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DETERMINISM AND RESPONSIBILITY[1]

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THERE is an old saying concerning the Christian ministry. "Every man must be an Arminian when he preaches, and a Calvinist when he prays." That is, in the first case he must emphasize free-will; and in the second, divine providence. This is far more than an epigram; it is an effective statement of an intellectual difficulty which besets religion, philosophy and science alike. Even the most case-hardened mechanist of the old nineteenth-century school had no qualms about asking his neighbor at table to pass the butter.

It is bold to attempt even a partial resolution of this ancient antinomy; but I am convinced that it may be very considerably clarified with the aid of concepts derived from physical science. In a round-table discussion, voices of protest would rise here. "Have you forgotten Heisenberg?" "Has not modern physics abandoned determinism, and committed itself to a principle of indeterminacy?"

Some ground must be cleared here before the discussion can proceed. It is not only in past centuries that mischief has been done by the unfortunate choice of a name. If the great physicist who discovered the "uncertainty principle" had only called it the "Principle of limited measurability" (as Max Born did a few years later) we might have been spared a great part of the "awful outbreak of intellectual licentiousness" which Bridgman all too truly foresaw among the half-informed.

The principle is of the type which Whittaker has recently called Postulates of Impotence.[2] Like New-

[1] A paper presented at the Third Conference on Science, Philosophy and Religion, New York, August 28, 1942.

central line in the R panel (labeled R'_n). The upper and lower limits as shown in the $\overline{X}$ and R panels are the limits set by adding to and subtracting from the mean values of these statistics ($\overline{X}'$ and R'_n) three times an estimate of their standard deviations. The estimation of these limits has been made from tables given in reference 7 for determining the "control limits" from the ranges. Assuming that the values of $\overline{X}$ and R are normally distributed, the probability of an individual value falling outside these limits solely as a result of sampling error would be only about .003.

It is apparent from the figure that there has been no significant change in the variability within 5-year periods—the points in the R panel cluster well within the limits. This is true even of the last four periods. In the case of the mean values, however (panel $\overline{X}$), the points for the last three periods are all below the lower limit and that for the period immediately preceding (including the years 1921–1925) is not far above the lower limit. The obvious interpretation is that the mean catches for at least the past three 5-year periods are significantly different from those of the period 1876–1920. If such a series of points outside the "control limits" were observed during the course of producing a manufactured product it would be taken as clear indication that something had gone wrong with the process and that things were getting rapidly worse. Even a single point outside the limits would be viewed with suspicion and an investigation started. There seems to be no reason to make a different interpretation of the data bearing on the runs of Columbia River Chinook salmon.

If such a control chart of the production of Chinook salmon on the Columbia River could have been presented in 1930 it would have shown that the 5-year period ending with that year was "out of control" and this should have been taken as a warning that something was wrong with the production process. As a result investigations could have been started to determine the causes of the reduced productivity and measures taken that might have prevented or at least delayed the progressive depletion that followed. As a matter of fact the need for such action was not felt because the true situation was not generally recognized. The catches had been small for a few years, it is true, but there had been poor years before and fishermen, canners and fisheries administrators alike took counsel of their hopes and looked forward to a return of the better catches that had prevailed so long. An occasional biologist recognized the danger and as early as 1925 the writer made the following statements: "The pack . . . has remained practically stationary for a number of years during which time the intensity of fishing has been increased. . . . We may assume, therefore, that the present intensity of fishing is too great and is resulting in a dangerous reduction of the reserve of breeding adults." And suggestions were offered for minimizing "the danger of seriously depleting the supply of fish before some indication of the imminence of such depletion has become apparent."[9] In the light of present knowledge it would appear that a control chart of the sort now available would have given exactly the sort of information that was needed.

If such information had been available in 1930 and if the production of Chinook salmon had been a commercial venture under statistical control is it too much to think that something effective might have been done promptly toward maintaining production at a higher level? It seems altogether probable that the low average level of the catches in the 5-year period ending with 1930 would have been a "basis for action." The scientific management of fishery resources is not quite so simple as maintaining quality in a production line of a factory but the importance of maintaining productivity of biological natural resources is much greater on account of the serious losses that result from depletion and the long time required for rehabilitation of once depleted resources.

This control chart method of statistical analysis may well prove to be of rather general application in biology and particularly in the management of fishery and wildlife resources. It is concise, positive, easy to apply and points out variations due to heterogeneity of data promptly while there is still a chance that the causes are still operative and can be identified.

WILLIS H. RICH

FISH COMMISSION OF OREGON AND STANFORD UNIVERSITY

9 Willis H. Rich, *Bulletin U. S. Bureau of Fisheries*, XLI, 1925.

BOOKS RECEIVED

ALLEN, GLOVER M. *Extinct and Vanishing Mammals of the Western Hemisphere*. Illustrated. Pp. xv + 620. American Committee for International Wild Life Protection.

GLAUERT, H. *The Elements of Aerofoil and Airscrew Theory*. Illustrated. Pp. 228. Cambridge University Press and Macmillan. $3.50.

HUXLEY, JULIAN. *Evolution, The Modern Synthesis*. Pp. 645. Harper and Brothers. $5.00.

MIZWA, STEPHEN P. *Nicholas Copernicus, 1543–1943*. Illustrated. Pp. 88. The Kosciuszko Foundation.

SMITH, EDWARD S., MEYER SALKOVER and HOWARD K. JUSTICE. *Analytic Geometry*. Illustrated. Pp. xii + 298. John Wiley and Sons. $2.50.

STUHLMAN, OTTO. *An Introduction to Biophysics*. Illustrated. Pp. 375. John Wiley and Sons. $4.00.

TWYMAN, F. *Prism and Lens Making*. A Text Book for Optical Glassworkers. Illustrated. Pp. 178. Adam Hilger, Ltd., London.

U. S. Public Health Service. *The Anopheline Mosquitoes of the Caribbean Region*, by W. H. W. KOMP. National Institute of Health Bulletin No. 179. Illustrated. Pp. 195. U. S. Government Printing Office. 35¢.