Report to CIE
For ICCAT Bluefin Tuna Stock Assessment Meeting
July 22 to 31, Madrid, Spain

Dr. Din (DingGeng) Chen

International Pacific Halibut Commission

Executive Summary

As a member of the Center for Independent Experts (CIE), my general impression of this meeting was that it was well-organized and scientifically sound.

The meeting was organized in plenary format for all participants and divided into Eastern and Western subgroups. The contents for the general plenary were of interest to all participants, which included the CPUE standardization, stock assessment methods with discussion, and a report of progress on daily activities. The division of Eastern/Western groups was made due to the different stock status. The Western group tackled both the western stock assessment and methodological development, whereas the Eastern group worked mainly on the eastern stock assessment, due to data uncertainties prohibiting methodological development.

I participated in the Eastern group discussions and assisted with the group's CPUE standardization, assessment runs for the VPA-2Box, and the projection. In

addition, I was also called upon by the Western Group to help regarding some of its technical issues.

Based on my activities and impressions of this meeting, this report is organized into three parts: The first focusing on the meeting format; the second regarding the methods used in the meeting; and the third concentrating on the assessment of data. In each part, I describe my general impressions and findings, followed by my comments and recommendations.

1. Meeting Format

1.1. General impression

The meeting began on July 22, 2002, at the ICCAT Secretariat in Madrid, Spain, with participants from Canada, the European Community, Japan, Libya, Morocco, Tunise, USA, Chinese-Taipei, Malta, Turkey, and the ICCAT Secretariat (see Appendix I). Dr. Joseph Powers (USA) chaired as overall meeting coordinator, and Drs. Jean-Marc Fromentin (France) and Michael Sissenwine (USA) served as co-chairmen for the eastern and western stocks, respectively.

The meeting began in plenary session to review documents submitted by all national agencies regarding their catch data, farming, tagging, and CPUE series standardization. The plenary continued to the morning of July 23rd for the VPA stock assessment models. The details for the presentations and comments are summarized in the “Report of the ICCAT SCRS, Atlantic Bluefin Tuna Stock Assessment Session”, one of the submitted documents listed in Appendix 2.

After the July 23rd plenary, participants broke into Eastern and Western groups. The plenary session resumed every morning to report on and review the subgroups' progress.

1.2. Recommendations

1.2.1. Recommendation for visual presentation

I suggest that visual presentations (for example, PowerPoint) be used in future meetings. During the present sessions, many of the participants were confused while attempting to follow the presentations and discussions. By using visual presentations, the presenters would be better prepared to share their scientific data, thus more effectively engaging discussion and receiving comments.

1.2.2. Recommendation to train more analysts for assessment model runs

Within the Eastern Group, Dr. Laurence Kell was the only person working on the assessment model. Dr. Kell is an excellent analyst and is well-organized for all the assessment needs using the Microsoft Excel package. However, due to the extensive requirements for different assessment scenarios, he was under much pressure to get all these runs completed. I suggest a training session for more people in the Eastern Group that could be led by experts such as Dr. Kell. Such sessions should be completed prior to the meeting (within a day or two) for some of the national modelers with good technical and analytical background to expedite the assessment in the Eastern group.

Furthermore, it is important that the assessment procedures are fully understandable to others, particularly how the models perform when underlying assumptions are changed or violated.

2. Methods

2.1. CPUE Standardization

2.1.1. Questionable CPUE series standardization

CPUE standardization is the first step for the stock assessment VPA modeling. Then any questionable analyses and assumptions occurring standardization process may introduce additional biases or uncertainties to the assessment results, besides the uncertainties from the well-discussed data issues.

The methods adopted and used in this Working Group consisted of the generalized linear model, extended to include the random effects of some interaction terms (i.e. GLM/GLMM). The GLMM procedure is used to deal with the lack of time series independence between observations in catch rate (Cooke and Lankester 1996; Cooke 1997). Most of the analyses assume that the error distributions for this model are log-normal, delta lognormal, or negative binomial.

Use of these procedures is expected to capture the statistical distribution of the residuals in the CPUE data series, along with the effects of such temporal and spatial factors, such as year, month, and area, among others. Some of the series were found to deviate from the assumed distribution with bimodal and skewed residual distributions. Some of the analyses were revised to comply with this residual distribution (SCRS/2002/103)

I question the suitability of the GLM/GLMM adopted by SCRS to standardize the CPUE indices with the assumption that the CPUE data or model residuals are spatially independent within areas. This obviously deviates from the reality of fish populations. Fish populations are often spatially correlated, and a positive correlation can be intuitively expected since it is common that fish abundances at nearby sites are similar. High abundance areas will tend to correlate positively with other nearby high abundance sites, and vice versa.

This can be expected from most of the submitted documents (e.g. Figure 1 from SCRS/02/081; Figure 1 and 2 of SCRS/2002/103; Figure 1 of SCRS/01/020). However, this positive spatial correlation within areas was ignored in the standardization of CPUE data with the erroneous assumption adopted by SCRS with the GLM/GLMM procedures that the data within areas are independent.

It can be easily shown that by ignoring this spatial correlation, the variance of the mean (LSmean used as CPUE indices from SCRS) is smaller than the CPUE indices with the embedded spatial correlation (which should be adopted by SCRS). Then the CVs input to the VPA are smaller than they should be. It can be seen that if $I_j \, (j = 1, \cdots, n)$ are n CPUE data points, then:

$$\begin{aligned} Var(\bar{I}) &= Var\left(\frac{I_1 + \cdots + I_n}{n}\right) \\ &= \frac{1}{n^2}\left\{\sum_{j=1}^{n} Var(I_j) + 2 \times \sum_{j<k} Cov(I_j, I_k)\right\} \end{aligned} \qquad (2.1)$$

If $I_j \, (j = 1, \cdots, n)$ are supposed to be identically independently distributed with variance σ^2 (default assumption in the ICCAT CPUE standardization procedure), then

(2.2)
$$Var(I_j) = \sigma^2 \quad \text{for all } j = 1, \cdots, n$$
$$Cov(I_j, I_k) = 0 \quad \text{for all } j, k = 1, \cdots, n$$

In this situation, equation (2.1) with the erroneous assumption from equation (2.2) becomes

$$Var(\bar{I}_{no}) = Var\left(\frac{I_1 + \cdots + I_n}{n}\right) = \frac{1}{n^2}\left[\sum_{j=1}^{n} Var(I_j)\right] = \frac{\sigma^2}{n}.$$

However, with the embedded positive spatial correlation, i.e., $\mathrm{Cov}(I_j, I_k) \geq 0$ for all $j,\ k = 1, \cdots, n$, it can be easily seen from equation (2.1) that:

(2.3)
$$Var(\bar{I}_{yes}) \geq Var(\bar{I}_{no})$$

where $Var(\bar{I}_{yes})$ denotes the variance calculated with spatial correlation, and $Var(\bar{I}_{no})$ denotes the variance from ICCAT calculation.

In summary, the CVs inputted to the VPA model are smaller than they should be.

2.1.2. The consequence of the faulty CPUE indices for the VPA model

The consequence of this questionable CPUE standardization to the VPA model can be seen from the relationship of the inputted CPUE series and the VPA model likelihood function using the log-normal distribution as an example (page 13, Table 3, VPA-2box Version 3.0, User's Guide):

(2.4) $$-\ln L = \sum_i \sum_k \sum_y 0.5\left[\left(\frac{\ln\left(I_{iky} / \hat{I}_{iky}\right)}{\hat{\sigma}_{iky}}\right)^2 + \ln\left(\hat{\sigma}_{iky}\right)\right]$$

In (2.4), $\hat{\sigma}_{iky}$ is modeled as $\hat{\sigma}^2_{iky} = \left(Input_{iky} \times \hat{I}_{iky} \times v_{ik}\right)^2$, where $Input_{iky}$ are the inputted CVs and the v_{ik} are the weighting factors.

It is obvious from (2.4) that by ignoring the spatial correlation, the inputted CV series (which are smaller than they should be) will result in an erroneously larger (in absolute value) $\ln L$. That is why most of the VPA runs yielded so large an $\ln L$. The same logic is applied to the modeled AIC, AICc and χ^2 statistics.

In summary, the inputted CVs that ignore the spatial correlation do not affect the VPA model with equal weighting since the inputted CVs are not used in the VPA model fitting. However, they affect the VPA model with all other forms of weighting. The simple consequence of the erroneous inputted CV is that the values for the VPA likelihood function and the lack-of-fit statistics of AIC, AICc and χ^2 tend to be larger than they should be, implying that the assumed distribution and the VPA model do not fit the data. After incorporating the spatial correlation, the values of all these statistics should be decreased to correctly measure goodness of fit, as readily seen from the definition of these statistics (SCRS/02/86).

Further research incorporating the spatial dependence of CPUE data, as well as the impact of ignoring this spatial dependence (as adopted by SCRS) should be undertaken. In fact, it is not surprising to see from the outputs of all the VPA models that the model diagnostic statistics are so large. In my view, because the first step of the stock assessment, to standardize the CPUE, is questionable, the assessment based on these series for VPA modeling can also be misleading and may even prove meaningless in some cases.

2.1.3. An example

To investigate and illustrate the consequences of CPUE standardization that ignored spatial dependence, I approached some delegates hoping to acquire one or two of their CPUE data sets for this purpose. I found out that within SCRS, these data are confidential and cannot be shared among other delegates for research and validation purposes. Therefore, as an Independent Expert from the CIE (not to be confused with the CIA), I was not able to obtain the presented CPUE data from this meeting to illustrate this point.

Since Atlantic bluefin tuna (BFT) data are not for disclosure to the public, so I used Pacific halibut data[1] to demonstrate the result from (2.3). The data for this analysis are taken from the 1999 IPHC scientific survey conducted in northern British Columbia, Canada, and it covers survey station numbers 2040-2150 (Fig. 1). Since this is a single year's data, there are no interannual, area effects. The GLM model would be just:

$$CPUE_j = \mu + \varepsilon_j \quad (2.5)$$

where ε_j can be modeled as some suitable distribution, such as normal, log-normal, Poisson, etc. corresponding to the data distribution.

It can be seen from Figure 2 that the CPUEs (the indicator of fish abundance) are correlated with each other, with the higher CPUEs associated with higher CPUEs, and vice versa. The CPUEs are simply not independent, and they are not random samples. This is also true for BFT (Figure 5).

These CPUE data are not normally distributed (left plot of Figure 3), as discovered from SCRS for most of the BFT CPUE data. In fact, the distribution is highly skewed. However, the log transformed CPUE (right panel of Figure 3) behaved more normally than the un-transformed data. With the log-transformed data, the mean log-CPUE is 4.025, and the CV is 0.249.

To incorporate the spatial autocorrelation into the CPUE standardization, the geostatistical method (Cressie 1993; Chiles and Delfiner 1999) should be used. The core component of this method is the variogram model to obtain the covariance $Cov(I_j, I_k)$ from (2.1). Generally, the most commonly used variogram model is the spherical or Matheron model (Matheron 1970). In geostatistics, this model is as important as the normal distribution is to traditional statistics (Clark 2000). Other models are also as applicable, including the exponential and Gaussian models. Their mathematical formulations are as follows:

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[1] The CPUE data for that data is publicly available from my institution's webpage, at http://www.iphc.washington.edu.

(2.6)

$$\gamma(h)=\begin{cases}\gamma_0+\gamma_1\times\left[1-\exp\left(-\dfrac{h}{r}\right)\right] & \text{Exponential model}\\[2ex] \gamma_0+\gamma_1\times\left[1-\exp\left(\dfrac{h^2}{r^2}\right)\right] & \text{Gaussian model}\\[2ex] \gamma_0+\gamma_1\times\begin{bmatrix}\dfrac{1.5\times h}{r}-\dfrac{0.5\times h^3}{r^3} & h<r\\ 1 & h\geq r\end{bmatrix} & \text{Spherical model}\end{cases}$$

where γ_0 is the nugget effect, which represents a discontinuity at the origin of the variogram with amplitude γ_0, corresponding to unobserved small-scale variance and observation error; γ_1 is the sill or maximum level of heterogeneity and *r* is the range of influence, which is the distance beyond which there is practically no spatial correlation between data points. Consequently, the expression levels off to a constant magnitude at a distance greater than *r* represented by $\gamma_0+\gamma_1$, and is generally of the same magnitude as the statistical variance of the sample population.

For these halibut CPUE data, the fitted variogram model can be seen from Figure 4a. From this plot, one can conclude that the CPUEs for stations within 1.35 degree are not independent. Figure 4b shows the covariance structure as a function of distance and Figure 4c the correlation structure as a function of the distance. Both figures demonstrate that the CPUEs are correlated with the neighboring CPUEs.

After incorporating this spatial correlation the estimated CV is 0.418, which is higher than the CV (0.249) derived from ignoring the spatial correlation.

2.1.3. A proposal

On the last day of this meeting, Prof. Isik Oray from Turkey (Faculty of Fisheries-University of Istanbul) and I proposed to jointly investigate the CPUE standardization procedures incorporating spatial correlation for two purposes. One was to develop an improved procedure for the CPUE standardization, and the other to fill the gap of no CPUE indices from the Eastern side of Mediterranean Sea, where there are no usable CPUE indices.

Prof. Oray is working on putting the raw data together and with the detailed descriptions of the fisheries and biological background. We hope to have a working paper for next meeting.

2.1.4. Further recommendation for investigation of CPUE

Besides the spatial autocorrelation, I recommend that the working Group review methods of developing, standardizing, and evaluating the usefulness of CPUE series as indices of abundance. Further investigation should be conducted for the random effects on which interaction terms from the factors of year, month, area and how these terms should be included as random effects.

In analyses with zero catches in the CPUE data, a common procedure is to add a constant of about 10% of the average value to all of the CPUE data and take the natural logarithm of the result (e.g., SCRS 02/103; SCRS 02/108; SCRS 02/109). I recommend that the Group further investigate the logistics and sensitivity of this procedure. My research (Chen and Pounds, 1998), investigating the chemical interaction from toxicological data for chemical mixtures, indicated that the conclusions are very sensitive with this added small constant. With slight change of this added constant (say, from 10% to 8% or 11%), the conclusions could be from a significant model to non-significant model, and visa verse.

In fact, the zero observation can be modeled from other distributions, such as Poisson, and negative binomial, among others. Further analysis to compare the statistical properties of these various approaches is required to develop recommendations on how to address zero catches in CPUE data.

2.2. Mixing

2.2.1. Management consequence of mixing and recommendation

The assessment of North Atlantic bluefin tuna has been traditionally conducted based on two separate stocks in the north Atlantic: one on the western side and the other on the eastern side of the Atlantic (including the Mediterranean Sea). It has been also assumed that the mixing of the two stocks is negligible, and that management decisions for the western Atlantic stock have no effect on the eastern Atlantic stock, and vice versa. However, recent tagging experiments have demonstrated that the migratory patterns of these two stocks are much more complex and extensive than has been previously assumed. SCRS/02/088 stated that “if the degree of mixing of the two stocks is greater than the 1-2% which is currently assumed, then the recovery of the depleted western stock might not be possible under the existing management regime and additional management measures might be needed”.

To realistically quantify the mixing rates, tagging data from ICCAT should be properly analyzed. SCRS/02/93 briefly described the tagging experiments conducted from ICCAT. The ICCAT electronic tag database has documented more than 16,000 fish tagged-and-released over 50 years. This database has not been fully mined (SCRS/02/93). I recommend that the SCRS investigate this database for a proper analysis.

2.2.2. Recommended models for the analysis of ICCAT tagging database

In fish stock assessments undertaken to estimate fish-stock abundance, the incorporation of fish movement (Quinn et al. 1990; Fournier et al. 1998; Punt et al. 2000) becomes more plausible as spatial models become computationally feasible. Biases and uncertainties can be reduced if models incorporate migration and mixing.

To analyze the tagging data, Quinn and Deriso (1999) comprehensively reviewed different forms of movement models, including: the diffusion model (Hilborn 1987; Deriso et al. 1991; Fournier et al. 1998); the generalized movement estimation (Ishii 1979, Sibert 1984, Anganuzzi et al. 1994; Xiao 1996, Xiao et al. 1999; Xiao and McShane 2000); and the movement-estimation mark–recapture methods (Seber 1982, Brownie et al. 1985, Schwarz et al. 1993).

Doubts have been raised in SCRS that the data quality and tag non-reporting rate could be major obstacles in using this database. However, based on my observations and impressions while attending this assessment meeting, I believe that the quality of the tagging database might be sounder than the CPUE and the catch data presently used for the VPA stock assessment model.

If tag non-reporting is the main concern for the SCRS, recent development for mark-recapture analysis can be used to deal with this problem, as described by McGarvey and Feenstra (2002). The authors discuss how the analysis can deal with problems of nonreporting. An estimator of movement rates can be developed that does not use the number originally tagged but is fitted to the relative proportions recaptured in each cell in each time step subsequent to release. With the use of the proportion, rates of processes occurring in the tag-release spatial cell, such as short-term tagging mortality and survival, cancel out from the predicted likelihood probabilities. Similarly, rates in the recapture cell for processes of ongoing tag loss, natural mortality, and tag nonreporting, if they can be reasonably approximated as being uniform across cells, also cancel out.

2.2.3. Recommendation for implementation of new mass-marking experiments

Another recommendation is for ICCAT to implement new mass-marking experiments, in order to estimate mixing rates and the associated fishing mortality. However, before doing this, I suggest undertaking some investigations of the existing tagging database to ascertain what can be done with the existing data in order to develop a new design for the future mass-marking. This would include an effective design for tagging mortality, tagging shedding, reporting rates to get a higher confidence level in stock assessment, migration patterns, and growth.

2.2.4. Simple idea to analyze the SCRS tagging database

Since I do not have a detailed background on the SCRS database and have not seen any tagging data, I cannot conclude much. However, I emphasize and foresee that we may be able to conduct some useful analyses with the tagging database for at least some independent and parallel modeling, along with the VPA assessment model. Instead of attempting solely to create and imagine all types of scenarios, we might be able to use real data to gauge the plausibility of some outcomes.

From what I observed at the meeting, the Committee seems to worry a lot about the tag reporting rate and its confounding with fishing mortality, which is, of course, related to catch. Provided that the reporting rate is the same for the two regions, even if they change with time, they have no appreciable (in the sense that enough releases and recaptures are achieved and are available) effects. If we are modeling two regions (Western/Eastern) and if the two regions have different rates of reporting, then with a bit of mathematical manipulation, we might be able to estimate a ratio.

The movement rates can be estimated as a 2x2 matrix of constants (if few data are available), or as 2x2 matrix for each year (if there are plenty of data).

3. Data issues

I reiterate here the aforementioned recommendations on data issues such as reported catches, catch-at-size, and CPUE indices, particularly the quality of the catch, effort, and catch-at-size data available for conducting quantitative assessment, especially in the eastern Atlantic. It is clear from this committee that many of the model inputs on the assessment are uncertain or even biased, including doubts over the catches in recent years, the absence of the size distributions for many fisheries and the uncertainties of available CPUE indices as measures of overall stock abundance. These uncertainties or biases make it difficult to develop a quantitative stock assessment and easier to forward misleading recommendations.

3.1. Recommendation to start observer programs

I strongly recommend that onboard observer programs be initiated and implemented as soon as possible to monitor catches and catch-at-size data. This recommendation is based on the fact that the catches are sometimes misreported and the catches-at-size can be based on small sample sizes (for example, the catch-at-size data from Mexico are based on only two fish). With the implementation of the program, the quality of the data would be enhanced on catches and catch-at-size. This program would also be useful for collecting data on discards and on their subsequent estimation, such that discarding effects can be fully included in the stock assessment. This program can be also used to achieve sufficient sampling on catches and discards, and thus avoid the need for pooling or substitution.

3.2.Recommend to initiate ICCAT scientific survey

Finally, I recommend that ICCAT scientific survey programs for fishery independent CPUE indices be initiated, whereby the ICCAT would have independent patterns for the reported CPUE indices, as the original data from every nation's CPUE indices are not currently available to the Commission.

In addition to serving as a new CPUE series for stock assessments, the survey results can be used to compare and contrast abrupt changes in fish populations or to mediate for differences in national CPUE series.

References:

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. **5**1: 734–742.

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.

Chen, D.G. and Pounds, J.G. 1998. A non-linear isobolgram model with Box-Cox transformation to both sides for chemical mixtures. International Journal of Environmental Health Perspectives, Vol. 106, Supplement 6, 1367-1371.

Chiles, J. Delfiner, P. 1999. Geostatistics: modeling spatial uncertainty. John Wiley & Sons, Inc. New York.

Clark, I. 2000. Practical Geostatistics. Elsevier Applied Science, London. The early version of 1979 is free available on line at http://uk.geocities.com/drisobelclark/practica.html

Cooke, J.G. 1997. (Rev.) A procedure for using catch-effort indices in bluefin tuna assessments. Int. Comm. Conserv. Atl. Tunas Col. Vol. Sci. Pap. 46(2):228-232.

Cooke, J.G. and Lankester, K. 1996. Consideration of statistical models for catch-effort indices for use in tuning VPAs. Int. Comm. Conserv. Atl. Tunas Col. Vol. Sci. Pap. Vol. 45-2:125-131.

Cressie, N.A.C. 1991. Statistics for Spatial Data. John Wiley & Sons, Inc, New York.

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.

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. **5**5: 2105–2116.

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.

Hilborn, R. 1990. Determination of fish movement patterns from tag recoveries using maximum likelihood estimators. Can. J. Fish. Aquat. Sci. **4**7: 635–643.

Ishii, T. 1979. Attempt to estimate migration of fish population with survival parameters from tagging experiment data by the simulation method. Investig. Pesq. **4**3: 301–317.

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.

Matheron. G. 1970. La theorie des variables regionalisees et ses applications. Tech rep fascicule 5, Les Cahiers du Centre de Morphologie Mathematique de Fontainebleu, Ecole Superieure des Mines de Paris.

Punt, A.E., Pribac, F., Walker, T.I., Taylor, B.L., and Prince, J.D. 2000. Stock assessment of school shark, *Galeorhinus galeus*, based on a spatially explicit population dynamics model. Mar. Freshw. Res. **5**1: 205–220.

Quinn, T.J., II, and Deriso, R.B. 1999. Quantitative fish dynamics. Oxford University Press, New York.

Quinn, T.J., II, Deriso, R.B., and Neal, P.R. 1990. Migratory catch-at-age analysis. Can. J. Fish. Aquat. Sci. **4**7: 2315–2327.

Schwarz, C.J., Schweigert, J.F., and Arnason, A.N. 1993. Estimating migration rates using tag recovery data. Biometrics, **4**9: 177–193.

Seber, G.A.F. 1982. The estimation of animal abundance and related parameters. 2nd ed. Griffin, London.

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.

Xiao, Y. 1996. A framework for evaluating experimental designs for estimating rates of fish movement from tag recoveries. Can. J. Fish. Aquat. Sci. **5**3: 1272–1280.

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. Vincent, Australia, by conditional likelihood. Trans. Am. Fish. Soc. **12**9: 1005–1017.

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. **5**6: 868–874.

Figures

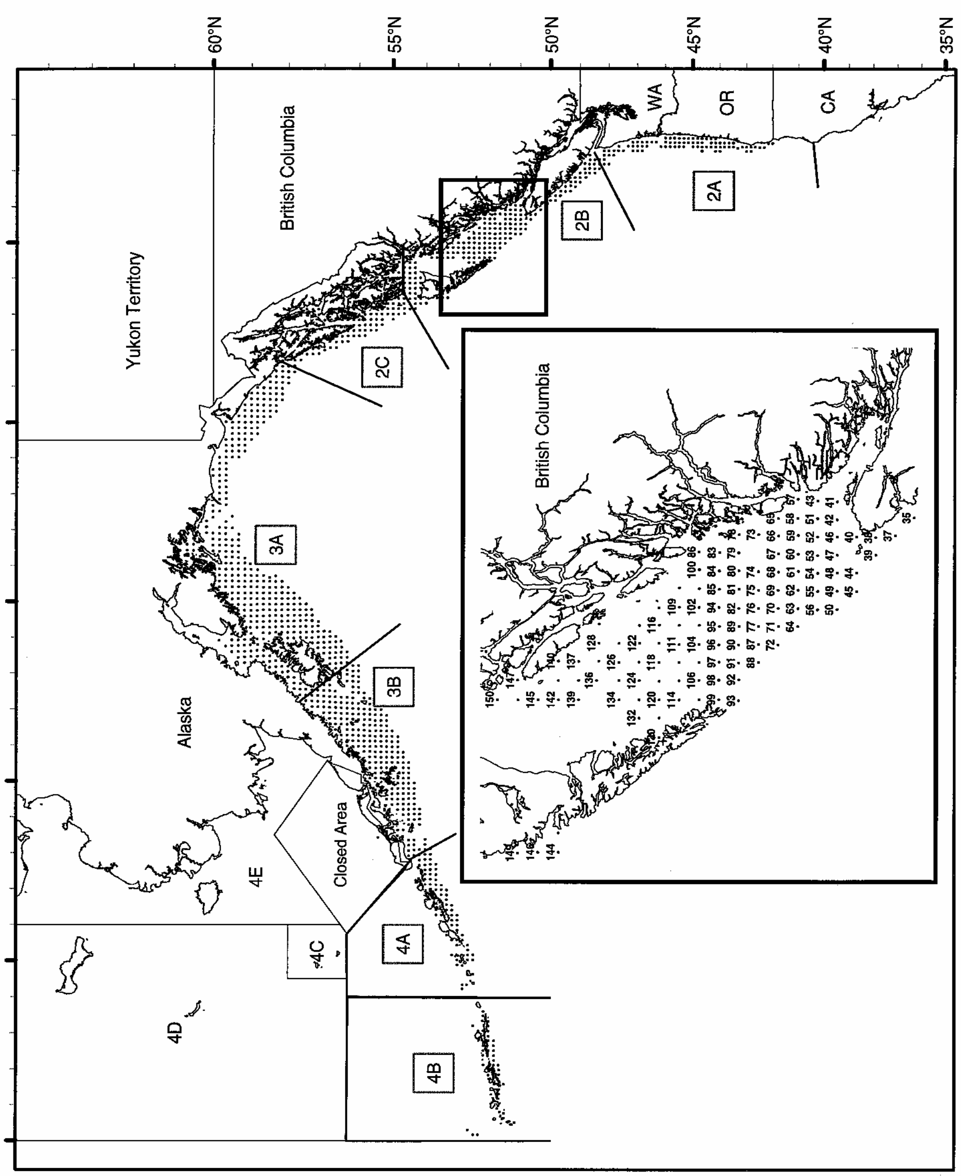

Figure 1: IPHC scientific survey map with the data from northern British Columbia, Canada in the insert.

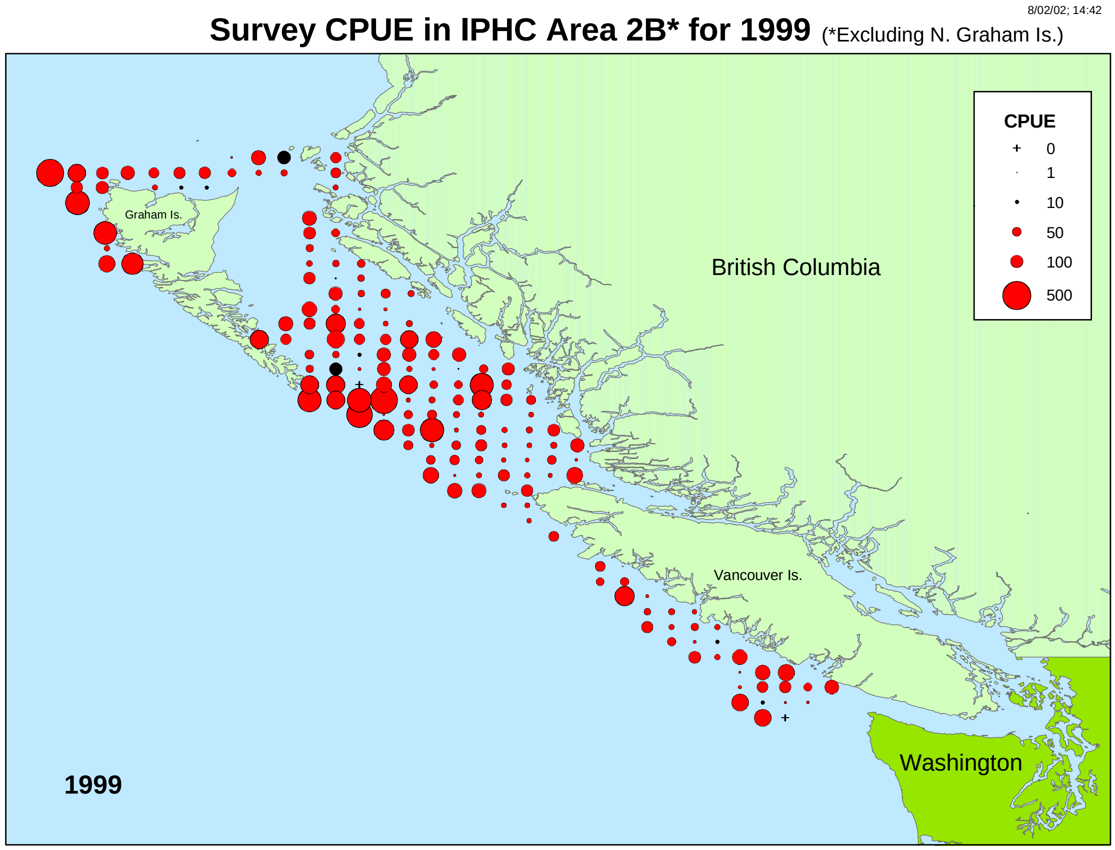

Figure 2: The CPUE distribution of 1999 scientific survey

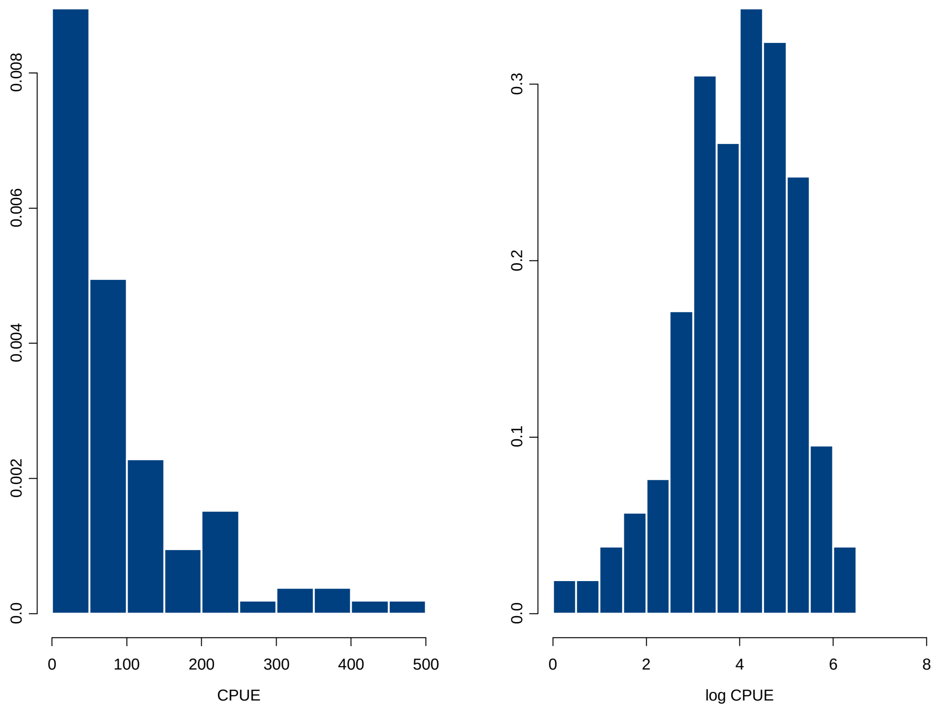

Figure 3: Distribution of CPUE (left plot) and the log-CPUE (right plot).

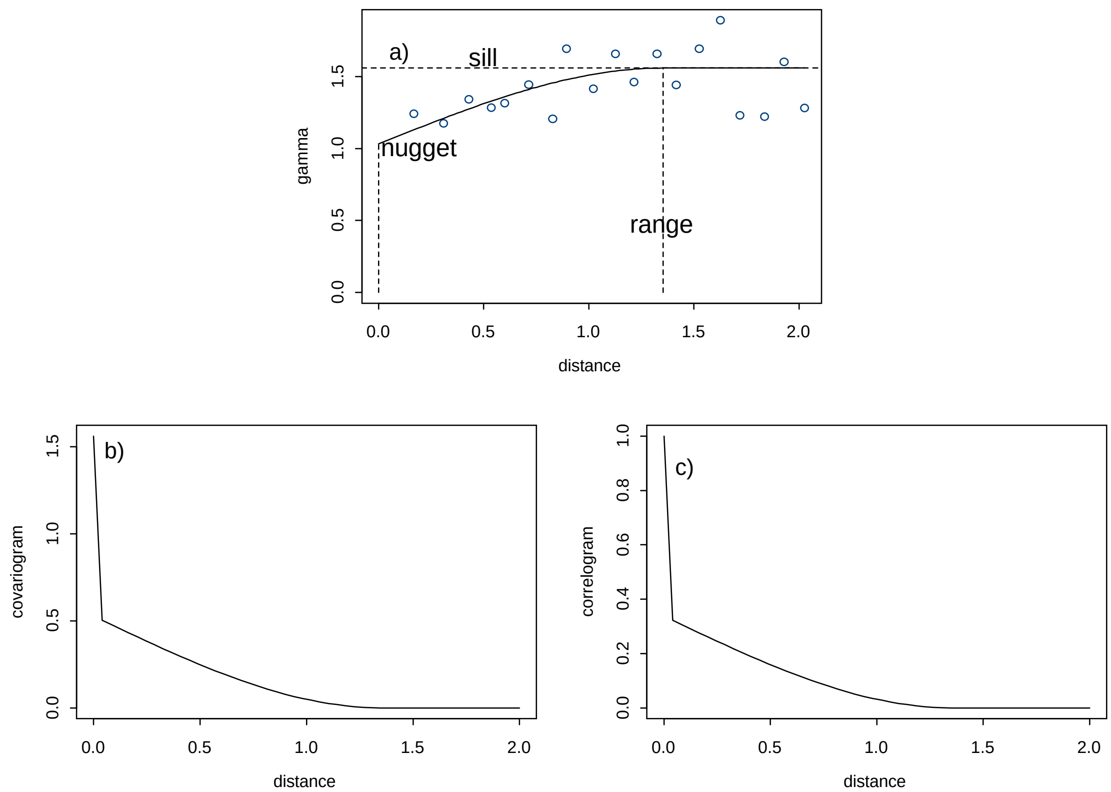

Figure 4: The variogram (plot a), covariogram (plot b) and correlogram (plot c) for the 1999 CPUE to show spatial autocorrelation based on the data from Figure 2. The distance is in the unit of degree.

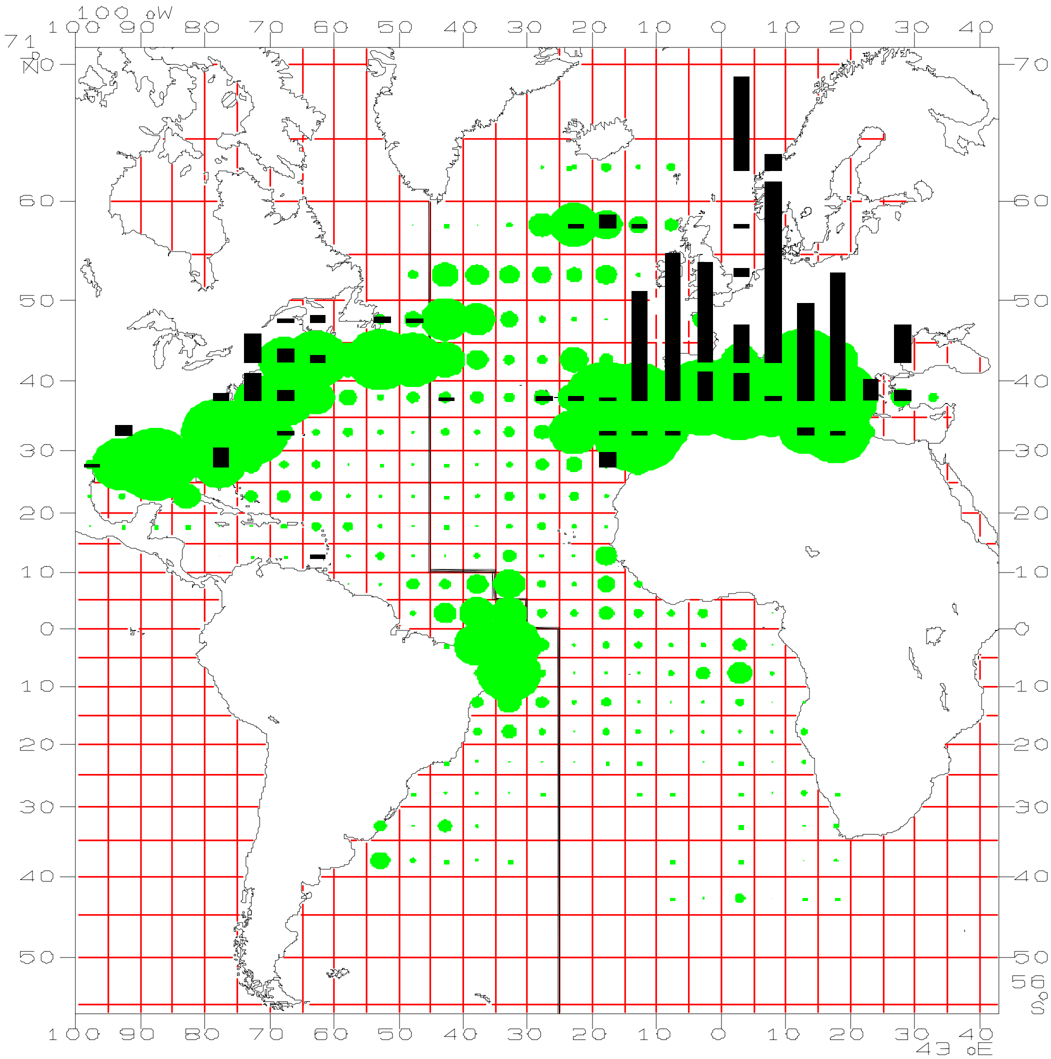

Figure 5 (BFT-Fig. 1): Distribution of Atlantic bluefin catches by longline (circles) and surface gears (bars) for the period 1950-1999.

Appendices:

Appendix 1: List of Participants

CANADA

Neilson, John D. Department of Fisheries and Oceans, Biological Station, St. Andrews, New Brunswick E5B 2L9. Tel: +1 506 529 5913, Fax: +1 506 529 5862. E-Mail:neilsonj@mar.dfo-mpo.gc.ca

EUROPEAN COMMUNITY

Arrizabalaga, Haritz. AZTI, Txatxarramendi Ugartea z/g, 48395 Sukarrieta (Bizkaia) – ESPAÑA. Tel: +34 94 602 94 00, Fax: +34 94 687 00 06. E-Mail:harri@suk.azti.es

de la Serna Ernst, Jose Miguel. Ministerio de Ciencia y Tecnología (MCYT), Instituto Español de Oceanografía, Apartado 285/ Puerto Pesquero s/n, 29640 - Fuengirola, Málaga – ESPAÑA. Tel: +34 952 476 955, Fax: +34 952 463 808. E-Mail:delaserna@ma.ieo.es

Mejuto García, Jaime. Ministerio de Ciencia y Tecnología (MCYT), Instituto Español de Oceanografía, Muelle de Animas, s/n, Apartado 130, 15080 A Coruña – ESPAÑA. Tel: +34 981 205 362, Fax: +34 981 229 077. E-Mail:jaime.mejuto@co.ieo.es

Ortiz de Urbina, Jose Maria. Ministerio de Ciencia y Tecnología (MCYT), Instituto Español de Oceanografía, Apartado 285, 29640 Fuengirola, Malaga –ESPAÑA. Tel: +34 952 476 955, Fax: +34 952 463 808. E-Mail:urbina@ma.ieo.es

Rodríguez-Marin, Enrique. Ministerio de Ciencia y Tecnología (MCYT), Instituto Español de Oceanografía, Promontorio de San Martín, s/n. 39004 Santander – ESPAÑA. Tel: +34 942 29 10 60, Fax: +34 942 27 50 72. E-Mail:rodriguez.marin@st.ieo.es

Fromentin, Jean Marc. IFREMER - Centre de Recherches Halieutique Méditerranéenne et Tropical, BP 171 - Bd. Jean Monnet, 34203 Sète Cedex – FRANCE. Tel: +33 4 99 57 32 32, Fax: +33 4 99 57 32 95. E-Mail:jean.marc.fromentin@ifremer.fr

Ferreira de Gouveia, Lidia. Chefe de Divisao De Tecnicas E Artes de Pesca, Direcçao Regional das Pescas, Estrada da Pontinha, 9000 - Funchal, Madeira – PORTUGAL. Tel: +351 291 203200
Fax: +351 291 229691. E-Mail:lidiagouveia@hotmail.com

Kell, Laurence. CEFAS - Lowestoft Laboratory, Pakefield Road, Lowestoft NR33 OHT - UNITED KINGDOM. Tel: +44 1502 524 257, Fax: +44 1502 524 511. E-Mail: l.t.kell@cefas.co.uk

JAPAN

Hiramatsu, Kazuhiko. National Research Institute of Far Seas Fisheries, 5-7-1, Chome Orido, Shimizu-shi - Shizouka 424-8633. Tel: +81 543 366 014, Fax: +81 543 359 642. E-Mail: hira@affrc.go.jp

Kamikawana, Kazuhide. International Division, Federation of Japan Tuna , Fisheries Co-Operative Associations, 2-3-22 Kudankita, Chiyoda-Ku, Tokyo 102-0073. Tel: +81 3 3264 6167, Fax: +81 3 3234 7455. E-Mail:section3@intldiv.japantuna.or.jp

Miyabe, Naozumi. National Research Institute of Far Seas Fisheries, 5- 7-1, Chome Orido, Shimizu-shi - Shizuoka 424-8633. Tel: +81 543 366 045, Fax: +81 543 359 642. E-Mail: miyabe@fra.affrc.go.jp

Miyake, Makoto P. Scientific Advisor, Federation of Japan Tuna Fisheries Co-operative Associations, 2-3-22 Kudankita, Chiyoda-Ku, Tokyo 102 0073. Tel: +81 422 46 3917, Fax: +81 422 43 7089. E-Mail:p.m.miyake@gamma.ocn.ne.jp

Suzuki, Ziro. National Research Institute of Far Seas Fisheries, 5-7-1, Chome Orido, Shimizu-shi - Shizouka 424-8633. Tel: +81 543 366 041, Fax: +81 543 359 642. E-Mail: zsuzuki@fra.affrc.go.jp

Takeuchi, Yukio. Mathematical BilogyDivision -Pelagic Resource Section, National Research Institute of Far Seas Fisheries, 5-7-1, Chome Orido, Shimizu-shi, Shizuoka 424-8633. Tel: +81 543 366 039, Fax: +81 543 359 642. E-Mail:yukiot@fra.affrc.go.jp

LIBYA

Omar-Tawil, Mohamed Y. Marine Biology Center, P.O. Box 30830 Tajura, Tripoli. Tel: +218 21 369 001, Fax: +218 21 369 002. E-Mail:omartawil@yahoo.com

MAROC

Srour, Abdellah. Directeur, Centre Régional de l'INRH à Nador, B.P. 493, Nador. Tel: +212 56 60 08 69, Fax: +212 56 60 38 28. E-Mail:srour@inrhnador.gov.ma

TUNISIE

Hattour, Abdallalh. Institut National des Sciences et Technologies de la Mer, 28 Rue du 2 Mars 1934, 2025 Salambô. Tel: +216 71 730 420, Fax: +216 71 732 622. E-Mail: abdallah.hattour@instm.rnrt.tn

UNITED STATES

Apostolaki, Panayiota. Renewable Resources Assessment Group, Department of Environmental Sciences and Technology, RSM, Prince Consort Road - Imperial College, London, SW7 2BP - UNITED KINGDOM. Tel: +44 20 758 95111, Fax: +44 20 758 95319. E-Mail: y.apostolaki@ic.ac.uk

Babcock, Elisabeth. Wildlife Conservation Society, Marine Conservation Program, 2300 Southern Blvd, Bronx, New York 10460. Tel: +1 718 220 2151, Fax: +1 718 364 4275. E-Mail: bbabcock@wcs.org

Brown, Craig A. NOAA Fisheries, Southeast Fisheries Center, Sustainable Fisheries Division, 75 Virginia Beach Drive, Miami, Florida 33149. Tel: +1 305 361 4590, Fax: +1 305 361 4562. E-Mail: craig.brown@noaa.gov

Brown, Stephen K. Office of Science & Technology, NOAA – Fisheries, 1315 East-West Hwy, Silver Spring, MD 20910. Tel: +1 301 713 2363, Fax: +1 301 713 1875. E-Mail: Stephen.K.Brown@noaa.gov

Butterworth, Doug S. Professor -Department of Mathematics and Applied Mathematics, University of Cape Town, Rondebosch 7701 - SOUTH AFRICA. Tel: +27 21 650 2343, Fax: +27 21 650 2334. E-Mail:dll@maths.uct.ac.za

Chen, Ding Geng. Research Scientific/Quantitative Analyst, International Pacific Halibut Commission, University of Washington - PO Box 95009, Seattle, Washington, WA 98145-2009. Tel: +1 425 990 5884, Fax: +1 206 632 2983. E-Mail:Din@iphc.washington.edu

Cordue, Patrick. Director, Innovative Solutions Limited, PO Box 22235, Wellington -NEW ZEALAND. Tel: +64 4 479 0151, E-Mail:patrick.cordue@isl-solutions.co.nz.

Hester, Frank J. LMR Fisheries Research,Inc., 2726 Shelter Is.Dr.# 369, San Diego, California 92106. Tel: +1 858 792 6515, Fax: +1 858 792 6519. E-Mail:fhester52@aol.com

McAllister, Murdoch K. Renewable Resources Assessment Group, Deparment of Environmental Sciences and Technology, RSM Building Prince Consort Road - Imperial College, London SW7 2BP - UNITED KINGDOM. Tel: +44 207 594 9330, Fax: +44 207 589 5319. E-Mail: m.mcallister@ic.ac.uk

Mohn, Robert. Marine Fish Division, Bedford Institute of Oceanography, PO Box 1006, Dartmouth, Nova Scotia B2Y 4A2 – CANADA. Tel: +902 426 4592, Fax: +902 426 1506. E-Mail: mohnr@mar.dfo-mpo.gc.ca

Ortiz, Mauricio. NOAA Fisheries, Southeast Fisheries Center, Sustainable Fisheries Division, 75 Virginia Beach Drive, Miami, Florida. 33149. Tel: +1 305 361 4288, Fax: +1 305 361 4562, E-Mail:mauricio.ortiz@noaa.gov

Powers, Joseph E. NOAA Fisheries, Southeast Fisheries Science Center, 75 Virginia Beach Drive Miami, Florida 33149-1099. Tel: +1 305 361 4295, Fax: +1 305 361 4219. E-Mail: joseph.powers@noaa.gov

Punt, André E. School of Aquatic and Fishery Sciences, University of Washington, Box 355020 Seattle, WA 98195-5020. Tel: +1 206 221 6319, Fax: +1 206 685 7471. E-Mail: aepunt@v.washington.edu

Scott, Gerald P. NOAA- Fisheries, Southeast Fisheries Science Center, Sustainable Fisheries Division, 75 Virginia Beach Drive, Miami, Florida. 33149-1099. Tel: +1 305 361 4220, Fax: +1 305 361 4219. E-Mail:gerry.scott@noaa.gov

Sissenwine, Michael P. Northeast Fisheries Science Center, Office of the Science & Research Director, NOAA/NMFS - 166 Water St. Woods Hole, Massachussetts 02543-1026. Tel: +1 508 495 2233, Fax: +1 508 495 2232. E-Mail:michael.sissenwine@noaa.gov

Observers

Non Contracting Cooperating Parties

CHINESE-TAIPEI

Hsu, Chien-Chung. Institute of Oceanography, National Taiwan University, P.O. Box 23-13, Taipei. Tel: +886 2 3362 2987, Fax: +886 2 2366 1198. E-Mail:hsucc@ccms.ntu.edu.tw

Non-contracting Parties

MALTA

Farrugia, Andreina. Ministry of Agriculture and Fisheries, Barriera Wharf – Valletta. Tel: +356 21 655 525, Fax: +356 21 659 380. E-Mail:andreina.farrugia@magnet.mt

TURKEY

Oray, Isik K. Faculty of Fisheries -University of Istambul, Ordu Cad. nº 200, 34470 Laleli – Istanbul. Tel: +90 212 514 0388, Fax: +90 212 514 0379. E-Mail:isikoray@yahoo.com

SCRS CHAIRMAN

Pereira, Joao Gil. SCRS Chairman - Universidade dos Açores, Departamento de Oceanografia e Pescas, 9900 - Horta, Açores – PORTUGAL. Tel: +351 292 200 431, Fax: +351 292 200 411. E-Mail: pereira@notes.horta.uac.pt

ICCAT SECRETARIAT

Restrepo, Victor
Kebe, Papa
Palma, Carlos

C/ Corazón de María, 8 - 6ª planta. 28002 Madrid. Tel: +34 91 416 5600, Fax: +34 91 415 2612. E-Mail: info@iccat.es

Appendix 2: List of Documents

SCRS/02/010. GFCM-ICCAT Meeting Report. Anon.

SCRS/02/036. General review of bluefin tuna farming in the Mediterranean area . Miyake, P.M., J.M. de la Serna, A. di Natale, A. Farrugia, N. Miyabe, V. Ticina

SCRS/02/081. Updated standardized CPUE indices for Canadian bluefin tuna fisheries based on commercial catch rates . Porter, J.M., M. Ortiz, and S.D. Paul

SCRS/02/085. Preliminary results of aerial surveys of bluefin tuna in the western Mediterranean sea. Jean-Marc Fromentin, Henri Farrugio, Michele Deflorio and Gregorio De Metrio

SCRS/02/086. Specifications and clarifications regarding the ADAPT VPA assessment / projection computations carried out during the September 2000 ICCAT west Atlantic bluefin tuna stock assessment session.. Punt, A.E. and D.S. Butterworth.

SCRS/02/087. An initial application of the spatial structure framework for North Atlantic bluefin developed at the September 2001 bluefin mixing workshop using simple age-aggregated models. . Punt, A.E. and D.S. Butterworth.

SCRS/02/088. A scenario-based framework for the stock assessment of North Atlantic bluefin tuna taking into account trans-Atlantic movement, stock mixing and multiple fleets. Apostolaki P., E.A. Babcock and M. McAllister

SCRS/02/089. Standardized catch rates of bluefin tuna, thunnus thynnus, from the rod and reel/handline fishery off the northeast United States during 1980-2001. Brown, C.

SCRS/02/090. Standardized catch rates for large bluefin tuna, thunnus thynnus, from the U.S. pelagic longline fishery in the gulf of Mexico and off the florida east coast. . Cramer, J.

SCRS/02/091. Updated index of bluefin tuna (*Thunnus thynnus*) spawning biomass From Gulf of Mexico ichthyoplankton surveys. Scott, G., and S.C. Turner

SCRS/02/092. Distribution of western-tagged Atlantic bluefin tuna determined from implantable archival and pop-up satellite archival tags. Block, B., et al.

SCRS/02/093. Atlantic bluefin tuna: additional considerations on mixing on the feeding grounds . Frank Hester

SCRS/02/094. Sex-ratio by length-class of bluefin tuna (*Thunnus thynnus L.*) caught by Maltese Longliners.. Farrugia, A.

SCRS/02/095. Description of Maltese bluefin tuna (*Thunnus thynnus L.*) fisheries. Farrugia, A.

SCRS/02/096. Revision of historical catches of bluefin tuna made by Maltese longliners. Farrugia, A.

SCRS/02/097. Historical catch of bluefin tuna (*Thunnus Thynnus*) and little tuna (*E. Alletteratus*) from a Libyan trap net. Tawil, M.Y.

SCRS/02/101. Update of bluefin tuna catch-at-size database. Kebe, P., C Palma, J Cheatle

SCRS/02/102. Catch, effort and standardized catch per unit effort for the eastern Mediterranean blufin tuna stock caught by Taiwanese longline fishery up to 2001. Hsu, C., and H. Lee

SCRS/02/103. Standardized bluefin CPUE from the Japanese longline fishery in the Atlantic including those for mixing studies. Miyabe, N., and Y. Takeuchi

SCRS/02/104. Longterm fluctuations in bluefin tuna trap catches: Are they environmentally driven?. Ravier-Mailly C., and J.M. Fromentin

SCRS/02/107. New tendances in the Turkish bft fisheries in 2001-2002. Oray,i.k. And Karakulak

SCRS/02/109. Updated Standardized Catch Rates for bluefin tuna from the trap fishery in the straits of Gibraltar. Ortiz de Urbina, J. and J.M. de la Serna.

Appendix 3: Statement of Work

STATEMENT OF WORK

Consulting Agreement between the University of Miami and Dr. Din Chen

Background

Atlantic bluefin tunas are a valuable commercial and recreational fishery resource. The fishery takes place throughout the North Atlantic Ocean and the Mediterranean Sea. Many countries from Europe, North America, Asia, Africa, South America and the Carribean participate in the fishery.

The fishery is subject to international management by the International Commission for Conservation of Atlantic Tunas (ICCAT). The ICCAT convention establishes Maximum Sustainable Yield as the objective for management. Scientific advice for fisheries management is prepared by ICCAT's Scientific Committee on Research and Statistics (SCRS). ICCAT manages Atlantic bluefin tuna as two separate management units for the Western Atlantic and Eastern Atlantic (including the Mediterranean Sea). The Western Atlantic bluefin tuna population has been sharply reduced in abundance from the 1970s. ICCAT adopted a rebuilding plan for the Western Atlantic fishery in 1998, which is still in force. Overfishing is now occurring in the Eastern Atlantic, with the catch far exceeding estimates of the yield that can be sustained.

Management of bluefin tuna, particularly for the Western Atlantic management unit, has been controversial for decades. The fishing industries (both commercial and recreational) believe the stock has not declines as seriously as indicated by ICCAT assessments, and that more recover has occurred in recent years. Environmentalists have argued that the Western Atlantic bluefin tuna fishery is an extreme example of overfishing, and that the rebuilding process has just begun, at best. Part of the controversy over bluefin tuna is related to ICCAT's use of two management units. It has always been known that there is some migration across the management unit boundary, but recent evidence indicates the mixing between Western and Eastern Atlantic management units could be quite important from a management perspective.

More detailed background can be found on the ICCAT web site at www.iccat.es by clicking on "Download Reports, Regulations, etc.", and then clicking on:

- "Executive Summaries of Species Status, Oct. 2001- Bluefin": For the most recent management advice;
- "Last Detailed Species Assessment Report-Bluefin": For details on the most recent assessment which was conducted in 2000;
- "Other Reports of 2001- Bluefin Mixing Meeting": For a description of recent information on mixing and its implications; and
- "Work plans for Species Working Groups- Bluefin": For the work plan for the 2002 assessment meeting for bluefin.

These four documents will also be sent electronically (see Appendix I for a tentative list of submissions to the ICCAT bluefin tuna session).

Role of the Consultant

The consultant is to participate as an objective scientific expert member of the US Delegation to the ICCAT bluefin tuna assessment meeting, 22-30 July 2002 at ICCAT Headquarters in Madrid. The US Delegation will be composed of scientists funded by the fishing industry and environmental interests, as well as US government scientists. In the past, the diversity of perspectives of the scientists within the US delegation has made it difficult to reach consensus on assessment results and management advice. The participation of independent experts from the Center for Independent Experts (CIE) is intended to add expertise, help reach a balanced consensus, and lend credibility to the outcome.

The last "bulleted" document (work plan) above gives a description of the work to be carried out during the assessment meeting. The second "bulleted" document (Detailed Assessment) describes the statistical methods used to calculate abundance indices (i.e., general linear models), preparation of catch at age matrices (by cohort slicing), the assessment methodology (a version of ADAPT), and other models (e.g., Age Structured Production Models). The consultants must have the expertise and experience to understand these methods and models and to help guide the assessment meeting to use them properly from a scientific perspective.

In addition to participating in the ICCAT meeting for nine days, the consultant will be expected to spend five days preparing for the meeting (reviewing past assessments and documents submitted to the current meeting), and two days following the meeting preparing a report. The consultant's duties will not exceed a total of 19 days.

Specific Responsibilities of the Consultant

Specific tasks and timings are itemized below:

1. Read and become familiar with the four documents noted above listed in the Background session of this SOW, SCRS documents submission to the assessment meeting provided to the consultants in advance of the meeting (a list of expected submissions is attached), and other relevant documents;

2. Participate in the entire ICCAT assessment meeting of 22-30 July 2002;

3. As a participant in the meeting, conduct analyses and prepare portions of the meeting report as assigned by the head of the US Delegation for the Western Atlantic bluefin tuna assessment;

4. Prepare a report addressing the following points:

    - Highlighting impressions of the conduct of the meeting and how it might be improved in the future;

    - Discussing strengths and weaknesses in the analyses and advice resulting from the assessment meeting; and

    - If, and only if, the assessment meeting fails to provide unambiguous advice by consensus, the individual consultants will provide their own expert advice within the context of work plan and requirements of the ICCAT rebuilding plan for Western Atlantic bluefin tuna. Specifically, they should advise on the appropriate total allowable catch level consistent with the rebuilding plan, and on management units (i.e., should ICCAT change from its current two management units, and if so, how?).

5. No later than August 9, 2002, submit the written report[2] (see Appendix II) addressed to the "University of Miami Independent System for Peer Review," and sent to Mr. Manoj Shivlani, via email to mshivlani@rsmas.miami.edu.

[2] The written report will undergo an internal CIE review before it is considered final. After completion, the CIE will create a PDF version of the written report that will be submitted to NMFS and the consultant.

ANNEX I: TENTATIVE LIST OF SUBMISSIONS FOR THE ICCAT BLUEFIN TUNA SESSION

Specifications and clarifications regarding the ADAPT VPA assessment/projection computations carried out during the September 2000 ICCAT West Atlantic bluefin tuna stock assessment session - Punt, A E and Butterworth, D S - SCRS/02/086

An initial application of the spatial structure framework for North Atlantic bluefin developed at the September 2001 bluefin mixing workshop using simple age-aggregated models - Punt, A E and Butterworth, D S - SCRS/02/087

A scenario-based framework for the stock assessment of North Atlantic bluefin tuna taking into account trans-Atlantic movement, stock mixing and multiple fleets - P. Apostolaki , M. McAllister and E. A. Babcock - SCRS/02/088

Standardized catch rates of bluefin tuna, thunnus thynnus, from the rod and reel/handline fishery off the northeast United States during 1980-2001 - Craig A. Brown - SCRS/02/089

Standardized catch rates for large bluefin tuna, thunnus thynnus, from the U.S. pelagic longline fishery in the gulf of Mexico and off the florida east coast. - Jean Cramer - SCRS/02/090

Updated index of bluefin tuna (thunnus thynnus) spawning biomass From Gulf of Mexico ichthyoplankton surveys - Gerald P. Scott and Stephen C. Turner - SCRS/02/091

Updated information on electronic tag results from bluefin tuna tagged in the western Atlantic Ocean - Barbara A. Block and Andre Boustany - SCRS/02/092

Atlantic bluefin tuna: additional considerations on mixing on the feeding grounds - Frank Hester - SCRS/02/093

ANNEX II: REPORT GENERATION AND PROCEDURAL ITEMS

1. The report should be prefaced with an executive summary of findings and/or recommendations.

2. The main body of the report should consist of a background, description of review activities, summary of findings, conclusions/recommendations, and references.

3. The report should also include as separate appendices the bibliography of all materials provided and a copy of the statement of work.