Supplementary material

Technical description of the simple age-structured OM

1. Life history characteristics

The length at age (l_a) is modeled following a von Bertalanffy growth model (Equation 1.1 [E1.1] in Suppl. Table 1) and the weight at age (w_a) is obtained from the weight–length relationship by the power function (E1.2). The maturity at age (m_a) is used to define the proportion of the mature female population at age and it follows a logistic function (E1.3). The sex ratio is assumed 1:1.

2. Spawner-recruit relationships (Beverton-Holt based on mature female biomass)

The unfished equilibrium spawning biomass per recruit (ϕ_0) is modeled as shown in E2.1 and the median-unbiased unfished recruitment (*R0*) is 1,000,000. Expected annual recruitment of age 1 fish is computed from the Beverton-Holt spawner-recruit model (E2.2).

3. Initial condition

The number of fish in age group a in the initial year is modeled by considering fishing mortality in spawning biomass per recruit (E3.1–E3.5). The spawning biomass of fish in year 1 is calculated based on mature female biomass (E3.6).

4. Age-based population dynamics

The abundance of fish at age 1 ($N_{1,y}$) corresponds to annual recruitment of age 1 (E2.2) with recruitment deviations (E4.1). The abundance of each subsequent age of each year is modeled assuming exponential decay (E4.2–E4.4). The spawning stock biomass of fish in each year is calculated based on mature female biomass (E4.5). The abundance and biomass of fish in each year are calculated as shown in E4.6–E4.7.

5. One fleet (simple-logistic selectivity)

Time-invariant logistic selectivity function is assumed for the fishery (E5.1). The landings at age a during year y is determined using the Baranov catch equation (E5.2). The landings in weight are calculated as shown in E5.3.

6. One survey (simple-logistic selectivity)

Time-invariant logistic selectivity function is assumed for a fishery-independent survey (E6.1). The fishery-independent survey abundance index (I_y) is scaled to the mean I_y over time (E6.2–E6.4).

7. Time series of *Fmult*

The fully selected fishing mortality rate (*Fmult*) in each year is modeled on the basis of linear increasing values (f_y) and its lognormal deviates (E7.1). Currently, the first year of f_y is defined as 0.01 and the last year of f_y is defined as 0.39.

8. Observed data

Observed landings are modeled with a lognormal observation error (E8.1). Proportion at age data for landings are simulated using random draws from multinomial distributions with a sample size of 200 (E8.2–8.3).

Time series of relative abundance (in numbers) derived from the survey is modeled with a lognormal observation error (E8.4). Proportion at age data for surveys are simulated using random draws from multinomial distributions with a sample size of 200 (E8.5–E8.6)

9. Output data

The output data include simulated data from the population, such as spawning stock biomass (mt) per year, abundance (in number) per year, biomass (mt) per year, abundance at age (in number) per year, landings at age (in number) per year, and landings (×1000 in number and mt) per year.

The output data also include true reference points calculated from the simulated data, such as maximum sustainable yield (*MSY*), fishing rate at *MSY* (F_{MSY}), spawning stock biomass at *MSY* (SSB_{MSY}), equilibrium recruitment at *MSY* (R_{MSY}), biomass (both male and female) at *MSY* (B_{MSY}), exploitation rate at *MSY* (E_{MSY}), spawners per recruit at *MSY* (spr_{MSY}), and spawning potential ratio at *MSY* (SPR_{MSY}) which is unfished spawners per recruit divided by spr_{MSY}. The fishing rate, along with equilibrium landings at fishing rate and equilibrium *SSB* at fishing rate are also saved as output data. The relative *F* (F/F_{MSY}) and relative *SSB* (SSB/SSB_{MSY}) are also saved as output data.

The output data from the observation model include observed landings (1000 fish or mt) per year, observed proportion at age for landings per year, observed survey index (scaled) per year, and observed proportion at age for survey per year.