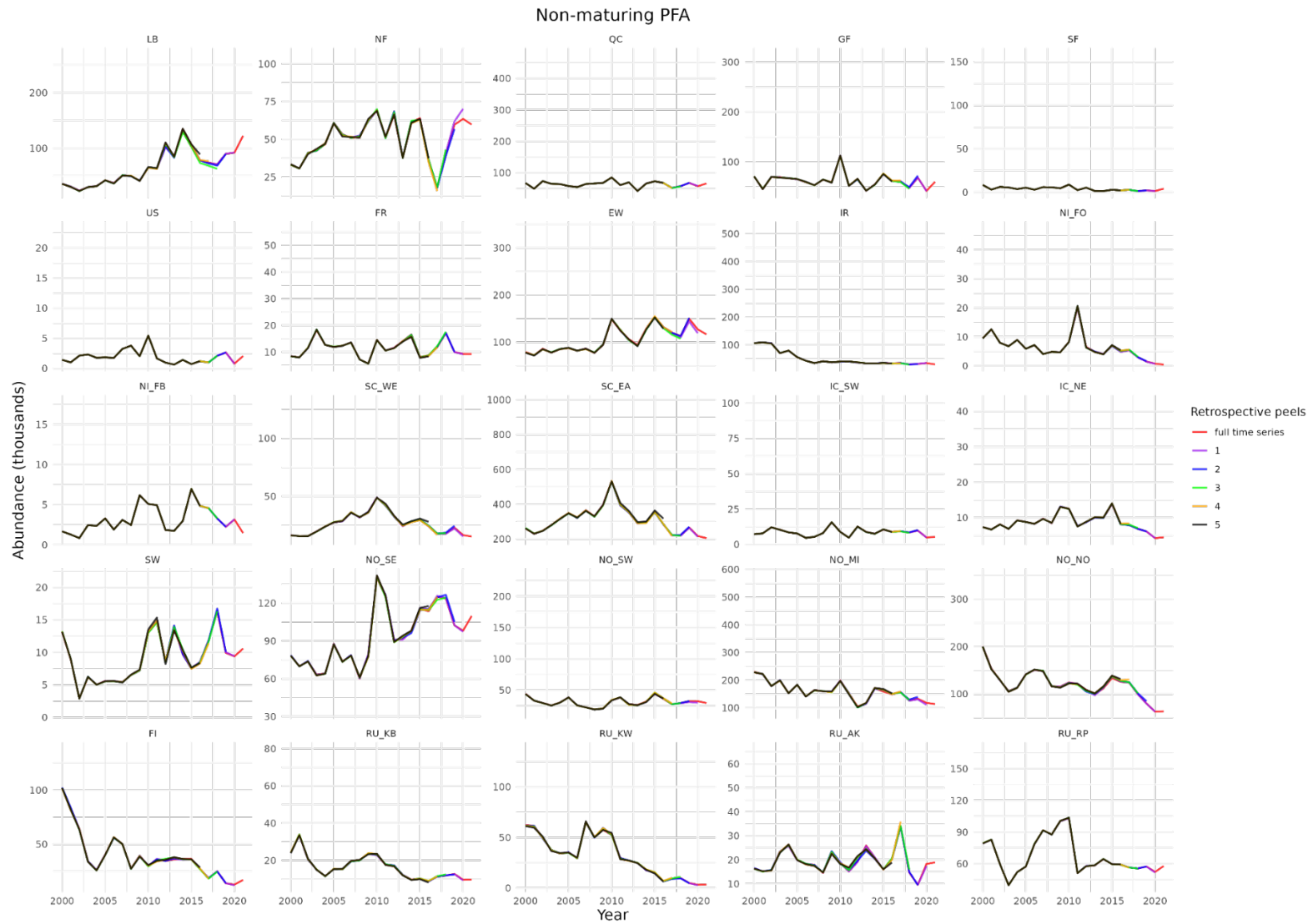


Figure 3. Retrospective patterns for non maturing PFA. The lines in each panel show the medians of the Bayesian posterior distributions of non maturing PFA, obtained by using the full time series of data (1971-2022) and five retrospective peels (1 to 5 years of data removed from the full data set). Note the graph is cut after year 1990 to increase resolution. The full time series are visible in Sup Mat 1.

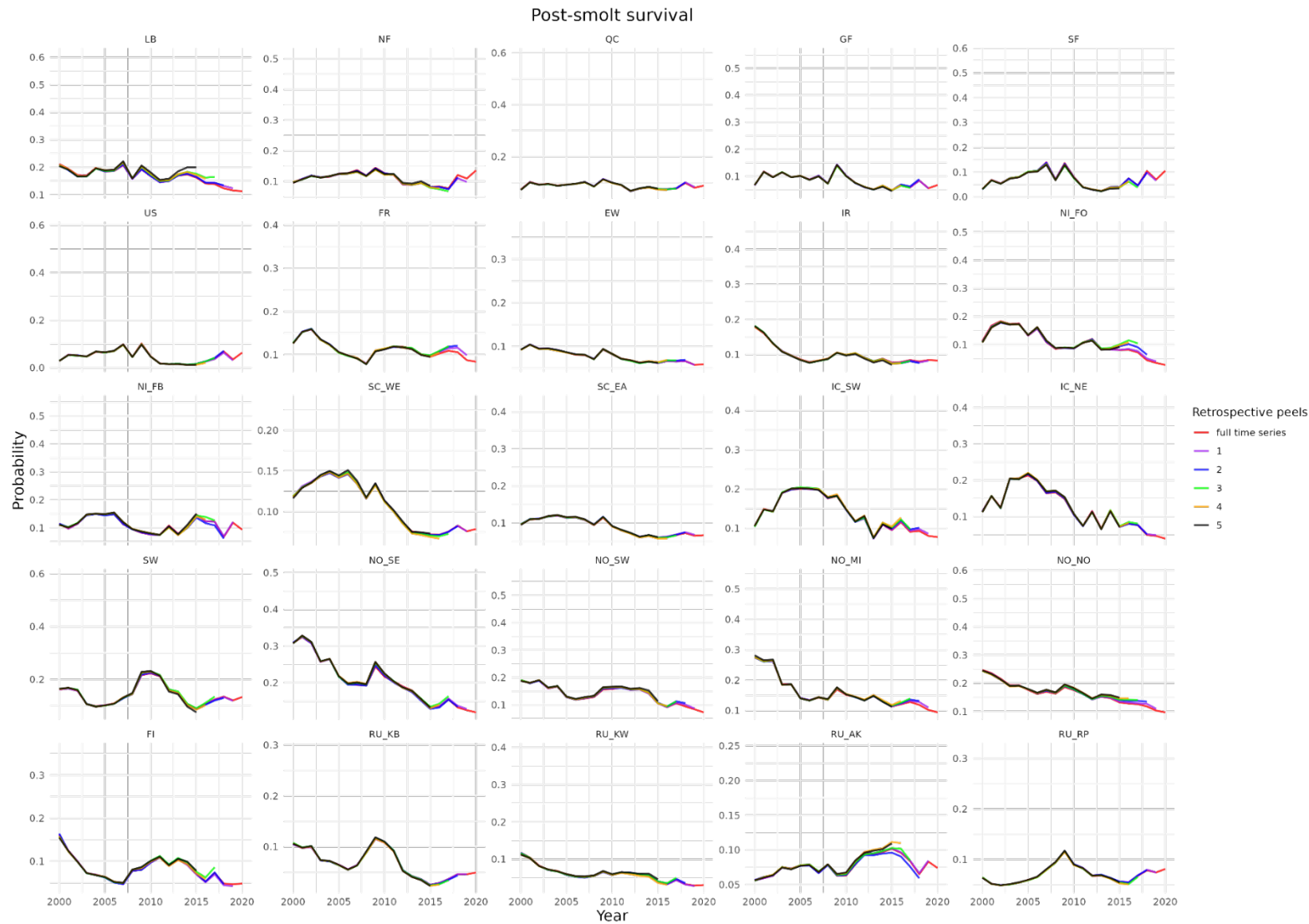


Figure 4. Retrospective patterns for the smolt-to-PFA marine survival. The lines in each panel show the medians of the Bayesian posterior distributions of the smolt-to-PFA marine survival, obtained by using the full time series of data (1971-2022) and five retrospective peels (1 to 5 years of data removed from the full data set). Note the graph is cut after year 1990 to increase resolution. The full time series are visible in Sup Mat 1.

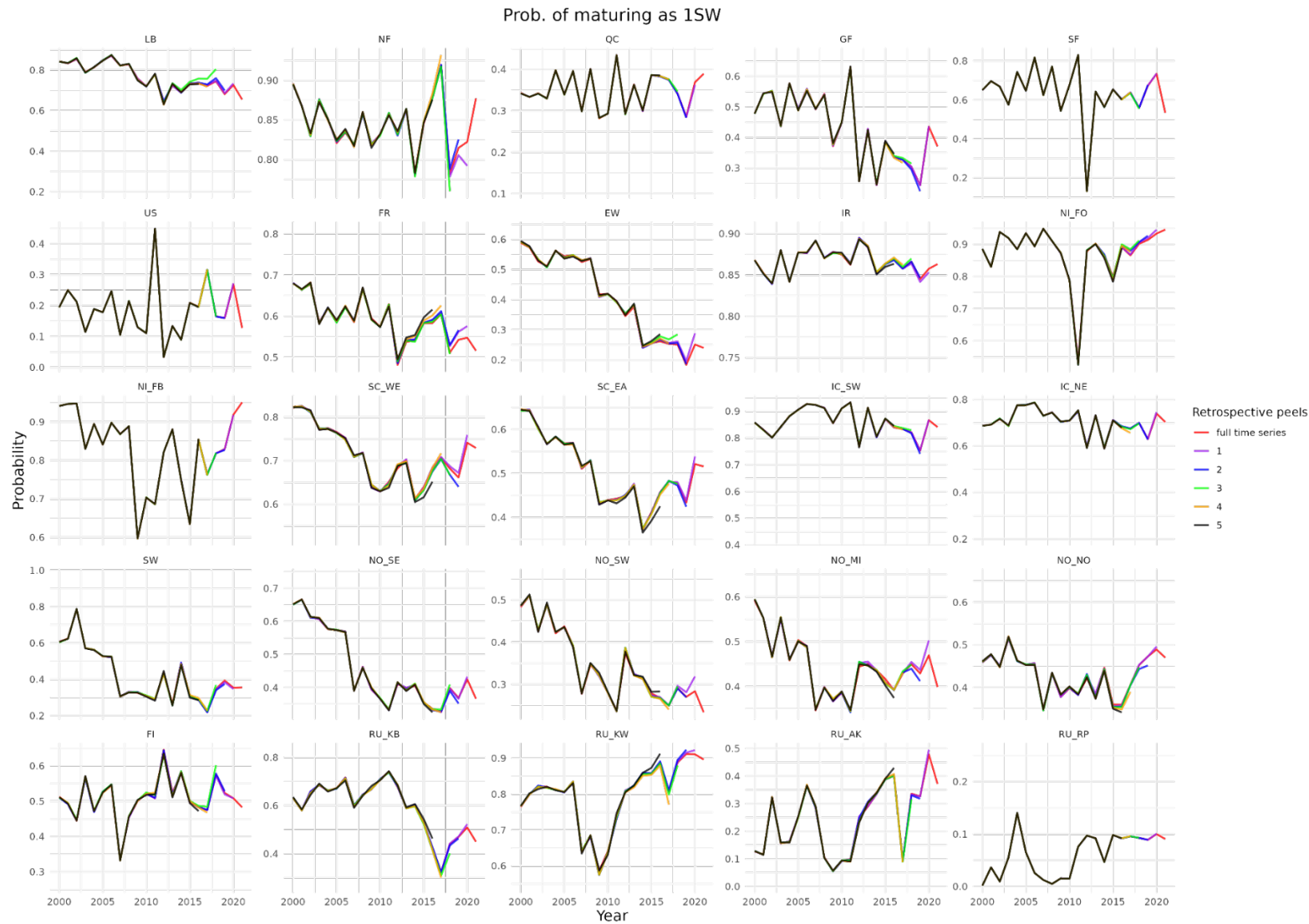
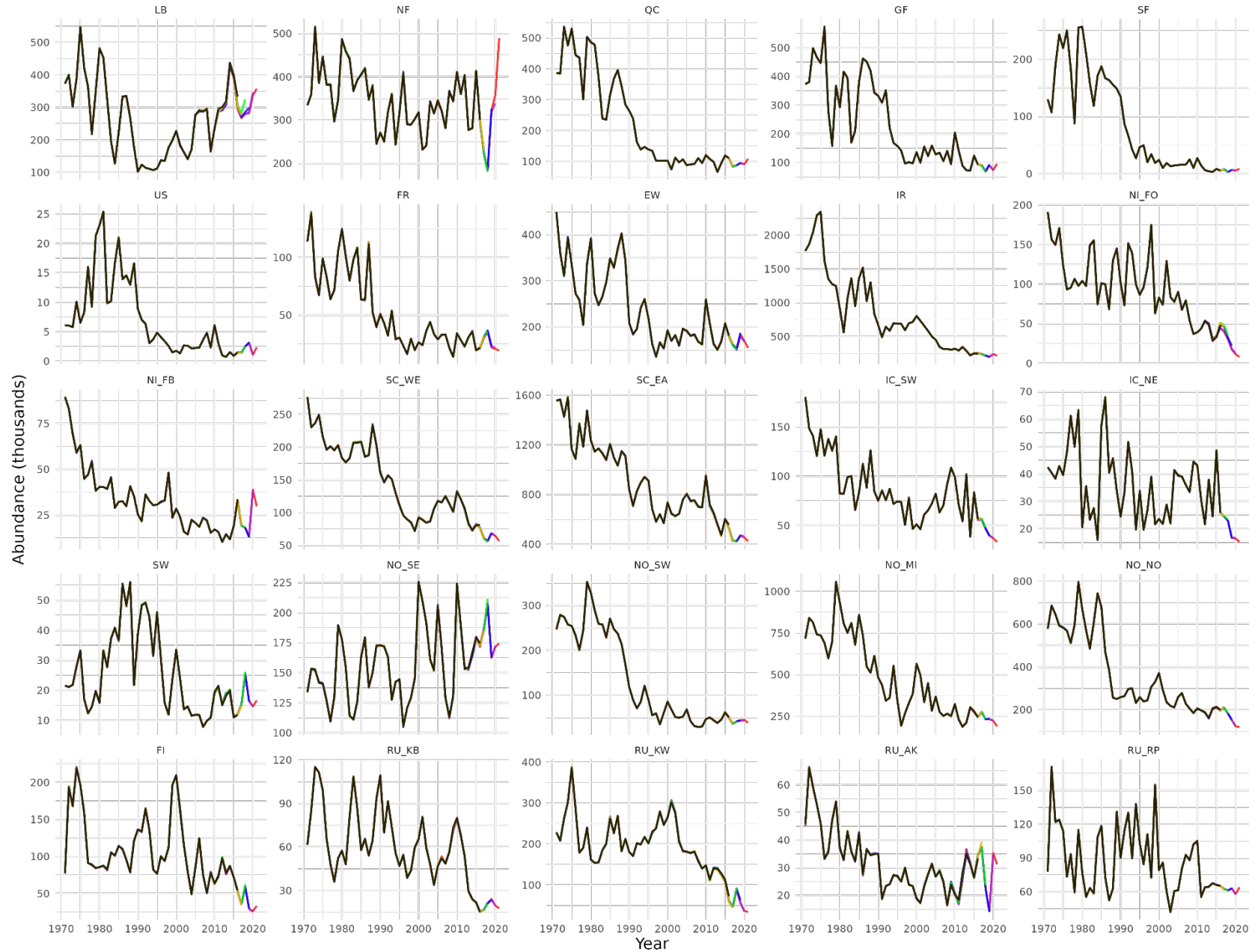


Figure 5. Retrospective patterns for the probability to mature as 1SW. The lines in each panel show the medians of the Bayesian posterior distributions of the probability to mature as 1SW, obtained by using the full time series of data (1971-2022) and five retrospective peels (1 to 5 years of data removed from the full data set). Note the graph is cut after year 1990 to increase resolution. The full time series are visible in Sup Mat 1.

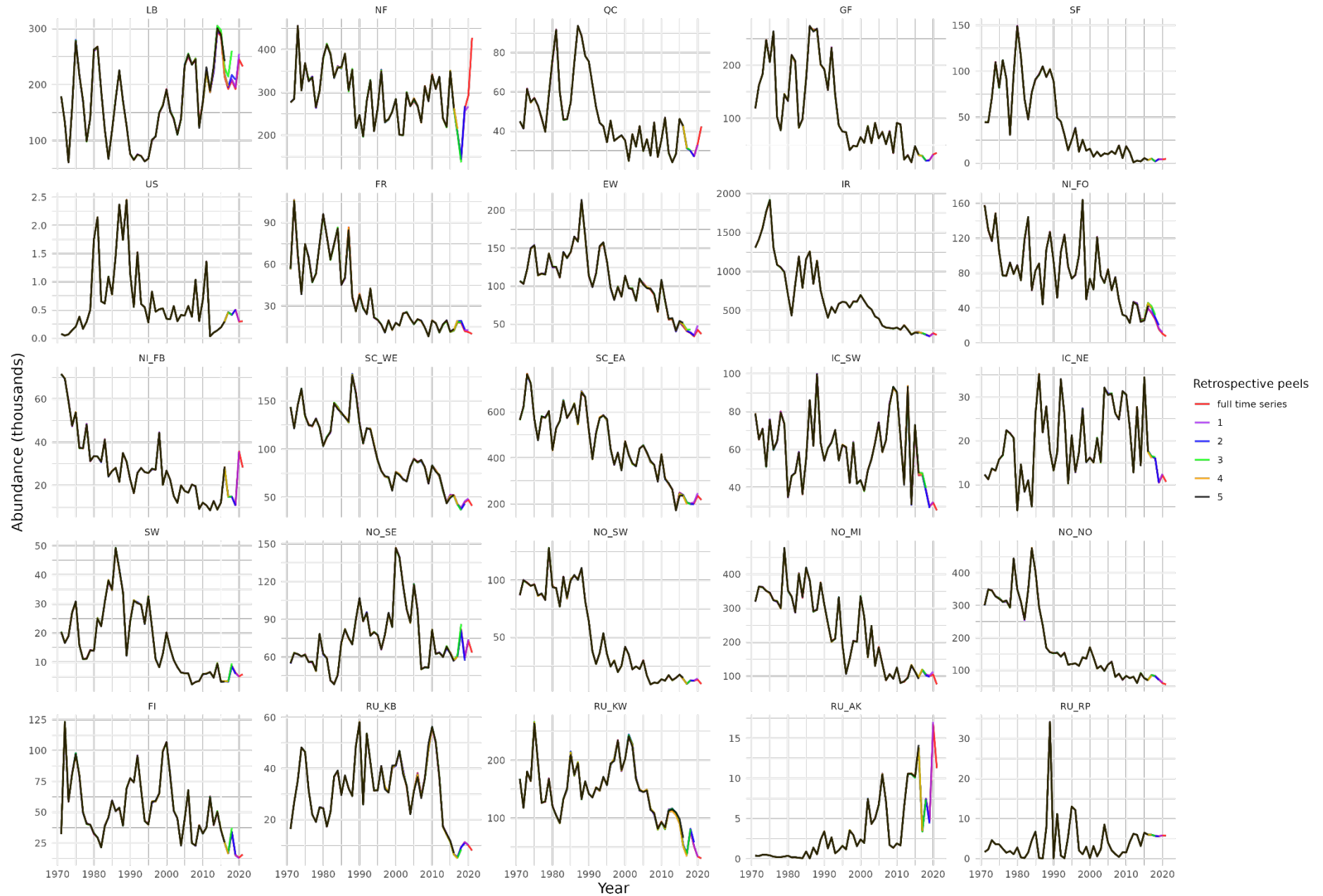
Sup Mat 1.

Retrospective patterns for the PFA (total, mature, non mature), the smolt-to-PFA survival and the probability to mature as 1SW. The lines in each panel show the medians of the Bayesian posterior distributions obtained by using the full time series of data (1971-2022) and five retrospective peels (1 to 5 years of data removed from the full data set).

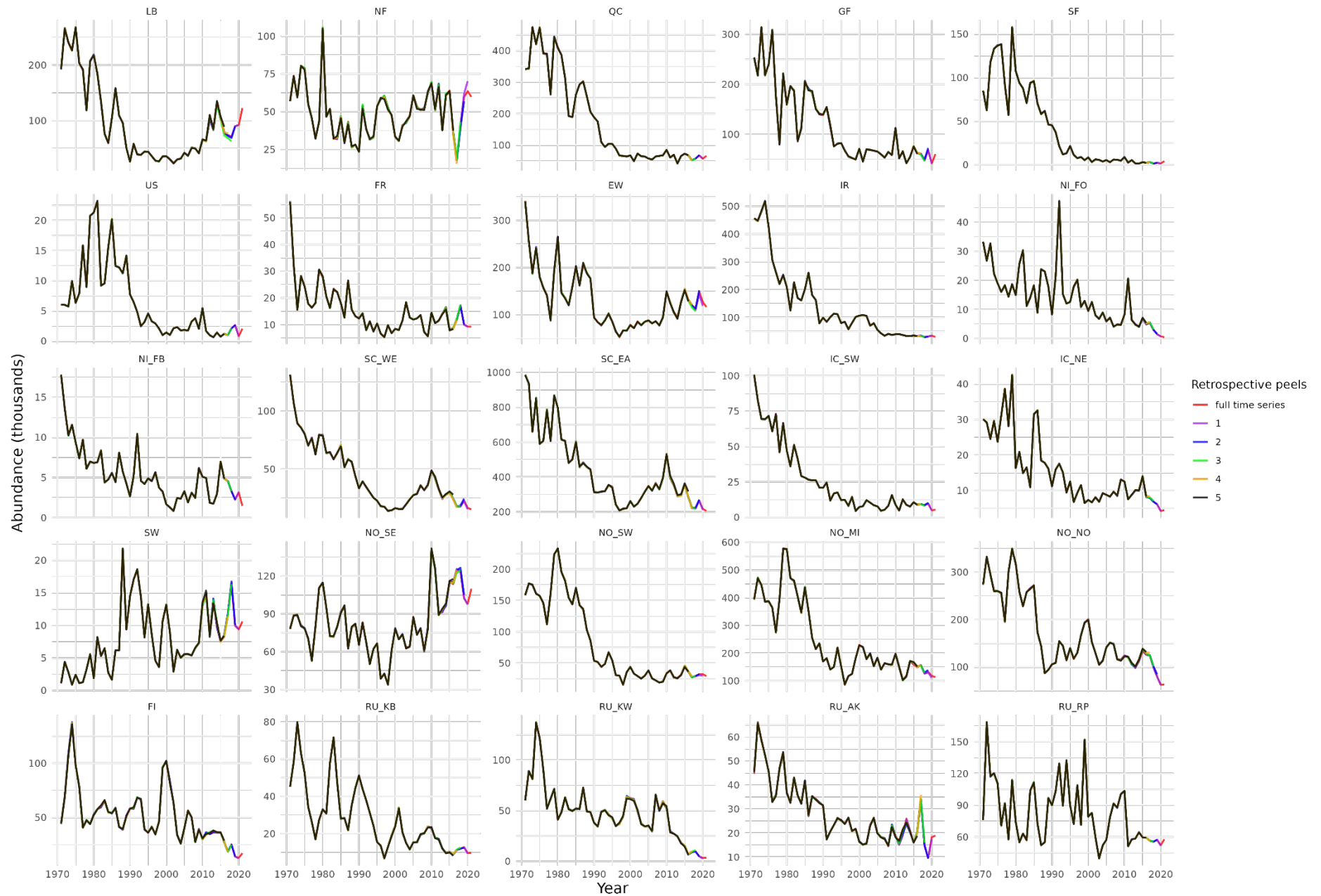
Total PFA



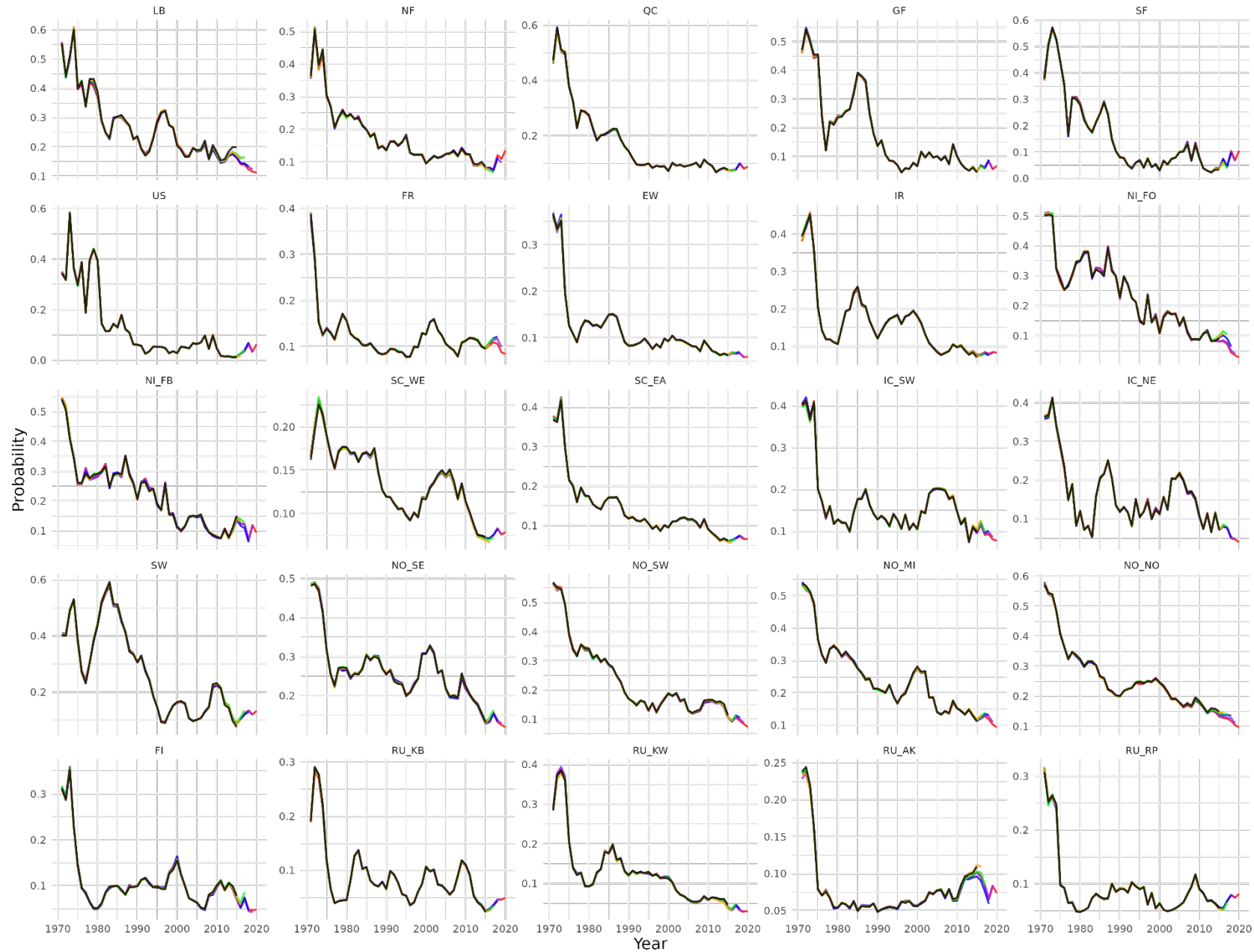
Maturing PFA



Non-maturing PFA



Post-smolt survival



Prob. of maturing as 1SW

