CALCULATION OF FISH POPULATIONS FROM ACOUSTIC DATA

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INTRODUCTION

The biological interpretation of acoustic fish abundance data depends on the characteristics of the target population, which should in turn determine the type of acoustic equipment deployed. In practice, however, the development of signal processing gear has limited the application of acoustic methods to fish stock assessment. Primarily the problem is one of fish density, with species diversity, behaviour and size range as secondary factors. In this paper I would like to outline the biological sources of error in the calculation of fish abundance from echosounder data.

SURVEY TECHNIQUE

If fish can be discriminated in range or by transmissions, we can count signals above an amplitude threshold to obtain the number of targets per transmission, or per unit sampling distance. This technique, fish counting, was first used by Norwegian (Midttun and Saetersdal, 1957) and English (Richardson *et al*, 1959) fisheries scientists to obtain relative fish abundance estimates of large, single fish in midwater. Cushing (1968) later used an estimate of the sampled volume to calculate absolute target density. Since fish echoes can only be detected above the threshold level (which is set to exclude noise or small fish) this volume is dependent on the target strength of the fish in the population, which is limited to non-shoaling species or those which disperse at night. Usually the populations must be sampled by fishing gear to determine the species composition and size distribution. These data can then be used to calculate fish abundance from the echo density data.

With this technique it is possible to mistake the interfering echoes from two or more fish for an individual target, and thus to underestimate the stock, and probably assess the sampled volume wrongly. This brings us to pulse length analysis techniques, such as that which was developed at the Fisheries Laboratory, Lowestoft (Carpenter, 1967), which can be used when fish densities are such that not all signals can be discriminated in range. Here the signals below a given cycle number, which is dependent on the amplitude threshold, can be treated as for single targets, but signals of longer duration must be treated as "shoal" fish. The cycle discrimination number and amplitude threshold must be chosen with care since large individual fish will, in practice, often give "long" echoes. Pulse height analysis of single targets will probably enable fish size distributions and *in situ* target strengths to be calculated.

The signals from "shoal" fish can be fed to an integrator, but as 40 log R TVG is normally used on populations of dispersed targets, a sampled volume estimate is required in order to calculate target densities. Integration can be used for any density of fish, with the reservations mentioned by Robinson (this meeting), but it is more often employed with populations for which a 20 log R TVG is appropriate. In this case the number of fish or their biomass is proportional to the integrated echo intensity and is independent of range. A volume back-scattering strength can be calculated and converted to fish abundance with a suitable target strength. It is important to identify the composition of the scattering population in this case, since integration methods do not usually discriminate signals from few large fish and those from many small targets, ie biological "noise" levels may be high where small scatterers are present with larger target species.

TARGET STRENGTH

The application of a target strength to acoustic data in order to calculate fish biomass or numbers depends once again on the population being studied. In a mono-specific situation such as blue whiting spawning aggregations (Pawson *et al*, 1975), a target strength based on the mean length or a given biomass of that species is probably sufficient, unless the size range is large or the fish are distributed in schools of different sizes. If the population consists of several species which vary considerably in shape and size as in Lake Turkana (Pawson, 1975), it may not be possible to estimate a suitable target strength. Between these extremes are mixed populations of fish of similar morphology, where a general target strength can be used, and where the calculated biomass can be apportioned according to the composition of sampling catches. This category also includes mono-specific populations with an uneven size distribution and is discussed by Nakken, this meeting.

I do not propose to discuss the available methods of target strength measurement, but would like to point out the resulting sources of error. The actual target strength of fish in a given sampled volume depends on their distribution in the beam (aspect, directivity), their behaviour (attitude) and their physiological state (morphology), as well as their species and size. The directivity function may be calculated, together with aspect, on the basis of beam pattern and probability statistics, and a mean value found. The error involved here is calculable. The fishes' behaviour can only be judged by photography or direct observation, and must be assumed for practical surveying purposes at present. The fishes' state of maturity, condition factor etc can be assessed by capture or calculation, although the swimbladder volume is not easily determined. There is a real difficulty in extrapolating experimental target strength data to survey situations, and these sources of error are probably the largest contributor to abundance estimate inaccuracy.

OTHER CALIBRATION PARAMETERS

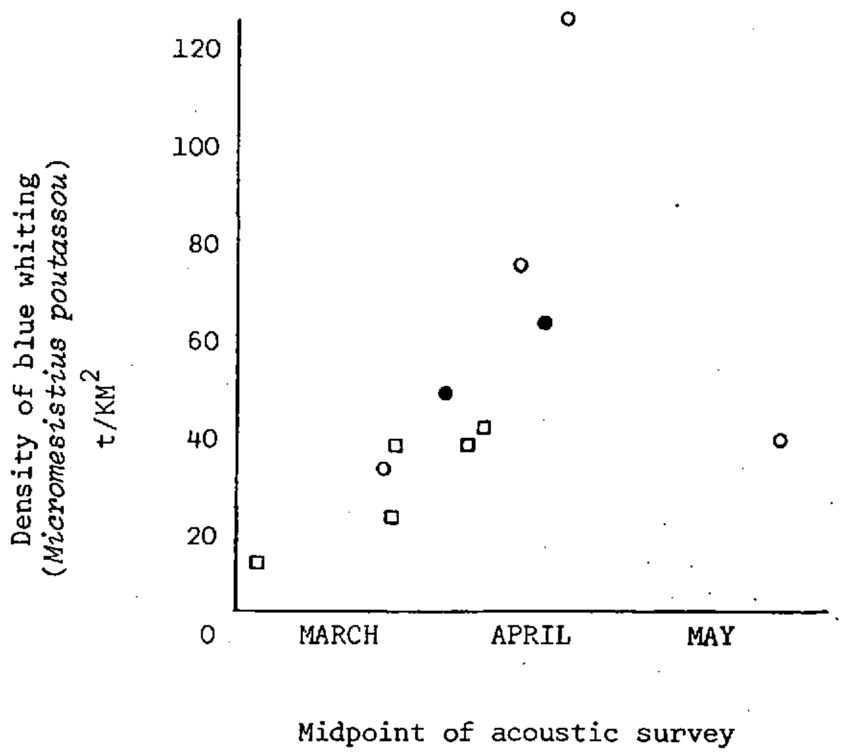
It is not necessary to know a target strength in order to convert echo abundance to absolute fish abundance. Integrated intensities can be correlated with independent means of measuring fish abundance, such as trawl catches, visual estimates or echo counting. Obviously the precision now depends on the correlation significance and the accuracy of the independent method. Most methods of fish capture have an efficiency or selection factor which must be determined for the calculation of absolute abundance. Probably the most effective method at present is to catch entire schools with a purse seine. An optical or acoustic evaluation of fish density in schools or layers, together with measurements of the extent of their distribution would provide accurate information, but such techniques are not fully developed at the moment.

RAISING FISH DENSITY TO TOTAL BIOMASS

Once a fish density is calculated for the sampling unit (eg one transmission or a nautical mile) the distribution over the survey area must be evaluated and raised to give total biomass. Acoustic surveys serve two main purposes, to construct a density distribution of the species in question, and to estimate their biomass. If only the latter is required, a sampling survey may be designed to obtain a density frequency distribution. Its mean can be found by using a normalising transformation and the survey area raised by this amount. If both are required it may be simpler (and more accurate) to construct a contour chart of the fishes' density distribution, to determine the mean density for each contour interval, and to raise these areas and sum them to give total abundance. It is worth noting here that the various densities of a fish population within a survey area could require different acoustic measurement techniques in order to give the most reliable estimate of total abundance. The error involved in these calculations can easily be quantified, although the estimate of the biomass contribution of each species in a mixed population relies on the accuracy of other sampling techniques.

The design of acoustic survey tracks is, ideally, to promote statistical significance of results by following random sampling procedures. However, since the basis of most acoustic surveys is a prior knowledge of the general distribution of the species under consideration, non-randomness can easily be imposed. Practically, however, the environment and available ship's time often decide the best survey grid. Distribution of fish may vary from widespread scatter over the total survey area (eg Lake Turkana, Pawson, 1975), through a congregation of the target species in one stratum (eg blue whiting, Pawson *et al*, 1975), to a few dense aggregations in a very limited area of the total available to the species (eg mackerel off Devon and Cornwall in winter, Johnson, pers comm). A knowledge of the migrations and biology of the fish will enable the acoustic survey to be made at the optimum time, ideally when a large proportion of the stock is congregated in easily delimited monospecific aggregations.

Figure 1 shows that the estimate of the biomass of blue whiting spawning to the west of the British Isles in March and April each year is very much dependent on the timing of the acoustic survey. The data shown are the mean densities of blue whiting over the total area in which they were recorded by each ship's survey.



o RV CIROLANA 1974, 1975

• RV SCOTIA 1974, RV EXPLORER 1975

□ GO SARS 1972, 1973, 1974

Figure 1 Temporal distribution of estimated mean blue whiting densities during Norwegian, Scottish and English acoustic surveys, 1972 through 1975.

CONCLUSIONS

The aims of this paper are to present the biological factors which contribute a variance to the estimates of fish abundance from acoustic data, and to provoke discussion. Essentially these factors are either calculable or must be inferred, and because the latter category is still a large one at the present, *in situ* methods of calibration of acoustic equipment are very important. The difficulty mentioned above of applying experimental target strength measurements to data from acoustic fish abundance surveys might be lessened if target strengths were expressed as dB/kg of a particular species, and if as much attention was paid to the biological characteristics of the targets as to the acoustic system parameters.

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DISCUSION FOLLOWING THE PAPER BY DR.M.G.PAWSON : CALCULATIONS OF FISH POPULATIONS FROM ACOUSTIC DATA

MR.EDWARDS: Could you clarify a point about the mackerel survey you described, I would like to know how you get the area of the shoals from such an open grid ?

DR.PAWSON: The open grid is merely used for determining where the fish are. We then carry out a very close grid over the areas of main concentration.

MR.EDWARDS: Similarly there appears to be some doubt on part of the Blue Whiting survey where fish are marked but the survey grid does not cover them.

DR.PAWSON: We interpolated between transects and made an arbitrary choice of contour intervals. Then we took a sample of the levels within each contour to get a real mean rather than just a median point of the contour, worked out the total areas within each contour level and raised these to give a total abundance. This was then checked by going through the whole data doing a logarithmic transformation of the levels, taking a mean of that, and raising by the total survey area. The results were very close.

MR.NAKKEN: I disagree if I understood you to say that TS is not necessary.

DR.PAWSON: All I meant to say was that it is not imperative to have TS data to be able to make an acoustic estimate of abundance.

MR.NAKKEN: If you can get in-situ TS measurements and get them with the equipment you use for survey, then this is ideal because the calibration errors are then removed.

DR.CUSHING: I wish to make a point about biomass integration generally. At one time we used to count individual fish and use a discriminator. The advantage was that we got numbers of single fish and could say that they were a particular size. Generally the arrangement was such that those above 20 cm length only were counted. But in integration where a biomass estimate is obtained that consists of numbers times weight. Little numbers times big weight or big numbers times little weight and this raises a problem; your samples have to be quite rigorously taken to ensure that there is no nonsense in the biomass. For example, the Blue Whiting surveys could have myctophids in the Blue Whiting layer. The trawl mesh is set for the Blue Whiting and nothing but Blue Whiting are caught. However, the echo sounder detects the myctophids if they are present and the trawl would need to have a suitable cover fitted to detect them.

Long Range Sonar for Fish Survey

by

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Since 1969 the Institute of Oceanographic Sciences has been operating a long range side-scan sonar (Project GLORIA - Geological Long Range Inclined Asdic) designed to provide near plan view records of the topography of the deep sea floor out to a maximum of 27 km.

On two occasions GLORIA I was used to study herring fisheries in the Minch. Results of the first survey have been published (Rusby et al., 1973). The second survey produced broadly similar results which is encouraging from the point of view of the technique, but which somewhat reduces the pressure to fully analyse and publish them.

GLORIA II is now being designed and built to be more easily handled in a seaway, to be double sided and to be modular enough for use on ships other than DISCOVERY. The sonar is being built primarily for geophysical surveys, but if it has application in other fields this unique national facility can be so used by interested parties.

Rusby, J. S. M., Somers, M. L., Revie, J., McCartney, B. S., and Stubbs, A. R. (1973). An experimental survey of a herring fishery by long-range sonar. Mar. Biol. 22: 271-292.

DISCUSSION FOLLOWING THE PAPER BY DR.B.S.McCARTNEY : LONG RANGE ACOUSTIC SURVEY

DR.R.W.G.HASLETT: Is it possible to use GLORIA for non-linear acoustic effects at low frequency ?

DR.J.S.M.RUSBY: Yes, we have demonstrated that it can produce the necessary secondary source level.

MR.NAKKEN: Were the fish aggregations shown on the slides fish shoals or scattering layers.

DR.McCARTNEY: It is difficult to be definite about this but echo sounder records were taken at the same time and shoals appear on these. At times rather diffuse layers were seen.

DR.RUSBY: There were great differences between day and night. At night the purse seiner working with us was catching the dense shoals which were close to the surface. The shoals appeared to be interlinked albeit loosely and were spread over many km.

DR.McCARTNEY: The longest ribbon shoal we saw was about 15 km. Fishing was generally good up to two-o-clock in the morning but fell off sharply as the shoals appeared to disperse.