Illustration of the use of the age-structured production model diagnostic tool in the assessment of the North Pacific albacore stock[1]

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Summary
The most recent assessment for the north Pacific albacore stock was performed using an age-structured statistical integrated model built on the Stock Synthesis 3 platform. Integrated models incorporate a suite of data and assumptions, and use likelihood methods to estimate the parameters. Recently, diagnostics to assess whether integrated models are correctly specified have been developed such as the likelihood profile on the scale parameter and the age-structured production model (ASPM) diagnostic. The use of the ASPM diagnostic in the assessment for the north Pacific albacore stock is illustrated and the insights gained from it are discussed. The ASPM diagnostic showed that the north Pacific albacore stock biomass, like other tuna stocks in the Pacific Ocean, is essentially driven by recruitment variability. Also, the ASPM diagnostic has shown that, in general, the length-composition data do not have a disproportionate effect on the stock assessment model results. In the middle of the time-series, however, the abundance indices and the length-composition data have contradictory information. Model misspecification needs to be explored for the middle period in the stock assessment model. It is recommended that the ASPM diagnostic tool be used in the next assessment for the north Pacific Albacore stock since it seems to provide new insights into the assessment model and the dynamics of the stock.

Introduction

The most recent assessment for the North Pacific albacore tuna stock was performed using an age-structured statistical integrated model built on the Stock Synthesis 3 platform (ALBWG 2014). Integrated models incorporate a suite of data and assumptions, and use likelihood methods to estimate the parameters. Recently, diagnostics have been developed, such as the likelihood profile on the scale parameter and the age-structured production model (ASPM) diagnostic, to assess whether the model is correctly specified.

A set of model diagnostics was used in the 2014 base case assessment model of North Pacific albacore to assess issues associated with convergence, structure, parameter misspecification, and data conflicts (ALBWG 2014). The following traditional diagnostic tools were employed: i) model convergence tests; ii) residual analysis; and iii) retrospective analysis. In addition, a likelihood profile on the scale parameter (virgin recruitment parameter in a logarithm scale $\ln(R_0)$, the "R_0 profile"; Lee *et al.* 2014, Wang *et al*. 2014) was also used. The R_0 profile indicates the influence of each data component on the estimate of the productivity of the stock. This tool was used to assess whether the relative data weightings were appropriate and/or whether the model was misspecified. Contradictory information among different data components (*i.e*. favoring different values for R_0) points to potential model misspecification. Age-structured statistical models for tunas are typically fit to length-composition data due to the lack of age-composition data. In the model, the weight given to these data is a function of the variance parameter of the likelihood function. Since the length-composition data are assumed to follow a multinomial distribution in Stock Synthesis, the variance is a function of the sample sizes. Due to the high correlation between the sizes of fish in a single school, the sample sizes are typically less than the number of fish sampled. For example, in purse seine fisheries which catch one or a few schools in a set, the sample size may be more closely related to the number of sets or wells sampled rather than the number of fish sampled. For longline fisheries, which cover a larger spatial range and many schools, determining the effective sample size is more complicated. In the albacore stock assessment, the scaling factor was chosen arbitrarily so that the size-composition data do not drive the estimated trends of biomass in the model, which should follow the indices of abundance (Francis 2011). If the signals from different data types regarding the scaling parameter are contradictory, model misspecification and the weighting of different data types needs to be addressed.

The ASPM diagnostic was proposed by Maunder and Piner (2015) as a way to further evaluate model misspecification, and ascertain the influence of composition data on the estimates of trends and absolute abundance. Also, it is helpful for assessing whether the catch alone can explain the trends in the indices of abundance. The goal of this document is to illustrate the application of the ASPM diagnostic using the most recent stock assessment of North Pacific albacore, and discuss how this tool can give insight into the North Pacific albacore model, in order to evaluate the usefulness of this tool in the development of the model for the next assessment for the stock planned for 2017.

Methods

The ASPM diagnostic is based on the full assessment model of North Pacific albacore (ALBWG 2014) which is an integrated statistical age-structured stock assessment model constructed using Stock Synthesis version 3.24f (SS3; Methot and Wetzel 2013). The ASPM diagnostic for the SS3 model is computed as follows: (i) run the SS3 base case model; (ii) fix selectivity parameters at the maximum likelihood estimate (MLE) from the base case model, (iii) turn off the estimation of all parameters except the scaling parameters and the parameters representing the initial conditions (a parameter for the equilibrium recruitment and a parameter for the equilibrium fishing mortality), set the recruitment deviates to zero (early recruitment and model period recruitments), and set the recruitment bias correction to zero (in order to achieve this in SS3 V3.24f the estimation phase of the recruitment deviates needs to be set to a large number, e.g. 50, and the maximum estimation phase needs to be set to a smaller value, e.g. 10); (iv) fit the model to the indices of abundance only; (v) compare the estimated trajectory to the one obtained in the base case. Next, the model is run as for the ASPM, but with recruitment estimated. Finally, the model is run as for the ASPM with the recruitment estimates set equal to the MLE values from the base case integrated model.

If the ASPM is able to fit well the indices of abundance that have good contrast (*i.e*. those that have declining and/or increasing trends), Maunder and Piner (2015) suggest that this is evidence of the existence of a production function, and the indices will likely provide information about absolute abundance. They refer to this situation as “the catch explains the indices well”; in the opposite case, where there is no good fit to the indices, the catch alone cannot explain the trajectories depicted in the indices of relative abundance. This can have several causes: (i) the stock is recruitment-driven; (ii) the stock has not yet declined to the point at which catch is a major factor influencing abundance; (iii) the base-case model is incorrect; or (iv) the indices of relative abundance are not proportional to abundance. Checking whether the stock is recruitment-driven involves fitting the ASPM with the recruitment deviates fixed at the values estimated in the base case integrated model (BC). If the ASPM with recruitment fixed at BC values is still not able to capture the population trajectory estimated in the integrated model, it can be concluded that the information about scale in the integrated model is coming from the composition data. Large confidence intervals around the abundance estimated by the ASPM also indicate that the index of abundance has little information on absolute abundance.

The North Pacific albacore stock assessment model of 2014 was fit to four indices of abundance (ALBWG 2014): two indices of juvenile abundance and two indices of adult abundance. The two indices of juvenile abundance are related to fisheries F1 (Japanese pole-and-line fishery in quarters 1 and 2, 1972-1989) and F2 (Japanese pole-and-line fishery in quarters 1 and 2, 1990-2012). The two indices of adult abundance are related to the fisheries F8 (Japanese longline quarters 1 to 4, 1975-1992) and F12 (Japanese longline quarters 1 to 4, 1993-2012). The ALB working group decided to have two time blocks in both the juvenile and adult indices because of operational changes in the fisheries (ALBWG, 2014).

Results and discussion

The abundance trend estimated by the ASPM is very different from those estimated in the assessment model. The ASPM diagnostic shows a decline on the adult component at the beginning of the series followed by a flat biomass series (Figures 1-3), which indicates that the changes in the abundance indices cannot be explained by the catches alone.. A deterministic model cannot explain the large increases in abundance, and the subsequent large catches, caused by periods of higher recruitment. Also, there is little contrast in abundance within the assessment period, which causes the indices to have almost no information about a productivity function. This does not mean that the catches are not influencing the abundance, and the impact of each fishery on the stock can be evaluated using a fishery impact plot (Wang *et al.* 2009, ALBWG 2014).

ASPM is able to estimate the scale of the biomass only when recruitments are allowed to vary, either by estimating the recruitment within the ASPM or by fixing the recruitments to the values estimated by the base-case model (Figures 2 and 3). As with yellowfin tuna (Minte-Vera *et al.* 2016) and to some extent bigeye tuna (Aires-da-Silva *et al.* 2016) in the eastern Pacific Ocean, the stock size of North Pacific albacore seems to be driven essentially by recruitment. The ASPM with estimated recruitments follows the trend from the base case model closely, mainly at the end of the time-series; it seems that the indices of abundances have enough information about the variability in recruitment, and that the length-composition data are not completely driving the abundance trends in the base case model. This is expected, given the small weight given to these data in the final base case model (ALBWG 2014), in accordance with the modelling philosophy adopted by the ALBWG of prioritizing the indices of relative abundance because abundance indices are a direct measure of population trends and scale (Francis 2011). These results indicate that the abundance information, both absolute and relative, contained in the CPUE-based indices of relative abundance cannot be interpreted without accounting for the fluctuations in recruitment.

In the years prior to 1998, the biomass trajectory ($SSB_{t,}$ spawning stock biomass in year *t*) from ASPM with estimated recruitments is smaller than the one from both the base case integrated model and the ASPM with recruitment fixed at BC values, dropping below 20% depletion (SSB_t/SSB_0<0.2) in some years (Figure 2). indicating that for those years there is extra information from the length-composition data about the biomass.

In recent years, the biomass trajectories for the ASPM with estimated recruitments have similar uncertainty than those estimated using either the base case integrated model or the ASPM with recruitment fixed at BC values. In the middle of the trajectory (~1980 – 1998), however, the uncertainty in the estimated biomass trends from the ASPM with estimated recruitments is much lower than those of the base case integrated model or the ASPM with recruitment fixed at BC values.(Figure 3). It seems that the length-composition data not only drove upward the estimated trend in abundance during this period, but also provided added uncertainty in the middle of the time series. These results indicate that the indices of relative abundance and the length-composition data have contradictory information during this period. Model misspecification needs to be explored. For example, changes in selectivity or changes in growth patterns around this period need to be investigated.

Conclusions and recommendations

The ASPM diagnostics has shown that the North Pacific Albacore stock, similarly to other tuna stocks in the Pacific Ocean, is essentially driven by recruitment variability. Also, the ASPM diagnostics has shown that overall the length-composition data does not have a disproportional effect on the stock assessment model results, but in the middle of the time-series the abundance indices and the length-composition data have contradictory information. For this period, model misspecification needs to be explored.

We recommend that the ASPM diagnostic tool be used in the next assessment of the North Pacific albacore stock as shown in this research, since it is seems to provide new insights about the assessment model and the population dynamics of the stock.

REFERENCES

Aires-da-Silva, A., C.V. Minte-Vera, and M.N. Maunder. 2016. Status of bigeye tuna in the eastern Pacific Ocean in 2015 and outlook for the future. Inter-Amer. Trop. Tuna Comm., 7th Scient. Adv. Com. Meeting. SAC-07-05a.

Albacore Working Group (ALBWG). 2014. Stock assessment of albacore tuna in the North Pacific ocean in 2014. Report of the Albacore Working Group Workshop, April 2014. ANNEX 11. Report of the Fourteenth Meeting of the International Scientific Committee for Tuna and Tuna-like Species in the North Pacific Ocean, Plenary Session, 16-21 July 2014, Taipei, Taiwan.

Francis, R.I.C.C. 2011. Data weighting in statistical stock assessment models. Can. J. Fish. Aquat. Sci. 68:1124-1138.

Lee, H.H., K.R. Piner, R.D. Methot, and M.N. Maunder. 2014. Use of likelihood profiling over a global scaling parameter to structure the population dynamics model: an example using blue marlin in the Pacific Ocean. Fish. Res. 158: 138-146.

Maunder, M.N., and K.R. Piner. 2015. Contemporary fisheries stock assessment: many issues still remain. ICES Journal of Marine Science, 72: 7–18. doi:10.1093/icesjms/fsu015

Methot, R.D., and C.R. Wetzel. 2013. Stock synthesis: a biological and statistical framework for fish stock assessment and fishery management. Fish. Res. 142: 86-99.

Minte-Vera, C.V., A. Aires-da-Silva, A., and M.N. Maunder. 2016. Status of yellowfin tuna in the eastern Pacific Ocean in 2015 and outlook for the future. Inter-Amer. Trop. Tuna Comm., 7^{th} Scient. Adv. Com. Meeting. SAC-07-05b.

Wang, S.-P., M.N. Maunder, A. Aires-da-Silva, and W. H. Bayliff. 2009. Evaluating fishery impacts: Application to bigeye tuna (*Thunnus obesus*) in the eastern Pacific Ocean. Fish. Res., 99: 106-111.

Wang, S.-P., M.N. Maunder, K.R. Piner, A. Aires-da-Silva, and H.H. Lee. 2014. Evaluation of virgin recruitment profiling as a diagnostic for selectivity curve structure in integrated stock assessment models. Fish. Res., 158: 158-164.

Figures

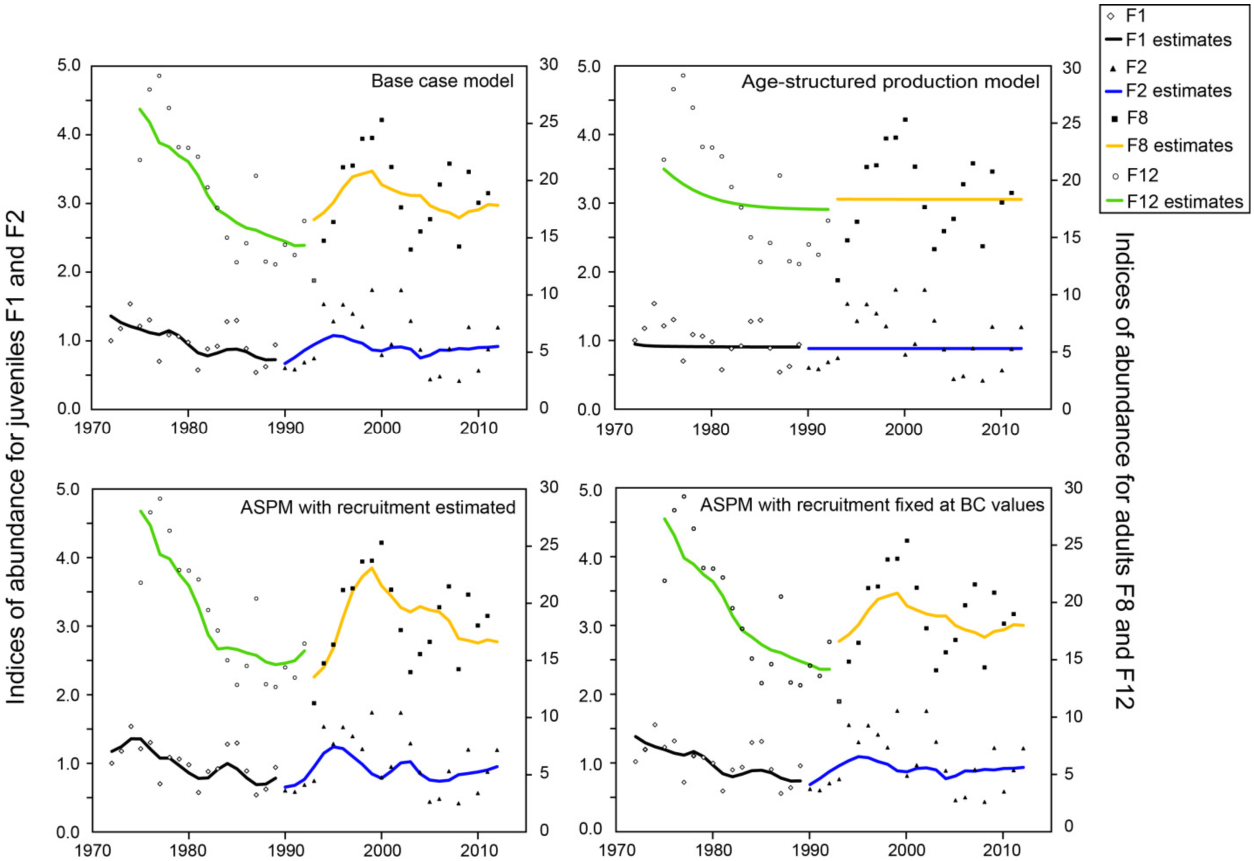

FIGURE 1. Age-structured production model (ASPM) diagnostic: model fit (lines) to the four CPUE indices (symbols) used in the stock assessment of North Pacific Albacore. F1 and F2 are juvenile indices of abundance (pole-and-line fisheries). F8 and F12 are adult indices of abundance (longline fisheries).

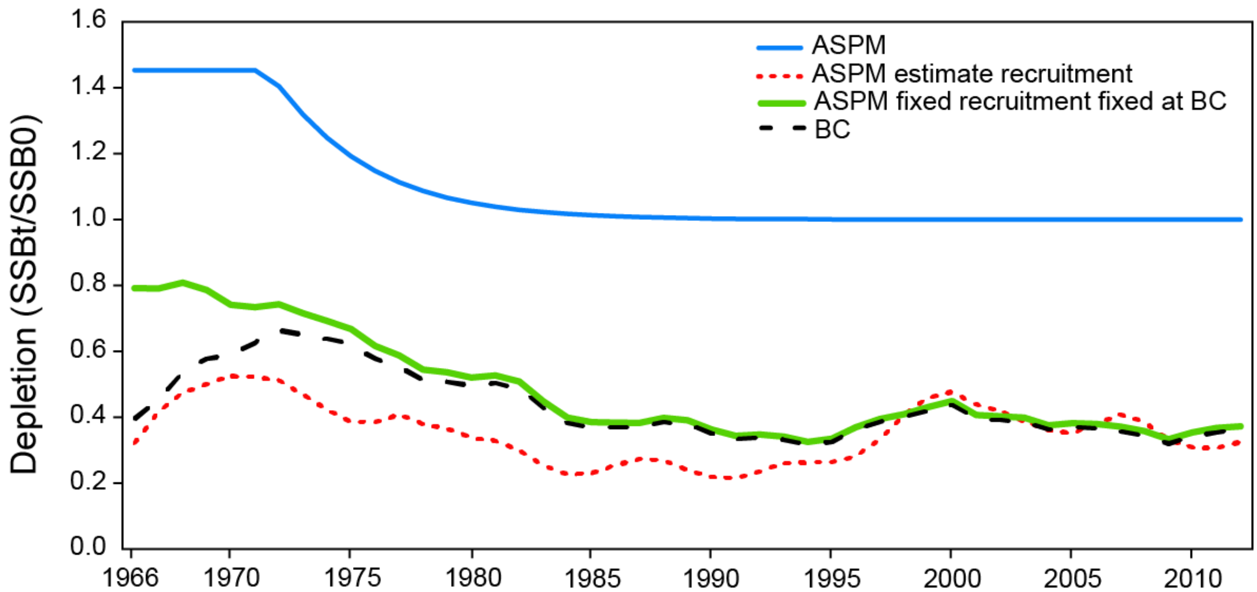

FIGURE 2. Comparison of estimates of the depletion (spawning stock biomass in year *t* relative to the virgir spawning stock biomass, SSB_t/SSB_0) of North Pacific albacore stock from the age-structured production model (ASPM) diagnostic. SSB trends are shown for the base case integrated model (BC), the age-structured production model (ASPM), the ASPM with recruitment deviations estimated, the ASPM with recruitment deviations fixed at the estimates from the base-case model.

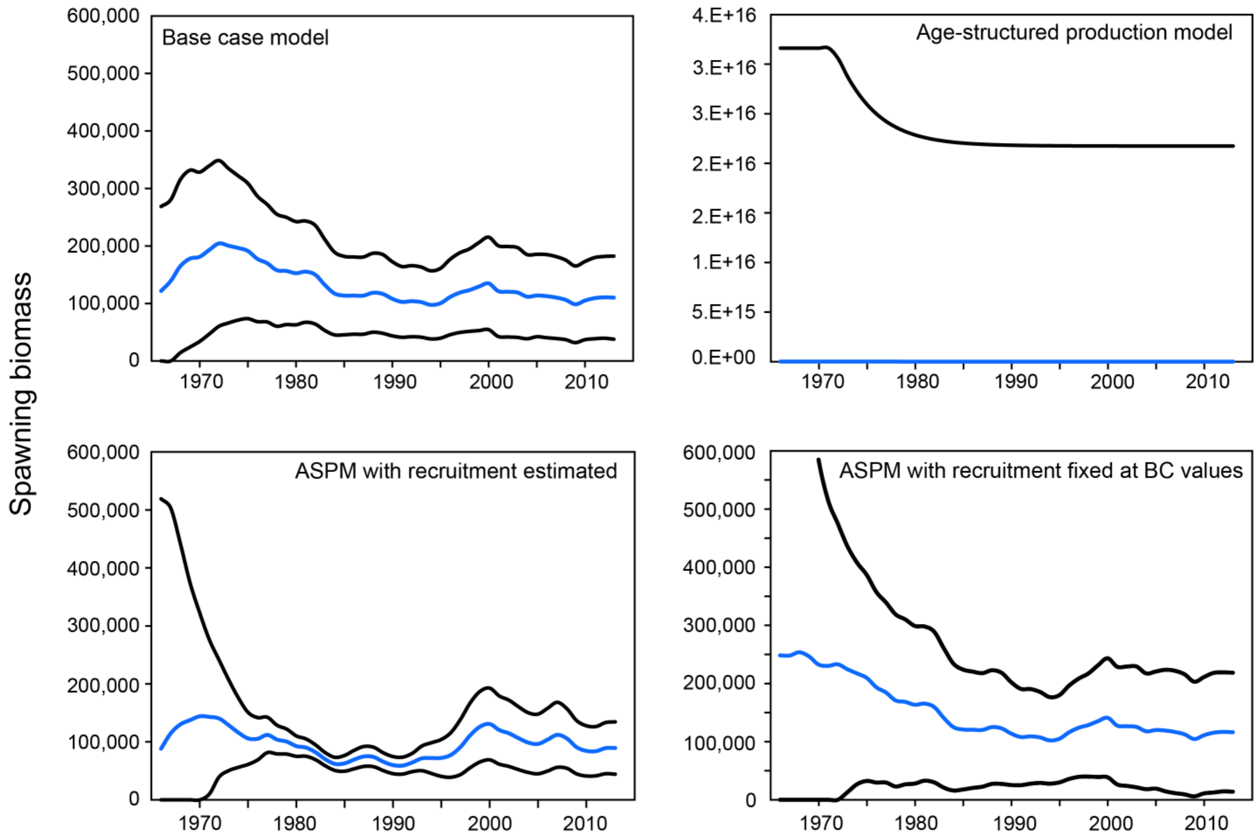

FIGURE 3. Comparison of estimates of the spawning biomass (SB) of North Pacific albacore from the age-structured production model (ASPM) diagnostic. In each panel, the blue line with dots illustrates the maximum likelihood estimates, and the black lines indicate the approximate 95-percent confidence intervals around those estimates.