S2. Life Cycle Closure: Advances in Process Understanding

A cross-system comparison of internal and external forcing regulating growth of small pelagic fish throughout ontogeny

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The weight of small pelagic fish is highly variable, yet the underlying factors affecting growth throughout ontogeny are poorly known and often unaccounted for in stock assessments and fisheries management at large. In this study, **we performed a preliminary cross-system comparison and assessment of key factors regulating the growth of sardine and anchovy stocks throughout ontogeny**.

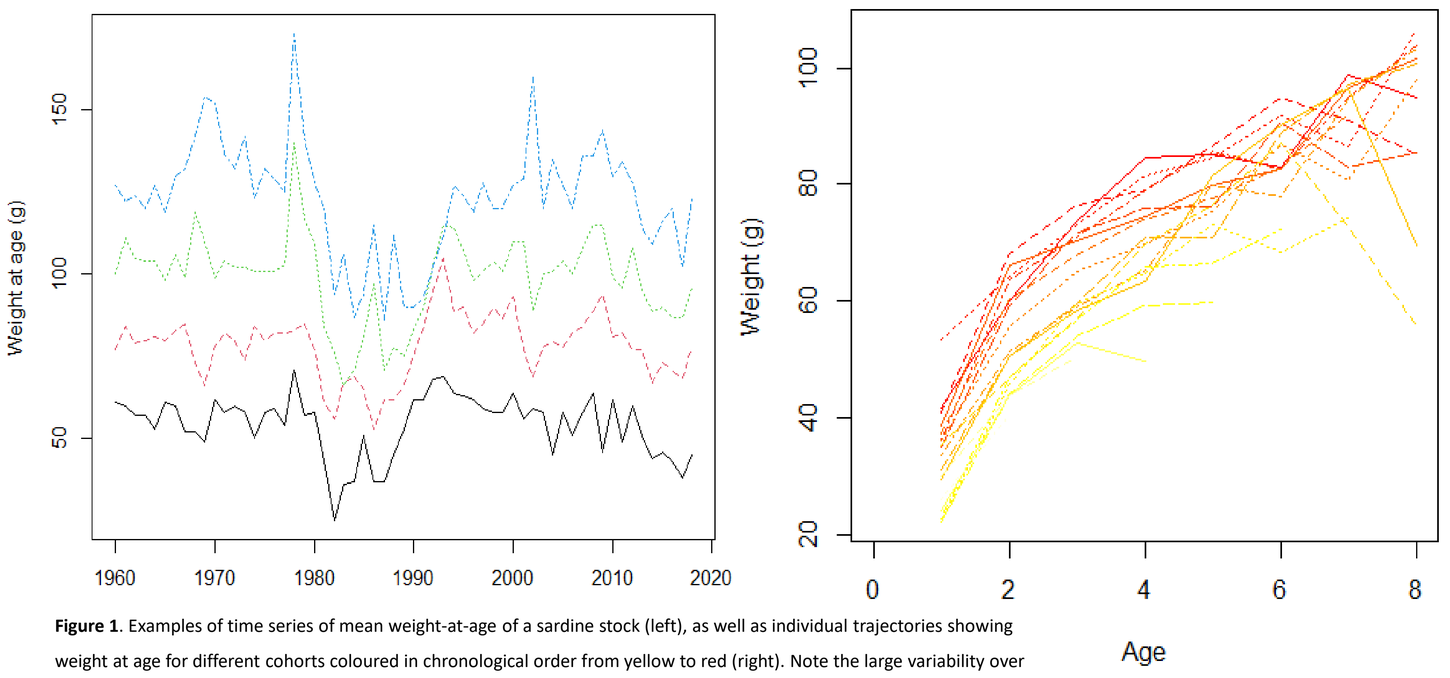

Figure 1. Examples of time series of mean weight-at-age of a sardine stock (left), as well as individual trajectories showing weight at age for different cohorts coloured in chronological order from yellow to red (right). Note the large variability over time and between cohorts.

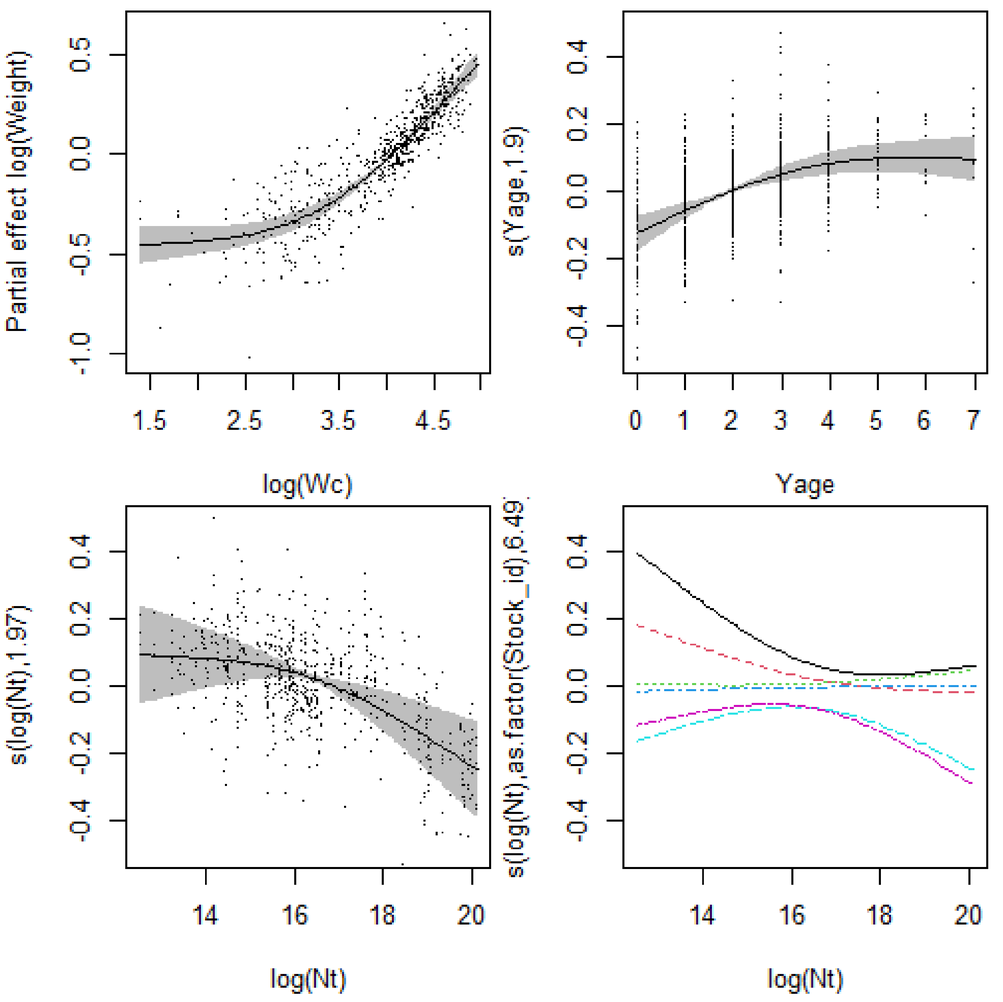

Fig. 3. GAM smooth plots showing the fitted partial effect of log(weight) in the preceding time step, age and total log(abundance), when modelled jointly, or separately for each stock (bottom right). Black lines and grey areas show the fitted responses with 95% CI and points the partial residuals.

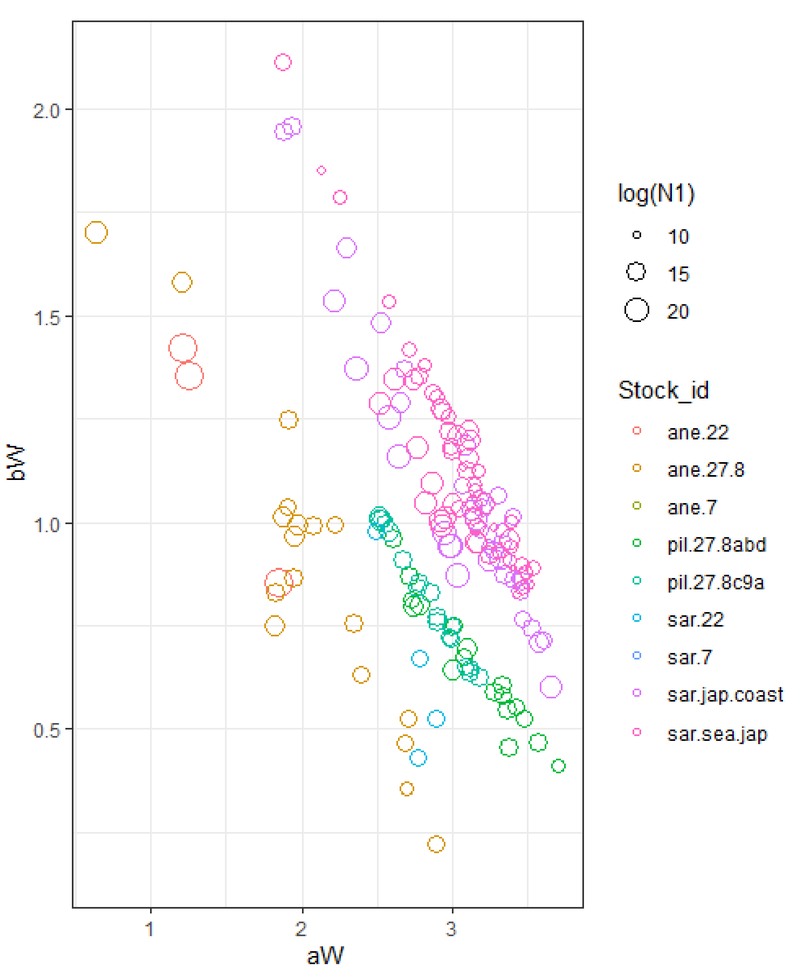

Fig. 2. Fitted model parameters reflecting the initial weight (intercept, a) and growth rate (slope, b) for each individual cohort across stocks. Size of circles indicate the total log(abundance) for each corresponding cohort.

We **compiled long-term time series of weight-, length- and numbers-at-age from available stock assessments worldwide**. Species analysed are European anchovy and sardine, as well as W. Pacific sardine (Sardinops melanostictus). To compare and visualize changes and differences in individual growth curves across cohorts and stocks, linear regression models where fitted for each cohort with log(weight) as response and log(age) as a predictor (see Fig. 1 above). Subsequently, the fitted parameters of the set of models, i.e., reflecting the initial weight (intercept, a) and growth rate (slope, b) were extracted and plotted against each other (Fig. 2). Just like the individual growth curves these parameters reflect pronounced differences and changes between stocks and species (especially between sardines and anchovies.)

To examine the effects and relative importance of both internal density-dependent effects and external (environmentally driven) forcing acting on growth within and across cohorts and species, a joint mixed GAM was setup with log(Weight) at time t as response and the weight in the previous time step (t-1), as well as the age and total log(abundance) as predictors, the latter representing potential density-dependent growth. In addition, stock id was added as a random effect.

The results show significant positive effects of weight and age in the preceding time step, reflecting the increase in weight over time and age of each cohort (Fig. 3). More interestingly, **our results show a significant negative, non-linear effect of total abundance, indicating a potential effect of density-dependence acting primarily at high population abundances.** Similar results were obtained using random forest indicating the robustness of results to model choice (not shown here).

Future steps: (i) add more stocks, potentially other SPF species; (ii) collect environmental data known to affect growth for each stock area (e.g., SST, zooplankton), (iii) re-run analysis.

If you have available data on weight, length and abundance of sardine and anchovy and would like to contribute to the study please contact: Martin Huret (martin.huret@ifremer.fr) and Martin Lindegren (mli@aqua.dtu.dk).

This work is conducted within the Activity 5 (Internal and external drivers of growth, reproduction and survival) of the WG on Small Pelagic Fish.