Investigations on the Number of Trials Required for Statistical Comparison of Fishing Gears

A. K. KESAVAN NAIR

Central Institute of Fisheries Technology, Cochin-682 029

The number of fishing trials required for comparing the efficiency of fishing gears was investigated. A unique solution to this problem did not appear to exist because of the heterogeneity of the experimental material. Sequential experimentation and analysis have been found to be a practical approach to this problem. By this, the experiment can be terminated utmost after 35 days' fishing for catches with standard error per unit as per cent of the mean about 30% or less(after logarithmic transformation). For data with mean catches less than 1.5 kg analysis of variance approach does not appear to be meaningful.

To compare the efficiency of fishing gears, one of the statistical designs used is the randomised block design where a block is constituted by consecutive hauls made in the same area on the same day. The fishing gears tested for their relative efficiencies form the treatments. For economy and to get quick results, the optimum number of trials are useful. Solution on the number of trials require information on the estimate of variance (σ) in the population and a specification of the largest confidence interval to be tolerated or the smallest mean difference. Simple estimate of the sample size as well as estimates specifying the probability of success are given by Panse & Sukhatme (1957), Snedecor (1961), Cochran & Cox (1963) and Kempthorne (1967). Information on the variance is normally obtained from a previous experiment or from a knowledge of the range. Panse & Sukhatme (1957) have stated that in the absence of information on the variability, the number of replications should be sufficient to ensure at least about 12 degrees of freedom (d.f) for error. Tables on the number of replications required for a given probability of obtaining a significant result have been given by Cochran & Cox (1963). These numbers correspond to a range of 2 to 20 in the standard error per unit expressed as per cent of the mean. For large values of standard error as per cent of the mean, the number of replicates are to be worked out. Formula to work out the number of blocks relevant to randomised block experiments has been given in Snedecor (1961). Results of an investigation conducted to estimate the optimum number of trials are reported in this communication.

Materials and Methods

The present investigation on the number of replicates is an empirical study using three sets of data. The data were arranged sequentially for 10, 15, 20, 25, 30 and 35 days. At each stage the number of blocks were estimated using the formula.

$$b = \frac{(Qa,\ f)^2\ (s^2_o)\ Ff,\ f_o}{\delta^2} \quad \ldots\ldots\ldots\ldots 1$$

given by Snedecor (1961). Here, 'a' is the number of treatments tested, f = (a–1) (b–1) corresponding to a large value of b, S_o, the standard error per unit (an estimate of σ), f_o, d.f. corresponding to the mean square S_o^2 and δ, the least population difference in the means, the proposed experiment is expected to detect with p = 0.75. The values of Qa, f and Ff, f_o orginally tabulated by May (1952) and Merrington & Thompson (1943) respectively were taken from Snedecor (1961). For a given number of blocks b, the lowest differences in the means which the experiment would detect, were worked out from,

$$\delta = \frac{Qa,\ f\ (s_o)\ \sqrt{Ff,\ f_o}}{\sqrt{b}} \qquad ....2$$

The variation in the estimates of parameters when based on increasing number of blocks and also the relationship between some estimated parameters were studied graphically.

Results and Discussion

The mean (m), $S_o{}^2$, standard error per unit as percent of the mean ($\frac{S_o}{m}$ x 100) and b, estimated from consecutive trials of 10, 15, 20, 25, 30 and 35 days (using MICRO 2200 of Hindustan Computers) after logarithmic transformation for the three sets are given in Table 1. The b's were estimated for detecting 20% or more difference in the means (δ=20% of the mean) with p = 0.75. The standard error per unit as per cent of the mean ranged between 17 to 40% for the first set, 14 to 24% for the second and 53 to 74% for the third. Thus the experimental material appeared to be heterogeneous. From its relationship with the number of blocks used to estimate, the estimated number of blocks were found to be more stable and realistic for sets 1

Table 1. *Showing the mean, standard error per unit, standard error per unit as percent of the mean and b, computed from* 10, 15, 20, 25, 30 *and* 35 *days of fishing trials.*

A. Set 1

No. of days	Mean (m)	Standard error per unit (So)	Standard error per unit as per cent of the mean (So/m x 100)	b	Significance of difference between treatments
10	0.2756	0.10984	39.8	62	NS
15	0.4063	0.09561	23.5	21	*
20	0.5435	0.09103	16.7	10	*
25	0.6293	0.18425	29.3	30	NS
30	0.6699	0.20201	30.1	32	NS
35	0.7475	0.20059	26.8	25	NS

B. Set 2

No. of days	Mean (m)	Standard error per unit (So)	Standard error per unit as per cent of the mean (So/m x 100)	b	Significance of difference between treatments
10	0.4084	0.09767	23.9	23	*
15	0.5401	0.09735	18.0	12	*
20	0.6505	0.08962	13.8	7	**
25	0.6889	0.11922	17.3	11	**
30	0.7845	0.12506	15.9	9	*
35	0.8471	0.14996	17.7	11	**

C. Set 3

No. of days	Mean (m)	Standard error per unit (So)	Standard error per unit as per cent of the mean (So/m x 100)	b	Significance of difference between treatments
10	0.3008	0.17570	58.4	133	*
15	0.2880	0.15193	52.7	103	**
20	0.2578	0.14743	57.2	116	*** ($P< 0.1$)
25	0.2375	0.13764	57.9	117	*** ($P< 0.1$)
30	0.2285	0.16174	70.8	173	*** ($P< 0.1$)
35	0.2391	0.17717	74.1	188	*** ($P< 0.1$)

NS = Not significant, * = Significant at 5% level,
** = Significant at 1% level, *** = Significant at 0.1% level

and 2 (Fig. 1). Set 3, for which the estimated numbers of blocks are larger, the estimates do not stabilize but increase

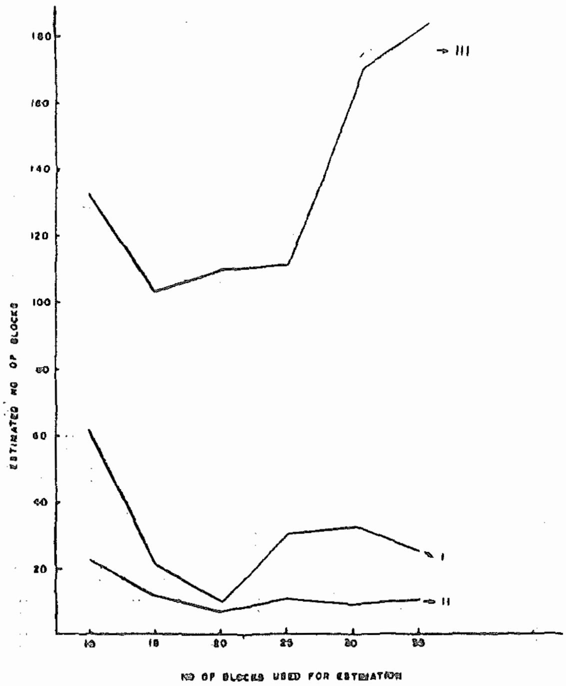

Fig. 1. Relation between estimated number of blocks and number of blocks used for estimation

with increasing number of blocks from which the estimates were made. Thus the large sample property of estimates was not found to be satisfied for this set within the available range of values. This is because

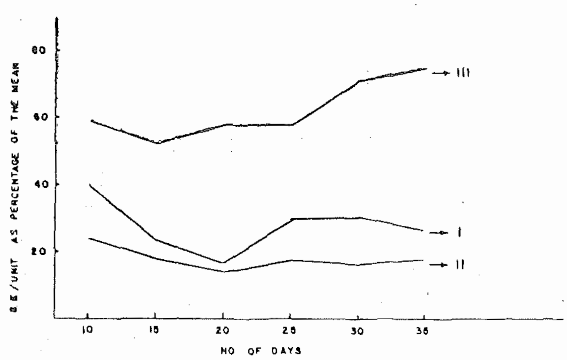

Fig. 2. Relation between standard error per unit as percentage of the mean and number of days

the estimated number of blocks increases with increase in the standard error per unit and as found from Fig. 2, the estimated standard error as per cent of the mean increases when the number of blocks (days),

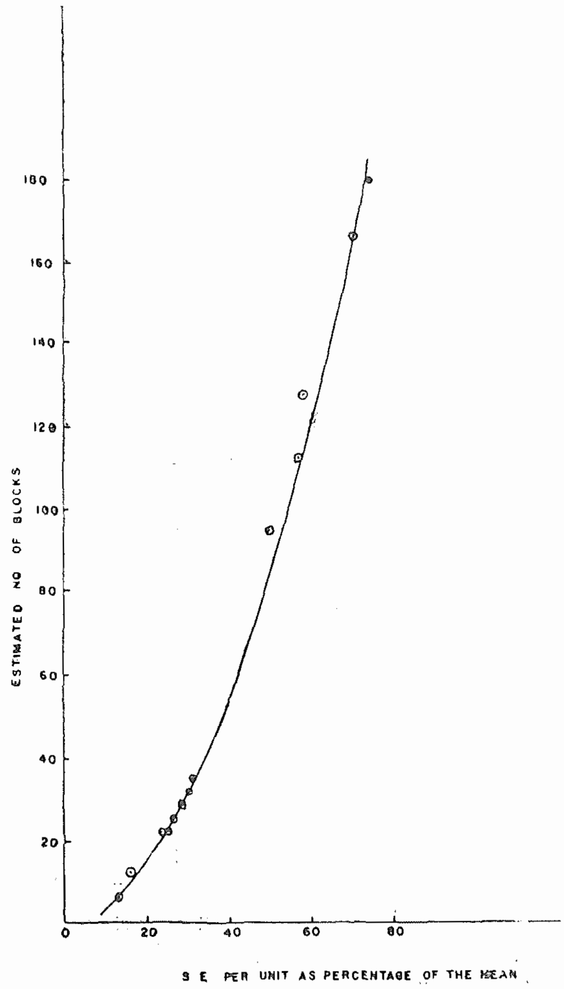

Fig. 3. Relation between estimated number of blocks and standard error per unit as percentage of the mean

from which this is estimated, increases. The standard error per unit as per cent of the mean are also relatively larger (above 50%) for this set. To know how much larger the estimated number of blocks should be for larger increase in standard error per unit as per cent of the mean, figure 3 is employed. A common curve appears to adequately represent the three sets of data. The figure shows that for standard error larger than about 30% of the mean large number of blocks are required. For such sets of data (as in set 3), the estimation of number of blocks do not seem to be useful, because experiments requiring very large number of replications are not desirable from practical and economic points of view. Such data calls for other method of handling. As found from Fig. 4, larger standard errors per unit as per cent

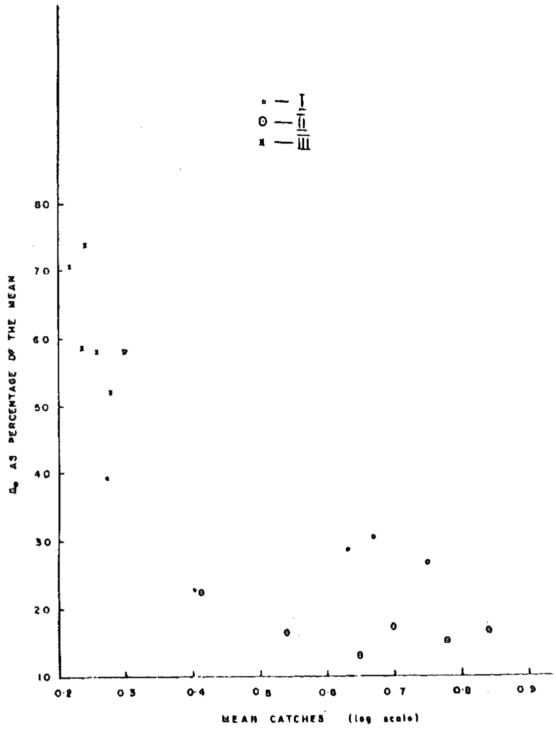

Fig. 4. Relationship between mean catch and S_o as per cent of the mean

of the mean are associated with smaller mean catches, the rate of increase in the former being rapid for decrease in the latter below a certain level. For instance, for the mean catch less than 0.4 (1.5 kg in original scale), the standard error as per cent goes above 40. Thus, when the catch is very poor, standard error as per cent of the mean and consequently the number of blocks required becomes very large making the analysis of variance less meaningful. The fact that when the availability of fish in the exploited area is very poor, catches will not reflect the efficiency of gears supports this conclusion.

With variations in the number of blocks, changes in the level of significance of the difference in treatment effects could be observed (Table 1). For set 3, though the significance level was very high ($P < 0.1$), the δ – value computed from equation (2) for 35 blocks was 46.1% of the mean showing that the experiment would detect only treatment effects as large as 46.1%. But the corresponding δ – values for sets 1 and 2 were 16.7 and 11.0% of the mean respectively, which agree with the originally set δ – value of 20% or less. These results also support the observations made in the preceding paragraph.

In conclusion, as a practical procedure, the accumulated data can be analysed sequentially at the ends of 10, 15, 20......days and depending on the standard error as per cent of the mean, a decision on the number of trials can be made with 35 days' trial. If the standard error per unit as per cent of the mean stabilizes at about 30% or below, the experiment can be stopped and the decision at this stage can be taken as conclusive. The population which gives rise to such sets of data is probably less affected by fluctuations in the availability of fish because the replenishment and removal balance the sub-populations in the exploited area. For such data, analysis of variance as applied to randomised block design can be reasonably attempted after logarithmic transformation. But when the catches are poor, say, with a mean catch less than 1.5 kg, standard error per unit will increase necessitating experimentation in very large number of blocks which would be impractical as well as uneconomical and analysis of variance approach would not be useful for such data.

Cochran & Cox (1963) and Tippet (1952) have discussed the usefulness of sequential experimentation when the treatments can be applied to a unit in definite time sequence and when the process of measurement is very rapid so that the yield or response on any unit is known before the experimenter treats the next unit in the time sequence. It can be seen that these conditions are fully satisfied for fishing experiments. The sequential experimentation has also the advantage that the experimenter can stop the experiment and examine the accumulated results before deciding whether to continue the experiment or not.

The author is grateful to Dr. C. C. Panduranga Rao, Director, Dr. P. N. Kaul and Shri K. Krishna Rao, all of Central Institute of Fisheries Technology for encouragement, to Dr. K. Alagaraja, Scientist, Central Marine Fisheries Research Institute, Cochin for critically going through the manuscript and suggesting improvements and to Shri H. Krishna Iyer for helpful comments.

References

Cochran, W. G. & Cox, G. M. (1963) *Experimental Design*. John Wiley & Sons, New York, 611 p

May, J. M. (1952) *Biometrika* **39**, 192

Kempthorne, O. (1967) *The Design and Analysis of Experiments*. Wiley Eastern University Edition. Wiley Eastern Pvt. Ltd., New Delhi, 628 p

Panse, V. G. & Sukhatme, P. V. (1957) *Statistical Methods for Agricultural Workers,* Indian Council of Agricultural Research, New Delhi, 361 p

Snedecor, G. W. (1961) *Statistical Methods*. The Iowa State College Press, Ames, Iowa U. S. A., 534 p

Tippet, L. H. C. (1952) *Technological Application of Statistics*. John Wiley & Sons, Inc., London, 186 p