**Exercise 4. Stock status in stock assessment paradigms with multiple hypotheses (Arctic Sardine MU1)**

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| **Exercise Goal:** Identify ways to approach defining a single metric of stock status for Arctic Sardine MU1 in a data-rich context when there is more than one model that is an acceptable characterization of the population dynamics are there are two hypotheses about changes in productivity over time. |

**Background:**

* Assume that the key uncertainty for characterizing the dynamics of the fishery is the assumed “resilience” of the stock, in terms of the steepness (h) of the stock recruitment relationship.
* Assume there is also uncertainty in whether the dynamics are stationary or if there has been a change in productivity over time.
* Analysts are conducting a simulation evaluation to identify a management procedure that is robust to these two uncertainties. Suppose there are three hypotheses about the degree of resilience of the stock represented by different assumed steepness (h) values for the Beverton-Holt (BH) stock recruitment relationship and two hypotheses relating to stationary: growth and recruitment are non-stationary or stationary.
* An age structured model for Arctic Sardine MU1 has been fit. This is the same modelling approach that was used for Exercise 3. For this exercise, three models are fit and the model from Exercise 3 is Model 2 below:
* Model 1: Low resilience: steepness of BH stock recruitment relationship (*h*) = 0.65
* Model 2: Moderate resilience: *h* = 0.75 (consider as the best estimate of *h*)
* Model 3: High resilience: *h* = 0.95

**Dataset (for each model):**

* Annual weight-at-age (g), maturity-at-age (proportion mature), and vulnerability-at-age (proportion selected to the fishery) over the historical time period
* Model-estimated spawning stock biomass (*SSB* in kt), recruitment at age 0 (*Rec* in billions), total biomass (*B* in kt), catch (kt), fishing mortality rate (*F*), empirical acoustic index of SSB (kt) for years 26-50
* Unfished spawning biomass per recruit (phi0) and steepness (*h*) calculated using annual weight-at-age and maturity-at-age
* A dynamic unfished spawning stock biomass (dynamic SSB0) has been provided for the historical time series (a projected SSB from the beginning of the time series with *F*=0 using the recruitment deviations from the model fit with no catch. The dynamic SSB0 was estimated 2 different ways based on the assumed changes in weight-at-age over time (see Exercise 3)

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| **Exercise Activity:**   1. Evaluate at least 2 approaches to defining a metric of stock status for Arctic Sardine MU1, and identify the preferred approach. 2. As a group, complete the slides in the Powerpoint File. The last slide will be presented by a group member at the beginning of the workshop tomorrow. Explain:    1. **Candidate approaches** considered, and their pros and cons    2. The **preferred approach and rationale**       1. Does the choice reflect any candidate **best practice** criteria?       2. Any underlying **assumptions** of the preferred approach?    3. Include a **time series plot(s)** of the metric that illustrates the stock status over time.    4. Recommend **a status** for the stock (above or below the LRP).       1. How is **uncertainty** in stock status taken into account? |

**Some options:** (some calculations have been started in the R script)

* Model-based indicator (e.g., SSB) and theoretical or historical LRP based on one model/one hypothesis for dealing with uncertainty about changes in productivity over time.
* Model-based indicator (e.g., SSB) and theoretical or historical LRP based on information from multiple models and both hypotheses about changes in productivity over time.
* Empirical indicator (acoustic index of SSB) and LRP

**Candidate Criteria for Best-Practice Indicators and LRPs:**

* Consistent with an objective to avoid serious harm to the stock
* Based on the best available information
* Operationally useful
* Reliably estimated

**Table 1. Data Files for Exercise 4**

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| File Type | File Name | Description |
|  | Exercise 4 Background Figures.html | Fishery background and figures |
| R (programming language) - Wikipedia | ex4\_data.rda | R data object: a list with elements:  WAA = data frame (weight-at-age by year)  MAT = data frame (maturity-at-age by year)  VUL65 = data frame (vulnerability-at-age by year for model with h = 0.65)  VUL75 = as per VUL65 but for h = 0.75  VUL90 = as per VUL65 but for h = 0.90  D65 = data frame (SSB, recruitment, total biomass, catch, F, acoustic index, unfished spawning biomass, steepness, dynamic SSB0 estimates, by year for model with h = 0.65)  D75 = as per D65 but for h = 0.75  D90 = as per D65 but for h = 0.90 |
| C:\Users\barretttj\AppData\Local\Microsoft\Windows\INetCache\Content.MSO\3B9046F.tmp | ex4.R | R script that imports data with plots and calculations started |
| C:\Users\barretttj\AppData\Local\Microsoft\Windows\INetCache\Content.MSO\3B9046F.tmp | functions.R | R script with functions (in main LRP directory) |