

UTILIZATION OF RESOURCE SURVEY RESULTS
IN STOCK ASSESSMENT

by

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1. INTRODUCTION

The first part of the course was concerned with a study of the main mathematical models (Gulland, 1969; FAO, 1977; Gaddy, this publication) traditionally employed to evaluate:

present level of exploitation of a stock;

maximum catch potential, etc., and

the consequences of changes in the rate and mode of exploitation on production and yields.

The second part dealt with resource surveys, specifically with planning surveys and analysis of the findings (Doubleday, this publication).

The way in which survey results can be used in stock assessment, i.e., how they can supply the answers to the points listed above, has yet to be studied.

Basically, resource surveys provide estimates of the relative or absolute density (or the biomass) of a stock or of some of the strata composing it (Ultang, 1977). Besides the opportunity surveys offer for collecting data on as yet unexploited stocks, their main interest lies in the fact that even when the catchability coefficient q is still unknown, as in the case of relative biomass surveys, we can expect it to remain constant through appropriate distribution of sampling effort (planning of surveys) and standardization of sampling methods. In this way we can remove deviations, in time as well as in exploitation rate or size of stock, which only too often introduce bias into the estimates of fishing mortality ($F = qf$) and abundance of stock ($B = \frac{Y}{qf}$) based on measurement of fishing effort f

(FAO, 1976; Rothschild, 1977). It is immediately evident that biomass surveys can reduce the difficulties encountered in the assessment of fishing effort through fishery statistics.

However, the biomass and density estimates supplied by surveys are in themselves insufficient to answer the different questions which arise during stock assessment. Data on catch volume and composition, and on exploitation methods, are obviously necessary to establish the relations between the size and composition of the stock and fishing pressure. Two fundamental conclusions can be drawn from these preliminary remarks:

biomass surveys do not eliminate the necessity for catch and catch per unit effort statistics, and

the analysis and interpretation of the relation between biomass and catches, as well as between these and fishing effort, remain based on the classical mathematical assessment models.

Therefore, the objective of this section is to review what supplementary data and which evaluation model equations can be used to take full advantage of resources survey results. This review will distinguish between the different survey techniques so as to take into account the fact that they do not necessarily concern the same life history stages, for example, eggs and larvae, prerecruits, exploited phase, and the estimates they provide, are not always related to the same parameters, for example, absolute or relative biomass, population structure, and distribution in space and time (Table 1).

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Table 1

Principal survey methods classified according to the population stages they concern and the population parameters which can be estimated from them

Population strata surveyed	Parameters required	Survey methods
eggs and larvae	-number and absolute biomass of spawners (\bar{P}_s and \bar{B}_s) and of the exploited phase (\bar{P}_e and \bar{B}_e) -future recruitment R_0 (absolute number)	plankton nets
prerecruits, recruits	-relative number, $\frac{1}{q} R_c$ or $\frac{1}{q} N_t$ (more rarely, absolute number R_c or N_t)	fishery (general trawling, dredging) acoustic methods (for example, if there is a space-time segregation of recruits or prerecruits)
exploited phase	absolute biomass, \bar{B}_e	acoustic methods with calibration direct counts (sessile animals, shellfish, salmon, whales) fishing (trawling, dredging, etc.) with estimation of q
	relative biomass, $\frac{1}{q} \bar{B}_e$ composition: selectivity (selection factor, partial recruitment) growth (K, L) mortality (M, F) space-time distribution	acoustic methods without calibration fishing (trawling, dredging, etc.) without estimates of q uncalibrated acoustic fishing methods

It is clear that only survey methods whose object is evaluation of the biomass, composition, and average distribution of a stock will be considered here. Other types of survey will not be considered in this section, for example:

pilot boat reconnaissance in order to guide commercial fleets toward fish concentrations; experimental fishing aimed at development or improvement of fishing gear or methods, and simulation of commercial fishing in order to evaluate the potential profitability of a new type of exploitation.

2. ESTIMATION OF PRERECRUIITS

2.1 Prerecruit Surveys

Three methods are commonly used to survey cohorts before they have fully entered the recruited stage, as well as their partial availability to exploitation, i.e.:

egg and larval surveys;
surveys of prerecruits and recruits, and
selectivity experiments.

(a) Egg and larval surveys

This survey method was developed mainly to take advantage of ease of sampling provided by eggs and, to a lesser extent larvae, compared to the exploited phase (Smith and Richardson, 1977; Saville ed., 1977). With respect to adults, eggs and larvae are usually:

more concentrated in space and time;
more uniformly distributed, and
passive, i.e., less able to avoid the sampling gear.

However, these advantages are not present in all cases. In tropical regions in particular, the duration of the spawning season and the complexity of its variations in time may require a heavy sampling effort if we wish to obtain sufficient precision in the estimation of annual spawning.

In principle, egg and larval surveys should allow estimation of:

the spawning biomass and, by extrapolation, the exploited biomass, and subsequent recruitment.

Unfortunately, it is known that the great variability in the stock/recruitment relationship prohibits in practice the assessment of biological recruitment (R_0) resulting from eggs and larvae whose numbers have been determined. On the contrary, the relation number of eggs/parental biomass is, in this case, easier to determine. When sampling of all the eggs spawned during a season can be carried out with an acceptable precision and cost (vessel time and identification and sorting of eggs and larvae are always costly), and when the relation between the number of eggs spawned and the exploited biomass^{1/} can be established with sufficient reliability, this method can lead to good evaluations of adult biomass (Ahlstrom, 1968; Tanaka, 1974).

$$1/B_0 = \frac{P}{F} \frac{Y_t}{Y_f}$$

equation in which

B_0	=	exploited biomass
P	=	total number of eggs spawned during the year
F	=	total number of eggs spawned during the year per female weight unit
Y_t	=	total catch weight during the year (inclusive of immature fish)
Y_f	=	total weight of mature females in the annual catch

It can also be difficult to establish the number of eggs/exploited biomass ratio. This applies to species spawning at intervals which are frequently found in tropical regions. With these species, maturation of oocytes during a single spawning season occurs in successive waves (Fontana, 1969; Fontana and Le Guen, 1969). In order to determine fecundity per female, it is necessary to establish, in addition to the number of eggs released at each spawning, the number of annual spawnings according to the size or weight of gravid females. Evaluation of the first parameter is difficult and requires monitoring the female stock throughout the spawning season. In fact, it is impossible to determine from only one observation of a female's ovaries, whether the total number of eggs they contain corresponds to all those she may actually have spawned during the season. One (or several) egg layings may have occurred before the observation; not all visible oocyte classes will necessarily be released before the end of the season; new classes could eventually form before the end of the same season; lastly, the hypothesis of a variation in the number of emissions according to size of females cannot be ruled out. These complexities, in addition to the need for more intense sampling in general, explains why so far egg and larval surveys have been much less successful in tropical regions.

(b) Surveys of prerecruits and recruits

In order to avoid excessive errors caused by the high variability of the survival rate during the first life stages of cohorts, one tends to delay surveys until after the critical phase. When the pre-exploitation phase is short, we are often faced by the following dilemma: how do we delay surveying so as to bring the margin of error in forecasts to an acceptable level, yet leave enough time so that these forecasts can be applied to the future exploitation scheme?

Usually surveys involve individuals which have reached adult morphology, habitat and behaviour. Therefore the sampling methods are similar to those generally employed in surveying the adult phase. This means a loss of the ease of sampling offered by the earlier stages. Obviously, the sampling effort will be concentrated on the areas (nursery) and periods where and when prerecruits and recruits are concentrated. For example, the prerecruits of many demersal stocks are sampled by using trawl nets having smaller mesh size than commercial trawls. With such trawling surveys, the catchability coefficient q is usually unknown. Therefore we obtain estimates of the relative number, $\frac{1}{q} N_t$. In some favourable cases (non-mobile animals like shellfish, and for pelagic species in which the different distribution of juveniles makes it possible to assess their biomass by quantitative acoustic methods), the absolute number can be estimated.

(c) Selectivity experiments

Strictly speaking, selectivity studies are not surveys. However, it seems appropriate to speak of them here since, on the one hand, they make it possible to establish when, during its lifetime, and how, a cohort enters a fishery and on the other hand, this kind of observation is often carried out during a survey cruise.

2.2 Interest of Prerecruit Assessments

The use of exploited biomass estimates from egg and larval surveys will be dealt with in this publication on the exploited phase. However, it is stressed that these estimates are the most important since they are assessments of absolute biomass, which, as shall be seen, allow more complete and directly applicable conclusions than abundance indexes.

Recruitment

In order to make use of these prerecruit estimates, $N_{t,obs}$, the first stage consists of calculating the recruitment to the fishery:

$$R_0 = N_{t,obs} e^{-M(t_0 - t_{obs})}$$

The use of this equation implies knowledge of the time interval $T = t_c - t_{obs}$ and the mortality coefficient M . These two constants can be determined in several ways: observation of the timing of appearance of recruits into the fishery makes it possible to calculate T ; the decline in numbers N_t , if it can be followed by repeated surveys during the pre-exploitation phase, allows estimation of M and T . Estimates of M can also be used from the exploited phase.

R_c can then be combined with the production per recruit calculations, either directly if the absolute value of R_c is known, or if only indices are available, by comparison with the recruitment levels observed previously. In the first case, the various results of the evaluations (Y , c/f , B , etc.) can be expressed as absolute values.

Global production models include recruitment fluctuations, although with a time lag, to which three phenomena contribute:

the necessity of adjusting the model to the data for a certain period during which recruitment may have been on average different from that of the cohorts which will be exploited;

the time lag between the collection of statistics and their incorporation in the updating of the models, and

the techniques of calculation used to simulate equilibrium conditions.

In order to analyse the risks of bias in relation to changes in recruitment, it is useful to distinguish between:

density-dependent factors in the stock: these mainly influence the shape of the right-hand portion of the yield-curve (Laurec, 1977), and

factors independent of density: these will act upon the dispersion of the observation points if their action on recruitment is random; they will influence the height of the curves $Y = g(f)$ and $cpue = g'(f)$ in the case of long-term variations in recruitment related, for instance, to changes in the biotic capacity of the environments.

It is obvious that fluctuations of the latter type will have dire consequences if they cannot be taken into account. In this case, the mean recruitment of cohorts which will be exploited could differ substantially from that during the period used to fit the model. These variations in recruitment may be progressive or sudden. Figure 1 illustrates an extreme case of sudden variation: it deals with the drop in production of that part of the Ivorian demersal stock fished by the trawlers, which coincided with the explosion of the triggerfish stock (Balistes caprisacus) (FAO, 1979).

Although it is not yet proven that the population explosion of triggerfish provoked a drop in the recruitment of the species trawled for, this example does illustrate clearly which errors may occur in determining short-term management measures (setting of a catch quota, for instance), if yield and production curves in relation to effort cannot be adjusted to the level of average recruitment of the age classes soon to be exploited.

In this context, it must be noted that a progressive drift in recruitment levels is more likely to pass unnoticed than sudden jumps. Published literature contains numerous examples of optimistic management formulations, following application of insufficiently critical global assessment models to fisheries which developed during a succession of temporary high recruitment levels (Sissenwine, 1978).

Whatever the origin of long-term variations in recruitment, the inertia of global models will be intensified by the delay, currently one to two years, which occurs between the collection of the data and their application to the updating of the model.

Lastly, the model's inertia will be further increased by the techniques currently used to simulate equilibrium conditions, since these recommend averaging efforts (Gulland's technique) or biomasses (Schaefer's technique) over several years.

An early estimate of number of recruits is particularly useful for species whose recruitment varies widely. For a variation of the same amplitude, over the same period of time, the value of this estimate will be increased if the fishery includes only a small number of age classes, since in that case the fished population will show a greater impact due to fluctuations in recruitment. This would be the case for species with short life-spans, or stocks whose number of age classes substantially contributing to catches has been sharply reduced by exploitation, and in fisheries harvesting during a short time span in the life of the cohorts. In all situations of this kind, an early knowledge of recruitment can reduce the likelihood of overfishing in the case of a decline of recruitment or, conversely, of under-exploitation.

Selectivity and size at first capture

For simplicity of calculations and practical applications, the Beverton and Holt model assumes constant population parameters over fairly long time periods, as far as possible during the time it takes a cohort to pass through a fishery. This is the case for the fishing mortality coefficient F . Hence the selectivity curve (catch probability according to length) becomes a mortality curve according to age, assuming that F operates directly from age t_0 , (i.e., average age at first capture), and only from that age onward (knife edge selection, Figure 2).

The Ricker model does not require this approximation. Therefore, it is able to represent more complex selectivity schemes more closely and, in general, can accommodate widely differing strategies of survival of a cohort, through one or several fisheries. Such strategies are frequently evaluated in practice by cohort analysis (estimating partial recruitment). This explains why cohort analysis and the Ricker yield model are frequently used together in fisheries where the simplifying hypothesis of constancy of dynamic parameters is inadequate.

Specifically, global models take no account of selectivity or, more generally, the form of the F vector. The interpretation of this type of model by equations of production per recruit shows that we must expect deviations of the Y/f and $cpue/f$ curves, similar to those caused by variations in recruitment, if size at first catch and, more generally, the F vector change. If such changes have occurred at sporadic intervals in the history of the fishery (due to changes of legal trawl mesh size, for example), it will be useful to draw a separate curve for each period for which a given mesh size was in effect.

A special case occurs when the rejection scheme (percentage of rejections per length interval) changes while the mode of exploitation (F vector) remains unchanged. In that case, the real yield and production curves in terms of F will not be altered; only their expression deduced from landing statistics will change. In order to compare the evaluations for the entire documented history of the fishery, the statistics must be corrected so as to use the same rejection scheme throughout the period considered.

3. SURVEYS OF THE EXPLOITED PHASE

3.1 Absolute Biomass and Abundance Indices

For our purposes, different methods of sampling the exploited phase can be classified into two categories: those leading to absolute biomass estimations, and those providing only abundance indices (relative biomass). The first type includes calibrated acoustic surveys,

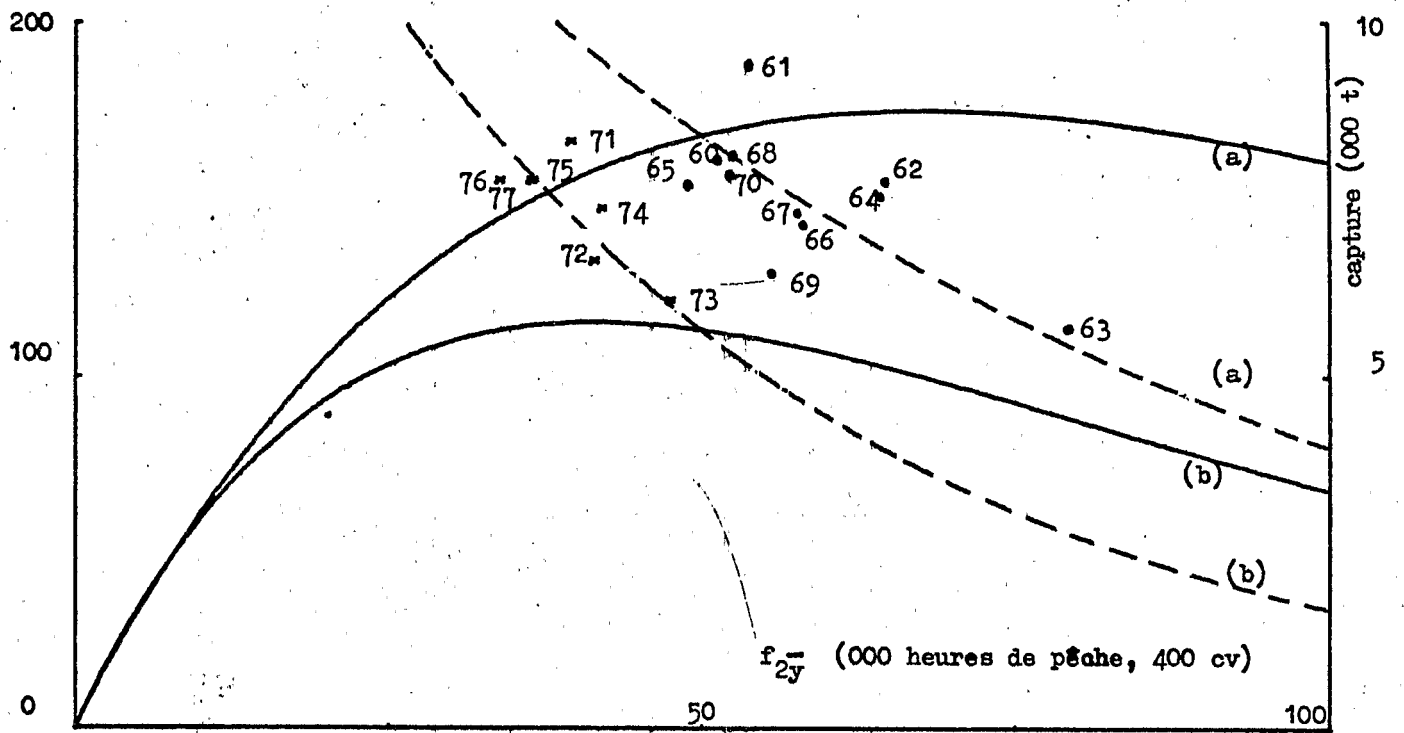


Figure 1. Trawl catches on the Ivorian continental shelf (0-120 m): relation between cpue and fishing effort (-----) and resulting yield curves (————), a) before and b) after the explosion of the balistes stock (1972) (FAO, 1979).

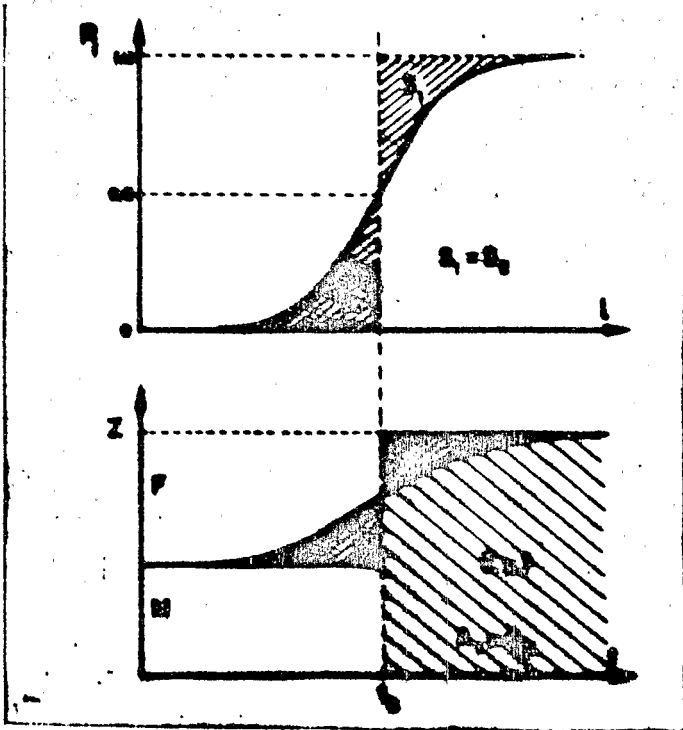


Figure 2. Schematic transposition of the selectivity curve into a mortality curve according to the Beverton and Holt model.

direct censuses (enumeration of stationary species like shellfish, salmon running upstream, or whales at the surface) and inventories made with fishing gear whose efficiency can be measured adequately in advance. Surveys of the second type include all those (therefore also uncalibrated acoustic surveys), in which the catchability coefficient is not known.

In the following section we shall see the utilization of these two types of estimation in stock assessments. In all cases, it is important to have a firm grasp of all the terms of the unit catch/total biomass ratio of the stock so as to be able to calculate them if we wish to obtain an estimate of the absolute biomass, or to keep them constant so as to obtain abundance rates that can be directly comparable. Demersal stocks which can be fished and surveyed with a trawl or any other equivalent sweeping gear (for example, a dragnet), are good examples of the different factors intervening successively between average biomass of stock as a whole, and catch per haul. Given the most complex case, we can distinguish:

supply, which expresses the percentage of individuals constituting total stock existing at a given moment in a particular area or volume of water being surveyed;

accessibility, representing the proportion of individuals available in a certain sector and present in the volume of water where a fishing effort (or procedure) can operate. For example, the part of a sole stock which is present on a rocky bottom, will not be accessible to trawl fishing;

exposure, corresponding to the proportion of accessible fish which are actually present in the field of operation of the gear during a given fishing operation. For example, the exposure of shrimp to the trawl will vary in 24-hour periods if they have a tendency to bury themselves periodically in the bottom sediment, or rise off bottom at certain phases of the tide;

catchability, expressing the proportion of exposed individuals potentially captured by the gear during a fishing operation; in other words, the proportion already having entered the trawl (or run into a gillnet, or taken a bait in the case of other fishing gear); and

selectivity (or retention), which measures that proportion of individuals in the potential catch which is finally retained.

It should be mentioned that the same or similar sources of bias are encountered in the different types of surveys. Supply, accessibility or exposure all influence survey methods, and must be considered in survey planning (optimization of the distribution of the sampling effort in space and time in relation to the stock to be surveyed), and in interpretation of gross measurements. These aspects have been analysed in detail in this publication.

On the contrary, measurement of the catchability coefficient, in other words, measuring the efficiency of the gear and calibrating it, poses serious obstacles related to the determination of gear efficiency for capture of vulnerable individuals. In the case of a traditional trawlnet having sweeplines, two factors operate against each other:

avoidance, by which a certain fraction of individuals actively leave the volume of water in front of the mouth of the trawl, in reaction to the approach of the gear, and

the herding into the space swept by the trawl mouth of those fish present in the area swept by the sweeplines.

In the absence of observations on these factors, it can sometimes be assumed that the two phenomena cancel each other making the trawl efficiency equal to 1 (i.e., catch weight = absolute biomass in the area swept by the footrope). In this case, it must be recognized that ignorance of the value of q could introduce a bias into the total biomass estimate higher than that allowed for in the sample design. An attempt can be made, while fishing, and by quantitative acoustic surveying or by using underwater television cameras, etc.,

to gauge the real density of fish present in front of the trawl immediately before the avoidance and herding phenomena occur. The use of new trawl types with very large vertical and horizontal extensions, frequently operated by pair trawlers, is now becoming widespread. Since their efficiency coefficient should be close to 1, we may ask whether their use, without sweeplines, for fisheries surveys will not reduce the problems raised by trawl standardization. In any case, the collaboration of a fishing gear specialist should help to determine the probable value of the catchability coefficient for a given gear and species.

One may note that acoustic surveys raise the same theoretical problems of standardization, if not the same technical ones, as those listed for trawl surveys; we may mention the problem of avoidance of shoal areas within a given volume of surface water. Surveyed questions of calibration of equipment according to the species studied and the establishment of recording thresholds to eliminate superfluous echoes (plankton, species not included in the survey, e.g., demersal fish, bottom, etc.).

3.2 Utilization of Absolute Biomass Estimates

The simplest instance is when we have only a single measurement. The approximation equation of Gulland (1971) is:

$$Y_{\max} = X M \bar{B}_0$$

This affords an estimate of the order of magnitude of maximum catch potential of an unexploited stock. The value of coefficient X is taken as equal to 0.5, or is established by application of production tables (Beverton and Holt, 1966), if we have an idea of the value of parameters M/K and l_c/L_∞ for the species considered. If it has been possible to establish the age distribution of the surveyed biomass, the value of M in the above equation can be deduced by comparison of the numbers of the different age classes captured at the same time (catch curve). Otherwise we shall choose an M value by comparing M and K (Beverton and Holt, 1959) or M and maximum age (Tanaka, 1960; Pauly, 1978), or by analogy with these values known for related species. In the case of an already exploited stock, Cadima (In Troadec, 1977) suggests that in the absence of other data, $M\bar{B}$ be replaced by $Z\bar{B}$ in the above equation. We then get:

$$Y_{\max} = X Z \bar{B} = X(F+M)\bar{B} = X(F\bar{B}+M\bar{B}) = X(Y+M\bar{B})$$

It is interesting to compare this conclusion with that reached by Allen (1971) in his analysis of the relation between biological production (total catch weight and natural deaths) and biomass, according to the growth and mortality models currently used to represent cohort development. He shows that if mortality is exponential, the $\frac{P}{B}$ ratio is equal to both

Z and the inverse of the average age or life expectancy of a cohort, regardless of the growth model applied, except for the exponential model with instantaneous rate constant ($w_t = w_0 e^{gt}$).

If we assume that, as is often observed in practice, at close to the point of maximum equilibrium production F approaches M, the maximum catch potential will indeed represent approximately half of the biological production. Therefore we have:

$$Y_{\max} \approx \frac{P_{\max}}{2} \approx 0.5 Z \bar{B}$$

which is the same equation as that proposed by Cadima.

In the case of multi-species fisheries (tropical trawl fisheries, in particular), comparison of the global potential, as deduced from assessment surveys of the specific total biomass, and that obtained from the maximum sustained yield calculated by application of a production model to the fishery statistics of the fleet exploiting the same multi-species resource, can lead to interesting observations. Generally, the estimate obtained by the second method is lower than that reached using the first; often, in fact, much lower (FAO, 1979; Domain, 1979, In Troadec and Garcia, eds., 1979). This relative underexploitation of the resource is generally due to the fact that fishing effort is concentrated on target species and hence on privileged time and space strata (Pope, this publication).

The comparison between the species composition of the biomasses and catches should indicate toward which species effort should be targeted.

The estimation of the potential yield and of the exploitation rate it will give rise to, will be only approximate in any case. Such conclusions will have to be refined as exploitation develops, by the analysis of fishery statistics and biological data and, eventually, by repeating the surveys. In the latter case we shall obtain a series of \bar{B} estimates corresponding to different exploitation rates.

These \bar{B} values and the respective catches can be applied directly in a global model. We can use Schaefer's original equation (1954):

$$Y_e = \Delta B = K \bar{B}_e (B_\infty - \bar{B}_e)$$

wherein:

- ΔB = mean relative rate of relative increase
- Y_e = annual catch in equilibrium situation
- \bar{B}_e = mean annual biomass in equilibrium situation
- B_∞ = mean annual biomass of virgin stock
- K = a coefficient

This equation permits calculation of (see Cadima, 1977 or Caddy, this publication):

$$Y_{\max} = \frac{K B_\infty^2}{4} \quad \text{or} \quad F_{\max} = \frac{K B_\infty}{2}$$

This way of using the model will avoid biases in the cpue and effort resulting from variations of the catchability coefficient q with time or exploitation level.

Knowledge of the absolute biomass also allows direct evaluation of F and consequently q . For this we shall use the equations:

$$\frac{Y}{\bar{B}} = F = qf \quad \text{and} \quad \bar{B} = \frac{1}{q} \text{cpue}$$

If we have a series of annual absolute biomass estimates and the respective catch or nominal effort statistics, we will be able to study the form of the $F = g(f)$ relation (Rothschild, op. cit.) and eventually to replace the q constant by the appropriate $g(f)$ function.

Generally, the biomasses observed are not in equilibrium. Therefore, in applying global models we must have recourse to expedients to simulate in-equilibrium conditions. For example, if we know the average biomass \bar{B}_i for each year and the respective Y_i total catches, we can use Schaefer's (1954) approximation that biomass B_i at the start of year i is equal to the arithmetical mean:

$$\frac{\bar{B}_{i-1} + \bar{B}_i}{2}$$

Similarly, at the start of year $i + 1$ we will have:

$$\bar{B}_{i+1} = \frac{\bar{B}_i + \bar{B}_{i+1}}{2}$$

The equation of the relative mean natural growth rate will then be:

$$\Delta B_i = (B_{i+1} - B_i) + Y_i = \left(\frac{\bar{B}_{i+1} - \bar{B}_{i-1}}{2} \right) + Y_i$$

and the relative natural growth rate will be given by the function (see Cadima, 1977):

$$f(\bar{B}_i) = \frac{B_i}{\bar{B}_i} = \frac{1}{2} \left(\frac{\bar{B}_{i+1} - \bar{B}_{i-1}}{\bar{B}_i} \right) + \frac{Y_i}{\bar{B}_i}$$

3.3 Application of Relative Biomass Estimates

In order to use this type of estimate, it is essential to have a series of annual values corresponding to different exploitation levels. Inasmuch as the problem of standardization of measurements will have been solved, we shall obtain abundance indices ($\bar{I}\bar{B}$) which will evolve parallel to the biomasses, in other words:

$$\frac{\bar{I}\bar{B}_1}{\bar{I}\bar{B}_2} = \frac{\bar{B}_1}{\bar{B}_2}$$

Thus we avoid the biases inherent in the q "coefficient" in the measurement of effort and catch per unit effort of commercial fleets. We can then calculate, independently of f, an index of fishing mortality ($\bar{I}\bar{F}$) = $\frac{Y}{\bar{I}\bar{B}}$ which can be used as a measure of fishing effort in global models. This procedure eliminates the risk of autocorrelation between f and y/f in the adjustment of a global model to catch and effort statistics (Ricker, 1975; Sissenwine, 1978).

3.4 Data on Stock Distribution

It is useful to recall here that a good knowledge of the identity and distribution of stocks is necessary to the planning and interpretation of assessments. Such information serves first of all as a basis for determining the apportionment of raw data to stocks which can be considered unitary, and also suggests improvements which should be introduced into the matrix of data collection. Commercial catch sampling is an invaluable source of data of this type. However, insofar as commercial operations do not cover these stocks adequately in space and time, recourse to surveys will be the only way of acquiring the missing information. After that, these data will be essential for the interpretation of evaluations. Thus the evolution, during a fishery's history, of the geographic distribution of fishing operations in relation to that assumed for the stock, will make it possible to foresee changes of the F vector and therefore eventual results likely in the application of a global model.

Regarding fisheries management, the redefinition of territorial rights to resource exploitation, which constitutes one of the fundamentals of the new regime of the law of the sea, considerably increases the importance of data on the identity, distribution and migrations of stocks, including their rate of mixing between adjacent exclusive economic zones. In fact, it can be expected that schemes for allocation of the total allowable annual catch between the countries concerned will no longer be based on past performances of national fleets, but on the distribution, within areas under respective national jurisdictions, of stocks and their main life history stages (spawning stock, juveniles, adults, etc.). Fishery statistics (catch per unit effort) are one source of data of this type. But here, too, surveys can provide the desired coverage and data which can be compared with greater precision (FAO, 1979a).

4. CONCLUSIONS

Depending on the technique employed, resource surveys lead primarily to estimates of either absolute or relative biomass. In principle, the first type is superior since it affords an initial estimate of maximum catch potential.

The value of biomass surveys increases considerably when we have series covering several years corresponding to different levels of exploitation, since the effect of fishing on stock and its production can then be analysed precisely. In that case the superiority of absolute over relative biomass surveys is considerably less, since both result in equally comparable abundance estimates. This involves correct planning of the distribution of the sampling effort in space and time, so as to maintain biases caused by variations of supply and accessibility within acceptable levels, and maintain full standardization of sampling gear and procedures so as to keep the catchability and selectivity factors constant. It is also important that the objectives (stocks, type of survey) should be defined clearly, and this initial choice maintained throughout the period planned for the programme. One of the causes of failure frequently observed in survey programmes lies in confusion and change in objectives, so that very soon the variations observed in yields can no longer be attributed to specific parameters (annual variations of biomass, seasonal or daily variations of supply, differences in efficiency of fishing gear, changes in mesh size, etc.), amongst all those factors which can influence yields.

These problems of standardization sampling gear for surveys and the reduction of biases produced by differential changes in the distribution of sampling effort and stock, are not basically different from those that arise during collection and interpretation of commercial fishing effort measurements for fishing mortality estimation. The superiority of surveys lies in the fact that they make it possible from the outset to measure separately, and in principle, control the different parameters intervening between stock biomass and catch in each sampling interval; even though at the price of a substantial decrease in the intensity of observations.

Therefore surveys provide a method of monitoring that allows us to follow the evolution of stock biomass accurately on the basis of fishery statistics. However, surveys are not an alternative. As was shown in sections 3.2 and 3.3, in order to analyse the effects of fishing on stocks it is not enough to follow the variation of their biomass. We must be able to link these variations to at least one fishery parameter (total nominal catch or effort). Therefore the organization of regular survey programmes cannot be a pretext in any case for reducing the effort devoted to strengthening statistics collection programmes. This conclusion is reinforced by another consideration. Stock assessment is only the first stage in the formulation of plans for rational exploitation of resources. Their implementation involves the possibility of transposing the conclusions of such assessment in terms of exploitation levels (limitation of catch capability, fishing effort or catches). This transposition, i.e., estimation of the probable impact of existing methods of capture, can only be made by means of fishery statistics.

Therefore the data provided by surveys supplement those traditionally forming the basis for stock assessment methods. Moreover evaluation models are essential to the complete interpretation of survey results. Therefore resource survey programmes should be decided, designed, applied and their results interpreted in close collaboration with the research teams responsible for evaluation.

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FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS
Rome, 1980