Col.Vol.Sci.Pap. ICCAT, 25 : 57-61 (1986)

SIGNIFICANCE OF CHANGES IN CATCH AND FISHING EFFORT IN THE EASTERN ATLANTIC YELLOWFIN TUNA FISHERY

D. Au
NMFS, Southwest Fisheries Center
P. O. Box 271, La Jolla, California, U.S.A.

SUMMARY

Confidence limits for judging the significance of the 1984 reduced catch and effort value in the eastern Atlantic surface yellowfin tuna (Thunnus albacares) fishery are derived. The 5 percent bounds for equilibrium yield-effort relationship through the 1968-1983 data were determined from a Monte Carlo procedure. The 5 percent and 1 percent lower bounds for individual data points were obtained from a basic statistical procedure. The general approach can be used to judge the significance of more than one data point.

RESUME

Les limites de confiance pour juger l'importance des valeurs réduites de 1984 de prise et effort de la pêcherie de surface de l'albacore (Thunnus albacares) de l'Atlantique sont étudiées. Les limites de 5% de la relation d'équilibre rendement-effort des données de 1968-1983 ont été déterminées à partir d'une procédure de Monte Carlo. Les faibles limites de 5 et de 1% des points de données individuels ont été obtenues en suivant une procédure statistique de base. L'approche générale peut être utilisée pour juger de l'importance de plus d'un point de données.

RESUMEN

Se deducen los límites de confianza para juzgar el significado de los reducidos valores de captura y esfuerzo en 1984, en la pesquería de superficie de rabil (Thunnus albacares) en el Atlántico Este. Los límites del 5% de la relación en equilibrio rendimiento-esfuerzo de los datos 1968-1983 se determinan a partir de un procedimiento de Monte Carlo. Los límites más bajos del 5% y 1% de valores de datos individuales se obtuvieron a partir de procedimientos estadísticos básicos. El enfoque general puede utilizarse para juzgar la importancia de más de un punto de datos.

Introduction

In 1983 there was a decline in eastern Atlantic catches of yellowfin tuna. This was followed in 1984 by a still greater decrease in catches that resulted from FISM, and also some Spanish, purse seiners transferring to the Indian Ocean fishing grounds. The fleets fished in both oceans in 1985. Some movement of fishing effort between the eastern Atlantic and the Indian Ocean will likely be a feature of the fishery hereafter. How should decreases in fishing effort, and resulting catch, be interpreted in terms of the yield or production curve for the Atlantic yellowfin stock?

The relationship between catch and fishing effort is not a simple regression problem. The level of catch at any given effort level depends not only on population size and production, but also on the rate at which the given effort is approached, the previous level of effort, and how long the new effort level is maintained. The distribution of catches at any specific period is a function of the pattern of fishing at that time in the evolving fishery and represents various departures from the equilibrium situation. Fitting yield or production curves through such data requires adjustments, through averaging techniques, in order to bring those data into equilibrium conditions. These adjustments are imperfect. Therefore, the significance of departures of catch and effort from the average, as defined by the yield curve, has to be judged with respect to non-equilibrium data whose frequency distribution is strongly dependent upon unique fishing patterns of the past.

In this paper the above difficulties are circumvented in part by using a stochastic approach to defining the yield curve. The significance levels of different negative departures from the estimated equilibria are then shown.

Data and Methods

Eastern Atlantic surface fishery catches (baitboat and purse seine catches) of yellowfin were used because this fishery has been most affected by inter-ocean movements of the purse seiners. The Fonteneau CPUE index (Fonteneau 1984, Fonteneau et al. 1984) was used to derive effective fishing effort. These data are shown in Table 1.

The production model fitting program PRODSIM (Bartoo and Coan 1983) was applied to the catch-effort data to determine the 95% confidence belt of equilibrium catch curves. In PRODSIM each catch and effort datum is allowed to vary by a specified percentage of error; a Monte Carlo procedure is then invoked to choose randomly at each of n trials a new set of 16 data points near to the observed catch and effort levels. An equilibrium yield curve is fitted through each of these sets, using PRODFIT (Fox 1975). For this paper, PRODSIM was run with 1000 trials, and error was specified as ± 10% with uniform distribution, for both catch and effort. This level of error, and its distribution, is considered reasonable (Bartoo and Coan 1983). The PRODSIM procedure allows randomization only about the observed data; therefore the effect of fishing patterns in determining the overall shape of the yield curve is preserved. By this procedure an envelope defining possible yield curves through the observed data can be defined.

The significance of an observed new level of catch and effort, e.g. that following departure of part of the fishing effort to other fishing areas, must be ascertained differently. Suppose we consider a new point on the catch-effort graph as being a separate sample of size n=1. What is the probability of it being different from the previously observed unadjusted data population used to define the yield curve? This is a special case of comparing the means of two groups of unequal sample size. An appropriate test, under the null hypothesis of no difference between the means, is (Sokal and Rohlf 1981):

$$t = \frac{x_1 - \bar{x}_2}{s_2\sqrt{\dfrac{n_2 + 1.}{n_2}}} \qquad (1)$$

where t is the statistic of Student's t-distribution with d.f. = $n_2 - 1$, $\bar{x}_2$, n_2, and s_2 are the mean, number, and standard deviation from the large sampled population, and x_1 is the observed value of the sample of size 1. Because the significance of decreases in catch and effort is in question, a one-tailed t-test is applied. For a given probability level (alpha-level) P, $x_1(P)$ is the value of x_1 giving that level of P:

$$x_1(P) = \bar{x}_2 - t(P)\ s_2\sqrt{\frac{n_2 + 1}{n_2}}. \qquad (2)$$

The difficulty lies in the uncertainty of s_2, the standard deviation of catches at the effort level being considered, bearing in mind the nature of these catches as discussed above. In this paper the 1975-1983 catches were used for this purpose. They are situated near the top of the yield curve and are in that sense homogeneous. The standard deviation of these 9 catches was 10.331; that of the log transformed values was 0.0412.

Results

Figure 1 shows the relationships for the 1968 - 1983 catch-effort data for the eastern Atlantic surface yellowfin fishery. The curves with shape parameters m = 1 and 2 were derived deterministically, i.e., not using the Monte Carlo procedure. The m = 2 curve affords a better fit but there are reasons for preferring the m = 1 curve (see Au 1983). The envelope (dotted lines) surrounding these curves contain 90% of all the production curves fitted by PRODSIM in 1000 trials of randomly picked points, assuming a ± 10% error in both catch and effort. This envelope can be considered the 90% confidence belt of the expected regression of catch on effort. Since one-tailed tests are appropriate, the lower limit of this belt defines the 5% significance boundary.

Below this belt are shown the 5% and 1% significance limits for individual catch levels departing from the best mean regression (m = 2 curve). Assuming a log-normal distribution of catches the 5% and 1% limits were found by dividing the values of the m = 2 curve by the antilogarithm of the subtraction term in Eq. (2). The 5% and 1% boundaries can be used to decide if new catch-effort values are significantly lower than previously observed values.

Discussion

The "bootstrap" method of obtaining random data sets based upon one observed sample set is a useful method of inferring the confidence limits of a yield curve. It assumes the observed data set was obtained by a stochastic process, and other data sets are equally likely in the same evolving fishey. Provided the level of error chosen is reasonable, the significance of the difference between various fitted regressions through the same data can be judged. Unless the error level is very large, the confidence belt around the best regression through the original data will not be large. This will be true regardless of the exact frequency distribution of error specified around each data point.

If in a certain year there is a marked decrease in fishing effort, there will likewise be a sharp decrease in catch due to the "fishing down" effect. When this new catch-effort point is compared with the catch-effort values previously observed in the vicinity of the new effort level, it must be remembered that each, as a population, came from a different state of the fishery. By definition each population is therefore different. If it is unlikely that equilibrium will be established in the fishery, preventing the means from ever converging, then it is not very meaningful to ask if the populations are significantly different or not. On the other hand it is possible, in another sense, to think of an equilibrium population with very wide variance, in which case one can ask if the new catch-effort point is different from the equilibrium value. Then critical probability levels for rejection of the null hypothesis of no difference can be calculated, using elementary statistics, as was done for Figure 1. The only problem is that of estimating the variance of the equilibruim population. It can be done by standard regression techniques or by simply taking the variance of a representative subset of the data, as was done here. In each case there remain questions about representativeness of data observed under clearly non-equilibrium conditions. Here, the 1975-1983 data were used, and it was assumed the catches had a lognormal distribution. Multiplicative effects on biological variables tend to generate skewed distributions (Montroll and Schlesinger 1982) and the lognormal distribution is a suitable representation of most such cases (Cassie 1968).

The significance of the 1984 catch and effort decrease can be ascertained by plotting the finally accepted value in Figure 1 and comparing its placement with respect to the probability boundaries shown. As more years of the "new" fishing rgime become available, the significance of mean departures of 2, 3, ..., n_1 values from the equilbrium yield-effort line can be evaluated using the statistic for comparing two samples of size n_1 and n_2 from which Eq. (1) was derived:

$$t = (\bar{x}_1 - \bar{x}_2) \Big/ \sqrt{\frac{(n_1 - 1)s_1^2 + (n_2 - 1)\, s_2^2}{n_1 + n_2 - 2} \cdot \frac{n_1 + n_2}{n_1\, n_2}}$$

$$d.f. = n_1 + n_2 - 2$$

The above approach assumes a new lowered level of fishing effort is approximately maintained. It is more likely however that the fishing fleets will grow, induced by the two-ocean fishery, and that the fraction of fishing effort applied to the eastern Atlantic will sometimes fluctuate strongly when total effort is large. The status of the eastern Atlantic yellowfin stock should therefore be monitored very closely as such a situation develops.

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Table 1. Catch and Effort Statistics of the Eastern Atlantic Surface Yellowfin Tuna Fishery.

Year	Catch (10^3T)[1]	CPUE[5]	Effort (10^3 Days)
1968	55.2[2]	5.80	9.52
1969	61.0[3]	5.47	11.15
1970	43.9[4]	2.77	15.85
1971	43.9	2.15	20.42
1972	59.7	3.14	19.01
1973	59.9	2.51	23.86
1974	74.9	2.75	27.24
1975	94.1	2.20	42.77
1976	96.4	2.30	41.91
1977	99.6	2.69	37.03
1978	100.0	1.93	51.81
1979	104.8	1.97	53.20
1980	98.7	1.87	52.78
1981	122.4	1.76	69.55
1982	121.1	1.42	85.28
1983	102.0	1.47	69.39

1 ICCAT 1985
2 Prorated
3 ICCAT 1983
4 ICCAT 1984
5 Fonteneau et. al. 1984, Fonteneau 1984.

Figure 1.

The catch-effort relationship for the eastern Atlantic, surface yellowfin tuna fishery. The m = 1 and m = 2 curves are the equilibruim relationships. The dashed envelope contains 90% of 1000 trial curves fitted to the data, assuming a random ± 10% error function with each datum at each trial. The 5% and 1% lines mark the level for rejection of new catch-effort values for being significantly different from the previously observed values.