Unpacking historical salmon records

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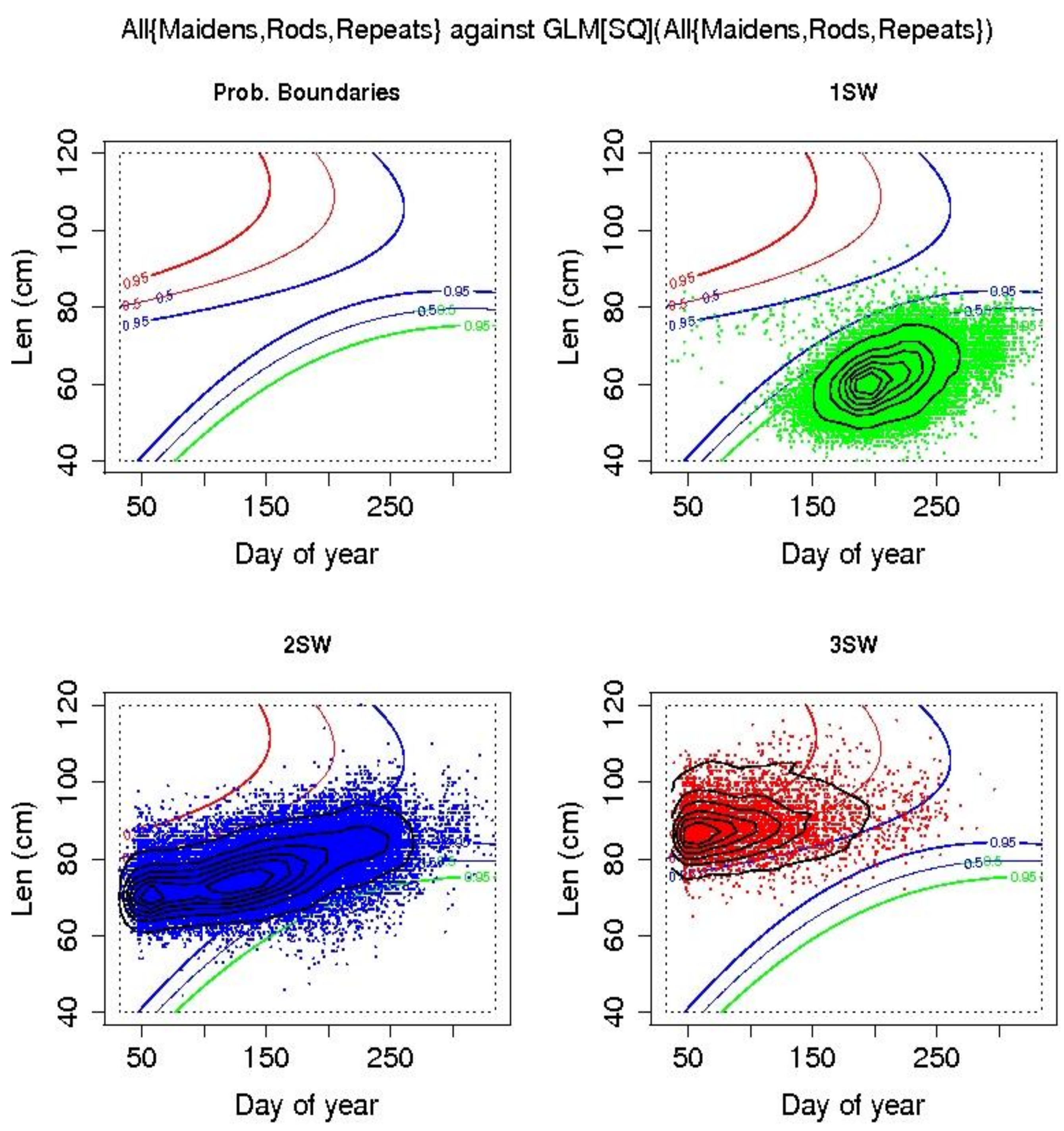
Life-cycle. Juvenile Atlantic salmon hatch in river gravel, and grow for a number of years in freshwater before emigrating to sea. They remain at sea for a number of years before returning to their natal river to spawn.

Fishery. Historically, the main Scottish Salmon fisheries operated in coastal and estuarine waters. More recently, rod and line sport fishing has dominated – currently yielding some £73m annually. In both cases the commercial and conservation value of a fish depends on its sea-age.

Photo courtesy of David Hay, Marine Scotland



Determining the sea-age of a returning salmon requires microscopic scale examination; making the introduction of differential conservation rules highly problematical. We have developed a probabilistic model relating sea-age to the length (L) of a caught fish and the day of the year (D) on which it was captured, which can identify 1 sea-winter fish with better than 98% accuracy and distinguish 2 and 3 sea-winter fish with 80% success.

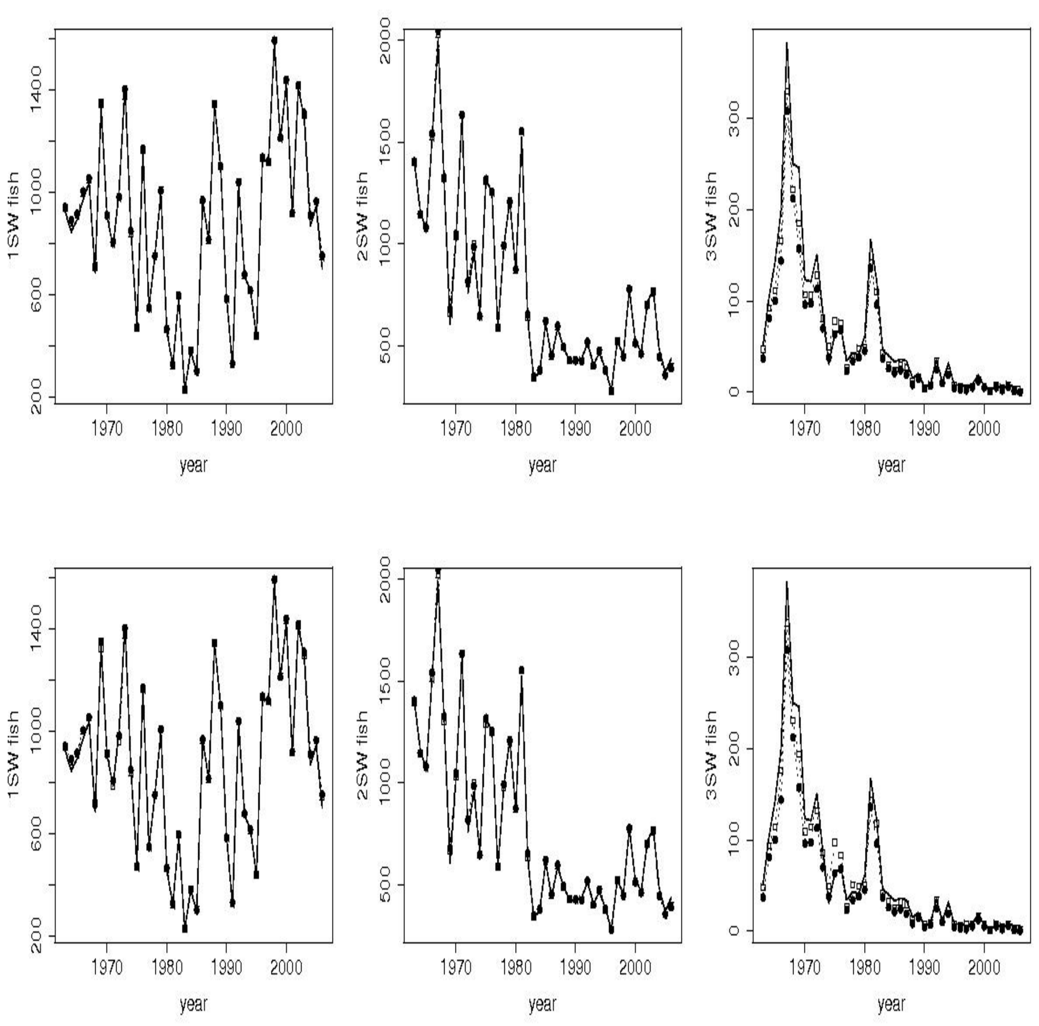
The model. The probability (P_1) that an individual of length L caught on day D has sea-age =1 is given by

$$\mathrm{logit}(P_1) = \theta_0 + \theta_d D + \theta_{dd} D^2 + \theta_L L + \theta_{LL} L^2 + \theta_{Ld} LD$$

where the parameter set $\{\theta\}$ maximises

$$L \equiv \prod P_1(L_i, D_i)^{k_i}\left[1 - P_1(L_i, D_i)\right]^{1-k_i} \qquad k_i = \begin{cases} 1 & \text{if } ScaleSeaAge_i = 1 \\ 0 & otherwise \end{cases}$$

We model the sea-age probability of a multi-sea winter fish (i.e. one which is not sea-age 1) in an exactly similar way. Results for a pan-Scottish scale-aged dataset of 150000 individuals with each observations plotted as a point – 1SW=green, 2SW=blue, 3SW=red – are shown opposite.



Recovering time-series data. Since the probability distributions shown above are independent of site and time we can use them to recover time-series data. On the ***left*** we show results of a test on data from the North Esk, where we can compare exact scale aged counts (solid) with maximum probability counts (upper three frames, points), and also examine how seriously performance is degraded when we use data pooled in 2cm classes and monthly time intervals (lower three frames). On the ***right*** we show a reconstruction of a very long-term dataset from the Great Hirsel beat on the River Tweed.