CIE Review Report
for Albacore Tuna Assessment Review

Dr. Ding-Geng (Din) Chen
Fisheries Statistics Consultant

Prepared for
Center for Independent Experts

December 21, 2011

TABLE OF CONTENTS

EXECUTIVE SUMMARY

The International Scientific Committee for Tuna and Tuna-like Species in the North Pacific Ocean (ISC) conducted a stock assessment of Albacore tuna in the North Pacific Ocean (NPO) and subsequently requested an independent peer review by the Center for Independent Experts (CIE). I was selected as one of the CIE reviewers for this task.

As a general background, Albacore tuna in the NPO are harvested multi-nationally primarily using troll, pole-and-line, and longline gear whereas in the US, major fisheries from troll and pole-and-line fleets are based in Washington, Oregon, and California. The stock assessment of albacore tuna in the NPO was conducted by staff of the Pacific Islands Fisheries Science Center, the Southwest Fisheries Science Center, in collaboration with scientists from members of the International Scientific Committee for Tuna and Tuna-like Species in the North Pacific Ocean (ISC), within the ISC's Albacore Working Group in FY 2011. A stock assessment report was produced following the June 4-11, 2011 in the stock assessment workshop titled "Stock Assessment of Albacore Tuna in the North Pacific Ocean in 2011"(see Appendix 1). The results of this assessment are more optimistic than the 2006 assessment based on two main changes: 1) the fishing mortality in 2006-2008 has decreased relative to 2002-2004 and 2) the new assumptions regarding growth in the 2011 assessment where in previous assessments, a VPA model was used with growth curve parameters derived from a study in the 1960s using relatively outdated aging techniques and a limited size range. However, in this current assessment, they are based on an SS3 model with growth curve parameters derived from a recent study using modern aging techniques and a substantially larger range of fish sizes. The new growth curve, with a lower $L\infty$, resulted in a higher scaling of biomass and a more positive assessment of stock status.

Reviewing the assessment report and its supporting documents, I have concluded that this 2011 assessment was scientifically sound and appropriate, and that it adequately reflects the best available fish population dynamics and biology, fishery data, and modeling techniques up to date. Therefore this assessment can be used to provide scientific advice on the status of the North Pacific albacore stock.

Specifically, the methods for Albacore tuna assessments are appropriate given the available knowledge about this stock up to date. A seasonal, length-based, age-structured, forward simulation population model was used for this assessment. The assumed population dynamics are consistent with the current understanding and knowledge of the Albacore tuna fish biology. The data inputted for this model were comprised of quarterly catch-at-length data, sixteen age-aggregated fisheries defined by gear, location, season, and catch units; eight abundance indices; a new growth curve estimated within the model; and conditional age-at-length data not previously available. Transition from VPA model in previous assessments to the present assessment model SS3 was validated with both the SS3 base-case model and the VPA reference run to give similar historical trends in SSB and recruitment as seen in Figure 41 in the report. Both runs estimate that F2006-2008 is lower than F2002-2004 and that the pattern of F-at-age has shifted from being highest on mature age classes to highest on juvenile age classes. This shift in F-at-age is consistent with results of fishery impact analysis, which indicates that the surface fisheries capturing juveniles have the largest impact on biomass levels in this stock historically and in recent years. An array of sensitivity runs were also performed to confirm with the conclusions from other documented research and analysis. Further validation of the assessment methods was done from extensive sensitivity analyses and other ancillary analyses as detailed in Sections 5.5 to 5.11. I therefore endorse this assessment at this present knowledge.

Nevertheless, several weaknesses and future research recommendations were identified during this review which should be used to improve future stock assessment for this species. These include issues of the natural mortality (M) estimate**,** CPUE standardization without incorporating spatial autocorrelation, assessment model convergence, and parameter confounding which are detailed in the TORs.

1. BACKGROUND

Designated by the Center for Independent Experts (CIE), this author was invited as one of the reviewers (Appendix 2: Statement of Work) to review the 2011 stock assessment of North Pacific Ocean (NPO) Albacore tuna conducted by the International Scientific Committee for Tuna and Tuna-like Species in the North Pacific Ocean.

Results of the 2011 assessment are more optimistic than the 2006 assessment because fishing mortality in 2006-2008 has decreased relative to 2002-2004 and because of new assumptions regarding growth in the 2011 assessment. Previous assessments used a VPA model with growth curve parameters derived from a study in the 1960s using relatively outdated aging techniques and a limited size range. The current assessment is based on an SS3 model with growth curve parameters derived from a recent study using modern aging techniques and a substantially larger range of fish sizes. The new growth curve, with a lower $L\infty$, resulted in a higher scaling of biomass and a more positive assessment of stock status.

On November 21, 2011, Mr. Manoj Shivlani, the CIE lead coordinator, informed me by email that I was selected for the Pacific albacore stock assessment review. Following his email, his assistant, Mr. Roberto Koeneke, provided me with the "Statement of Work" (Appendix 2) along with other contract information. After signing the contract, I received three emails from Dr. Steve Teo (Southwest Fisheries Science Center) on November 22, 2011, for background and assessment documents (Appendix 1: Bibliography of materials provided for review) associated with this review. Since then, I reviewed the assessment report ("STOCK ASSESSMENT OF ALBACORE TUNA IN THE NORTH PACIFIC OCEAN IN 2011") and consulted the background materials as listed in Appendix 1 as well as some additional research on related publications in preparing this review report.

I would like to commend to Manoj Shivlani and Roberto Koeneke for their excellent job arranging the contract and providing information for the review.

2. SUMMARY OF FINDINGS

This part is organized according to the terms of reference (TOR) in the review Statement of Work (SOW) (Appendix 2) to address the strengths and weaknesses of the following TORs. The numbered points are the key findings, followed by a detailed discussion, if any.

TOR 1: Review the assessment methods: determine if they are reliable, properly applied, and adequate and appropriate for the species, fisheries, and available data.

Generally, the methods for Albacore tuna assessments are appropriate given the available knowledge up to date on fish biology, fishery data and modeling techniques. A seasonal, length-based, age-structured, forward simulation population model was used for this assessment with the assumption that there is a single well-mixed stock of albacore *in the North Pacific Ocean. The assumed population dynamics are consistent with the current understanding and knowledge of the Albacore tuna fish biology. The data inputted for this model were quarterly catch-at-length data, sixteen age-aggregated fisheries defined by gear, location, season, and catch units (weight or number); eight abundance indices; a new growth curve estimated within the model; and conditional age-at-length data not previously available. The appropriateness of assessment input data and the analytical approaches have been reviewed extensively in previous workshops and reports. In my review of the report and the supporting documents, I conclude that this assessment is appropriate and adequate at the current knowledge of this stock. The assessments of this species generally provide the best available science for management advice. There are several, specific strengths and weaknesses in this assessment as outlined as follows.*

Strengths

1. The assessment report and the associated supporting documents

I first comment and appraise the effort from the assessment Working Group (WG) to produce such professional report ("Stock Assessment of Albacore tuna in the North Pacific Ocean in 2011") in reference to all other supporting documents as listed in Appendix 1. Albacore tuna population biology is well documented in Section 2 with references to stock structure, reproduction, growth, movement and food habits which led to the available data in Section 3 with corresponding assessment methods and models in Section 4 for this species. Section 5 detailed the results from all aspects of model fitting, sensitivity runs and other ancillary analysis followed by the current stock status and conservation advice in Section 6 and future research recommendations in Section 7.

2. The validation of new assessment method

I endorse the new SS method used in this assessment after reviewing the report in comparison with VPA. Transition from the VPA model in previous assessments to the present assessment model SS3 was validated with both the SS3 base-case model and the VPA reference run to give similar historical trends in SSB and recruitment.

As seen from the assessment report, both the base-case SS3 model and the VPA reference run estimated similar historical trends in SSB and recruitment as seen in Figure 41. Both runs estimate that F2006-2008 is lower than F2002-2004 and that the pattern of F-at-age has shifted from being highest on mature age classes to highest on juvenile age classes. This shift in F-at-age is consistent with results of fishery impact analysis, which showed that the surface fisheries capturing juveniles had the largest impact on biomass levels in this stock historically and in recent years. Several sensitivity runs were also performed to confirm with the conclusions from other documented research and analyses. I concur with the WG that the SS base-case model is representative of the population dynamics and abundance of north Pacific albacore and to be used for this assessment.

3. Further validation of the assessment methods.

Extensive sensitivity analyses and other ancillary analyses further validated the SS base-case assessment methods in this stock assessment as detailed in Sections 5.5 to 5.11. The

WG did an excellent job in designing and conducting the sensitivity analyses to further validate this method. I agree that this assessment is based on the best available biology, fishery data, and modeling techniques at this time. The assessments of this species generally provide the best available science for management advice. From my review, I consider this assessment to be scientifically sound at the present knowledge despite some concerns I have regarding the data and methods.

Weaknesses

1. Issue on fixing the natural mortality (M) estimate at 0.3 yr^{-1}

It is well known that M is a key parameter in fish stock assessment. The fact that M=0.3 in this assessment is very problematic. The assessment Working Group (WG) made the effort with a sensitivity run at M = 0.4 which led to a substantial higher scaling of SSB and recruitment as illustrated in Figure 27. This further confirmed the needs on substantial investigations using more sensitivity runs or estimating this M from other methods, such as tagging experiments external to the SS3. This is a high priority in future assessment and research.

2. Issue on CPUE standardization without incorporating spatial autocorrelation.

As indices of relative fish abundance, CPUE was standardized for 8 fisheries as indicated in Section 3.6 with a statistical generalized linear model (GLM) using data from year, season and area as main effects. Albacore tuna are spatially distributed in North Pacific Ocean and any methods ignoring this spatial distribution would introduce bias. I reviewed the reports from Table 2 and I failed to identify the applied GLM method in this assessment incorporated the spatial autocorrelation in the process of CPUE standardization. A remedy can be found from Nishida and Chen (2004) using SAS proc mixed. Further discussion can be found in TOR5.

3. Issue on assessment model convergence and parameter confounding.

There are a larger number of parameters estimated from the assessment models; parameter confounding and local optimization are bound to be a problem. The WG acknowledged the issue of local convergence and conducted a jitter analysis which led to the conclusion that "the model was caught on a local rather than global minimum in the log-likelihood space". This is serious in interpreting model outputs and making conclusions based on the model results as well as providing fishery management advices. Advanced search algorithms, such as genetic algorithms and simulated annealing should be attempted. There are extensive references in the literatures in mathematical modeling and Chen et al. (2000) was one of the early ones in fishery research.

In addition, this local convergence is entangled with the parameter confounding since if the model parameters are confounded, the search algorithm will stuck at the ridge of the log-likelihood surface so to introduce local convergence. In the SS3 model, there is a known confounding effect for the steepness parameter in the stock-recruitment model. A plausible solution is to re-parameterize this stock-recruitment model and replace the steepness into other management parameters as illustrated in Schnute and Kronlund

(1996, 2002) or Schnute and Richards (1998) to eliminate this confounding effect. Further recommendations can be found in TOR 5.

4. Issue on bias from the length-weight relationship.

Weight-Length relationships are used in this assessment to convert catch-at-length to weight-at-length data as seen in Sections 4.2.2 and 4.12.2. There is a known bias in inverse logarithmic transformation in estimating length-weight relationship. The WG might have corrected this bias, but there is no description in the report. If not, please refer to Hayes et al. (1995) and TOR 5.

TOR 2. Evaluate the assessment model configuration, assumptions, and input parameters (fishery, life history, and spawner recruit relationships): determine if data are properly used, input parameters seem reasonable, models are appropriately configured, assumptions are reasonably satisfied, and primary sources of uncertainty accounted for.

The assessment models of SS3 in comparison to VPA are considered to be appropriate for the available data from my review. The input data and parameters are generally reasonable corresponding to this stock at present level of knowledge and understanding of this stock. The assessment model is adopted from Stock Synthesis (SS) Version 3.11b (Methot 2011; http://nft.nefsc.noaa.gov/Stock_Synthesis_3.htm) to this Albacore tuna species with best available input data from its life history, fisheries and typical stock-recruitment relationships. Even there are some drawbacks in SS3, this model is the best available at this assessment.

With this SS model, the WG compiled all best available data from fishery catch and effort, CPUE, size compositions and conditional age-at-length based on Albacore tuna life history with proper biological and demographic assumptions about fish population dynamics to be used for the model fitting. In review the assessment report, I deem that the data are properly used, input parameters seem reasonable, models are appropriately configured, assumptions are reasonably satisfied, and primary sources of uncertainty accounted for. Several specific strengths and weaknesses are outlined as follows.

Strengths

1. The model and its assumptions

Further to the strength outlined in TOR1 on model validations from VPA to SS3 for this species, Stock Synthesis is widely used in the arena of fishery stock assessment which is an age and size-structured model that projects the survival, growth and reproduction of individual age classes. The SS model can incorporate ageing errors and individual variation in growth with advantages in population model to simulate the size and age structure of the Albacore tuna population and the observation model to use the data from the 16 fisheries and selectivity functions to fit the simulated population to the observed data.

An additional strength of this model is the statistical model using a log-likelihood approach to best-fit parameters in order to minimize the log-likelihood objective function from both the data and prior information with weights to control different type of data and parameter influencing the total likelihood. This model is an advanced statistical model demanding comprehensive understanding of advanced statistical modeling and fishery assessment techniques.

Corresponding to this SS3 model, the biological and demographic assumptions specific to Albacore tuna was outlined in Section 4.2 on using von Bertalanffy growth function, a seasonal specific weight-at-length function, sex ratio, natural mortality rate and the standard Beverton and Holt stock-recruitment relationship. Further assumptions on maximum age, movement, stock structure, selectivity function, catchability and likelihood weighting were explained in details in this report with references to the supporting documents listed in Appendix 1.

In reviewing the report, I concluded that the WG made the best effort to properly apply this SS model to this species. The selected input parameters and the assumptions were reasonably satisfied for this assessment.

2. The input data

To fit the SS3 model for Albacore, the WG compiled 4 types of data for this assessment. There are fishery-specific catches, length compositions sampled from the catches, abundance indices derived from logbooks, and conditional age-at length data. These data were compiled from 1966 through 2009 as outlined in Section 3 in the report for spatial and temporal stratifications as well as the 16 fisheries for this species. The acquisitions of the raw data and the standardization of these raw data in order to input to SS3 were detailed in the section as well as the reference papers in Appendix 1. This is the key step in assessment and the WG organized several workshops to finalize the data. In reviewing those references, I deemed that the data have been compiled with their best effort.

Weaknesses

Further to the weaknesses outlined in TOR1,

1. The steepness parameter.

The WG has acknowledged that the steepness parameter (h) of the stock-recruitment relationship is a difficult parameter to be estimated along with the SS3 model and they concluded that because model derived estimates of SSB and recruitment commonly lack sufficient contrast in biomass levels, especially low biomass levels, to enable steepness to be reliably estimated (ISSF 2011). Then the steepness (h) of the stock-recruitment relationship was fixed at 1.0 in the present assessment. The WG regarded that "further research on plausible steepness values prior to the next assessment is a high priority recommendation."

In fact, this steepness parameter can not be estimated independently since it is totally confounded with R_0 and S_0 as I have raised this comment before. A mathematical derivation is iterated in TOR5. So any efforts to estimate the steepness parameter are useless and totally waste the time.

If the mathematics is not believable, a simple simulation can demonstrate the point. The WG can use Albacore tuna dynamics with a range of plausible h values, then use SS3 or any profile likelihood function to estimate it. I can guarantee that there are a high proportion of failed searches to estimate the h. The remedy for this confounding is to get rid of this h and re-parameterize the SR using the management parameters as illustrated in Schnute and Kronlund (1996, 2002) or Schnute and Richards (1998). This task might be out of the scope of the WG, but should be taken into serious consideration in future assessments.

2. Migration issues

As stated in Section 2.4, North Pacific Albacore are highly migratory and these movements are influenced by oceanic conditions with observed seasonal movements. However, this assessment was conducted without any migration component and this seasonal movement rates were not explicitly modeled. I recommend that further tagging studies should be implemented to quantify the spatial migration since any violation of this assumption can lead to misinterpretation of abundance data and unreliable stock assessments.

3. Sex-specific growth

Usually there is a growth difference between sexes. For Albacore tuna, it is reported there was a sex-specific growth after maturity in the western Pacific Ocean, with males achieving larger sizes than females. Consequently, a sex-specific growth model would be more informative for this stock and this is one of the research priorities before next assessment.

TOR 3. Evaluate the adequacy of the sensitivity analyses in regard to completeness and incorporation of results.

The sensitivity analyses in this assessment are the most impressive part. Based on the SS base-case model, the WG examined the effects of plausible alternative assumptions in three categories as (1) data weighting, (2) biology, and (3) selectivity, which were detailed in Table 5 and Sections 5.6.1 to 5.6.11. In each sensitivity run, comparisons were made to spawning stock biomass and recruitment estimates and trajectories, as well as F-at-age for two temporal periods (2002-2004 and 2006-2008). Collectively, these sensitivity runs revealed uncertainty in the absolute estimates of biomass and fishing mortality while the trends in these parameters remained relatively robust to the different assumptions in these sensitivity analyses. This is considered highly appropriate from my review.

It is well known that there are so many parameters and assumptions in the assessment model to be altered for sensitivity analyses. In review these sensitivity analyses, I concluded that the WG made the best effort in evaluating possible scenarios in this stock assessment and I have no further comments.

TOR 4. Evaluate the adequacy, appropriateness, and application of the methods used to project future population status.

Future projections for a fish stock are largely dependent on the recruitment and fishing mortality patterns as well as other factors affecting fish survival. In this assessment, the future projections of Albacore tuna was performed using the base-case model configuration assuming current fishing mortality (F2006-2008) and random resampling of historically estimated recruitment (1966-2007) during the stock assessment period as seen in Figure 34. Further to this base-case model, two additional scenarios with low recruitment (1978-1987) and high recruitment (1988--2004) phases in the estimated historical recruitment time series were included as sensitivity runs. These recruitment patterns are combined with different fishing mortality patterns of lower $F_{2006\text{-}2008}$ *and higher* $F_{2002\text{-}2004}$. *This is adequate and appropriate at this point. There are several strengths and weaknesses in the future projections as outlined as follows.*

Strengths

1. Sensitivity investigations

There are several factors affecting future projections of fish population. The WG investigated the combinations of two key factors on fish recruitment and fishing mortality patterns. The three recruitment patterns are:

> Base-case run 1: 1966 to 2007, average R = 47,895,000, CV = 0.24;
> Run 2: low recruitment, 1978 to1987, average R = 35,171,000, CV = 0.16;
> Run 3: high recruitment, 1988-2004, average R = 54,373,000, CV = 0.22.

These recruitment patterns were combined with different fishing mortality patters of lower F2006-2008 and higher F2002-2004. The conclusions made sense that the lower the fishing mortalities, the higher the SSB. With fishing mortality of (F2006-2008), SSB would be expected to fluctuate around the historical median SSB, while with higher fishing mortality rate at F2002-2004, the SSB would be decreasing to below the base-case scenario. The WG also conducted other sensitivity runs which produced future median SSB trajectories in scale to SSB2008. In all these runs, only the low recruitment and high fishing mortality of F2002-2004 resulted that the SSB declines relative to SSB2008. All other runs resulted in future SSB about 15% above SSB2008 as summarized in Table 11 and depicted in Figure 37. In conclusion from these sensitivity runs, the future SSB were relatively insensitive to alternative structural assumptions and recruitment scenarios. Under the time series of recruitment and fishing mortality, the SSB is predicted to fluctuate around the historical median level over the 25-yr projection period. This is an adequate conclusion from my review.

2. Stable stock status

Stable stock status is the consequence of adequate assessment, which is the key for fish population conservation and management. In review of these sensitivity analyses, conclusions can be made that there is a stable stock status for conservation advice and the base-case model is considered to be relatively stable to produce a reasonable representation of the history of this stock abundance and F-at-age. This base-case model also confirmed that F2006-2008 has declined relative to F2002-2004 in consistent with the intent of previous conservation advice that there is no increase in F beyond the current level defined as F2002-2004-ALBWG 2007 to confirm the conservation goal. With the current recruitment and fish mortality patterns, the spawning biomass fluctuates around the long-term median at ~400,000 t. I agree with the WG's conclusion that overfishing for this stock is not occurring and that the stock is not in an overfished condition.

Weaknesses

1. Uncertainty estimates

Future projections always come with uncertainties. The further you forecast future fish abundance and stock status, the higher the uncertainty will be associated with this forecast. However, I have not seen any uncertainty estimates in this assessment. Parameter uncertainty should be included especially for biomass projection and stock status, which can be generated from the likelihood approach or ADMB.

2. Natural mortality

M is a vital parameter in fish stock future projections. We have known in fitting the SS model that a substantial higher scaling of SSB and recruitment as illustrated in Figure 27 resulted by changing M = 0.3 to M = 0.4. This M would have substantial impact on projections since M has an impact on SSB and recruitments. I would strongly recommend some sensitivity runs to be performed to investigate the impact of M on future projections of this stock.

3. Incorporate oceanic conditions

Future projections of fish stock are also dependent on oceanic conditions as fishery stock assessment and management are moving to ecosystem-based and multi-species approaches. Albacore tuna as a fish species in the North Pacific should be impacted by the oceanic conditions and regime shifts. I would recommend some sensitivity runs for this stock under different environmental conditions.

4. Figures presentation

This is a minor point on the presentation of figures. As an editor for several journals and author of several books, I was forced to be a little picky on the presentation styles on figures and tables. In this assessment report, there are 41 figures. Some are very informative and others are not. For example, the figures 35 and 36 were truncated on the top, but left a large empty space at the bottom. It would make the presentation more appealing by rescaling the y-axis limits. The same is the case for Figure 37, where the y-axis limits from 0.6 to 1.4 would make this figure better presented.

TOR 5. Suggest research priorities to improve our understanding of essential population and fishery dynamics and improvements to the assessment model.

For valid stock assessment, it is essential to collect adequate data based on the fish population dynamics to be used for an appropriate stock assessment model. Therefore the "data" and "model" are the two key components in the assessment process. The WG has identified six areas for future research priorities which included improving the age *and growth modeling, exploring spatial population pattern, improving CPUE data quality, investigating maturity and other data issues as well as improving SS3 models. I concur with the WG on these future research areas and encourage the WG to allocate appropriate resources to put it in action. Further to these areas, I would emphasize:*

1. **Growth heterogeneities**

Fish growth is sex-specific as well as regional-specific. For this species, it was evident that there was a sex-specific growth after maturity in the western Pacific Ocean, with males achieving larger sizes than females which would warrant a sex-specific growth model for this stock. Similarly, a regional growth difference should be investigated between eastern and western regions in the North Pacific.

2. **Movement**

It is known that Albacore are highly migratory as influenced by oceanic conditions with observed seasonal movements. However, the assessment was conducted assuming this stock was well-mixed and this seasonal movement rates were not explicitly modeled. Efforts should be given to examine the existing tagging data and plan further tagging studies so to estimate movement along with the estimation of natural mortality rate, growth in different regions and ground-truth abundance.

It is now a common practice for fish stock assessments to include the movement of fish in the process for estimating fish-stock abundance (Quinn et al. 1990). Bias can be reduced by incorporating migration and mixing. Quinn and Deriso (1999) comprehensively reviewed different forms of movement models, such as diffusion models (Hilborn 1987; Deriso et al. 1991; Fournier et al. 1998); generalized movement estimation (Ishii 1979, Sibert 1984, Anganuzzi et al. 1994; Xiao 1996, Xiao et al. 1999; Xiao and McShane 2000, Chen and Xiao 2006); and movement-estimation mark–recapture methods (Seber 1982, Brownie et al. 1985, Schwarz et al. 1993).

I recommend the WG to investigate these models for albacore tuna for better assessment.

3. **Natural mortality (M)**

M is fixed at 0.3 for current assessment and the sensitivity analysis using M = 0.4 gave a higher scaling of SSB and recruitment as well as a decreasing F-at-age. It is well-known in fish stock assessment that M is a key parameter. A plausible way to estimate M is to use tagging studies which again bring back the importance to analyze the existing tagging data as well as planning future statistically designed tagging studies as suggested above.

4. **Parameter uncertainty**

I have not seen any uncertainty estimates for any of the parameters in this assessment. Parameter uncertainty should be included especially for biomass projection and stock status, which can be generated from the likelihood approach or ADMB.

5. **Bias and bias correction of back-transformation from the estimated length-weight relationship**

This assessment used back transformation from estimated length-weight relationships as seen in page 10. It is known that there is a bias associated with this back-transformation and the bias is dependent on the estimated variance and correlation between the parameters as well as the specified length to be predicted with the smallest bias at the mean observed length as discussed in Chen (2004). In the situation of recruitment prediction, Chen (2004) has shown that the prediction bias could exceed 5%.

For this assessment, it is not clear from the assessment report whether the bias was corrected when the length-weight relationship was estimated. If not, I would recommend the WG to implement the bias correction. The bias correction under different scenarios has been developed accordingly and can be easily implemented as seen Hayes et al. (1995) and Chen (2004).

6. **Spatial CPUE standardization**

As commented on before, CPUE standardization should incorporate the spatial autocorrelation since fishery/survey data are dependent spatially. The statistical theory behind the simple GLM assumed that the observed CPUE data are independent. This is obviously invalid for fish population since it is common sense that fish move together, and the closer the observed fish abundance measurements, the more similar the measurements become. Chen and Leickly (2004) has shown that biases and resulted type-I error if ignoring this spatial autocorrelation. Nishida and Chen (2004) have outlined a plausible approach to incorporate this spatial autocorrelation into the GLM in CPUE standardization with an application to the yellowfin tuna (Thunnus albacares) longline CPUE data which should be readily applied to albacore tuna.

In addition, there is a special issue from Fisheries Research on using GLM to standardize fishery/survey data, which will serve as a reference for this type of analysis.

7. **Ecosystem based approach**

The effort to incorporate ecosystem indicators and environmental shifts in stock assessments is common. Albacore tuna as a fish species in the North Pacific should be impacted by the oceanic conditions and regime shifts. I would recommend the WG to investigate the possibility to use some of the ecosystem information to improve the assessment model. This information can be incorporated into stock-recruitment model. There are so many publications in the literatures in this direction. I just list a few of my publications for reference (**Chen 2001**). If the assessment team is interested in this approach, I will gladly provide guidance incorporating the fuzzy logic SR model into the assessment.

8. **Parameter confounding-the mathematical reiteration**

It is known that there is a parameter confounding between the steepness and other parameters. The re-parameterization of the original Ricker or Beverton-Holt stock-recruitment models to the Mace-Doonan formulation in SS may lead to numerical instabilities.

Steepness (h) and S_0 are more highly confounded in the Mace-Doonan formulation than the α and β parameters in the original Ricker or Beverton-Holt formulation. It can be mathematically proven that the steepness parameter *h* is confounded to the S_0 or R_0: The original Beverton-Holt stock-recruitment model is

1). $R_t = \dfrac{S_t}{\alpha + \beta S_t}$. Let this be rewritten as:

2). $R(S_t) = \dfrac{S_t}{\alpha + \beta S_t}$ since recruitment is a function of the stock size, where the α is the productivity parameter, representing the number of recruits per spawner at low numbers of spawners where the slope at the origin is $1/\alpha$. β controls the level of density dependence.

This definition was re-parameterized by a so-called steepness parameter, *h,* and reference-point type parameters at virgin population. The steepness parameter *h* is defined as the ratio of R_t to R_0 when $S_t = 0.2S_0$. The steepness parameter can also be interpreted as the fraction of the number of recruits in the virgin population (i.e. at time t_0) that is attained when its breeding biomass at time *t* is 20% of the virgin breeding biomass. Mathematically *h* is defined as:

3). $h = \dfrac{R(0.2S_0)}{R(S_0)} = \dfrac{R(0.2S_0)}{R_0}$.

It can be seen intuitively that with this re-parameterization, the parameters, *h*, S_0 and R_0 are highly confounded, which has made the parameter estimation impossible. Mathematically, this can be proven as follows. If *h* is independent of S_0 or R_0 from equation 3), then let us generate equation 3) more as:

4). $h(\lambda) = \dfrac{R(\lambda S_0)}{R(S_0)} = \dfrac{R(\lambda S_0)}{R_0}$ for any λ.

Then when λ=0.2, we get back to our traditional *h*, i.e. $h = h(0.2)$.
Therefore by re-arranging equation 4) as $R(\lambda S_0) = h(\lambda)R(S_0)$, for any λ and μ,

5). $R(\lambda\mu S_0) = R([\lambda\mu]S_0) = h(\lambda\mu)R(S_0)$

and

6). $R(\lambda\mu S_0) = R(\lambda[\mu S_0]) = h(\lambda)R(\mu S_0) = h(\lambda)h(\mu)R(S_0)$

Since the left side of equation 5) equals to the left side of equation 6), both the right sides should be equal, which leads to:

7). $h(\lambda\mu)R(S_0) = h(\lambda)h(\mu)R(S_0)$

This implies $h(\lambda\mu) = h(\lambda)h(\mu)$. Mathematically, $h(\lambda)$ should have the form of $h(\lambda) = \lambda^{\kappa}$ where κ is a constant.
Then from equation 3), $R(0.2S_0) = 0.2^{\kappa} R(S_0) = R_0$, i.e. the recruits of $R(0.2S_0)$ is proportional to, R_0 and we know from BH model this is not true. Therefore the definition

of steepness parameter in equation 3) is not independent of R_0 and is instead a function of R_0, which cannot then be estimated independently.

Another way to eliminate this confounding effect is to re-parameterize the SR using the management parameters as illustrated in Schnute and Kronlund (1996, 2002) or Schnute and Richards (1998).

References

1. Anganuzzi, A., Hilborn, R., and Skalski, J.R. 1994. Estimation of size selectivity and movement rates from mark–recovery data. Can. J. Fish. Aquat. Sci. 51: 734–742.
2. Brownie, C., Anderson, D.R., Burnham, K.P., and Robson, D.S. 1985. Statistical inference from band-recovery data—a hand-book. 2nd ed. U.S. Fish Wildl. Serv. Resour. Publ. No. 156.
3. Chen, D. G. B. Hargreaves, Ware, D. M and Liu, Yingnan (2000). A Fuzzy logic model with Genetic Algorithms for analyzing fish stock-recruitment relationship, Canadian Journal of Fishery and Aquatic Sciences, 57:1878-1887.
4. Chen, D.G. (2001). Detecting Environmental Regimes in Fish Stock-Recruitment Relationships by Fuzzy Logic. Canadian Journal of Fishery and Aquatic Sciences, 58(11):2139-2148.
5. Chen, D.G. and Richard Leickly (2004). A Test for Spatially Correlated Data: an Alternative to the traditional t-test. In GIS/Spatial Analysis in Fishery and Aquatic Sciences. Edited by Nishida, T., Kailola, P, J. and Hollingworth, C. E. p223-240.
6. Chen, D.G. and Xiao, Y. (2006). A general model for analyzing data from mark-recapture experiment with an application to the Pacific halibut. Environmental and Ecological Statistics. 13:149-161.
7. Chen, D.G. (2004). Bias and bias correction in fish recruitment prediction. North American Journal of Fisheries Management, 24:724-730.
8. Deriso, R.B., Punsly, R.G., and Bayliff, W.H. 1991. A Markov model of yellowfin tuna in the eastern Pacific Ocean and some analyses for international management. Fish. Res. 11: 375–395.
9. Fournier, D.A., Hampton, J., and Sibert, J.R. 1998. MULTIFAN-CL: a length-based, age structured model for fisheries stock assessment, with application to South Pacific albacore, Thunnus alalunga. Can. J. Fish. Aquat. Sci. 55: 2105–2116.
10. Hayes, D. B., Brodziak, JKT and O'Gorman, JB. (1995). Efficiency and bias of estimators and sampling designs for determining length-weight relationship of fish. Canadian Journal of Fishery and Aquatic Sciences, 52:84-92.
11. Hilborn, R. 1987. Spatial models of tuna dynamics in the western Pacific: is international management of tuna necessary? In Modelling and management of resources under uncertainty. Edited by T.L. Vincent, Y. Cohen, W.J. Grantham, G.P. Kirkwood, and J.M. Skowronski. Lecture notes in biomathematics. No. 72. Springer-Verlag, Berlin. pp. 276–286.
12. Ishii, T. 1979. Attempt to estimate migration of fish population with survival parameters from tagging experiment data by the simulation method. Investig. Pesq. 43: 301– 317.
13. McGarvey, R. and Feenstra, J.E. 2002. Estimating rates of fish movement from tag recoveries: conditioning by recapture. Can. J. Fish. Aquat. Sci. 59:1054-1064.
14. Nishda, T, Chen, D. G. and Mohri, Masahiko. (2007). Fuzzy logic analysis for the spawner-recruitment relationship of bigeye tuna in the Indian Ocean incorporating the environmental regime shift. Ecological Modelling. 203: 132-140.
15. Nishida, T. and D. G. Chen. (2004). Incorporating spatial autocorrelation into the General Linear Model with an application to the yellowfin tuna (Thunnus albacares) longline CPUE data. Fisheries Research 70:265-274.
16. Quinn, T.J., II, and Deriso, R.B. 1999. Quantitative fish dynamics. Oxford University

Press, New York.
17. Quinn, T.J., II, Deriso, R.B., and Neal, P.R. 1990. Migratory catch-at-age analysis. Can. J. Fish. Aquat. Sci. 47: 2315–2327.
18. Schnute, J. T. and Kronlund, A. R. (1996). A management oriented approach to stock recruitment analysis. *Can. J. Fish. Aquat. Sci.*, 53:1281-1293.
19. Schnute, J. T. and Kronlund, A. R. (2002). Estimating salmon stock-recruitment relationships from catch and escapement data. *Can. J. Fish. Aquat. Sci.*, 59:433-449.
20. Schnute, J. T. and Richards, L. J. (1998). Analytical models for fishery reference points. *Can. J. Fish. Aquat. Sci.*, 55:515-528.
21. Schwarz, C.J., Schweigert, J.F., and Arnason, A.N. 1993. Estimating migration rates using tag recovery data. Biometrics, 49: 177–193.
22. Seber, G.A.F. 1982. The estimation of animal abundance and related parameters. 2nd ed. Griffin, London.
23. Sibert, J.R. 1984. A two-fishery tag attrition model for the analysis of mortality, recruitment, and fishery interaction. Tuna and Billfish Assessment Programme, South Pacific Commission, Noumea, New Caledonia. Tech. Rep. No. 13.
24. Xiao, Y. 1996. A framework for evaluating experimental designs for estimating rates of fish movement from tag recoveries. Can. J. Fish. Aquat. Sci. 53: 1272–1280.
25. Xiao, Y., and McShane, P. 2000. Estimation of instantaneous rates of fishing and natural mortalities from mark–recapture data on the western king prawn Penaeus latisulcatus in the Gulf St. Vin-cent, Australia, by conditional likelihood. Trans. Am. Fish. Soc. 129: 1005–1017.
26. Xiao, Y., Stevens, J.D., and West, G.J. 1999. Estimation of fishing and natural mortalities from tag experiments with exact or grouped times at liberty. Can. J. Fish. Aquat. Sci. 56: 868–874.

Appendix 1: Bibliography of materials provided for review

On November 22, 2011, I received three emails from Dr. Steve Teo, Southwest Fisheries Center, with file attachments:

1. The stock assessment report in pdf file from the first email: "STOCK ASSESSMENT OF ALBACORE TUNA IN THE NORTH PACIFIC OCEAN IN 2011", REPORT OF THE ALBACORE WORKING GROUP STOCK ASSESSMENT WORKSHOP.
2. A zipped file in the second email with seven pdf files:
    1) **"ISC_11_ALBWG-12_Kiyofuji_etal.pdf":** "Preliminary North Pacific albacore population analysis using VPA-2BOX and future projection using PRO-2BOX for 1966 – 20091" by Kiyofuji, H., Iwata, S., Kai, M., Ichinokawa, M., Matsumoto, T., Uosaki, K. and Takeuchi, Y., National Research Institute of Far Sea Seas Fisheries, 5-7-1 Orido, Shimizu, Shizuoka, Shizuoka 424-8633 JAPAN, Email: hkiyofuj@affrc.go.jp
    2) "**ISC_11_ALBWG-02_Well_etal.pdf":** "Age and growth of North Pacific albacore (Thunnus alalunga)", R. J. David Wells, Suzanne Kohin1, Steven L. H. Teo1, Owyn E. Snodgrass1, Koji, Uosaki2. NOAA Fisheries Southwest Fisheries Science Center, 8604 La Jolla Shores Drive,La Jolla, CA 92037, USA, National Research Institute of Far Seas Fisheries 5-7-1 Orido, Shimizu-ku, Shizuoka 424-8633, Japan, Email: David.Wells@noaa.gov
    3) "**ISC_10-3_ALBWG-08_Chen_etal.pdf":** "Standardized CPUE and catch-at-age time series of North Pacific albacore exploited by Taiwanese loongline fisheries, 1995-2008), by Chen et al.
    4) "**ISC_10_ALBWG-07_Kiyofuji&Uosaki.pdf": "**Revision of standardized CPUE for albacore caught by the Japanese pole and line fisheries in the northwestern North Pacific", by Kiyofuji, H and Uosaki, K., National Research Institute of Far Sea Seas Fisheries, Fisheries Research Agency, 5-7-1 Orido, Shimizu-ku, Shizuoka-shi, 424-8633 Japan
    5) "**ISC_10-3_ALBWG-04_Matsumoto.pdf": "**Abundance indices of north Pacific albacore by Japanese longline for SS3 and VPA analyses", by Takayuki Matsumoto
    6) "**ISC_10-3_ALBWG3-02_Teo_etal.pdf": "**Time series associated with albacore fisheries based in the Northeast Pacific Ocean", by Steven L. H. Teo2, Hui-Hua Lee3, and Suzanne Kohin2
    7) "**ISC_10-2_ALBWG-07_Chen_etal.pdf": "**Standardized CPUE trend and age composition of North Pacific albacore exploited by Taiwanese longline fisheries, 1995-2008", by Chiee-Young Chen1, Fei-Chi Cheng1 and Shean-Ya Yeh.
3. A zipped file in the third email with 3 pdf files:
    1) **"Annex_4_ISC11_ALBWG_Final.pdf"--37 pages:** "Annex 4 REPORT OF THE ALBACORE WORKING GROUP WORKSHOP", International Scientific Committee for Tuna and Tuna-like Species in the North Pacific Ocean, 12-19 October 2010, La Jolla, California, USA
    2) **"Annex_5_ALBWG_Nov2Dec_06.pdf"--72 pages: "**ANNEX 5 REPORT OF THE ALBACORE WORKING GROUP WORKSHOP, International

Scientific Committee for Tuna and Tuna-Like Species in the North Pacific Ocean, (November 28 – December 5, 2006, Shimizu, Japan)

3) **"Annex_9_ISC-ALBWG_2011_Stock_Assessment_Workshop_Final"-- 150 pages: "**STOCK ASSESSMENT OF ALBACORE TUNA IN THE NORTH PACIFIC OCEAN IN 2011". The same stock assessment report**.**

Appendix 2: Statement of Work

External Independent Peer Review by the Center for Independent Experts

Stock assessment of albacore tuna in the North Pacific Ocean

Scope of Work and CIE Process: The National Marine Fisheries Service's (NMFS) Office of Science and Technology coordinates and manages a contract providing external expertise through the Center for Independent Experts (CIE) to conduct independent peer reviews of NMFS scientific projects. The Statement of Work (SoW) described herein was established by the NMFS Project Contact and Contracting Officer's Technical Representative (COTR), and reviewed by CIE for compliance with their policy for providing independent expertise that can provide impartial and independent peer review without conflicts of interest. CIE reviewers are selected by the CIE Steering Committee and CIE Coordination Team to conduct the independent peer review of NMFS science in compliance the predetermined Terms of Reference (ToRs) of the peer review. Each CIE reviewer is contracted to deliver an independent peer review report to be approved by the CIE Steering Committee and the report is to be formatted with content requirements as specified in **Annex 1**. This SoW describes the work tasks and deliverables of the CIE reviewer for conducting an independent peer review of the following NMFS project. Further information on the CIE process can be obtained from www.ciereviews.org.

Project Description: Albacore tuna in the North Pacific Ocean (NPO) are harvested multi-nationally primarily using troll, pole-and-line, and longline gear. The U.S. has major troll and pole-and-line fleets based in Washington, Oregon, and California. An assessment of albacore tuna in the North Pacific Ocean was conducted by staff of the Pacific Islands Fisheries Science Center, the Southwest Fisheries Science Center, and collaborating scientists from members of the International Scientific Committee for Tuna and Tuna-like Species in the North Pacific Ocean (ISC), within the ISC's Albacore Working Group in FY 2011. Results of the 2011 assessment are more optimistic than the 2006 assessment because fishing mortality in 2006-2008 has decreased relative to 2002-2004 and because of new assumptions regarding growth in the 2011 assessment. Previous assessments used a VPA model with growth curve parameters derived from a study in the 1960s using relatively outdated aging techniques and a limited size range. The current assessment is based on an SS3 model with growth curve parameters derived from a recent study using modern aging techniques and a substantially larger range of fish sizes. The new growth curve, with a lower L_∞, resulted in a higher scaling of biomass and a more positive assessment of stock status.

The assessment provides the basis for scientific advice on the status of the North Pacific albacore stock and will be a key foundation for international management decisions of the Inter-American Tropical Tuna Commission and Western and Central Pacific Fisheries Commission and its Northern Committee, and domestic management decisions by the Pacific Fishery Management Council (PFMC). An independent peer-review of the assessment is essential. The Terms of Reference (ToRs) of the peer review are attached in **Annex 2**.

Requirements for CIE Reviewers: Three CIE reviewers shall conduct an impartial and independent peer review in accordance with the SoW and ToRs herein. CIE reviewers shall have expertise, working knowledge, and recent experience in various subject areas involved in the review: tuna biology; analytical stock assessment, including population dynamics theory, integrated stock assessment models, and estimation of biological reference points; and Stock Synthesis and AD Model Builder. Scientists who are employed by or have significant interactions with the Inter-American Tropical Tuna Commission (IATTC) and the Western and Central Pacific Fisheries Commission (WCPFC), and the Secretariat of the Pacific Community (SPC), should not be considered as reviewers. Scientists associated with the ISC also should be excluded as reviewers. Each CIE reviewer's duties shall not exceed a maximum of 10 days to complete all work tasks of the peer review described herein.

Location of Peer Review: Each CIE reviewer shall conduct an independent peer review as a "desk" review of the necessary documentation of the current assessment of albacore tuna in the NPO. Therefore, no travel is required.

Statement of Tasks: Each CIE reviewer shall complete the following tasks in accordance with the SoW and Schedule of Milestones and Deliverables herein.

<u>Prior to the Peer Review</u>: Upon completion of the CIE reviewer selection by the CIE Steering Committee, the CIE shall provide the CIE reviewer information (full name, title, affiliation, country, address, email) to the COTR, who forwards this information to the NMFS Project Contacts no later than the date specified in the Schedule of Milestones and Deliverables. The CIE is responsible for providing the SoW and ToRs to the CIE reviewers. The NMFS Project Contacts will provide the CIE reviewers with the background documents and reports of the current assessment and sensitivity analyses to be peer reviewed. Any changes to the SoW or ToRs must be made through the COTR prior to the commencement of the peer review.

<u>Pre-review Background Documents</u>: Two weeks before the peer review, the NMFS Project Contact will send (by electronic mail or make available at an FTP site) to the CIE reviewers the necessary background information and reports for the peer review. In the case where the documents need to be mailed, the NMFS Project Contact will consult with the CIE Lead Coordinator on where to send documents. CIE reviewers are responsible only for the pre-review documents that are delivered to the reviewer in accordance to the SoW scheduled deadlines specified herein. The CIE reviewers shall read all documents in preparation for the peer review.

Please note that supporting documentation for the review is confidential, and reviewers are not to circulate these documents.

<u>Desk Review</u>: Each CIE reviewer shall conduct the independent peer review in accordance with the SoW and ToRs, and shall not serve in any other role unless specified

herein. **Modifications to the SoW and ToRs can not be made during the peer review, and any SoW or ToRs modifications prior to the peer review shall be approved by the COTR and CIE Lead Coordinator.** The CIE Lead Coordinator can contact the Project Contact to confirm any peer review arrangements.

Contract Deliverables - Independent CIE Peer Review Reports: Each CIE reviewer shall complete an independent peer review report addressing each ToRs in accordance with the SoW. Each CIE reviewer shall complete the independent peer review according to required format and content as described in Annex 1. Each CIE reviewer shall complete the independent peer review addressing each ToR as described in Annex 2.

Specific Tasks for CIE Reviewers: The following chronological list of tasks shall be completed by each CIE reviewer in a timely manner as specified in the **Schedule of Milestones and Deliverables**.

1) Conduct necessary pre-review preparations, including the review of background material and reports provided by the NMFS Project Contacts in advance of the peer review.
2) Conduct an independent peer review in accordance with the ToRs (**Annex 2**).
3) No later than 6 December 2011, each CIE reviewer shall submit an independent peer review report addressed to the "Center for Independent Experts," and sent to Mr. Manoj Shivlani, CIE Lead Coordinator, via email to shivlanim@bellsouth.net, and to Dr. David Die, CIE Regional Coordinator, via email to ddie@rsmas.miami.edu. Each CIE report shall be written using the format and content requirements specified in Annex 1, and address each ToR in **Annex 2**.

Schedule of Milestones and Deliverables: CIE shall complete the tasks and deliverables described in this SoW in accordance with the following schedule.

10 November 2011	CIE sends reviewer contact information to the COTR, who then sends this to the NMFS Project Contact
15 November 2011	NMFS Project Contact sends the CIE Reviewers the report and background documents
16–30 November 2011	Each reviewer conducts an independent peer review as a desk review
6 December 2011	CIE reviewers submit draft CIE independent peer review reports to the CIE Lead Coordinator and CIE Regional Coordinator
20 December 2011	CIE submits the CIE independent peer review reports to the COTR
23 December 2011	The COTR distributes the final CIE reports to the NMFS Project Contact and regional Center Director

Modifications to the Statement of Work: Requests to modify this SoW must be approved by the Contracting Officer at least 15 working days prior to making any permanent substitutions. The Contracting Officer will notify the COTR within 10 working days after receipt of all required information of the decision on substitutions. The COTR can approve changes to the milestone dates, list of pre-review documents, and ToRs within the SoW as long as the role and ability of the CIE reviewers to complete the deliverable in accordance with the SoW is not adversely impacted. The SoW and ToRs shall not be changed once the peer review has begun.

Acceptance of Deliverables: Upon review and acceptance of the CIE independent peer review reports by the CIE Lead Coordinator, Regional Coordinator, and Steering Committee, these reports shall be sent to the COTR for final approval as contract deliverables based on compliance with the SoW and ToRs. As specified in the Schedule of Milestones and Deliverables, the CIE shall send via e-mail the contract deliverables (CIE independent peer review reports) to the COTR (William Michaels, via William.Michaels@noaa.gov).

Applicable Performance Standards: The contract is successfully completed when the COTR provides final approval of the contract deliverables. The acceptance of the contract deliverables shall be based on three performance standards:
(1) Each CIE report shall completed with the format and content in accordance with **Annex 1**,
(2) Each CIE report shall address each ToR as specified in **Annex 2**,
(3) The CIE reports shall be delivered in a timely manner as specified in the schedule of milestones and deliverables.

Distribution of Approved Deliverables: Upon acceptance by the COTR, the CIE Lead Coordinator shall send via e-mail the final CIE reports in *.PDF format to the COTR. The COTR will distribute the CIE reports to the NMFS Project Contact and Center Director.

Support Personnel:

William Michaels, Program Manager, COTR
NMFS Office of Science and Technology
1315 East West Hwy, SSMC3, F/ST4, Silver Spring, MD 20910
William.Michaels@noaa.gov Phone: 301-713-2363 ext 136

Manoj Shivlani, CIE Lead Coordinator
Northern Taiga Ventures, Inc.
10600 SW 131st Court, Miami, FL 33186
shivlanim@bellsouth.net Phone: 305-383-4229

Roger W. Peretti, Executive Vice President
Northern Taiga Ventures, Inc. (NTVI)

22375 Broderick Drive, Suite 215, Sterling, VA 20166
RPerretti@ntvifederal.com Phone: 571-223-7717

Key Personnel - NMFS Project Contact:

Dr. Steve Teo
Southwest Fisheries Science Center, 8604 La Jolla Shores Drive, La Jolla, CA 92037
Steve.Teo@noaa.gov Tel: 1-858-546-7179, Fax: 1-858-546-7003

Dr. Hui-hua Lee
Pacific Islands Fisheries Science Center, 2570 Dole Street, Honolulu, HI 96822
Huihua.Lee@noaa.gov Tel: 1-808-983-5352; Fax: 1-808-983-2902

Annex 1: Format and Contents of CIE Independent Peer Review Report

1. The CIE independent report shall be prefaced with an Executive Summary providing a concise summary of the findings and recommendations, and specify whether the science reviewed is the best scientific information available.

2. The main body of the reviewer report shall consist of a Background and Summary of Findings for each ToR in which the weaknesses and strengths are described, and Conclusions and Recommendations in accordance with the ToRs.

3. The reviewer report shall include the following appendices:

   Appendix 1: Bibliography of materials provided for review
   Appendix 2: A copy of the CIE Statement of Work

Annex 2: Terms of Reference for the Peer Review

Stock assessment of albacore tuna in the North Pacific Ocean

1. Review the assessment methods: determine if they are reliable, properly applied, and adequate and appropriate for the species, fisheries, and available data.

2. Evaluate the assessment model configuration, assumptions, and input parameters (fishery, life history, and spawner recruit relationships): determine if data are properly used, input parameters seem reasonable, models are appropriately configured, assumptions are reasonably satisfied, and primary sources of uncertainty accounted for.

3. Evaluate the adequacy of the sensitivity analyses in regard to completeness and incorporation of results.

4. Evaluate the adequacy, appropriateness, and application of the methods used to project future population status.

5. Suggest research priorities to improve our understanding of essential population and fishery dynamics and improvements to the assessment model.

Please note that supporting documentation for the review is confidential, and reviewers are not to circulate these documents.