

ually. They swam actively out of the gloom, then veered away and circled for a short time before disappearing.

Continuing the descent, at approximately 180 m we became aware of the presence of a large concentration of fish at the periphery of the light field. The descent was stopped and we maneuvered in an attempt to obtain visual and photographic data. Each time the propulsion motors were activated, the fish would hurriedly retreat from view. Their movements were as a disciplined school. Several times we approached the school with the lights out, a technique which enabled the submersible *Alvin* to penetrate schools of myctophids in the Atlantic (Backus et al., 1968). Although we were never able to penetrate the school, the darkened submersible apparently attracted a few individuals who remained near the windows when the lights were switched on. Stunned by the sudden illumination, they remained transfixed long enough for good visual identification. The northern anchovy, with its projecting snout and thin body, is sufficiently distinct from other local clupeoids to give us confidence in our identification. Unfortunately, the photographs taken were blurred.

Three more blue sharks were observed at the same depth as the anchovy school. The deepest sighting was at 275 m. Because these were observed individually, the sightings could all have been of the same individual. Possibly, one of the same sharks sighted at 100 m may have followed *Deepstar* during the descent. We also observed a few squid, presumed to be *Loligo opalescens*, at the depth of the school. The spatial proximity of the sharks, squid, and anchovy suggests a predator-prey relationship, although no predation was observed.

The lower limit of the anchovy school was at 310 m and after dropping below it we descended to 590 m. There we released the descent weight and rose rapidly to the surface. The school was observed between 300 and 200 m during the ascent. The dive ended at 1407.

There is little doubt of the relationship between the anchovies and the large targets on the recording. It is difficult, however, to be sure that there is a correlation between the sharks and the discrete targets. Whatever is respon-

sible for these traces has a high acoustic target strength at 12 kHz. This can be seen by comparison on the figure with the trace made by *Deepstar*, a 2-m-diameter air-filled sphere.

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THE USE OF CONCENTRATION INDICES IN FISHERIES ^{1, 2}

The temporal-spatial distribution of organisms has generated considerable interest among biologists. This interest has generated many studies which deal primarily with the distribution of a single organism in space. In this note we consider the relationship between two organisms in space or time. We are interested, in particular, in an index of the relation between a predator (a fishing fleet) and a prey (the population to be harvested). We begin by writing

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the concentration index, suggested by Gulland (1955), which is the ratio of the ratio of averages catch-per-unit-of-effort statistic to the average of ratios catch-per-unit-of-effort statistic,

$$I_g = \left[\frac{\sum c}{\sum f} \right] \left[\frac{1}{n} \sum \frac{c}{f} \right]^{-1} \quad (1)$$

where the c denotes catch and the f denotes effort and the summations can extend over either space or time. The index I_g has appeared in many fishery papers such as, for example, Paloheimo and Dickie (1964), Calkins (1963), etc. We can see that when $I_g > 1$, the fishermen tend to be concentrating on the fish, when $I_g < 1$, the fishermen tend to be fishing where the fish are *not* most abundant, and when $I_g = 1$, there is no relation between the distribution of fish and fishermen. It might be mentioned, somewhat parenthetically, that the situation where $I_g < 1$ is rather unusual for single species fisheries, but possible in mixed species fisheries when computed for a single species that is not the main object of the fishery.

Now we observe that when the numerator and denominator of (1) are equal (that is, there is no relation between the distribution of the fish and the fishermen), we can write

$$\frac{\frac{1}{n} \sum c}{\frac{1}{n} \sum f} - \frac{1}{n} \sum \frac{c}{f} = 0 \quad (2)$$

Now multiply both sides of (2) by $\frac{1}{n} \sum f$ and note that whenever we sum a term and multiply by $\frac{1}{n}$ we have the average value of that term which we denote by the operator E , and so (2) becomes

$$E(c) - E\left(\frac{c}{f}\right)E(f) \quad (3)$$

which is, by definition, the covariance between catch-per-unit-of-effort and effort. It follows

then that when the numerator and denominator (the two bracketed terms in (1)) are equal and (2) holds, then (3) must also equal zero, implying that when there is no relation between the distribution of fishermen and fish as indicated by the equality of the numerator and denominator in (1), the covariance between catch-per-unit-of-effort and effort is zero, and hence the correlation between catch-per-unit-of-effort and effort is also zero.

The difficulty with (1) is that it provides an index that is conceptually difficult to interpret, does not contain all of the information that is in the data, is asymmetrical about the point $I_g = 1$, and has no upper bound. All of these difficulties can be alleviated by dividing the covariance in (3) by the geometric mean of the variances of c/f and f , yielding the correlation coefficient,

$$I_r = \frac{\frac{1}{n} \sum c - \frac{1}{n} \sum \frac{c}{f} \cdot \frac{1}{n} \sum f}{\sqrt{\widehat{\text{var}}\left(\frac{c}{f}\right) \cdot \widehat{\text{var}}(f)}} \quad (4)$$

where $\widehat{\text{var}}(c/f)$ and $\widehat{\text{var}}(f)$ refer to the usual sample estimates of variance. Thus I_r will be centered on zero, bounded by -1 and 1 . Positive values of I_r imply that high values of effort will be associated with high values of CPUE whereas negative values of I_r imply that high values of effort will be associated with low values of CPUE. When $I_r = 0$, CPUE is not correlated with effort, a condition which, as previously noted, is equivalent to $I_g = 1$.

The fact that I_r contains more information than I_g is demonstrated in the following example based on three contrived sets of data. These data are listed in Table 1 and depicted in Figure 1. We can see that the slopes of lines fitted to each of the three data sets are the same and that I_g for each data set is also the same, but that I_r is different for each data set measuring the variability in c/f for fixed f as well.

In many instances the region in time or space for which these indices are computed will contain relatively few, highly variable, observations. This situation, in particular, raises the question

TABLE 1.—Contrived data under conditions of low, intermediate and high variability which are used to demonstrate the indices I_g and I_r .

Low variability			Intermediate variability			High variability		
<i>c</i>	<i>f</i>	<i>c/f</i>	<i>c</i>	<i>f</i>	<i>c/f</i>	<i>c</i>	<i>f</i>	<i>c/f</i>
10	2	5	6	2	3	2	2	1
10	2	5	14	2	7	18	2	9
49	7	7	35	7	5	21	7	3
49	7	7	63	7	9	77	7	11
Σ 118	18	24	118	18	24	118	18	24
I_g	1.09		1.09		1.09			
I_r	1.00		0.55		0.44			

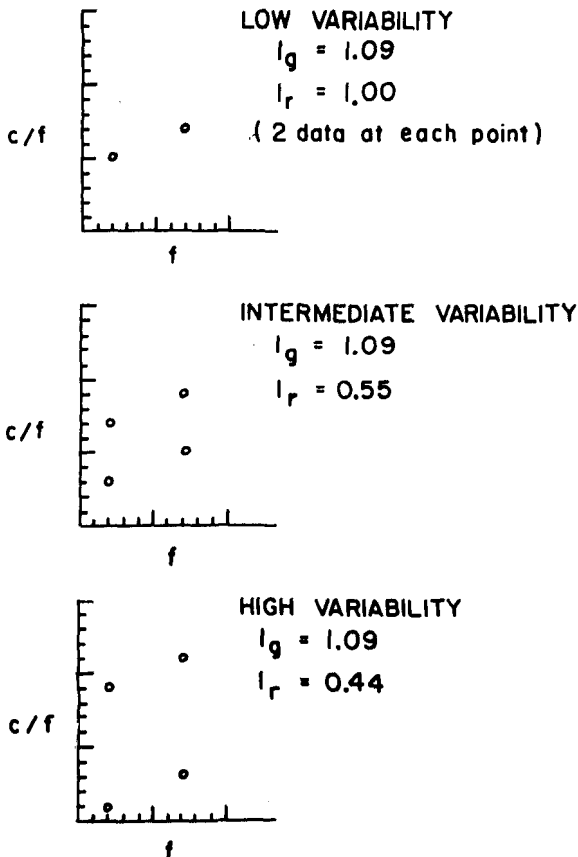


FIGURE 1.—Comparisons of I_g and I_r for c/f and f relations having different amounts of variability. The data are from Table 1.

of the amount of confidence that can be placed in any estimate of I_r or in I_g . The question of confidence can be resolved in the case of I_r if c/f and f are both drawn from the same (at least approximately) bivariate normal distribution. In the likely event that c/f and f are not at least approximately bivariate normal, then perhaps a transformation might be useful. It is also of interest to observe that since I_r is a correlation coefficient then we can interpret I_r^2 as the percentage of the total variability in c/f which is accounted for by regressing c/f upon f . Furthermore there is no reason, of course, why we could not extend this concept in multiple species fisheries to consider these sorts of data in a multiple correlation context.

The idea of using the correlation coefficient measuring the association between c/f and f as a concentration index is intuitively quite obvious and most likely would not be noteworthy except to call attention to the similarity to a commonly used index (I_g) which, in most instances, does not afford as large a scope for interpretation as does I_r . There are some cautions, however, which should be observed and these include, in addition to bivariate normality if we wish to construct confidence intervals, linearity in the relation between c/f and f . If, for example, the gear is saturated or data are pooled from various seasons, then linearity may not be a reasonable underlying model.

In the interpretation of either I_r or I_g it would be helpful to have auxiliary information because without this information it is impossible to determine whether increases in these indices result from an increased concentration of fishing on fish or fish on the location where fishermen happen to be fishing. Thus, these indices alone will not tell us whether changes in apparent abundance result from changes in actual abundance or changes in the skills of fishermen or both.

We should also draw attention to the fact that the relation of c/f and f is generally used in fisheries to determine "optimum" yield by regressing, usually annual, values of c/f upon f . This relation is frequently linear with a negative slope and is usually transformed into a parabolic function of c upon f indicating that level of f for which c is a maximum. The procedure outlined

has been criticized from a statistical point of view because c/f and f are obviously correlated. A measure of the magnitude of this correlation is clearly implied by (3) or (4).

Finally we should point out that our allusion to considering these indices as expressing relation among organisms was not careless because it seems to us that predator-prey relationships might be further elucidated through examination of concentration indices. For example, it would be interesting to relate the catch (in number of prey organisms) per predator stomach to the number of predator stomachs. This, however, is just a special case of the wealth of fishery-fish interaction models which could be applied to the prey-predator situation.

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SUITABILITY OF INTERNAL TAGS FOR ATLANTIC MENHADEN

Investigations of the Atlantic menhaden resource depend primarily on sampling and analyses of the commercial landings and studies of menhaden biology and ecology. Results of these studies give a broad understanding of the resource but sometimes lack the reliability of more direct evidence. Tagging and recovery of menhaden help provide the reliable information on movements, population size, availability, mortality, and growth rates required to better understand the resource.

The methods by which menhaden are caught, handled, and processed determine some of the requirements for tagging. Menhaden are captured in purse seines and are transferred by suction pumps from the nets to the vessels and from the vessels to the reduction plants. In the plant, the fish are cooked, pressed, dried, and ground into meal. From the time the fish are caught until they are processed into oil and meal, there is little opportunity to handle or see an individual menhaden. Consequently tags or tagged fish must be recovered by mechanical or electronic means. Internal ferromagnetic tags that are mechanically or electronically recoverable have been developed for Atlantic and Pacific herring, Pacific sardine, and anchoveta.

We conducted a series of experiments at Beaufort, N.C., to find a mark suitable for Atlantic menhaden. In 1959 we tagged young menhaden with a nickel-plated, steel tag, (Type A in Figure 1). The tagged menhaden died within a week, terminating the experiment. During 1960 we attempted to mark menhaden with fluorescent pigments and to develop a photoelectric detector. The occurrence of natural fluorescence in menhaden and other marine organisms made discrimination of marked fish impractical (Reintjes, 1963). In 1961-62 we resumed tests with internal tags to select a type suitable for menhaden and to demonstrate its recovery with magnets in a menhaden reduction plant.

Tagging Experiments and Tag Selection

We selected four ferromagnetic tags (Table 1 and Figure 1) for insertion in young Atlantic