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ANALYSIS OF SKIPJACK CATCH PER UNIT OF EFFORT (CPUE)

by

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1. ABSTRACT

A method is developed to generate relative indices of abundance from purse-seine catch data. The ratios through time of catches of the species of interest to a species with known abundance are used to create the index. This index is adjusted by the known abundance of the second species. The method is put into a general linear model (GLM) context to eliminate variation caused by other factors (*e.g.* latitude). The method is applied to skipjack tuna in the eastern Pacific Ocean caught in purse-seine sets on floating objects, using the known abundance of bigeye tuna from stock assessments. Additional analyses for yellowfin tuna are used as a test of the method by comparing the estimated index of relative abundance with stock assessment estimates of abundance. The results show some consistency with the stock assessment. However, adjusting for the known abundance of bigeye tuna reduced the correlation. Including additional explanatory variables in the GLM had little influence on the estimated relative index of abundance.

2. INTRODUCTION

Indices of relative abundance estimated from catch per unit of effort (CPUE) data are one of the most commonly used data types in fishery stock assessments. However, there are many problems with using CPUE data to create relative indices of abundance (Hampton *et al.* 2005). Analyses that attempt to overcome these problems are some of the most commonly applied in fisheries stock assessment (Maunder and Punt 2005). For example, general linear models are commonly used to standardize CPUE for factors such as month and area.

Purse-seine CPUE data are particularly problematic. It is difficult to identify the appropriate unit of effort for purse-seine CPUE data. In general, effort is defined as the amount of searching time required to find a school of fish on which to set the purse seine.

There are three types of purse-seine sets in the eastern Pacific Ocean (EPO) tuna fisheries: 1) on tuna associated with dolphins; 2) on tuna associated with floating objects; and 3) on unassociated schools of tuna. These different types of sets have different characteristics and catch different species compositions and sizes of tuna. Therefore, the types of purse-seine sets are more or less applicable for standard CPUE analysis. Since about 1993, most sets on floating objects are made on artificial floating objects, called fish-aggregating devices (FADs), which are planted by the fishermen and have locator beacons so that they can be found easily. These sets are particularly unsuitable for developing indices of abundance, because there is essentially no searching time for the FADs.

Currently, there is no reliable index of relative abundance for skipjack tuna in the EPO. This means that the stock assessments are uncertain (Maunder and Harley 2005). Few skipjack tuna are caught in the longline fisheries or dolphin-associated purse-seine fisheries. Unassociated purse-seine sets are generally intermingled with floating-object or dolphin-associated sets. Therefore, the only data set that can be used to estimate a relative index of abundance for skipjack tuna is that for the floating-object purse-seine fishery. A method to analyze the CPUE data from purse-seine sets on tuna associated with floating objects is required to improve the assessments of skipjack tuna in the EPO.

We present a method to estimate relative abundance of skipjack tuna using purse-seine catch data from sets on tuna associated with floating objects. The method works on the change in ratio of skipjack tuna to a species with known abundance. In this analysis we use estimates of abundance of bigeye tuna from the current stock assessment. To test if the method works, we apply the approach to yellowfin tuna and compare the results to the current yellowfin tuna stock assessment.

3. METHODS

We develop a method to estimate an index of relative abundance from catch data that is independent of effort. The method is based on the assumption that the ratio of the abundance of the species of interest (*A*) to the known abundance of species (*B*) is the same in the purse-seine catch ($\frac{A^{set}}{B^{set}}$) as in the population ($\frac{A^{pop}}{B^{pop}}$), or at least the relationship between the ratios is independent of the population size of either species.

$$\frac{A^{set}}{B^{set}} = q\frac{A^{pop}}{B^{pop}}$$

Therefore, the abundance is proportional to the known quantities

$$A^{pop} \propto \frac{A^{set}}{B^{set}} B^{pop}$$

A simple index of relative abundance can be calculated by

$$I_t = \frac{\sum_{i \in t} A_i^{set}}{\sum_{i \in t} B_i^{set}} B_t^{pop}$$

Summing the catch over all sets in a time period for each species rather than averaging the ratio of the species in each set avoids divide by zero problems when there is no catch of the known abundance species in a set.

However, each set may have different characteristics and this should be taken into consideration. A general linear modeling approach can be used to model *q*.

q is modeled using a log-linear model which ensures that the predicted ratio is positive

$$\hat{r}_i = \exp\left[\boldsymbol{\beta}\mathbf{X}_i\right]\frac{A_t^{pop}}{B_t^{pop}}$$

Where $r_i = \frac{A_i^{set}}{B_i^{set}}$

$$\ln\left[r_i\right] = \boldsymbol{\beta}\mathbf{X}_i + \ln\left[A_t^{pop}\right] - \ln\left[B_t^{pop}\right] + \varepsilon_i$$

Where $\varepsilon_i \sim N\left(0,\sigma^2\right)$

The logarithm of the ratio can be modeled using a linear model with an offset equal to the negative of the logarithm of the known abundance species and a time categorical variable to represent ln [A_t^{pop}].

If either A^{set} or B^{set} is zero, numerical problems occur. Therefore, a small constant is added to each.

4. APPLICATION

The change-in-ratio method is applied to skipjack tuna in the EPO using data from the floating-object purse-seine fishery. In addition, the method is applied to yellowfin tuna so that the results can be compared to estimates of abundance from a stock assessment. Initially, the raw catch ratios are computed and then the full GLM analysis is applied.

For the GLM analysis, first all the sets that have a combined catch of the species of interest and the known abundance species equal to zero are removed. We only use size-class 6 vessels from the IATTC observer program where there is data on latitude, longitude and sea-surface temperature (SST) and there are at least 50 qualifying sets for that vessel. The GLM uses a monthly time step, but the stock assessments are run on a quarterly time step. Therefore, the bigeye tuna abundance from the stock assessment for each quarter is applied to each month in that quarter for the regression.

5. RESULTS

The number of floating-object sets greatly increased during the 1990s (Figure 1). A corresponding increase in catch of tunas occurred during the 1990s (Figure 2). However, it was not until late 1994 that the catch of bigeye tuna increased (Figure 2), which is very evident in the catch-per-set data (Figure 3). This is probably because of the introduction of FADs around this period. The lower catch rates of bigeye in the early period caused the ratio of the yellowfin and skipjack to the bigeye catch to be much higher in the earlier period (Figure 4). Therefore, data before 1995 is not used in the analysis.

The ratio of yellowfin to bigeye catch in a set shows a similar trend to the relative abundance for floating-object vulnerable yellowfin from the stock assessment (Figure 5). However, the ratio is more variable, and the r-square between the ratio of yellowfin to bigeye in a set and the relative abundance for floating-object vulnerable yellowfin is only 0.11. The low r-square is probably due to the large spike in 2000. The relationship appears to deteriorate when the ratio is adjusted by the known bigeye abundance (Figure 6), but has a higher r-square of 0.15. The full GLM appears slightly better (Figure 7).

The influence of the known bigeye abundance is less obvious for skipjack, although it is the same because it uses the same bigeye abundance data (Figure 8). For the GLM analysis the data set is reduced and this may influence the results. However, if only a time effect is added to the GLM, there is little influence on the relative index of abundance (Figure 8).

The first variable included in the model based on the AIC criteria is latitude included as a factor, followed by SST as a quadratic and then vessel (Table 1). The model selection was stopped at this stage despite changes in AIC due to the large number of data points in the analysis and the lack of change in the relative index of abundance. For all models, the time effect was automatically included. The final relative index of abundance is similar to the relative index of abundance when only the time effect is included (Figure 9).

Changing the added constant to 1.0 or 0.01 had essentially no impact on the relative year effect.

TABLE 1. AIC values for models tested for skipjack tuna.

Model	AIC
SKJ.time	92857
SKJ.time.Lat	92766
SKJ.time.Lon	92859
SKJ.time.SST	92327
SKJ.time.Vessel	92565
SKJ.time.SST2	92320
SKJ.time.Lat2	92768

SKJ.time.Lon2	92817
SKJ.time.LatF	91942
SKJ.time.LonF	92712
SKJ.time.LatLon	92757
SKJ.time.LatF.SST2	91777
SKJ.time.LatF.Vessel	91591
SKJ.time.LatF.SST2.Vessel	91423

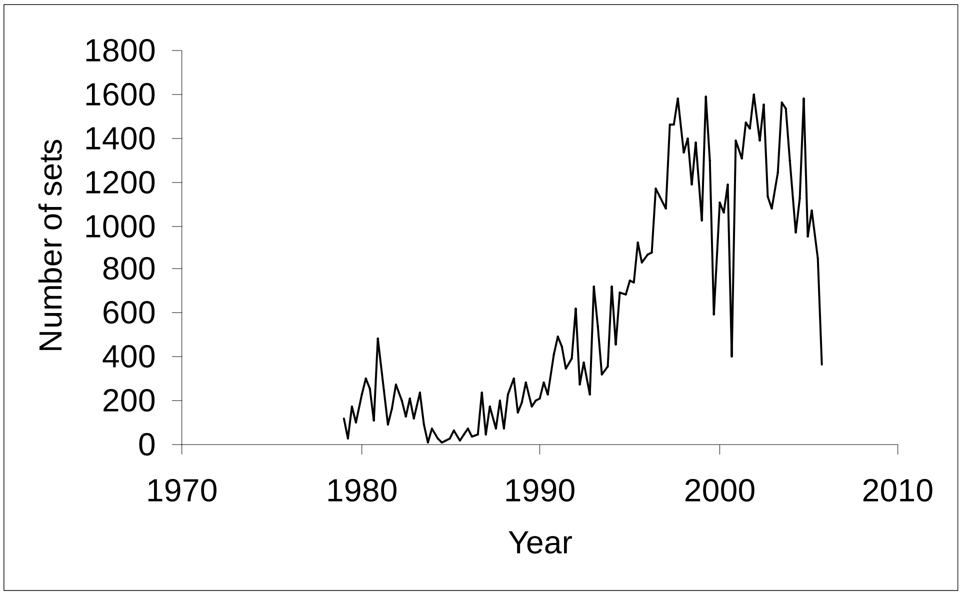

FIGURE 1. Number of floating-object sets in the database

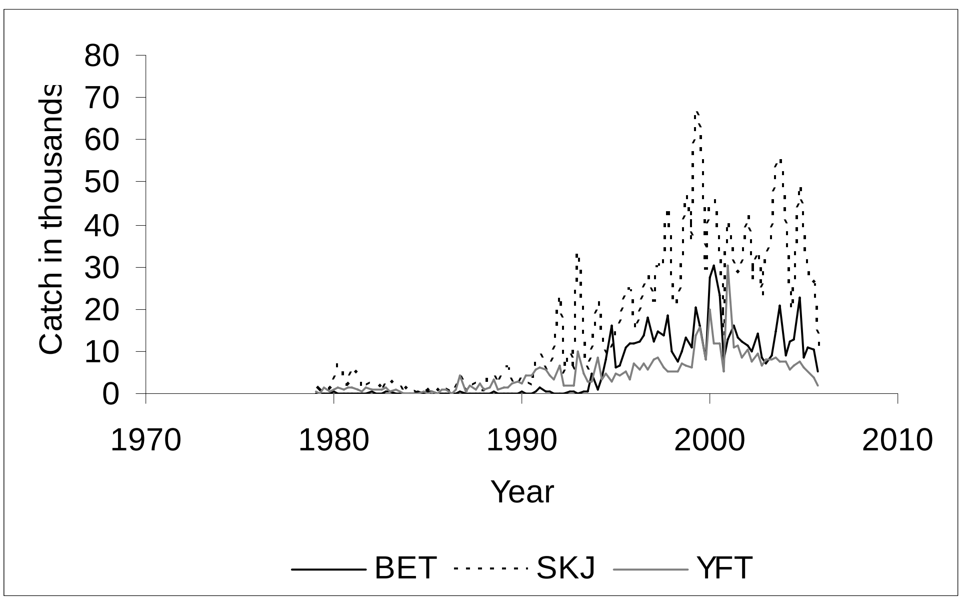

FIGURE 2. Catch by species, in thousands of metric tons

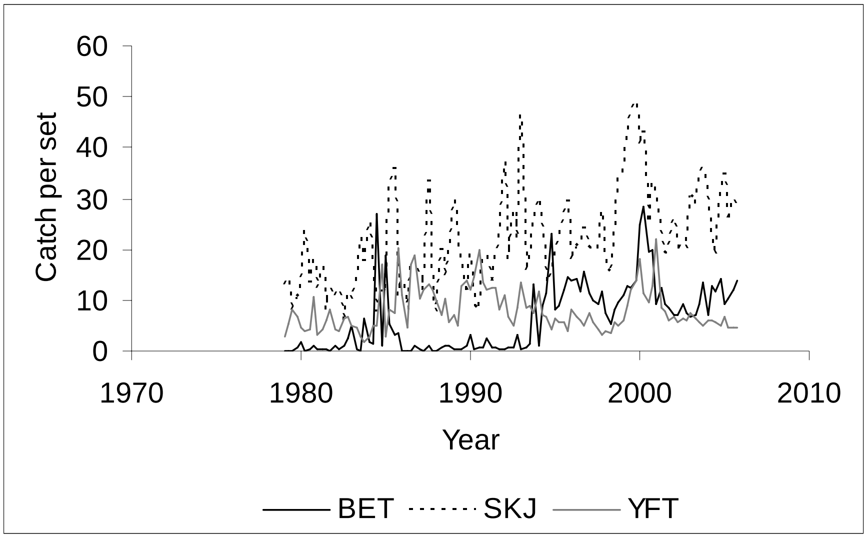

FIGURE 3. Catch rate by species

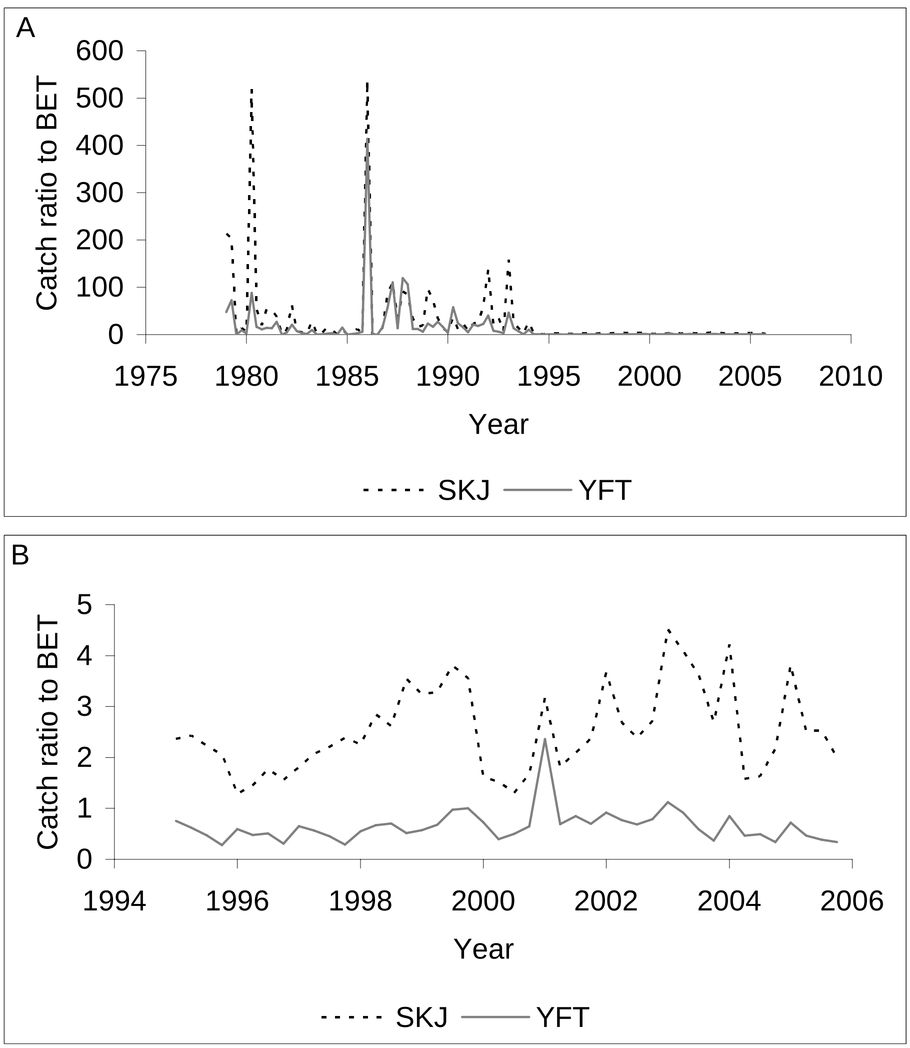

FIGURE 4. Ratio of skipjack and yellowfin to bigeye in the catch using all floating-object data for (A) the whole time period and (B) the period after the FAD fishery had expanded.

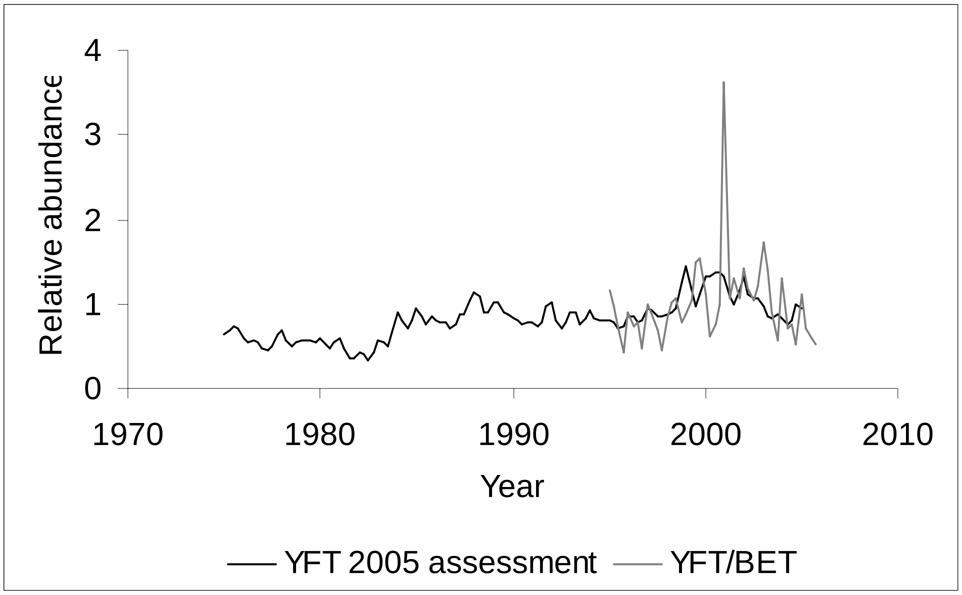

FIGURE 5. Comparison of the ratio of yellowfin to bigeye in the catch using all floating-object data over the period after the expansion of the FAD fishery with the relative abundance of floating-object vulnerable fish from the assessment.

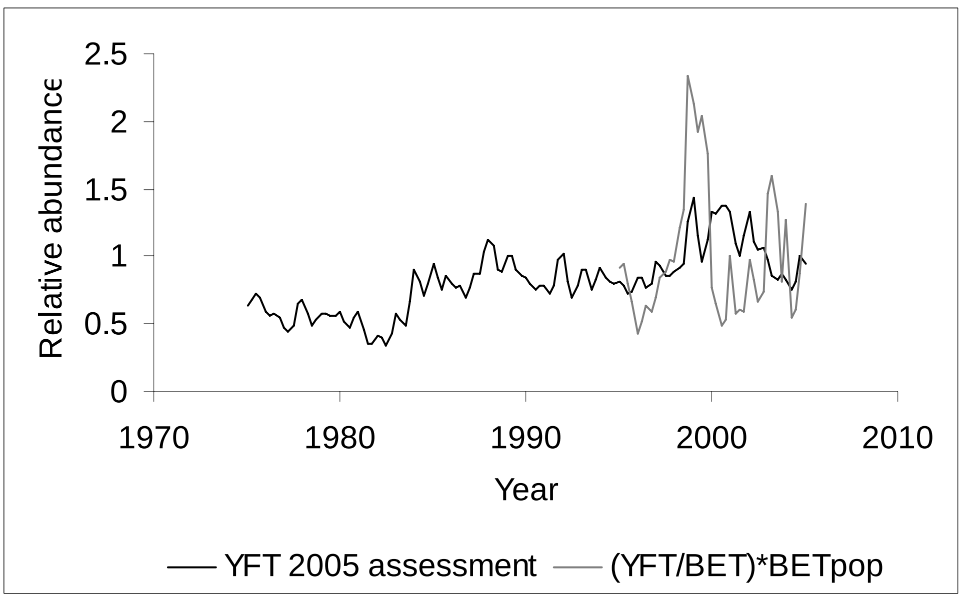

FIGURE 6. Comparison of the ratio of yellowfin to bigeye in the catch using all floating-object data over the period after the expansion of the FAD fishery adjusting for the known bigeye tuna abundance with the relative abundance of floating-object vulnerable fish from the assessment.

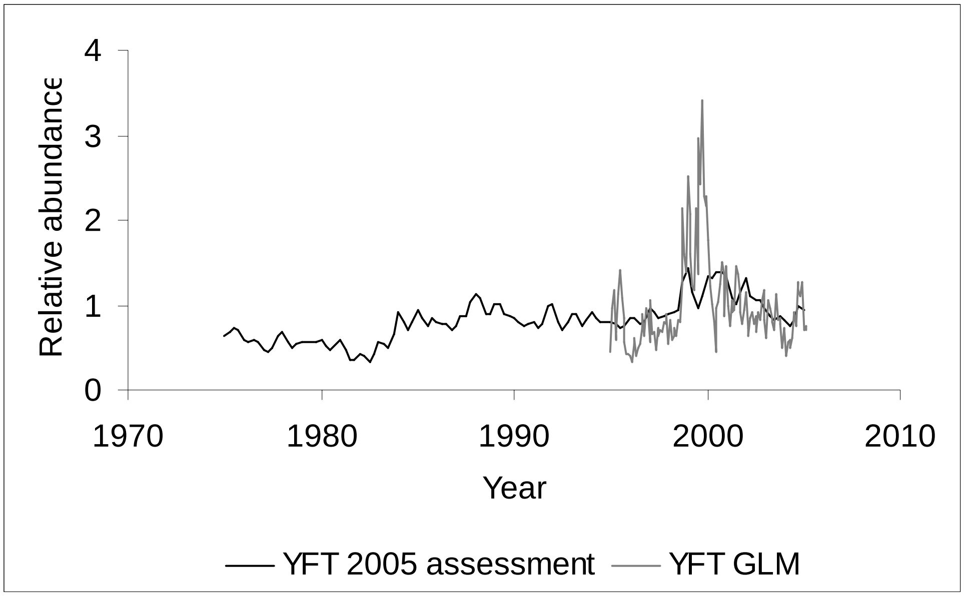

FIGURE 7. Comparison of the index of relative abundance from the GLM for yellowfin with the relative abundance of floating-object vulnerable fish from the assessment.

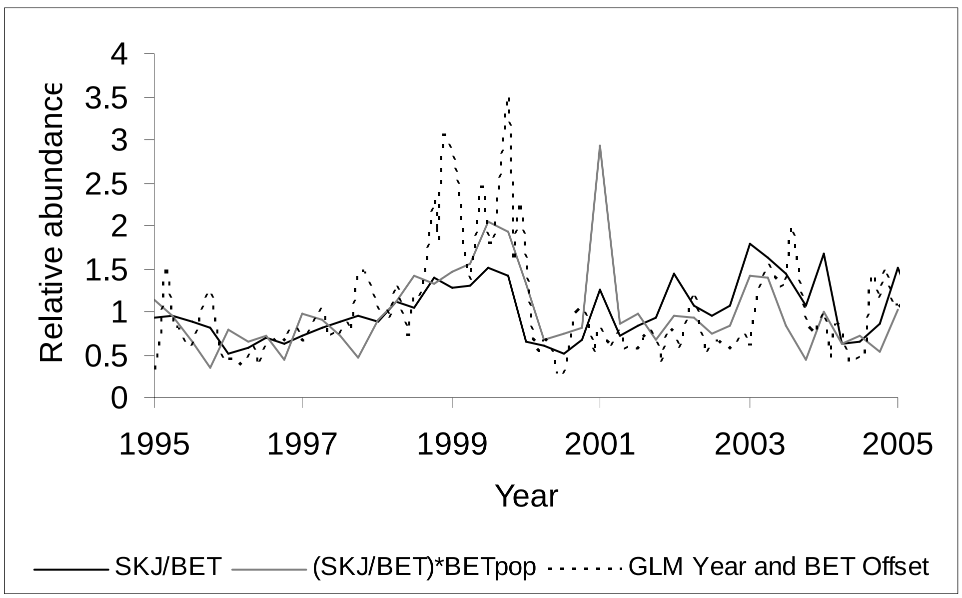

FIGURE 8. Comparison of the ratio of skipjack to bigeye in the catch using all floating-object data over the period after the expansion of the FAD fishery with and without adjusting for the known bigeye tuna abundance with the relative abundance estimated from the GLM on the limited data set using only the time effect.

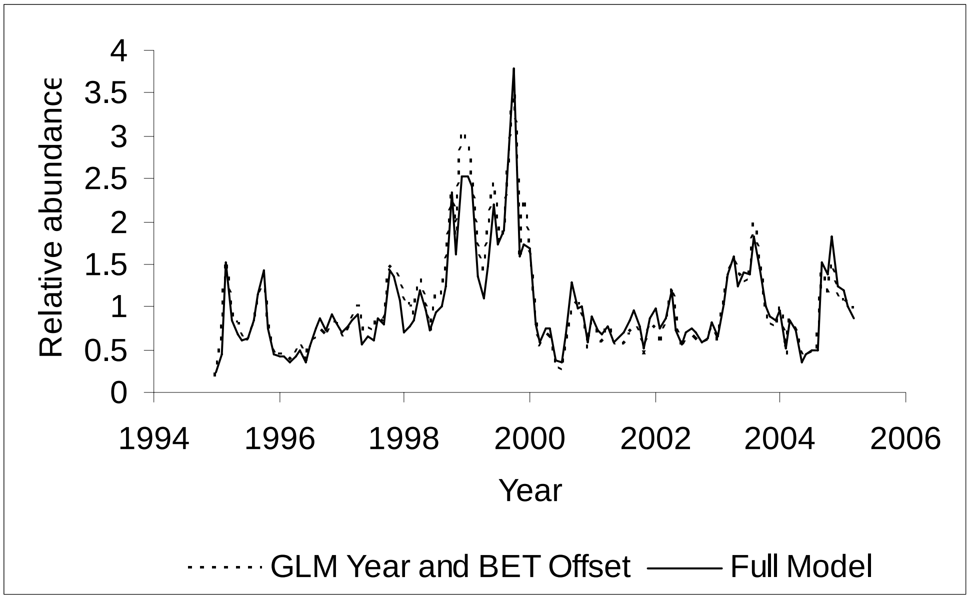

FIGURE 9. Comparison of the relative index of abundance from the full model with that using just the time effect.

6. DISCUSSION

There is a marked change in the catch rates of bigeye tuna in the floating-object fishery around 1994. This is probably due to the increase in the proportion of FADs in the fishery. Future applications of this method should focus just on the FAD (*i.e.* removing natural floating objects) fishery or the type of floating object should be included as an explanatory variable in the GLM analysis.

Zero catches for the species of interest or the known abundance species in a set causes numerical problems in the analysis. A constant was added to both catches to avoid this problem. The analysis was not sensitive to the value of this constant. However, data from periods before 1995 have many more zero catches, particularly for bigeye tuna, and these zeros may cause greater problems for an extended analysis.

The ratio of yellowfin catch to bigeye catch showed similar trends as the abundance of floating-object vulnerable yellowfin from the stock assessment, but is more variable. However, this relationship in trends was degraded when the ratio was adjusted for the known bigeye tuna abundance. This may indicate that the method is inadequate, or some inadequacies in the yellowfin or bigeye tuna abundance estimates from the stock assessments. Improvements to the analysis may include incorporating spatial structure or fish size into the analysis, as larger fish may show more variation in spatial distribution. Other explanatory variables could be included in the analysis (*e.g.* the catch of other species).

There may be a saturation effect in schools around FADs. This can be taken into consideration by modeling the logarithm of catch of the species of interest rather than the ratio and including the catch of the know abundance species as an explanatory variable, possibly as a higher-order term.

$$\ln\left[A_i^{set}\right] = \boldsymbol{\beta}\mathbf{X}_i + \boldsymbol{\beta}_2 \ln\left[B_i^{set}\right] + \boldsymbol{\beta}_3 \ln\left[B_i^{set}\right]^2 + \ln\left[A_t^{pop}\right] - \ln\left[B_t^{pop}\right] + \varepsilon_i$$

The estimated index of relative abundance for skipjack tuna indicates that the population is highly variable. There is an order of magnitude difference between the high and low abundance. The abundance was particularly high in 1999, with peaks in 2003 and 2004, which is consistent with the stock assessment (Maunder and Harley 2005).

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