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Methods to analyse the dynamics of exploited marine populations: Sampling methods

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SUMMARY: The models used to analyse the dinamics of fish populations must be fitted to the real data using biological and demographic parameters. The data, as well as the parameters, have to be estimated from sampling strategies devised according to the specific objective. In this lecture the problems of the various sampling methods related with the particular characteristics of Mediterranean fisheries are analyzed.

RESUMEN: Para conocer la dinámica de las poblaciones sometidas a pesca se emplean modelos que deben ser ajustados a datos reales mediante el empleo de parámetros biológicos y demográficos. Tanto los datos como los parámetros deben estimarse a partir de muestreos, que deben diseñarse en particular para cada objetivo. Aquí se analizan los problemas que estos muestreos pueden presentar en relación con las características de la pesca Mediterránea.

INTRODUCTION

One of the fundamental objectives of an ecologist on undertaking the analysis of an animal population is to achieve an accurate overall description of this population. But the marine environment does not lend itself to a census. Apart from some exceptional cases (enclosed environments in general) we must rely on samples.

Therefore strategies and techniques of sampling take on primary importance in the analysis of marine populations, whether or not these are exploited by man. Whether experimental ("scientific") or professional ("commercial"), fishing is the principal means available to carry out these surveys in the sea.

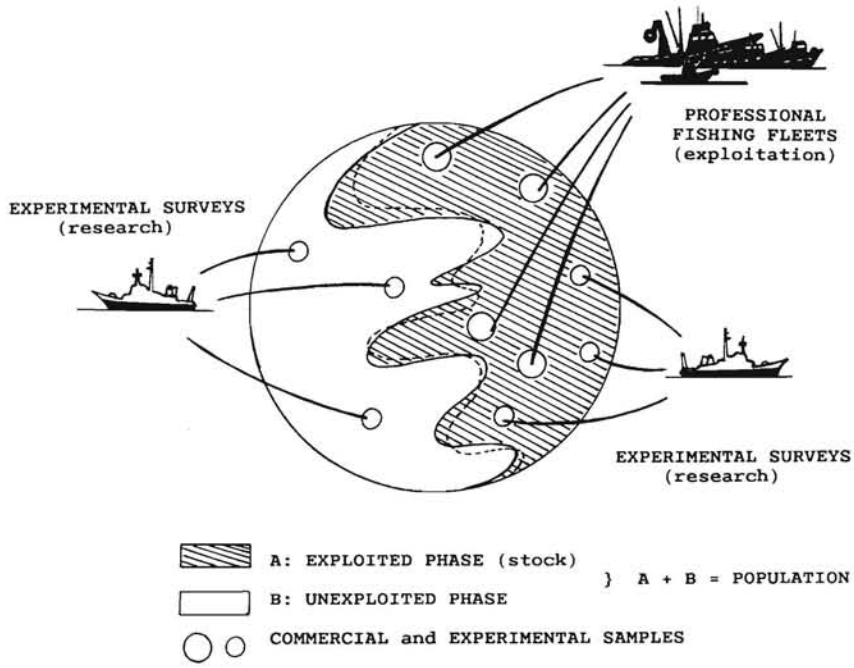
POPULATIONS AND STOCKS

Biology and ecology define an animal "population" as a homogeneous group of individuals of the same species which are found in a specific habitat and live together under their reciprocal influences proceeding from each and every one of them. The terminology of fisheries science introduces the notion of "stock", which should be considered as a management unit (Fig. 1).

A group consisting of all usable animals in a given geographical sector, stock as a unit holds potential for the regeneration of biomass caught by man.

It can be singled out in a very specific way to match all or part of a population in the biological sense of the term, or be less strictly selected, made up of many populations or fractions of populations, "harvestable phases" of populations (a typical Mediterranean instance).

With reference to this in the Mediterranean we only have —if it exists at all— a mapping of fishing activity. But this is not strictly speaking a matter of population maps in the biological sense of the term. We have in particular no certainty whatsoever of consistency and horizontal definition of populations.



Exploitable population sampling: schematic figure.

Fig. 1.

In this way the picture available to us today of specific population density remains essentially a reflection of differences in the intensity of fish stock exploitation between the different fishing fleets.

The whole question of sampling which would allow the elimination of this bias remains unanswered.

ANALYSIS OF WHOLE POPULATIONS

This presents us with a major problem; that of sampling the unexploited sections of marine populations. The solution to this nearly always comes about through experimental fishing. Setting aside certain specific cases (lagoon environments, the littoral) we become involved here in the necessity of using heavy machinery (ships, gear). This is very burdensome.

In the case of coastal species, in addition to its high cost, experimental fishing most frequently encounters the same problems as professional fishing; the unexploited sections of marine populations that live permanently or seasonally on uneven sea-bottoms are in general very difficult to sample. Certain age classes or certain life stages can thus remain almost inaccessible to quantitative analysis. Experimental fishing can make it possible to improve the sampling of juvenile stages that live on usable and therefore already exploited sea-bottoms (using non-selective fishing gears).

On the other hand these problems do not exist when sampling the species of the open sea using experimental fishing techniques.

ANALYSIS OF EXPLOITED PHASES OF MARINE POPULATIONS

The greater part of Mediterranean marine populations (and fish in particular) are the object of exploitation by professional fishing, whether this be as target species or whether as incidental catches in the nets of fisheries which are not specifically selective (such as trawling in particular). Also their analysis must necessarily take into account, in addition to purely natural biological parameters, a certain number of features describing exploitation or ensuing directly from it.

At the present time, the most widely used mathematical models are designed to describe the dynamics of the "exploited sections" of these marine populations. They make use of a certain number of basic assumptions which we can schematically divide into four large categories:

a) Biological parameters such as age, growth, fer

tility, sex-ratio, sexual cycles, migrations, "natural" mortality (or more precisely, that which is not due to fishing).

b) Total quantities of individuals of a species subject to reduction by fishing; in other words the catches brought in by the fishing apparatus.

c) Measurements of the "fishing effort" and of the "selectivity" of the vessels or the fleets exploiting marine populations.

d) Demographic composition of catches (diagrams of the distribution of size or age of individuals caught).

For evident and well known reasons (lack of access to the animals in their environment, poverty of statistical literature) which we shall not dwell upon here, these quantities can neither be measured nor studied with reference either to the entirety of populations or to the total sum of ships or cargoes unloaded.

It is currently admitted that the quality of the estimates regarding various parameters depends on that of the sampling procedures. For that matter, paraphrasing the article in FRONTIER (Sampling strategies in ecology, 1986), two major fundamental rules, which are too often neglected or broken, are worth remembering;

— one can only sample correctly if one knows exactly what is going to be done with the data obtained;

— the planning of sampling procedures and the planning of data treatment are so closely related that it is impossible to treat them separately.

The choice of a model appears therefore as a prerequisite which constitutes one of the main conditions for success of the sampling procedure, and subsequently of the analysis intended.

It should be kept in mind that a sample must facilitate the depiction either of a sub-group (juveniles, reproductive phase, male or female individuals, for example) or of a complete group (the whole population). This last instance is generally the one which most frequently preoccupies ecologists and resource managers. Whatever the case, this implies for a start that there is another important choice which affects the success of the sampling procedure; that of the biogeographical unit, "population" or "stock" to be sampled.

MODELS AND DATA NECESSARY

Mathematical modelling of biological characteristics

We shall not go into detail here about the mathematical models used for modelling these characteristics. They most frequently can be broken down into the calculation of a regression between two parameters: individual size and weight, size and age, age and fertility, etc...

Generally speaking, biological sampling must be able to cover the whole range of sizes (therefore ages) of the population studied. When a sample does not represent all of these, a purely mathematical extrapolation within a mathematical model of these to unobserved sections of the relevant populations must become the object of the most extreme circumspection.

Concerning growth for example, the model that is most often employed is that of von Bertalanffy. In the Mediterranean its use can cause difficulties to do with a large number of small-sized species whose initial development stages take place in the warm and fertile waters of the saline lagoons and the coastal fringes. If sampling does not take these individuals into account, the model cannot allow for a valid extrapolation since it underestimates the growth rate of the juveniles and overestimates that of the adults.

Mathematical modelling and quantitative evaluation of stocks

— Global models

These are the most simple. They allow the representation of chronological variations in the total biomass of a stock in equilibrium (and of the volume of the corresponding catches) in relation to chronological variations in fishing effort.

Hypotheses based on these models are especially limiting; on the other hand, they are very clear. The data necessary includes essentially the records of the annual fishing effort and the total catches.

Allowing that we have solved the problem of adequately defining fishing effort, we could imagine that the measurement of effort —generally strongly subject to the technical characteristics of the working units and to their strategies could be taken directly and in an exhaustive manner from the administration's statistical literature. Experience shows that, more often that not, this is not the case. The only way to carry out an evaluation of the effort is therefore a sampling of ships and fishing gear in the fishing ports.

As for fishing mortality applied to stocks, this translates in practice to a total catch of which a part is unloaded (the saleable part) and another discarded (since it is not saleable). A part of the fish cargoes escape from the statistics in the form of consumption by the fishermen or hidden sales for example. In

some rare cases one can detect the first of these components through the bias of the official statistics. In other cases —the greater majority— one must concentrate on sampling production after the cargos have been unloaded. However it must be kept in mind that statistics said to be of "fish caught" are no more in the best of cases than statistics of cargoes unloaded.

The only way to estimate the level of discards is by sampling at sea. This is the same for illegal catches (Sampling at the moment of capture) or in the market places.

In any case it amounts in the end to the collection of a significant sample of catches per unit of effort (PUE) which is able to facilitate the reconstruction of the mortality rate per total catch by extrapolation from the total fishing effort.

— Analytical models

In contrast with "global" modelling, "analytical" modelling of stocks of marine animals makes a much finer description of their dynamics possible, and also of the main mechanisms which regulate them. In effect these take into account the relations between spawners, recruitment, age, growth in length and weight, death rates, (natural and due to fishing), the structure of the stock and its biomass (often confused with that of the total population). Unlike the former models, they imply familiarity with a large number of parameters including utilization of resources as much as biology. Models based upon the concept of "virtual populations" ("cohort analysis" in the broad sense) rest in particular and at the start upon a familiarity with the demographic structure of the fish catches.

It occurs —rarely— that certain commercial statistics make this kind of information directly available (the division of production figures into "calibrated" categories). But in most cases it becomes necessary to carry out specific sampling for length composition.

SAMPLING PLANNING

Biological sampling

For the study of growth by reading hard parts (fish) or for the study of fertility and sex-ratio, a sample should classically cover the complete spectrum of sizes and should at least include one annual cycle. Sampling must be regularly distributed across a period of time in order to make cyclic phenomena evident such as the appearance of growth rings or the maturation of the sexual products.

This type of study implies the dissection of individuals. Some may come from research ships, but as a general rule it is necessary to buy animals in lots, which makes this kind of operation quite expensive.

At the level of sampling, the major difficulties arise from the uncertain geographical origin of the specimens harvested, and from the unevenness and the rarety of certain sizes or stages of development in the produce available in the marketplace. These difficulties arise directly from features of the operation of fishing (the spatio-temporal dynamics of the fishing fleets, and the selectivity of the fishing gear) and of distribution for sale (sorting of animals, discards of produce and the misreporting of undersize individual fish...). These factors are often at the bottom of a considerable element of bias when it comes to the interpretation of data.

The formulation of biological sampling strategy is therefore inseparable from a good knowledge of stock exploitation strategies (to which they are linked).

Sampling of fisheries parameters (halieutic parameters)

The objective of this is to evaluate the fishing effort exerted on the stock, total production and/or the catch per unit effort.

Once any two of these factors have been determined, the third can be immediately deduced from them. The collection of these data requires the formulation of a sampling strategy sufficient to allow for a correct extrapolation of totals from the sample material, at the same time as data treatment.

Firstly these preparations require a typology which makes possible the characterisation of the main types of units of exploitation which exert mortality on the stock studied. These also require an exhaustive preliminary census ("research framework") of the research units, including their working stations on the littoral, their work calendars and their commercial outlets. Using these sources of information we can produce a stratification of data in space and time and also determine the locations, the frequency and the intensity of sampling of the diverse components of the fishing effort and its production figures.

The main problems to be solved in order to reduce bias in the estimates have essentially to do with illegal fishing activities ("false professionals") and to unsold catches, discards, consumption by the fishermen themselves. Not taking sporting fishing into account may also lead to underestimate of considerable size for certain species.

Sampling of catch demography

On the whole this can easily be obtained through the gathering of the distribution figures for size frequency of animals caught, within the same spatio-temporal stratification used for sampling of fishing effort and catch sampling.

CONCLUSIONS

Fishing —and professional fishing in particular— can be considered as a form of sampling of marine populations of primary importance. But it must be kept in mind that we are concerned with a form of sampling which is biased by definition.

A major problem remains in the definition of the units to be sampled. In particular one must avoid confusing a priori, stocks and biological populations. The biogeographical picture which we have at our disposal of the latter matters is mostly no more than the reflection of resource management activities. The whole problem of a sampling procedure which would make it possible to do away with this bias remains to be solved.

One can sample correctly only if one knows exactly what to expect and what one is about to do with the data obtained: hence the importance of a well-considered choice, before initiating the analysis, of the conceptual tools to be used on the problems and of sampling strategies appropriate to them.

In practice, the carrying out of marine population sampling projects poses a major problem: that of its high cost, since it most frequently requires a considerable investment in manpower, and in travel, precisely speaking in heavy means at sea. From which we derive the interest, in a good number of instances, in developing mathematical models capable of improving the relationship between cost and precision. These models will generally be based on the analysis of variables obtained by various concentrations of sampling. Their purpose is to provide an evaluation of the level of precision as against a given cost. Their use can allow for a considerable reduction in the price of gathering data and of its distribution in the most efficient manner between the parameters and strata to be sampled.