MAS Case Study v1

Vignette

Case study v1 represents a simple two-population model with a hypothetical north-south latitudinal cline for the species characteristics between two areas. The two populations are loosely modeled as an abundant and migratory groundfish species with 9 true age classes comprised of ages 0 to 8 years and 1 plus group for ages 9 and older. The time horizon for assessment is 20 years and an annual time step with a single season is used for fishery dynamics modeling. Both populations are modeled as having two sexes but there is no difference between genders in either population. The two populations inhabit two areas and have distinct recruitment and demographic trajectories. Area 1 is more temperate (northerly) and area 2 is more southerly (subtropical). Both populations spawn in both areas. Population 1 is abundant in area 1 and less abundant in area 2. Population 2 is abundant in both areas 1 and 2. The two populations engage in feeding migrations between areas. Population 1 has lower net movement and recruitment distribution rates between areas than population 2. Population 1 has a somewhat lower natural mortality rate at age than population 2. Population 1 has greater stock-recruitment resilience in area 1 and lower stock-recruitment resilience in area 2 in comparison to population 2. Population 1 has slightly greater length at age and weight at length, or girth, in comparison to population 2. Both populations are 50% mature at age 3 but population 2 has more variability in maturity probability at age which is more knife-edged for population 1.

Both populations have life history characteristics that persist when individuals move among areas. This alludes to the issue of the relative importance of nature (genes) versus nurture (environment) for marine population dynamics. In this case, nature is paramount and the demographic characteristics of an individual are determined by their genetics and population of origin and not by the area which they occur. Further, the two populations are modeled as moving among areas, with population 2 exhibiting higher mixing rates for early life history stages, juveniles, and adults.

There is a mixed-population fishery in both areas. Two fishing fleets are harvesting the species; one fleet in each area. Both fleets are stable in operating characteristics throughout the assessment time horizon and fishery selectivity at age is constant through time for each fleet. Fishing fleet 1 has a fishery selectivity at age pattern that matches the maturity ogive of population 1 and fishing fleet 2 has a fishery selectivity at age pattern that matches the maturity ogive of population 2. The fishing effort in both fleets has changed through time. In the pre-time horizon period consisting of 10 years (indexed as years y = -9 to 0), both fleets have a constant annual fully-recruited fishing mortality rate of $F_{pre} = 0.1$.

In the first 10 years of the assessment time horizon (period 1, indexed as years y = 1 to 10), the fishing mortality increases in both areas as both fishing fleets expand in capacity. In area 1, the fully-recruited fishing mortality increases 4-fold to $F_{Period\ 1, Area\ 1} = 0.4$ while in area 2, F increases 2-fold to $F_{Period\ 1, Area\ 2} = 0.2$. In the second 10 years of the assessment time horizon (period 2, indexed as years y = 11 to 20), the fishing mortality decreases in area 1 and does not change in area 2. That is, the fully-recruited fishing mortality in area 1 decreases 50% to $F_{Period\ 2, Area\ 1} = 0.2$ in period 2, while the fishing mortality in area 2 remains at $F_{Period\ 2, Area\ 2} = 0.2$ in period 2. Overall, fishing mortality ramps up in the first period and then decreases or remains the same in period 2, leading to changes in the abundances of both populations.

There is a fishery-independent survey in both areas. The survey has had stable operating characteristics throughout the assessment time horizon. The survey selectivity at age is constant through time for each population. Survey selectivity for population 1 is slightly higher and less variable at age than for population 1. The survey produces a biomass index and survey age composition by year for each area.

Characteristics of Case Study v1

- 2 populations (labeled as populations 1 and 2)
- 2 areas (labeled as areas 1 and 2)
- 2 sexes (genders are female and male)
- Equal sex ratios at birth for both populations (Female fractions=0.5 for both populations)
- 10 age classes in each population model (true ages 0 to 8 and 9 and older, 9+)
- 20 year assessment time horizon (labeled as years 1 to 20)
- Single season (labeled as season 1, i.e., an annual time step)
- Constant movement matrices (labeled as $\underline{\underline{T}}^{(1)}$ and $\underline{\underline{T}}^{(2)}$)
    - For Population 1, $\underline{\underline{T}}^{(1)} = \begin{bmatrix} 0.9 & 0.1 \\ 0.1 & 0.9 \end{bmatrix}$
    - For Population 2, $\underline{\underline{T}}^{(2)} = \begin{bmatrix} 0.75 & 0.25 \\ 0.25 & 0.75 \end{bmatrix}$
- Constant natural mortality at age and by sex in each population (equal natural mortality rates for females and males by population, that is, $M^{(1)}_{a,g=female} = M^{(1)}_{a,g=male}$ and $M^{(2)}_{a,g=female} = M^{(2)}_{a,g=male}$)
    - For Population 1, $M^{(1)}_{(0,9+),g=female} = (0.5, 0.3, 0.2, 0.2, 0.2, 0.2, 0.2, 0.2, 0.2, 0.2)$
    - For Population 2, $M^{(2)}_{(0,9+),g=female} = (0.55, 0.35, 0.25, 0.2, 0.2, 0.2, 0.2, 0.2, 0.2, 0.2)$
- Beverton-Holt stock-recruitment curve by population and area without process error

- The deterministic BH curve by population and area is

$$R_{(y),s}^{(p)} = \frac{4h_s^{(p)} R_{0,s}^{(p)} B_{S,(y),s}^{(p)}}{B_{S,0,s}^{(p)}\left(1-h_s^{(p)}\right)+B_{S,(y),s}^{(p)}\left(5h_s^{(p)}-1\right)}$$

- Stock-recruitment steepness parameters by population and area. For population 1, steepness values by area are equal, $h_1^{(1)} = h_2^{(1)} = 0.75$, and for population 2, steepness is higher in area 2, $h_1^{(2)} = 0.7 \text{ and } h_2^{(2)} = 0.8$
- Unfished recruitment parameters by population and area.
  For population 1, the unfished recruitment parameter is 2-fold higher in area 1, $R_{0,1}^{(1)} = 10^7 \text{ and } R_{0,2}^{(1)} = 5 \cdot 10^6$, while for population 2, unfished recruitment values by area are equal, $R_{0,1}^{(2)} = R_{0,2}^{(2)} = 10^7$
- Unfished spawning biomass by population and area conditioned on unfished recruitment by population and area and movement and recruitment distribution parameter values. For population 1, unfished spawning biomass values are calculated to be $B_{S,0,1}^{(1)} = 70122 \text{ and } B_{S,0,2}^{(1)} = 35061$, while for population 2, the values are equal and roughly $B_{S,0,1}^{(2)} = 39049 \text{ and } B_{S,0,2}^{(2)} = 39049$

- Constant recruitment distribution matrices by spawning area and recruitment destination area for each population.
  - For population 1, the recruitment distribution matrix is $\underline{\underline{Q}}^{(1)} = \begin{bmatrix} 0.9 & 0.1 \\ 0.1 & 0.9 \end{bmatrix}$
  - For population 2, the recruitment distribution matrix is, $\underline{\underline{Q}}^{(2)} = \begin{bmatrix} 0.75 & 0.25 \\ 0.25 & 0.75 \end{bmatrix}$
- Constant length-weight relationships based on allometric weight (kg) at length (cm) curves by population, $W^{(p)}(L) = A^{(p)} \cdot L^{B^{(p)}}$.
  - For population 1, the length-weight parameters are $A^{(1)} = 2.5 \cdot 10^{-5} \text{ and } B^{(1)} = 3.0$
  - For population 2, the length-weight parameters are $A^{(2)} = 2.5 \cdot 10^{-5} \text{ and } B^{(2)} = 2.95$
- Constant modified von Bertalanffy growth curves for mean length at age by population with linear interpolation for within season values

$$L^{(p)}(a) = L_{\min}^{(p)} + \left(L_{\max}^{(p)} - L_{\min}^{(p)}\right) \cdot \frac{\left(1-\left(c^{(p)}\right)^{a-a_{\min}}\right)}{\left(1-\left(c^{(p)}\right)^{a_{\max}-a_{\min}}\right)}$$

where $a_{\min} = 1 \text{ and } a_{\max} = 7$ and $L^{(p)}(a)$ is the predicted length at age *a* at the start of the year and $L^{(p)}(a+\tau^*)$ is the predicted length at age $a+\tau^*$.

- For population 1, the growth curve parameters are $L_{\min}^{(1)} = 20,\ L_{\max}^{(1)} = 70,\ and\ c^{(1)} = 0.5$
- For population 2, the growth curve parameters are $L_{\min}^{(2)} = 20,\ L_{\max}^{(2)} = 65,\ and\ c^{(2)} = 0.5$
- The calculated mean length at the time of spawning as a fraction $\Delta_{Spawn}^{(p)} = 0.5$ within the year for ages 1 to 9+ is

$$L^{(p)}\left(a + \Delta_{Spawn}^{(p)}\right) = L_{\min}^{(p)} + \left(L_{\max}^{(p)} - L_{\min}^{(p)}\right) \cdot \frac{\left(1 - \left(c^{(p)}\right)^{a + \Delta_{Spawn}^{(p)} - a_{\min}}\right)}{\left(1 - \left(c^{(p)}\right)^{a_{\max} - a_{\min}}\right)}$$

  For ages 1 to 9+ and for age 0 is $L^{(p)}\left(0 + \Delta_{Spawn}^{(p)}\right) = \Delta_{Spawn}^{(p)} \cdot L^{(p)}(1)$
- The interpolated length at the time of catch as a fraction $\Delta_{Catch} = 0.5$ within the year for ages 1 to 9+ is

$$L^{(p)}\left(a + \Delta_{Catch}\right) = L_{\min}^{(p)} + \left(L_{\max}^{(p)} - L_{\min}^{(p)}\right) \cdot \frac{\left(1 - \left(c^{(p)}\right)^{a + \Delta_{Catch} - a_{\min}}\right)}{\left(1 - \left(c^{(p)}\right)^{a_{\max} - a_{\min}}\right)}$$

  For ages 1 to 9+ and for age 0 is $L^{(p)}\left(0 + \Delta_{Catch}\right) = \Delta_{Catch} \cdot L^{(p)}(1)$
- The interpolated length at the time of the survey as a fraction $\Delta_{Survey} = 0.75$ within the year for ages 1 to 9+ is

$$L^{(p)}\left(a + \Delta_{Survey}\right) = L_{\min}^{(p)} + \left(L_{\max}^{(p)} - L_{\min}^{(p)}\right) \cdot \frac{\left(1 - \left(c^{(p)}\right)^{a + \Delta_{Survey} - a_{\min}}\right)}{\left(1 - \left(c^{(p)}\right)^{a_{\max} - a_{\min}}\right)}$$

  For ages 1 to 9+ and for age 0 is $L^{(p)}\left(0 + \Delta_{Survey}\right) = \Delta_{Survey} \cdot L^{(p)}(1)$
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- Constant female logistic maturation ogives, equal to male ogives, by population

$$P_{Mature,g=female}^{(p)} = \frac{\exp\left(\dfrac{a - a_{50,g=female}^{(p)}}{\sigma_{Mature,g=female}^{(p)}}\right)}{1 + \exp\left(\dfrac{a - a_{50,g=female}^{(p)}}{\sigma_{Mature,g=female}^{(p)}}\right)} = \frac{1}{1 + \exp\left(-\left(\dfrac{a - a_{50,g=female}^{(p)}}{\sigma_{Mature,g=female}^{(p)}}\right)\right)}.$$

  - For population 1, the maturity parameters are $a_{50}^{(1)} = 3\ and\ \sigma_{Mature}^{(1)} = 0.1$
  - For population 2, the maturity parameters $a_{50}^{(2)} = 3\ and\ \sigma_{Mature}^{(2)} = 0.5$

- Spawning output proportional to female spawning biomass with male spawning biomass assumed to not affect spawning success.

- Fishing fleets (fleets 1 and 2) with fleet 1 in area 1 and fleet 2 in area 2. Three periods of constant effort and fishing mortality where the time periods are: pre-time horizon pre=[years -9: 0], period 1= [years 1:10], and period 2=[years 11:20].
    - For fleet 1, fully-recruited fishing mortality by time period is $F_{1,pre} = 0.1,\ F_{1,period\ 1} = 0.4,\ and\ \ F_{1,period\ 2} = 0.2$
    - For fleet 1, fully-recruited fishing mortality by time period is $F_{2,pre} = 0.1,\ F_{2,period\ 1} = 0.2,\ and\ \ F_{2,period\ 2} = 0.2$
- Constant logistic fishery selectivity at age by population for both fleets.

$$S_{v,a}^{(1)} = S_{v,a}^{(2)} = \frac{1}{1+e^{\frac{-\left(a-a_{50,v}\right)}{\sigma_v}}}$$

    - For fleet 1, the selectivity parameters are $a_{50,1} = 3\ and\ \ \sigma_1 = 0.1$
    - For fleet 2, the selectivity parameters are $a_{50,2} = 3\ and\ \ \sigma_2 = 0.5$
- Fishery catch at age by population, area, and gender for both fleets.

$$C_{v,y,s,a,g}^{(p)} = N_{y,s,a,g}^{(p)} \frac{F_{v,y,s}^{(p)} S_{v,y,s,a,g}^{(p)}}{\left(F_{v,y,s}^{(p)} S_{v,y,s,a,g}^{(p)} + M_{s,a,g}^{(p)}\right)} \left\{1-\exp\left[-\left(F_{v,y,s}^{(p)} S_{v,y,s,a,g}^{(p)} + M_{s,a,g}^{(p)}\right)\right]\right\}$$

- Fishery catch biomass at age by population, area, and gender by fleet.

$$C_{B,v,y,s,a,g}^{(p)} = W_{s,a,g}^{(p)} N_{y,s,a,g}^{(p)} \frac{F_{v,y,s}^{(p)} S_{v,y,s,a,g}^{(p)}}{\left(F_{v,y,s}^{(p)} S_{v,y,s,a,g}^{(p)} + M_{s,a,g}^{(p)}\right)} \left\{1-\exp\left[-\left(F_{v,y,s}^{(p)} S_{v,y,s,a,g}^{(p)} + M_{s,a,g}^{(p)}\right)\right]\right\}$$

- Constant logistic survey selectivity at age by population.

$$S_{Survey,s,a}^{(p)} = \frac{1}{1+e^{\frac{-\left(a-a_{50,Survey,s}^{(p)}\right)}{\sigma_{Survey,s}^{(p)}}}}$$

    - For population 1, the survey selectivity parameters are $a_{50,Survey,s}^{(1)} = 3\ and\ \ \sigma_{Survey,s}^{(1)} = 0.25$
    - For population 2, the survey selectivity parameters are $a_{50,Survey,s}^{(2)} = 2.75\ and\ \ \sigma_{Survey,s}^{(2)} = 0.5$
- Survey catch at age indices by area and gender with survey timing of Δ_{Survey}.

$$C_{Survey,y,s,a,g}^{(p)} = S_{Survey,s,a,g}^{(p)} N_{y,s,a,g}^{(p)} \cdot \exp\left(-\Delta_{Survey} \cdot Z_{y,s,a,g}^{(p)}\right)$$

- Survey catch biomass at age indices by area and gender with survey timing of Δ_{Survey}.

$$C_{Survey,y,s,a,g}^{(p)} = W_{Survey,s,a,g}^{(p)} S_{Survey,s,a,g}^{(p)} N_{y,s,a,g}^{(p)} \cdot \exp\left(-\Delta_{Survey} \cdot Z_{y,s,a,g}^{(p)}\right)$$

- Lognormal negative loglikelihood component for fishery catch biomass by fleet/area.

- $$-\log L_{C_{B,s}}\left(\underline{\Theta}\,|\,\underline{O}_{C_{B,s}}\right) = \sum_{y=1}^{Y}\log\left(\sigma_{C_{B,s}}\right)+0.5\sum_{y=1}^{Y}\left(\frac{\log\left(\frac{C_{B,y,s}}{E\left[C_{B,y,s}\right]}\right)}{\sigma_{C_{B,s}}}+0.5\sigma_{C_{B,s}}\right)^2$$ Where

  $E\left[C_{B,y,s}\right]$ is the predicted catch biomass in year *y* in area *s* and $\sigma_{C_{B,s}}$ is the logscale standard deviation of catch biomass in area *s* with $\sigma_{C_{B,s}} = 0.1$.

- Multinomial likelihood component for fishery age compositions by fleet.

  $$-\log L_{AC,v}\left(\underline{\Theta}\,|\,\underline{\underline{O}}_{AC,v}\right) = -\sum_{y=1}^{Y} n_{AC,eff,v,(y)} \sum_{b=1}^{n_{AC,bin,v}} O_{AC,v,b,(y)} \log E_{AC,v,b,(y)}$$

  Where the observed bin values, indexed by *b*, for the *v*th fleet composition data set with $n_{AC,bin,v}$ bins by year and season $\left(O_{AC,v,b,(y)}\right)$ relative to predicted bin values $\left(E_{AC,v,b,(y)}\right)$ based on a multinomial error distribution with annual effective sample sizes $n_{AC,eff,v,(y)}$.

- Lognormal negative loglikelihood component for survey biomass indices by area.

  $$-\log L_{C_{B,Survey,s}}\left(\underline{\Theta}\,|\,\underline{O}_{C_{B,Survey,s}}\right) = \sum_{y=1}^{Y}\log\left(\sigma_{C_{B,Survey,s}}\right)+0.5\sum_{y=1}^{Y}\left(\frac{\log\left(\frac{C_{B,Survey,y,s}}{E\left[C_{B,Survey,y,s}\right]}\right)}{\sigma_{C_{B,Survey,s}}}+0.5\sigma_{C_{B,Survey,s}}\right)^2$$

  Where $E\left[C_{B,Survey,y,s}\right]$ is the predicted survey catch biomass in year *y* in area *s* and $\sigma_{C_{B,Survey,s}}$ is the logscale standard deviation of catch biomass in area *s* with $\sigma_{C_{B,Survey,s}} = 0.3$.

- Multinomial likelihood component for survey age compositions by area.

  $$-\log L_{AC,Survey,s}\left(\underline{\Theta}\,|\,\underline{\underline{O}}_{AC,Survey,s}\right) =$$

  $$-\sum_{y=1}^{Y} n_{AC,Survey,eff,(y),s} \sum_{b=1}^{n_{AC,Survey,bin,s}} O_{AC,Survey,b,(y),s} \log E_{AC,Survey,b,(y),s}$$

  Where the observed bin values, indexed by *b*, for the *s*th area survey composition data set with $n_{AC,Survey,bin,s}$ bins by year and season $\left(O_{AC,Survey,b,(y),s}\right)$ relative to predicted bin values

$\left(E_{AC,Survey,s,b,(y)}\right)$ based on a multinomial error distribution with annual effective sample sizes $n_{AC,Survey,eff,(y),s}$.

- Lognormal likelihood component for recruitment deviations by area.
  NOT IMPLEMENTED IN CASE STUDY V1

$$-\log L_{C_{B,Survey,s}}\left(\underline{\Theta} \mid \underline{E}_{\Lambda_R}\right) = \sum_{y=1}^{Y} \log\left(\sigma_{\Lambda_{R_s^{(p)}}}\right) + 0.5\sum_{y=1}^{Y}\left(\frac{\log\left(\Lambda_{R_s^{(p)}}\right)}{\sigma_{\Lambda_{R_s^{(p)}}}} + 0.5\sigma_{\Lambda_{R_s^{(p)}}}\right)^2$$

  Where $\Lambda_{R^{(p)}_{(y),s}}$ is the population recruitment deviation year *y* in area *s* and $\sigma_{\Lambda_s^{(p)}}$ is the log-scale standard deviation of population recruitment in area *s*.

- Constant lambda weights for catch biomass, survey biomass, fishery age composition, survey age composition, and recruitment likelihood components.

MAS Case Study v1 Algorithm

1. Initialize

a. Set Model Domain Parameters
   i. NPop=2
   ii. NArea=2
   iii. NAge=10
   iv. NGender=2
   v. NInitYear=10
   vi. NYear=20
   vii. NSeason=1
   viii. Set ZFractionSpawning
   ix. Set ZFractionCatch
   x. Set ZFractionSurvey

b. Loop to Initialize Population Class
   i. Set Movement
      1. MovementType=(Constant,AllAges)
      2. Set Movement Parameters
   ii. Set NaturalMortality by Age,Gender,Area
   iii. Set Maturity by Age,Gender,Area
      1. MaturityType=(Constant,Logistic) by Gender, Area
      2. Set Maturity Parameters by Gender,Area
      3. Calculate Maturity by Age,Gender,Area
   iv. Set Length by Age,Gender,Area

1. LengthType=(Constant,Interpolate Age0,ModifiedVB) by Gender, Area
2. Set Length Parameters by Gender,Area
3. Calculate LengthStart by Age,Gender,Area
4. Calculate LengthSpawn by Age,Gender,Area
5. Calculate LengthCatch by Age,Gender,Area
6. Calculate LengthSurvey by Age,Gender,Area

v. Set WeightLength() by Age,Gender,Area
   1. WeightLengthType=(Constant,Allometric) by Gender, Area
   2. Set WeightLength Parameters by Gender,Area

vi. Set Weight by Age,Gender,Area
   1. WeightType=(Constant,Mean) by Gender, Area
   2. Compute WeightStart as Product(LengthStart,WeightLength())
   3. Compute WeightSpawn as Product(LengthSpawn,WeightLength())
   4. Compute WeightCatch as Product(LengthCatch,WeightLength())
   5. Compute WeightSurvey as Product(LengthSurvey,WeightLength())

vii. Set Recruitment by Area
   1. Set FemaleRecruitmentFraction by Area
   2. Set SpawningBiomassUnits by Area
   3. Set RecruitType(Equilibrium,Female,ModifiedBH,StanzaR=1) by Area
   4. Set Recruitment Parameters by Area
   5. Set RecruitmentDistribution by Area

c. Loop to Initialize Observation Class

   i. Loop to Initialize Fishery Observations by Population,Area,Gender
      1. Set CatchBiomassUnits
      2. Set FisheryCatchBiomass by Area
      3. Set FisherySelectivityType = (Constant,Logistic) by Population,Area,Gender
      4. Set FisherySelectivity Parameters by Population,Area,Gender
      5. Compute FisherySelectivity by Population,Area,Gender,Age
      6. Set FishingMortalityType=(InputF,SeparableF, NStanzaF=3,StanzaF{(-9,0),(1,10),(11,20)})
      7. Compute FishingMortality by Population,Area,Gender,Age

   ii. Loop to Initialize Survey Observations by Population,Area,Gender
      1. Set SurveyBiomassUnits
      2. Set SurveySelectivityType = (Constant,Logistic) by Population,Area,Gender
      3. Set SurveySelectivity Parameters by Population,Area,Gender

            4. Compute SurveySelectivity by Population,Area,Gender,Age
   d. Loop to Initialize Environment Class
   e. Loop to Initialize Analysis Class
      i. Set Objective Function Components for Observations by Area
         1. NLL for Fishery Observations
            a. FisheryCatchType=(Biomass,Normal,FisheryCatchStDev)
            b. FisheryAgeCompositionType(AllAges,Multinomial, FisheryEffectiveSampleSize)
         2. NLL for Survey Observations
            a. SurveyCatchType= (Biomass ,Lognormal, SurveyCatchStDev)
            b. SurveyAgeCompositionType(AllAges,Multinomial, SurveyEffectiveSampleSize)
      ii. Set Objective Function Components for Recruitment by Area
         1. **NOT IMPLEMENTED IN CASE STUDY V1**
         2. RecruitmentDeviationType=(Numbers,Lognormal, AR1,RecruitmentDeviationStDev,RecruitmentDeviationPhi)
      iii. Set ObjectiveFunctionComponentWeights
   f. Initialize Model Parameters

2. Initial Calculations

   a. Calculate Mean Length at Age by Population, Area, and Gender
      i. Spawning
      ii. Catch
      iii. Survey
   b. Calculate Mean Weight at Age by Population, Area, and Gender
      i. Spawning
      ii. Catch
      iii. Survey
   c. Calculate Unfished Spawning Biomass for Modified BH Recruitment Curve by Population and Area

3. Loop Over Time

   a. Calculate Population Size by Population, Area, and Gender
   b. Calculate Spawning Biomass by Population, Area, and Gender
   c. Calculate Recruitment by Population, Area, and Gender
   d. Distribute Recruitment by Population, Area, and Gender
   e. Calculate Catch at Age by Population, Area, and Gender
   f. Calculate Survey Catch at Age by Population, Area, and Gender
   g. Calculate Movement at Age by Population, Area, and Gender
   h. Calculate Quantities of Interest by Population, Area, and Gender

4. Evaluate the Objective Function

a. Calculate Catch Biomass NLL by Area If Applicable
b. Calculate Catch Numbers NLL by Area If Applicable
c. Calculate Fishery Index NLL by Area If Applicable
d. Calculate Survey Index NLL by Area If Applicable
e. Calculate Fishery Age Composition NLL by Area If Applicable
f. Calculate Survey Age Composition NLL by Area If Applicable
g. Calculate Fishery Size Composition NLL by Area If Applicable
h. Calculate Survey Size Composition NLL by Area If Applicable
i. Calculate Fishery Mean Weight NLL by Area If Applicable
j. Calculate Survey Mean Weight NLL by Area If Applicable
k. Calculate Recruitment Deviation NLL by Population and Area If Applicable
l. Calculate Objective Function Value