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A COST-EFFECTIVE DATA ACQUISITION SYSTEM FOR ASSESSMENT AND MANAGEMENT OF TROPICAL MULTISPECIES, MULTI-GEAR FISHERIES

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Rational management of fisheries in order to optimize harvests requires a constant input of data on the state of the fish stocks, and in particular, of their mortality rates. Such data are usually obtained by laborious gathering of catch and effort statistics, accompanied by separate investigations designed to produce estimates of the biological and fishery parameters which govern the productivity of the stocks. In most tropical countries, the diversity and complexity of multi-species, multi-gear artisanal fisheries makes conventional stock assessment very difficult to execute and often also prohibitively expensive.

However, over the past decade, the development of length-frequency based stock assessment methodologies has rendered many of the traditional data acquisition systems outdated or redundant. In particular, detailed estimates of catch and effort are no longer essential to the fishery manager, even though they remain highly desirable. In essence, all parameters necessary for a basic assessment of the state of a fish stock can now be derived from routine collection of length-frequency data.

Single-species assessment

In order to implement the system, length-frequency samples of the major species of fish need to be acquired on a regular systematic basis. Ideally, much of the data should be derived by routine test fishing by fisheries officers with a standardized array of gear. This routine fishing would give accurate information on catch composition, catch per unit effort, length-weight relationships and gear selectivity in addition to length-frequency data. Length-frequency and catch composition data gathered at commercial landings are also valuable but there is often uncertainty about where, how and when the catch was taken. If no fishing boat is available for the fisheries officer then careful sampling of commercial landings will still produce the desired result.

Reference to Figure 1 shows how this can be achieved. The prime requirements are sets of length-frequency data for the principal species in the fishery. If these are taken on a monthly basis or at other fairly regular intervals, it is likely that modal progression analysis will give estimates of the coefficient of growth, K, and the asymptotic length, L_∞. If there is any difficulty, as there often is, in interpreting the modal progression, the best fit of growth curves to the data can be obtained using the ELEFAN I routine (Pauly et al 1980, Pauly & David 1981).

Summation of the periodic samples, appropriately weighted for sample size and the time between successive samples, will give an estimate of the length-frequency composition of the catch. This estimate can be converted to a catch curve using the methods of Sparre (1983) or of Pauly and Gulland (Pauly 1982; Pauly et al 1981), as appropriate to obtain an estimate of Z, the coefficient of total mortality.

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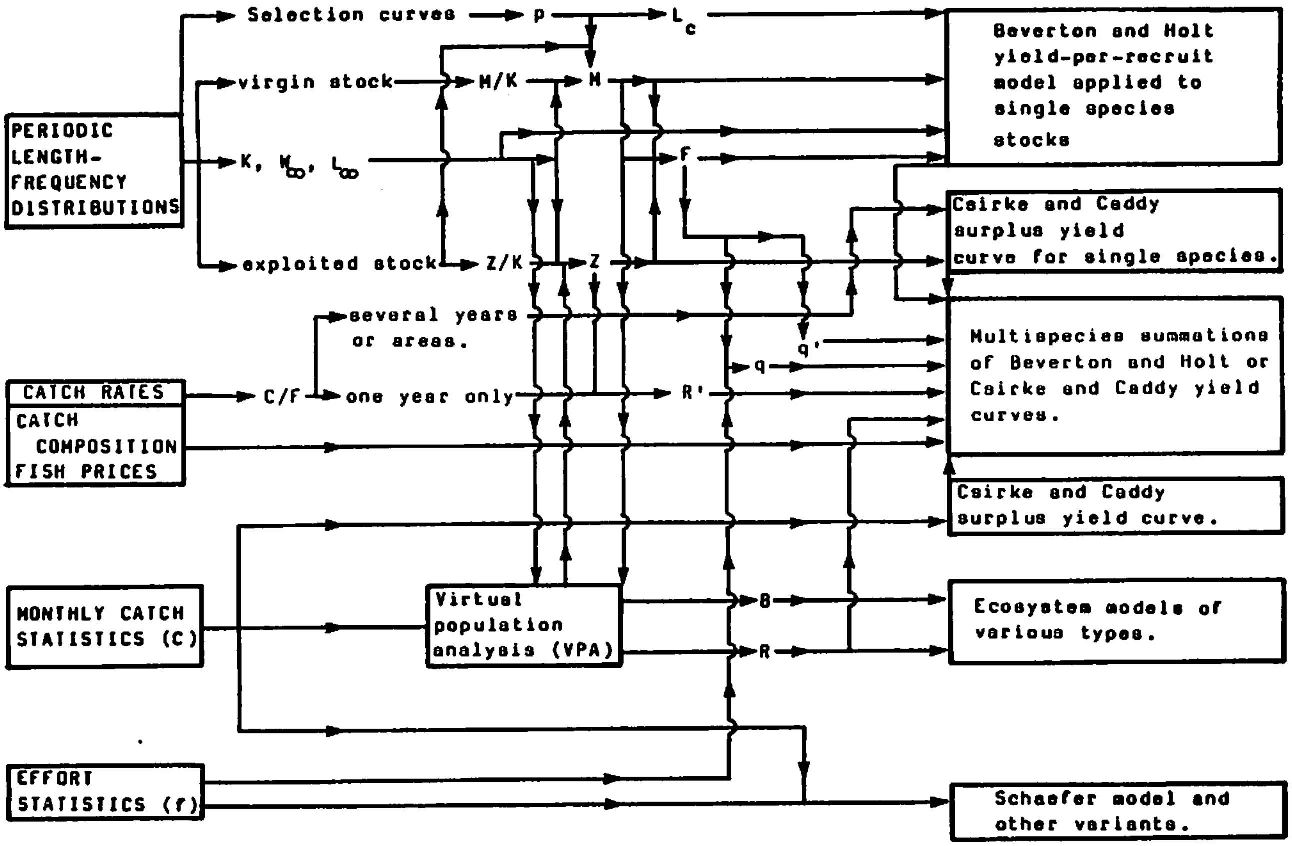

Fig 1. Flow chart for biological and fishery parameter estimations leading to fishery assessments. Required inputs are shown in the boxes on the left-hand side; outputs on the right. Notation as follows: B - biomass; C - catch of a species by numbers or by weight; F - fishing mortality coefficient; K - growth coefficient; L_c - mean length at first capture; L_∞ - asymptotic length; M - natural mortality coefficient ; p - probability of retention of fish in a given length group; q - catchability; q' - catchability index; R - number of recruits; R' index of recruitment; W_∞ - asymptotic weight; Z - total mortality coefficient.

Additionally if it has been possible to sample an unfished stock, or the prerecruits of the exploited stock, catch curves can be constructed which give estimates of the coefficient of natural mortality, M. It is also important to note that even if it has not been possible to estimate, K, the coefficient of growth, estimates of the ratio of Z/K or M/K can be derived from length- converted catch curves and these ratios are all that are required for conventional yield-per-recruit calculations (Munro, in press). If both Z and M or Z/K and M/K are known then the coefficient of fishing mortality, F or F/K, is obtained by subtraction. In the simplest case F will be almost constant over the entire exploited range but in a very diverse multigear fishery F will be size related.

Additionally, length-frequency data will give information on the selectivity of the fishing gear/s, and thus the mean size at first capture, L_c. If the selection curves can be determined, and hence the probability of retention, p, of successive length groups, there is a possibility of estimating the natural mortality rate, M, on a routine basis (Munro 1983; Munro and Palomarès 1983). Also, it then becomes possible to incorporate data on incompletely recruited length-groups by dividing successive length-frequencies by the probability of retention, in successive length-groups.

The foregoing should provide all the parameters required for the calculation of yield curves using the conventional yield per recruit models of Beverton and Holt (1957, 1964), or Gulland (1969). It is then possible to determine if the species in question is underfished or overfished in a technical sense. This is quite a simple exercise to conduct for the most valuable and/or abundant species in a fishery which is dominated by a single type of gear and is almost guaranteed to give meaningful results. It enables the fishery manager to at least evaluate the state of the most abundant species in a multispecies fishery and decide whether or not further investment is warranted or conservation measures are needed.

Multispecies assessments

The next step would be to try to combine all data for all species in order to obtain a single yield curve which includes <u>all</u> species and <u>all</u> gears in the fishery. This is very difficult to do and takes one to the frontiers of fisheries science --- but that is an excellent reason why it should be tried.

The most likely complication to emerge is that in a multigear fishery, and particularly if highly selective gear such as gill nets are in use, fishing mortality (F) is likely to be size-related and yield-per-recruit curves will have to be adjusted for progressive changes in fishing mortality. Beverton and Holt (1964) give a method for doing this.

If a number of yield-per-recruit curves are to be summed in order to obtain a single yield curve for all species, it is necessary to obtain an index of recruitment (R')from data on catch (C) per unit of effort (f) and mortality ($R' = Z \cdot C/f$)and also to weight the curves by value of the individual species. It is also necessary to know the catchabilities (q) of each species in order to plot the summed yield curves against the effort in the fishery. Each unit of fishing gear will generate a certain amount of mortality in each species in the fishery (defined as the "catchability", q) but if two or more gears are used simultaneously in a fishery, the separation of the fishing mortalities they cause is very difficult. Put another way, it is necessary to estimate the relative catchabilities of each species in different gears and express fishing effort in terms of some standardized value. For example, one trawler fishing for one night might generate the same mortality as (say) 4.7 lift nets and 2.0 beach seines. Thus it becomes necessary to have an inventory of fishing units and preferably, but not essentially, an estimate of the frequency with which they are used. The number of units of fishing gear per km^2 of fishing ground is often a useful measure of fishing intensity.

The easy way around the problem of estimating q is to use the average fishing mortality (F) generated in each species by the entire fishery <u>in a particular year</u> as an index of q (designated q'). Thus, the definition of catchability becomes the amount of fishing mortality generated by one fishing fleet in one year, thus F= q'. Yield curves can be derived that will show expected yield from all species if the fishing effort is increased or decreased <u>provided that the relative composition of the multigear fleet is unchanged.</u>

A word of caution needs to be injected at this point. We have very little knowledge of how species interactions affect the parameters of the Beverton and Holt yield equation or how the parameters might change when fishing effort is increased. It is self evident that within an exploited community some parameters <u>must</u> change when, for example, predators are selectively removed from the system. If the parameters change, then the yield curve must change and we become increasingly uncertain of the validity of the yield curve as fishing effort increases. Even here, we have some possible checks. For example, it might be possible to compare yield and catch composition from areas which are ecologically similar, but which differ in the amount of fishing effort exerted on the stocks. This will give some indication of whether or not the predictive model is valid.

The Beverton and Holt constant recruitment model is the only one which can be used if only one or a few years of length-frequency, catch-rate and catch-composition data are available. However, if the data cover several years or if data are derived from several ecologically similar areas which are fished at different intensities, one of the models of Csirke and Caddy (1983) can be used, in which catch rates are plotted against total mortality rates (Z) to produce a surplus yield curve. A fundamental assumption is that Z is constant over the exploited size range.

All of the foregoing analyses are possible on the basis of systematic and careful collection of length-frequency, catch-composition and catch-rate data derived either from routine fishing by fisheries officers or by monitoring commercial landings. In the case of small-scale near-shore fisheries, routine fishing would probably give the most reliable data.

Models based on catch statistics

The next step in data acquisition is the routine collection of catch statistics for the whole fishery. Under certain circumstances, this activity could replace the routine fishing but such an option would have to be very carefully evaluated. If monthly catch statistics are at least collected for, the most important species, several possibilities emerge. Firstly, the Csirke and Caddy (1983) model can be utilised which estimates a surplus-yield curve given inputs of catch and total mortality over several years. Secondly, and of far more importance, length-cohort analysis (Jones 1981) or length-structured virtual population analysis (VPA) becomes possible (Pope et al 1982). This requires inputs of monthly catch by species, growth parameters and the natural mortality coefficient and generates estimates of Z (and hence F), recruitment rate (R), population (P) and biomass (B) of the stock. Given a knowledge of biomass, many of the newly emerging ecosystem models can be applied, particularly if there is information on the trophic structure of the community.

Finally, as is apparent from Fig. 1, the collection of effort statistics adds very little to the system other than to permit the implementation of the outdated Schaefer (1954) model or the model of Schnute (1977) and the estimation of the catchability (q), either as an output of Schnute's model or as $q = F/f$. However, in a multigear fishery it is only possible to obtain meaningful estimates of q from a knowledge of the biomass of the stock and the average catch rates by specific gears.

Thus, while an inventory of fishing gears is useful, together with information on the seasonality of their use, it is no longer necessary to gather effort statistics or to attempt to standardize effort data. Put another way, the development of length-converted catch curves which yield reliable estimates of mortality has made fishing effort statistics largely redundant.

Implementing the system

All of the procedures mapped out in Fig. 1, other than the ecosystem models, can be implemented using nothing more than a programmable scientific calculator. Work is greatly speeded up and accuracy improved if a microcomputer is available as this permits implementation of specially prepared programs, such as the ELEFAN 0, I, II, III, and IV suite, prepared at ICLARM. The equipment for acquiring length-frequency data consists, even in quite elaborate form, of no more than fish measuring boards, preferably used with waterproof graduated paper, tally forms and access to an accurate balance to establish the length-weight relationships.

Routine fishing by government fisheries vessels needs to be carefully done and conducted with the same gears that are used in the fishery, plus one or more devices which will sample the prerecruits. The catches must be accurately identified weighed, measured, and sexed (and could then be sold to defray expenses). The catch-rate data combined with an inventory of the fishing gears will probably be entirely sufficient for making routine estimates of total landings. These will be adequate for general economic appraisal of the fishery and forward planning particularly if supplemented by periodic sample surveys. The foregoing will probably provide sufficient information for the management of most near-shore artisanal fisheries. Note the lack of any requirement for estimates of the monthly catch by species.

An important aspect of the routine fishing system is that it should normally be done using boats which are as similar as possible to those used in the fishery. The cheapest way of doing this probably is to simply charter typical fishing vessels. In particular, the system does not call for the acquisition of numerous research vessels. As a general case it is apparent that research vessels are needed for survey and development work in the early stages of a fishery or for very advanced scientific studies. There is no obvious need for routine operation of sophisticated research vessels by government agencies in those developing countries where most exploratory work has long since been accomplished and where the shortage of scientific manpower precludes effective use of a major vessel.

For specific fisheries, usually operating on an industrial scale, there will be a need for detailed catch and, preferably, effort statistics. Catch rates and catch composition can also be derived from the commercial fleet. The need for routine fishing by fishery officers operations is then largely eliminated. As stated previously, the use of monthly catch statistics in combination with length-frequency data for Virtual Population Analysis permits an evaluation of all parameters of the fishery including total biomass and numbers in the stock. An example of this technique applied to the Peruvian anchoveta fishery is given by Pauly and Tsukayama (in press).

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