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AN EXAMPLE OF THE USE OF MICROCOMPUTERS FOR POPULATION ASSESSMENT: INVESTIGATION OF THE EFFECTS OF UNCERTAINTY IN CATCH DATA ON RESULTS OF COHORT ANALYSIS

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SUMMARY

To demonstrate the utility of microcomputers in a conference setting, a microcomputer has been installed at this conference and will be available for demonstration at various times for the duration of the meeting. The main purpose in having a computer available at the conference is to allow analyses to be run on the spot when questions of data validity are raised. Programs for cohort analysis, and yield-per-recruit analysis are on hand.

An example exercise has been prepared investigating the effects of uncertain data inputs on the results of an analysis. Using a simple statistical model, stochastic errors were introduced into yellowfin tuna catch data from the eastern Atlantic, and the effects on the results of cohort analysis were recorded.

RESUME

Pour démontrer l'utilité d'ordinateurs dans une conférence, un micro-ordinateur a été installé pour cette conférence et sera mis à disposition pour démonstration durant toute la durée de la réunion. Le but principal est de permettre d'effectuer des analyses sur place lorsque des questions concernant la validité des données sont soulevées. Des programmes sont disponibles pour l'analyse des cohortes et de la production par recrue.

A titre d'exemple, un exercice a été fait pour étudier quels sont les effets d'entrées de données peu fiables sur les résultats d'une analyse. En utilisant uniquement un modèle de statistiques, des erreurs stochastiques ont été introduites dans les données de capture d'albacore dans l'Atlantique est, et on a enregistré les effets observés sur les résultats de l'analyse des cohortes.

RESUMEN

Para ilustrar la labor que los micro-ordenadores pueden efectuar durante el desarrollo de una reunión, se ha procedido a la instalación de uno, que podrá ser utilizado durante la conferencia que se está celebrando, y que estará disponible para llevar a cabo demostraciones.

El objetivo principal es permitir efectuar análisis "in situ" si surgen cuestiones sobre validez de datos. Se dispone de programas de análisis de cohortes y de rendimiento por recluta.

Se ha preparado un ejercicio como demostración, que investiga en que forma influye la entrada de datos inciertos en los resultados de un análisis. Utilizando un simple modelo estadístico, se introdujeron errores estocásticos en los datos de captura de rabil del Atlántico Este, registrándose los efectos producidos sobre los análisis de cohortes.

INTRODUCTION

It is appropriate, when considering results of fish population assessment, to ask how sensitive the results are to potential errors in the data. Indeed a persistent problem of population assessment in the International Commission for the Conservation of Atlantic Tunas (ICCAT) occurrs when results presented are questioned because of doubt regarding the validity of some of the data on which the assessment is based. Most techniques used to prepare assessments for ICCAT are complicated and require the use of computers. Typically, questions of data validity are raised at meetings far removed from the assessors' computers, therefore, the problem must await future investigation. The advent of microcomputers which population assessors can take to meetings, should enable this problem to be immediately addressed and resolved. It should be possible to rerun analyses (even during a meeting) to investigate the effects of altering particular input data. For example, we might suspect that certain catch data have been under-reported by approximately 25%, and we may want to correct for this under-reporting, rerun our analysis and see if the essential conclusions drawn from the analysis are changed.

Using the technique known as "Monte Carlo simulation", it is possible to go beyond testing specific alterations in input data. With the Monte Carlo method one can investigate the statistical implications of a given pattern of uncertainty in one or more of the input data. We might recognize, for example, that the real natural mortality lies somewhere whithin a range of possible values, perhaps within a factor of 0.5 to 1.5 of our best estimate. On the basis of our knowledge of the uncertainty in the estimate of natural mortality, the Monte Carlo technique allows us to investigate the range of possible outcomes from an analysis that makes use of the natural mortality estimate.

In the example exercise presented here, we test the effects of uncertainty in catch-at-age data on the results of reverse cohort analysis. We have chosen the Fry method of cohort analysis (Megrey, 1983) as opposed to Doubleday's method or Pope and Shepherd's "seperable VPA" method.

Outputs from reverse cohort analysis by the Fry method include an estimate of recruitment and an estimate of the vector of instantaneous fishing mortality rates, each element corresponding to an age class in the catch-at-age data. Inputs to this method of cohort analysis consist of numbers of fish caught in each age class, the natural mortality rate, and either the population at large at the end of the oldest age interval or the fishing mortality during the oldest age interval. It is possible to implicitly set the final fishing mortality to infinity and thereby compute the lower limit of possible recruitment and the upper limits of the elements in the fishing mortality vector (SCRS/83/58). This is the strategy we have adopted for this exercise. The remaining items of input data (natural mortality and catch-at-age vector) are not primary collected data but, in the case of natural mortality, a parameter estimated from research results, and in the case of catch in numbers at age, a transformation of basic collected catch data. Of these two potentially uncertain data inputs, we have addressed uncertainty in catch, not in natural mortality.

We have chosen to represent uncertainty in the catch data with independent normally distributed variates for the various elements of the catch-at-age vector. This is a simplification because uncertainty in catch in numbers at age can be broken down into uncertainty at the various stages involved in estimating catch in numbers at age. However, because this exercise is intended as an example, we have left such details for future analysis.

THE COMPUTER

The microcomputer used for this exercise (and the one on display) is an eight bit (Z80 processor) computer with a four mHz clock, 64 K bytes of memory, two eight inch diskette drives, a terminal and a small printer. The software is a CP/M operating system with several programming languages, including FORTRAN, available. This computer is an early version of the "La Jolla Standard Micro", a microcomputer system that is currently assembled at the Southwest Fisheries Center in La Jolla. It is not as easily transportable as many microcomputers currently on the market, but its architecture is such that it can be upgraded with relative ease as new processors and other devices become available. Upgrading of the La Jolla Standard Micro to new 16 bit processors (Intel 8086 and Motorola 68000) is now in progress.

DATA

For our example, we chose as input data the 1970 cohort of yellowfin tuna taken in the eastern Atlantic. Catch data, in numbers, are from Fonteneau (1981) for 21 quarterly age intervals. For purposes of demonstration we used the popular value 0.6 year^{-1} for the instantaneous rate of natural mortality. Following precedent, we assumed the popular, but probably unlikely, model that natural mortality is the same for all ages.

COMPUTATIONAL PROCEDURES

Catches in number at age were altered for the Monte Carlo procedure by multiplying nominal catches (as given by Fonteneau) by a normal random variate having a mean of 1.0 and standard deviation of 0.2. Normally distributed random numbers were produced by the Box-Muller method (Naylor et al., 1966). The altered catch values were thus distributed normally with mean equal to the nominal value and standard deviation of 0.2 times the nominal value. This means that approximately 99% of the values should fall within the range of 0.5 to 1.5 times the nominal value. Random numbers below 0.5 were set to 0.5 and numbers above 1.5 were set to 1.5, thus assuring that 100% of the altered catch values were in that range.

A program for reverse cohort analysis was implemented by us. The program generates a vector of fishing mortality values and a recruitment level, and it requires input of catch data in numbers at age for a particular cohort, a natural mortality value and either the population of the cohort at the end of the oldest age interval or the fishing mortality during the oldest age interval. The program allows the final fishing mortality to be implicitly set to infinity by setting the population at the beginning of the oldest age interval equal to the catch in that interval. This program was first run using he nominal catch data, giving what we call "deterministic" results for the ecruitment and for the fishing mortality vector.

The cohort analysis program was then changed into a subroutine that could be called many times by a main program, each time supplying a different set of catch data stochastically modified from the nominal catch data as described above. We ran the cohort analysis on 1000 stochastic catch-at-age vectors collecting frequency counts for elements of the fishing mortality vector and for recruitment.

RESULTS

Figure 1 shows the distribution of the generated random variate. As expected the variate appears to be distributed normally about its mean value, 1.0.

Distributions of recruitment and of age-specific fishing mortality rate resulting from 1000 runs of the simulated catch series are shown in Figures 2 and 3. Statistics describing the distributions of fishing mortality are listed in Table 1.

Though no statistical tests were performed, elements of the fishing mortality vector appear in general to be distributed normally about their means (Figure 2). Means differ only negligibly from the deterministic values calculated from the nominal data (Table 1).

The instantaneous rates of fishing mortality at age appears to be relatively more sensitive to uncertainty in catch at age and recruitment relatively less sensitive to this uncertainty. Letting catch vary between 0.5 and 1.5 times nominal values resulted in fishing mortality rates distributed between 0.4 and 1.8 times values calculated in the deterministic run. The same variation in catch resulted in a distribution of recruitment between only 0.8 and 1.2 times the value calculated from the nominal data.

Fishing mortality for all ages appears to be equally sensitive to uncertainty in catch when uncertainty is described as in our exercise. This is indicated by the lack of any trend in coefficients of variation for successive ages which suggests that there are no systematic increases or decreases with age in variability of calculated fishing mortalities.

DISCUSSION

Our primary purpose in this exercise is to demonstrate the use of microcomputers to test the effects on results of population assessment of uncertainty in input parameters in a meeting in which the uncertainty is noted. If such questions arise at this meeting, we hope the availability of the microcomputer will be of benefit.

Our second purpose is to illustrate the use of the microcomputer to test the effect of systematic uncertainty in input parameters on the results of cohort analysis, an important assessment technique used often by ICCAT scientists.

We chose Fry's method of cohort analysis. Though we have not tested the method ourselves we eliminated consideration of Pope and Shepherd's "seperable VPA" based on serious difficulties with the method discovered by Megrey who concluded that this method "...should not be used..." Megrey found good features in both Fry's and Doubleday's methods. We chose Fry's because of familiarity with the method by ICCAT scientists. To avoid problems due to the failure of the forward solution in some conditions, we chose the reverse solution of Fry's method.

Somewhat different results might be obtained with either Doubleday's or Pope and Shepherd's method. Different results might also have been obtained with the forward solution of Fry's method as was found in a study of the effects on results of cohort analysis of uncertainty in starting population (SCRS/83/57).

We found fishing mortality to be relatively more sensitive and recruitment relatively less sensitive to uncertainty in catch-at-age. It is probable that an individual element of the fishing mortality vector is most heavily influenced by error in the corresponding element of the catch-at-age vector, whereas the recruitment estimate is influenced by errors in all elements of the catch-at-age vector. The distribution of the recruitment vector would, therefore, be relatively narrower than the fishing mortality distributions because of a statistical averaging effect.

Of the two parameters used as input by cohort analysis we have chosen to model uncertainty in only one, catch in numbers at age. We did not test for sensitivity to uncertainty in the other parameter, natural mortality, or for possible uncertainty at each stage leading to catch in numbers at age. These uncertainties can be modelled and their effects on the results of cohort analysis tested in ways similar to those we have used here.

LITERATURE CITED

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Naylor, T., J. Balintfy, D. Burdick and K. Chu. 1966. Computer simulation techniques. John Wiley and Sons, 352 pp.

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Table 1. Statistics describing distributions of instantaneous fishing mortality rate calculated in stochastic runs.

Age (Quarters)	Fishing mortality (deterministic)	Fishing mortality (mean of Monte Carlo runs)	Standard of deviation	Coefficient variation
1	0.0491	0.0488	0.0099	0.2040
2	0.0893	0.0902	0.0176	0.1950
3	0.1713	0.1725	0.0353	0.2044
4	0.1808	0.1807	0.0358	0.1982
5	0.3832	0.3832	0.0769	0.2011
6	0.4367	0.4346	0.0874	0.2012
7	0.1897	0.1921	0.0389	0.2027
8	0.1825	0.1853	0.0362	0.1955
9	0.5332	0.5301	0.1007	0.1899
10	0.2915	0.2893	0.0584	0.2017
11	0.1993	0.2014	0.0485	0.2028
12	0.2960	0.2947	0.0603	0.2045
13	0.3996	0.3973	0.0786	0.1977
14	0.2877	0.2884	0.0579	0.2007
15	0.5065	0.5093	0.1007	0.1978
16	0.3568	0.3557	0.0712	0.2003
17	0.6429	0.6474	0.1269	0.1960
18	0.5622	0.5666	0.1184	0.2090
19	1.6047	1.6131	0.3026	0.1876
20	2.0563	2.0664	0.3978	0.1925
21	2.8712	2.9340	0.6038	0.2058

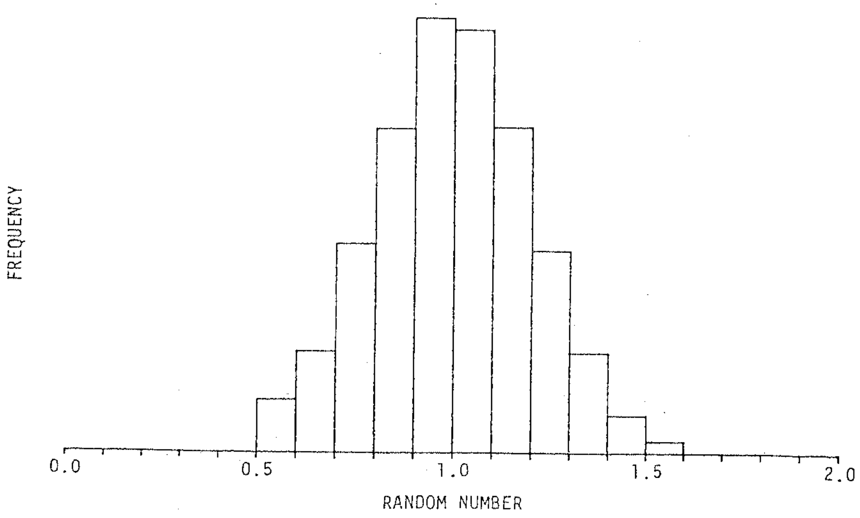

Figure 1. Distribution of the generated random variate.

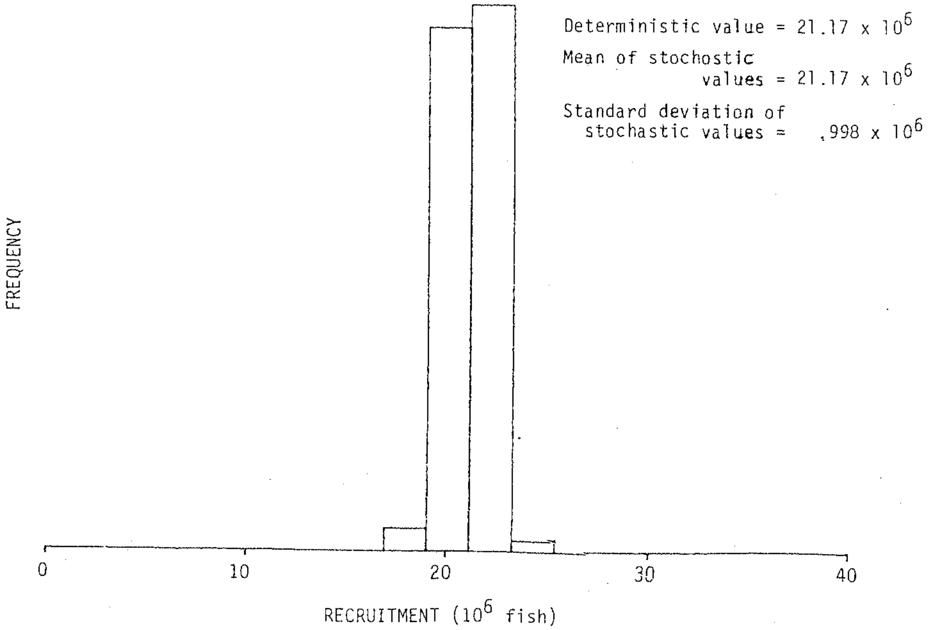

Figure 2. Distribution of recruitment calculated in stochastic runs.

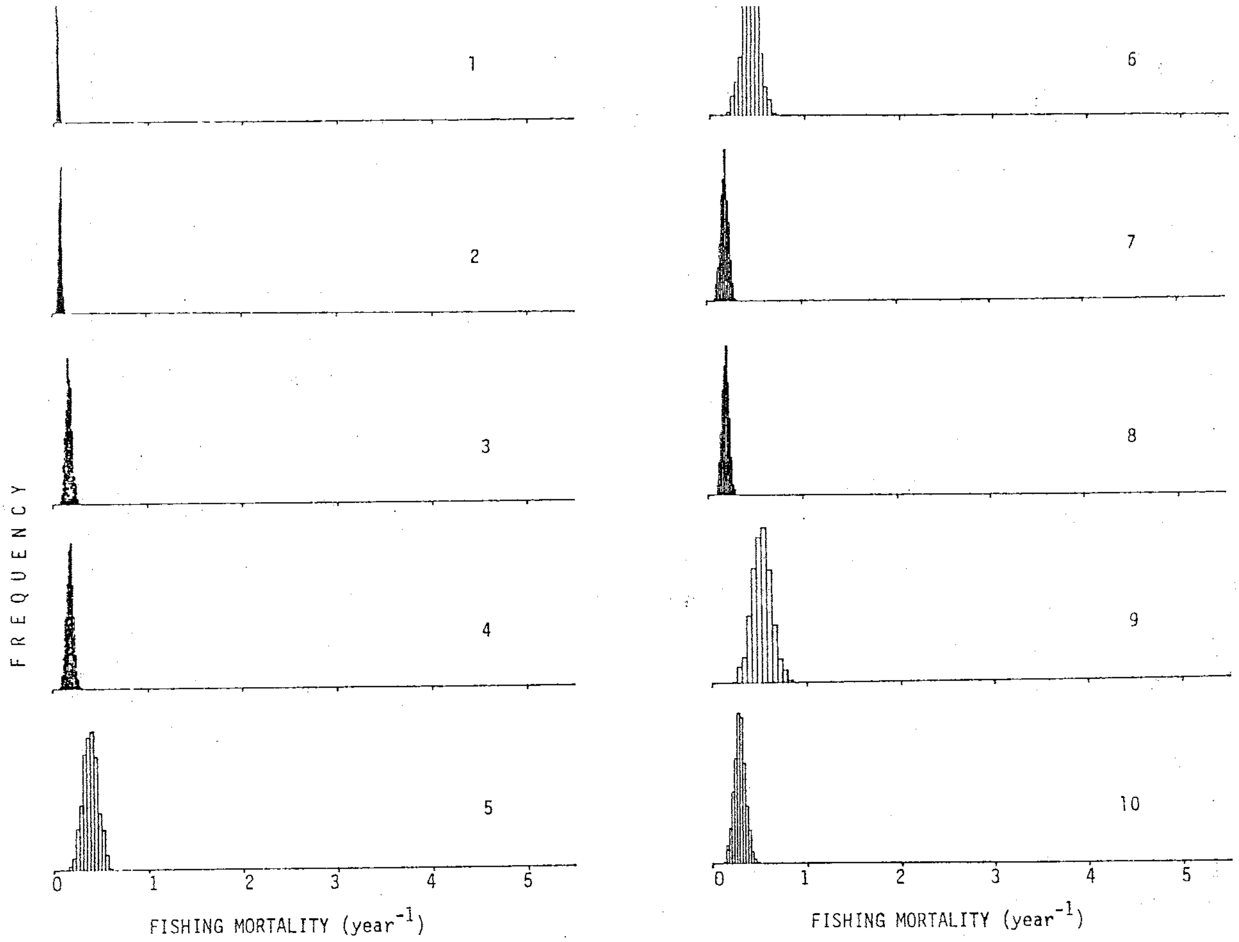

Figure 3. Distributions of instantaneous fishing mortality rate calculated in stochastic runs. (continued)

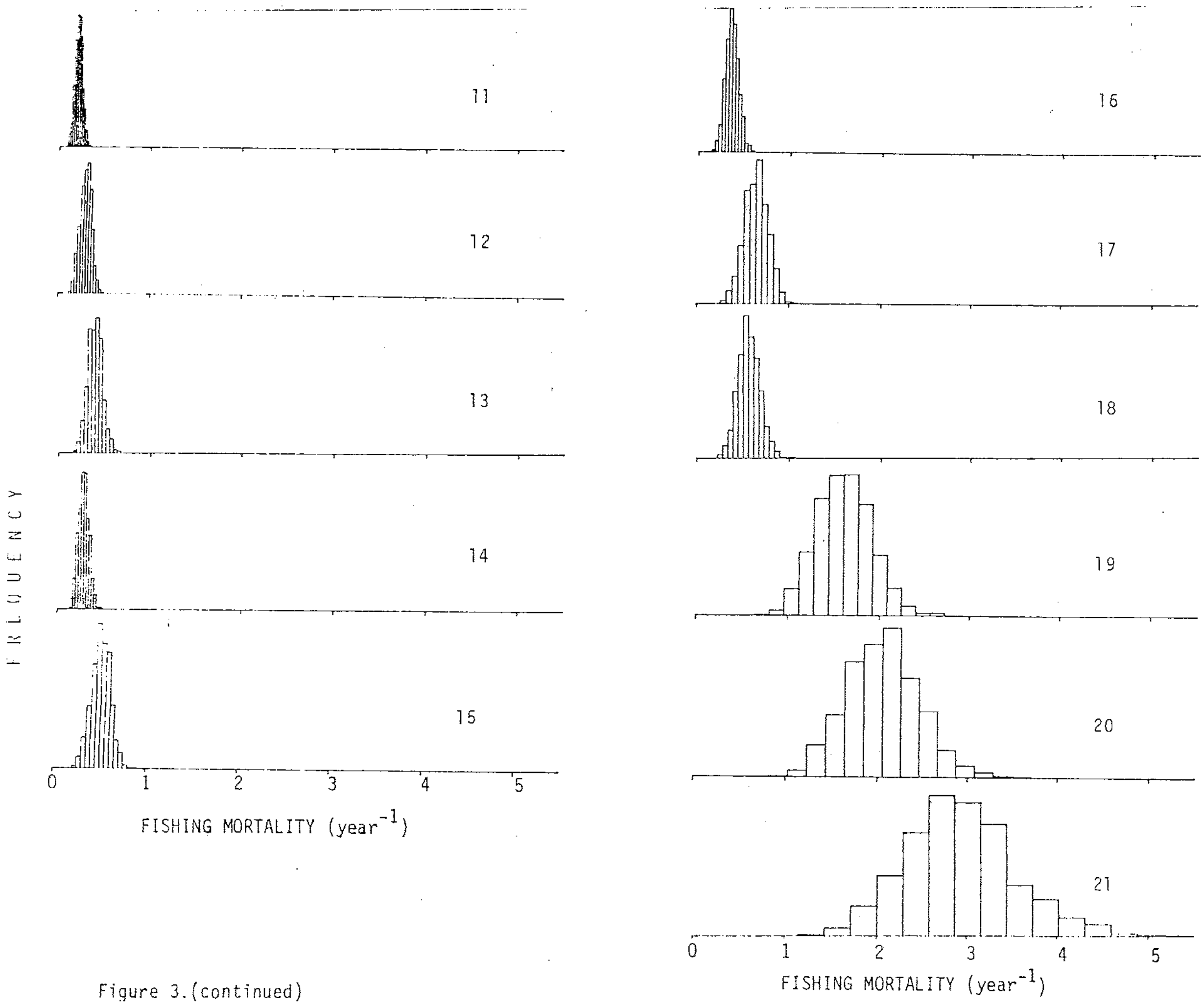

Figure 3.(continued)