Standardization of yellowfin tuna CPUE for U.S. purse seiners fishing in the central-western Pacific

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INTRODUCTION

U.S. purse seiners have fished in the central-western Pacific since the early 1970s. Beginning in June, 1988, the U.S. signed a Treaty with 16 Island nations that gave them access to a large area of the central-western Pacific rich in tropical tuna resources. As part of the data requirements of the Treaty, the U.S. fleet is required to submit a regional purse seine logbook, total landings and size composition of the catches.

The data from the fishery have been summarized and submitted annually to a Western Pacific Yellowfin Research Group (WPYRG) that has been conducting research on yellowfin tuna resources in the central-western Pacific since June, 1992. The purpose of this report is to complete an assignment of the WPYRG to standardize yellowfin tuna CPUE for the U.S. fleet in 1988-1997. This report, while extending a previous analysis (Kleiber 1993) that used data for 1988 - February 1993, uses a slightly different data and model treatment.

DATA AND METHODS

Three types of data are used in this analysis, logbook, length frequency and environmental. Unlike the previous analysis (Kleiber 1993) that eliminated data for fishing outside the study area and for vessels not active in the fishery for a significant part of the time, this analysis uses all of the data.

Logbook data (June 1988 - December 1997) are taken from U.S. Regional Purse Seine Logbooks (since June, 1996) and Catch Report Forms (1988 - May, 1996). The data include daily positions, the respective set time (assumed to be noon if no set on that day), types of sets (drifting object sets or free-swimming school sets), and catches of yellowfin tuna (*Thunnus albacares*) and skipjack tuna (*Katsuwonus pelamis*) and sometimes bigeye tuna (*T. obesus*). Over 93,290 individual vessel trip records are included. Monthly length-frequency data taken by National Marine Fisheries Service (NMFS) technicians in Pago

Pago, American Samoa are used to determine sizes of yellowfin tuna in the catches. The monthly Southern Oscillation Index (SOI) used in this analysis, 1988-1997, is from the Climate Analysis Center, NOAA. The index is a continuous variable of the atmospheric pressure difference between Tahiti and Darwin, Australia (Anon, 1993). Positive values indicate anti El Niño conditions and negative values El Niño conditions. The strength of the El Niño is indicated by the magnitude of the positive or negative values. During the period 1988-1997, two El Niño events occurred; one in 1992 and the other in 1997.

The logbook data are summarized for catch-per-unit effort (CPUE) by area and time strata. Two area strata are used; area 1 is west of 160°E longitude and area 2 is east of 160°E longitude. These areas were chosen as the fleet tends to aggregate in one or the other of these areas during certain years, a trend that is probably caused by availability of fish in the central-western Pacific or cyclic environmental conditions in the area. Area is considered a categorical variable (AREA). Time strata used are months and are converted to a continuous variable (MONTH), starting at 1 for January 1988 and extending to 120 for December 1997.

Besides the categorical variable AREA and continuous variable MONTH, that define the strata, and the SOI continuous variable, three other continuous variables are used. The first variable, set type (ASPSET), is drifting object or free-swimming school sets. An additional set type that divides the drifting objects into two categories, naturally occurring objects (logs, dead animals, debris, etc.) and rafts (man-made Fish Aggregation Devices, FADs), was also considered but dropped as very little information was available on rafts prior to 1996 and the CPUE=s on naturally occurring objects and rafts are almost identical. Set type is converted to a continuous variable (0 to 1) as the proportion of sets in each stratum on free-swimming schools and then transformed with the arcsine function as is typically done with proportional data. The second variable, amount of yellowfin tuna in the catch (ASPYFT), is converted to a continuous variable as the proportion of yellowfin tuna in the catch and transformed with the arcsine function. The last variable, yellowfin tuna sizes in the catch (ASSIZE), is converted to a continuous variable as the proportion of yellowfin tuna in the catch greater than 9 kg and transformed by the arcsine function.

The dependent variable CPUE is calculated for each stratum by summing the yellowfin tuna catch (metric tons) in each stratum and dividing by the corresponding number of days fishing. Since the logbooks do not record time between sets, time between the beginning of the sets and the end of sets, time drifting, time in port, etc, the actual number of days of effort associated with each vessel set is calculated as follows.

1) If a vessel makes only one set in a day, 1 day of fishing effort is assigned.

2) If a vessel makes more than one set in a day, 1 divided by the number of sets is assigned as the effort for each set.

3) A vessel that spends a partial day searching is assigned 0.5 days fishing effort.

4) A vessel that spends a full day searching is assigned 1 days fishing effort.

The method chosen to examine or standardize yellowfin tuna CPUE is the generalized additive model (GAM, Chambers and Hastie 1992). The dependent variable CPUE is modeled as the sum of 5 continuous variables and one categorical variable defined above as follows,

log(CPUE+.05)=á+lo(SOI)+lo(ASPSET)+lo(ASPYFT)+lo(ASSIZE)+ (1)
lo(MONTH)+as.factor(AREA)+å

Alo@ indicates that the variable is smoothed using the loess function and á is a constant and å is an error variable. This form of the GAM model was chosen to allow for modeling of terms nonparametrically using smoothers and in doing so letting the data suggest the nonlinearities.

RESULTS

The variables were viewed independently to observe which of them showed any trends in respect to the dependent variable CPUE+.05. The variables were plotted against CPUE on the logarithmic scale. The only variable to show a marked trend was the species composition variable ASPYFT (Figure 1); CPUE increased nonlinearly as the percent of yellowfin tuna in a stratum increased. Other variables showed only slight trends; CPUE decreased as the SOI changed from a El Niño (minus values) to anti El Niño (plus values) conditions (Figure 2), CPUE increased as MONTH/time increased (Figure 3) and CPUE increased between AREA 1 and 2 (Figure 4). While other variables showed a trend for only a portion of the data; CPUE dropped as the percent of free-swimming school sets (ASPSET) was greater than 80% in a stratum (Figure 5), and CPUE increased after the percent of yellowfin tuna greater than 9 kg in a set (ASSIZE) was greater than 70% (Figure 6).

The GAM function was test run to assess the appropriateness of using the loess smoothing. The test showed that all of the variables had significant nonlinear trends except for the ASPSET and ASSIZE variables. The trend of these variables was not significantly different from a linear trend and was therefore input as linear factors in the final run. The test run also revealed a need to adjust the loess algorithm to a coarser resolution in MONTH. Equation 1 was modified for the final run as follows:

log(CPUE+.05)=á+lo(SOI)+ASPSET+lo(ASPYFT)+ASSIZE+ (2)
lo(MONTH,span=0.66)+as.factor(AREA)+å

Figure 7 shows the results of the final GAM model. As expected the ASPYFT variable has the largest effect with the other variables having lesser effects. This can be confirmed by the chi square values in Table 1. Plots of the MONTH effect can be interpreted as the hypothetical standardized indices of yellowfin tuna abundance (Figure 8). The resulting abundance shows no significant trend over time.

DISCUSSION AND CONCLUSIONS

If the modeled results of yellowfin tuna CPUE over time (Figure 8) are accepted as indicating hypothetical yellowfin tuna abundance over time, we conclude that there is no significant trend over the time period examined. Our results follow rather closely those reported by Kleiber 1993 for the common time period despite the slightly different data treatment and model formulation. Clearly, the variable proportion of yellowfin tuna in the catch (ASPYFT) affects the current model most as it did in the previous analysis. Further, the definition of effort and data treatment appears to have effected little change in results from previous analysis. The most noticeable being a slight increasing trend in the unstandardized yellowfin tuna CPUE trend (Figure 3) in our analysis which was not seen previously.

We offer the caveat that these hypothetical modeled results may have unknown interaction effects and may be forced by variables unaccounted for in the model formulation. This is unchanged from previous analysis.

The data do display rather large changes in CPUE and variability (Figure 7) which is accounted for, in large part, by the model variables. All the modeled variables, with the exception of ASPYFT, have very subtle effects in the model, however all are significant. This is due in large part to the large amount of data (in excess of 93,000 observations).

Finally, we conclude that the addition of 5 years of data has not materially changed the conclusion, of no significant trend in CPUE, reached in the previous analysis. The conclusion is the same even when 5 years of data including 2 significant El Niño events are added, 2 instead of 10 area strata are used and no data are eliminated from the analysis.

LITERATURE CITED

Anonymous. 1993. Climate Diagnostics Bulletin. Climate Analysis Center, No. 93/8, 77p.

Chambers, J.M. and T.J. Hastie. 1992. Statistical Models in S. Wadsworth and Brooks, Pacific Grove, California, 608p.

Kleiber, Pierre. 1993. Yellowfin catch per effort in the Western Pacific by the United States purse seine fleet. Working paper of the 3rd meeting of the Western Pacific Yellowfin Research Group. Pohnpei, Federated States of Micronesia, June 21-23, 1993, 22p.

Table 1. Chi Square values for the continuous variables, ASPYFT (proportion of yellowfin tuna in a stratum), SOI (Southern Oscillation Index), and MONTH (time), used in a Generalized Additive Model of yellowfin tuna catch-per-unit effort of the U.S. purse seine fishery in the central-western Pacific.

VARIABLE	CHI SQUARE VALUE	PROBABILITY (CHI SQUARE)	DEGREES OF FREEDOM
ASPYFT	117.23	.00000	3.1
SOI	13.36	.00324	2.8
MONTH	10.15	.00301	1.4