populations X and Y. This independence distinguishes them from the effects of aggregation or concentration of the fishing units which refer to the relationship between these distributions. Although the proportion of the local density removed at X and Y is constant when the fishing power and vulnerability are constant, the absolute magnitude of the catch per unit effort is very different. It follows that the effective fishing mortality caused by unit effort at X and Y on the entire stock will also be different.

If the diagram represents the distribution of a stock in space, the use of echo-sounders may enable the fishing units to operate at X, improving the aggregation of the fleet on the stock by reducing the amount of search which would involve a disproportionate amount of fishing at Y. The same amount of fishing time thus becomes more effective.

It is also convenient to distinguish a special type of aggregation where the location of fishing activity is fixed (e.g. by the range of the vessels) but the distribution of the fish stock varies in relation to it. For example, the duration of a seasonal fishery may be determined by the rate of dispersion of the fish shoals. In years when this dispersion is delayed, a greater proportion of the fish stock is exposed to the fishing effort though this may itself remain constant. Again the effectiveness of the fishing effort is increased. Strictly speaking this could be distinguished as the vulnerability of the stock as opposed to the vulnerability of the fish, but it makes for simplicity to regard this as an instance where fishing effort has been able to aggregate more effectively upon the stock.

The concentration of fishing units upon the fish is usually determined by economic considerations. If the diagram represents the spatial distribution of a stock, the fleet might fish at Y because a second more valuable type of fish is especially abundant at that point. In this case the fishing units will not be concentrating on the main fish stock represented.

The variation of any one of these factors will influence the proportionality coefficient of the basic assumption, \( F = q_f f \), altering the effectiveness of the unit of effort \( f \). The types of variation to be expected can be viewed from a different standpoint which is discussed by GULLAND (Contribution No. 1). The most important factors of change are cyclical (seasonal variations) and long-term trends. The long-term trends in \( q \) are usually associated with changes in fishing power of the vessels and may be accommodated by the correct choice of unit of fishing effort, but the cyclical variations of \( q \) and their association with the estimation of fishing effort are also important owing to their theoretical implications.

From BEVERTON and HOLT's derivation \( F = q_f f \) represents the fishing intensity, or fishing effort per unit area; the total fishing effort conforms to this relationship only in the special case where the relative seasonal distributions of fish and fishing activity remain constant from year to year. GULLAND (1955) has discussed this in detail in the dual aspect of the problem, the estimation of an annual density index which is proportional to the true density of the population. He has demonstrated that the best estimate of this index of density is the weighted mean of the catch per unit effort in each sub-area, or month, the weighting factors being the areas or months, depending upon whether the variation occurs in time or space or both. This will be independent of the cyclical variation of \( q \), or at least take the best estimate of a mean \( q \) which may be constant from year to year.

However, in his consideration of the estimation of density, GULLAND points out that the density \( d_j \) in the \( j \)th time or space interval is related to the true density \( D \) by a further constant \( k_j \), i.e. \( d_j = k_j D \). Paraphrasing his comment (p. 31) "when the seasonal distribution in consecutive years is different, \( k_j \) will not be the same". In such cases there is no single figure which is a completely adequate measure of density for the whole year (which can be compared with the density of the stock in the previous year).

With respect to fishing effort we have the relationship \( F_j = k_j F \) or \( q_j f_j = k_j F \). Thus if there is a change in the cyclical variation of \( q_j \) the constant \( k_j \) will also vary and the effective fishing intensity measured by GULLAND's method will not be comparable between consecutive years.

Fishery biologists find it convenient to assume that \( k_j \) does not vary, but this may rarely be true when one considers the factors that influence \( q_j \). This is evident in complex fisheries. For example, consider two species of equal value which normally have comparable densities so that fishing is equally distributed between them. In a second year the stock of one species may contain a particularly abundant year-class. Fishing activity will then concentrate upon this species and \( q_j \) will change with respect to both. An estimate of fishing effort will remain the same because the weighting factors between areas or months have not changed, but the effectiveness of that effort will have been distorted.

This situation can arise in an ostensibly simple single-species fishery, such as the English Bear Island cod fishery. Figure 1 shows the fishing effort in each month of 1957 and 1960. In 1960 the winter fishery was not exploited, although in 1957 fishing activity at that time was comparable to the main summer fishery. The total fishing effort in these two years is not strictly comparable because the distribution of its effectiveness has varied.

These errors have considerable theoretical im-