**Exercise 3. Time-varying productivity (Arctic sardine MU1)**

**Exercise Goal:** Identify ways to approach defining an LRP for Arctic sardine MU1 in a data-rich context with time varying productivity. Annual weight-at-age, maturity-at-age, selectivity-at-age, and recruitment are provided.

**Exercise Questions:**

1. Identify the “preferred” approach to defining an LRP for Arctic sardine MU1 that you feel is most consistent with the candidate criteria for best-practice indicators and LRPs (and any other criteria you feel is important)
2. As a group, prepare a 1-2 slide (< 5 minute) presentation to explain:
   * Candidate approaches (indicators and LRPs) considered, and their pros and cons
   * The preferred approach (indicator and LRP)
   * The rationale for and underlying assumptions of the preferred approach and any considerations for the role of Arctic sardine as a forage fish
   * Include a time series plot of the indicator and add a line to represent the LRP. Extend the LRP line 10 years into the future to reflect the assumed future conditions (and therefore LRP) used in the projection period.

**Background:**

An age structured model has been fit for Arctic sardine in MU1. This is the same model that was used for exercise 2. For this exercise, consider that there is variability in the biological parameters (weight-at-age and maturity-at-age) and vulnerability-at-age over time.

**Dataset:**

* 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 (Rec of Age 0 in billions), total biomass (B in kt), catch (kt), fishing mortality rate (*F*), empirical acoustic index of SSB (kt) from 1999-2020
* 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 *SSB0* 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 4 different ways:

|  |  |  |  |
| --- | --- | --- | --- |
| Parameter | recruitment deviations | weight-at-age | maturity-at-age |
| dynamicSSB0a | annual | annual | annual |
| dynamicSSB0g | annual | mean over first 5 years | annual |
| dynamicSSB0m | annual | annual | mean over first 5 years |
| dynamicSSB0b | annual | mean over first 5 years | mean over first 5 years |

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

* Empirical indicator (acoustic index of SSB) and LRP
* Model-based indicator (e.g., SSB) and theoretical (e.g., *SSB0*, *SSBMSY*) LRP
  + Static – e.g. based on equilibrium assumptions using weight-, maturity-, and vulnerability-at-age data over a specific time period
  + Dynamic – e.g. using various assumptions for how changes in weight-at-age and maturity-at-age over time are considered
* Model-based indicator (e.g., SSB) and LRP based on stock recruitment relationship or historical SSB

Table 1. Data Files for Exercise 3

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| --- | --- | --- |
| File Type | File Name | Description |
|  | Exercise 3 Background Figures.html | Fishery background and figures |
| R (programming language) - Wikipedia | ex3\_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)  VUL = data frame (vulnerability-at-age by year)  D = data frame (SSB, recruitment, total biomass, catch, F, acoustic index, unfished spawning biomass, steepness, dynamic SSB0 estimates, by year) |
| C:\Users\barretttj\AppData\Local\Microsoft\Windows\INetCache\Content.MSO\3B9046F.tmp | ex3.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) |