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WORKING GROUP ON SHRIMP AGEING - OCTOBER 1989

Report of the Working Group on Progress in Age Determination of Pandalus

by

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1. Introduction

A working group on progress in age determination of Pandalus met at the Marine Research Institute, Reykjavik, Iceland from October 16 - 19, 1989. The meeting was convened by U. Skuladottir (Iceland) and chaired by D. G. Parsons (Canada). A total of 15 scientists attended the meeting representing Canada, Greenland (Denmark), Iceland, Norway, Sweden and USA and 10 papers were presented (SCR. Doc. 89/89 to 89/98, inclusive). In addition, there were demonstrations of various software packages as well as digital calliper data collection systems.

The objective of this meeting was to determine what progress had been made in age determination of Pandalus since the 1981 workshops held in Canada in May and November. At the 1988 June meeting of the Scientific Council, it was agreed that the meeting should take the form of a working group rather than a workshop, with the presentation of prepared papers. Attendance would include the participants of the 1981 workshop as well as others who might have relevant information to present.

2. Specific Topics of Presentations

a) Characteristics of Various Shrimp Stocks

There were five papers presented on the characteristics (growth, migration, mortality) of various shrimp stocks. Areas considered in the presentations included the Gulf of Maine, the Gulf of St.Lawrence and the Davis Strait in the Northwest Atlantic, Pavlof Bay in the western Gulf of Alaska and the Gullmarfjord on the Swedish west coast.

The high variability in the length frequency distributions (LFD's) of the Gulf of St.Lawrence shrimp population was analyzed with cluster analysis, dissimilarity variograms and multivariate correlograms. LFD's were never randomly organized but showed well-defined homogeneous assemblages which occurred over the grounds every year. The spatial organization, associated somewhat with the topography of the shrimp grounds, resulted from large gradients apparently related to the ontogenic depth migration of the shrimps. The growth rate was not stable over the spatial structures because of the effects of the migration of shrimps in the temperature gradient. The same approach, using a cluster analysis to combine similar samples, was taken to study the age and growth of shrimp in the Davis Strait. In general, modes occurred from year to year at approximately the same sizes both for males and females. However, there were several inconsistencies on a smaller scale that could be the results of

differences in the growth rate of individual cohorts and/or in the spatial organization of the LFD's. The comparison of the results from Davis Strait with more southern areas of the Northwest Atlantic indicated that the general pattern conformed well to the fact that growth and maturation are delayed in colder water, resulting in increased longevity. The participants agreed that multivariate analysis could be a very objective tool to pool samples in order to analyse them and therefore, in describing the spatial organization of a shrimp population. There was some discussion on whether or not the samples should be weighted by the catch when pooled together. It was apparent that computing numbers-at-age is not a simple task and that there is a need to integrate simultaneously the spatial structures and the density patterns of a population.

Data on LFD's from a collection of suprabenthic samples of the Gulf of St.Lawrence were also presented and indicated that the mean size of the first age-group in the shrimp population was about 7 mm (carapace length). Annual growth of the first three age-groups found at low temperatures (0.5-1.5 °C) was 4-5 mm/year. Summer growth rates were three times as high as those in the rest of the year. It was noted that the L-infinity value was very high for this area and was probably due to incomplete data for the older ages.

Based on LFD's of monthly trawl samples of the Gullmarfjord, von Bertalanffy growth curves were calculated for the 1982-85 year-classes. Variations in CPUE, sex ratios and LFD's before and after the water exchange indicated that new demographic patterns were produced as a result of migration of shrimp over the sill area during the water renewal period (late winter-early spring) each year. However, these demographic patterns can develop without migration during the stagnation period each year. It was apparent that seasonal variations in growth seem to be the rule in this fjord. The data indicated that growth rate differed between sexes and it was felt that this should be further investigated along with the correlation between variations in growth and ecological factors (eg. temperature, primary and secondary production).

LFD's collected from annual surveys of the Pavlof Bay shrimp stock over an 18 year period were studied to estimate age and mortality. Differences were observed in growth and mortality between dominant year-classes under a high density regime and a series of year-classes under lower abundance conditions. Discussions focused on density dependence vs temperature, high mortality due to cod predation and the apparent lack of fishery effects.

Elements of the assessment of the northern shrimp stock in the Gulf of Maine were presented. Landings, effort and CPUE in the 6 month fishery have all increased slightly in 1989. The summer research cruise index in numbers of shrimp > 22 mm per tow increased as well in 1989, indicating the beginning of recruitment of the strong 1987 year-class. Discussion of the assessment centred around the effects of occasional strong year-classes on modal analysis. The concept of availability of shrimp to the research and commercial trawls and its effects on biomass estimates and quotas were also discussed as was the necessity of obtaining oceanographic data (temperature and water mass displacement) to help explain the observed differences in growth and to see if there is a link with the population or the cohort density. The participants also agreed on the importance of identifying the very young cohorts (age 0 and 1) for all populations.

b) Models and applications

There were five presentations on various models and their application to shrimp length frequency data in order to determine the age structure or the numbers-at-age of the studied population. Samples of shrimp in Davis Strait were analysed with

the MIX program to investigate the sensitivity of modal analysis. It appeared that, in terms of goodness of fit, several "correct" answers could be obtained assuming different numbers of components for a single set of data. Also, for a single set of data and a given number of components, the starting values for standard deviations or the preparation of data may have a strong influence on the proportions of the components estimated by the analysis, particularly in cases in which the components are overlapped. Based on the observations, it appeared that it would be very difficult, in certain cases, to produce reliable catch-at-age data with this type of analysis, given the sensitivity of the estimated proportions to the input parameters.

A method for simultaneously analysing multiple length frequency data sets (MULTIFAN) was presented. The proportions of animals at age in each sample and the parameters of the von Bertalanffy growth equation are estimated objectively using a robust maximum likelihood method. The ability to simultaneously analyse multiple samples permits the method to exploit the extra information not available when analysing samples one by one. The method was applied to LFD's from the pink shrimp (P. jordani). The participants agreed that the method was very interesting and the discussion centred on the use of MULTIFAN with respect to the presence of seasonal growth, sampling bias associated with the first modes, the numbers of age-groups and the relationship between the variance and the mean length. The calculation of mortality rates using MULTIFAN requires sample weighting so that the length frequencies are representative of the population density. It was also felt that the variations in growth rates of cohorts could cause problems. However constraints on means and proportions can be incorporated if more structure is needed.

Shepherd's length composition analysis (SRLCA) was applied to research trawl survey catches of Gulf of Maine northern shrimp to test the ability of the method to interpret the age structure of annual length frequency distributions incorporating significant variation in growth and recruitment rates. The performance of the method was evaluated by comparing the von Bertalanffy growth parameters provided by SRLCA and subsequently derived age frequencies and instantaneous total mortality rates with previously accepted results using simple visual inspection of the annual LFD's. Shepherd's method was able to provide an interpretation of the data close to a priori assumptions, although some information external to the procedure was needed in order to select the best interpretation from among several locally optimal solutions. Participants noted that SRLCA might provide reasonable results for this stock in part because the growth rate results in annual LFD's that often exhibit very distinct modal structure. It was felt that for other shrimp stocks with a slower growth rate and some overlapped components, the modal structure of the LFD's may be not suitable for the SRLCA analysis.

A virtual population analysis was performed on data from a fjord in Iceland. Samples from the fishery and the February research surveys were used to build the catch-at-age matrix, using the method of Macdonald and Pitcher (1979) to determine the proportions and the mean length-at-age. The biomass of the most important year-classes of the shrimp stock obtained from the VPA was regressed against the corresponding indexes obtained from the research surveys (area swept method). There was a significant agreement between the two methods. Moreover, it was shown that the results for the biomass estimates of the 1-3 year olds could be used to predict a value for the research survey the following winter. Although the participants found the VPA promising because there was indeed good agreement between the two methods, they were concerned that there was generally a very high fishing mortality calculated for the age four animals (the oldest being age five). However, the authors pointed out that the convergence of the F-values was very rapid so the results for the younger age-classes should be reliable.

A new method was presented for a simultaneous analysis of length and age data of the Gulf of St.Lawrence shrimp. The model

essentially asks what synthetic population can be constructed which best fits the observed commercial catch and research survey length distributions? The model, called synthetic age population analysis (SAPA), uses a simultaneous cohort equation to build a population from the commercial sampling which is then fitted to the research data by using a non linear least squares technique. The required inputs are an estimate of the natural mortality, a template of the size distributions at each age, a pattern of selectivity and an estimate of the terminal F. The parameters to be fitted by the model are the starting F and the catchability coefficients. The participants felt that the model could be very useful in analysing shrimp data from some exploited populations. The simultaneous use of length and age facilitates an analysis using all available data, an important point considering the uncertainties involved with shrimp ageing. However, it was felt that the starting values for selectivity and mortality could be improved and it was stressed that the data must be representative if such analyses are to be valuable.

3. General Discussion and Conclusions

Following the presentation of papers, a session was held to focus the discussions on important issues related to the study of age and growth in Pandalid shrimp. It was generally agreed that progress had been made in age determination since the 1981 meeting and, based on the presentations, research appears to be proceeding at a rapid pace. Although it was noted that many of the questions concerning shrimp biology remain unanswered, the models currently being investigated show potential for resolving some of them. Information was presented addressing the problem of identifying the 0 age class and previous inconsistencies in describing stages of sexual development for transitionals and females with sternal spines have been corrected by the acceptance of the term 'primiparous females'.

Considerable discussion was generated concerning the assumption that modes in the length frequency data represent different cohorts. It was recognized that this assumption might not always be correct in that one age group could be represented by many modes or many ages could be contained within a single mode. Seasonal growth, lack of synchronicity in moulting, sex inversion and timing of sampling are factors which affect the interpretation of the length frequency distributions. Sampling throughout the year can provide valuable information to verify the existence of modes and follow growth on a finer time scale. Possible mixing of populations in a given area and spatial organization by size were also identified as contributions to the problem of modal interpretation and it was agreed that cluster analysis of length frequency data would be a useful method to investigate biogeographical relationships. It was further agreed that, in any exercise in modal analysis, it is advisable to consider sex composition and other biological parameters. Finally, the need to investigate new methods of age determination was stressed and it was noted that some work is currently being done in this area (e.g. cluster analysis of data on enzymes, age pigment, isotopes, etc.).

Density dependence was discussed extensively as a topic of special interest. Data from several areas, including Alaska, Iceland and the Gulf of Maine, indicated that density dependent factors might be affecting growth, mortality and/or maturity. It was noted that exceptionally strong year classes tended to exhibit the perceived density dependence particularly well and that any detectable changes in growth rate should be looked at as an indicator of changes in stock size. There was some strong disagreement on whether or not the observations were related to density or environmental factors such as temperature and it was felt that further study of the data was required before firm conclusions could be reached. Such studies should take into account any existing data on temperature.

One important issue identified at the 1981 workshop, the potential for bias in sampling, was discussed further at this meeting. Vertical migration was identified as a major factor contributing to sampling bias and it was recognised that the extent of this behaviour varies between areas. It was suggested that, when biomass is used as an index of abundance, sampling should be done the same way year after year. It was also suggested that time series models might be worth investigating for the analysis of such data. The role of hydroacoustics to address this problem also was discussed and it was generally agreed that much development was needed in the field before the methodology can be effectively applied to shrimp research. If there is potential, it might best be applied for stocks which are highly concentrated. Alternative survey designs were also discussed in relation to reducing bias in sampling and suggestions were made for stratification including temperature data (based on results from a hydrographic survey), two-phased surveys, spline approximation and systematic surveys rather than random surveys. Several of these options are currently being used in shrimp research in certain areas. Trawl selectivity also was discussed and, although it was recognized as a problem for introducing bias in length frequency data, it was noted as well that some studies have shown little or no selectivity in trawls after a certain amount of catch has been taken.

Consensus was reached on a number of issues and it was agreed that they should be listed in the report.

1. There is need to develop a growth model specifically for shrimp. The von Bertalanffy model was felt to be adequate in the meantime but it was stressed that seasonal growth should be incorporated for stocks for which the data are available.

2. More work should be focused on the definition of stocks and populations and their spatial organization. Mixing of different stocks in certain areas and mixing of samples from different locations might introduce bias in the description of growth for the whole area.

3. More data are needed on instars (moulting sequence), especially for fast growing populations, to ensure that modes in the length frequency distributions actually represent separate age groups. It was suggested that a shell condition index might be useful in this respect. It was also felt that the timing of the survey was an important factor when studying the age structure of a population. If seasonal growth is significant, it would be advisable to conduct surveys at the end of the growing season.

4. Density estimates should be expressed in common units for comparative purposes. It was agreed that density should be given as numbers per sq km, specifying mesh size and mean carapace length.

5. Hydrographic data should be collected more carefully and extensively to investigate the importance of changing environmental conditions in shrimp population dynamics.

6. Further efforts should be made to identify the age of the first mode in the length distributions from areas for which uncertainty remains.

7. More research needs to be directed towards identifying the factors that govern growth in Pandalid shrimp, including temperature, density and food availability.

8. New methods to separate modes in the length frequency distributions and to incorporate age and length simultaneously in population analysis were presented and discussed. It was agreed that these methods show potential and should be explored more extensively.

It was also obvious from the discussions that there were important biological differences between the populations of shrimp from the various areas. It was agreed that the questions which need to be answered would also vary between populations and that any research or management strategies adopted for one area might not necessarily apply to others.

4. Recommendations

The working group agreed that several of the points of discussion were worthy of being carried forward as specific recommendations to the Scientific Council of NAFO and these are given below.

1. It has been found since the 1981 workshop that, by examining the stomachs of important shrimp predators and by sampling in shallower areas with various benthic sleds, much information can be gained on the size of the 0 age class. Such methods should be continued in areas where the age of the first mode occurring in trawl catches still remains questionable.

2. In order to compare density estimates between areas, the information should be expressed in numbers of shrimp per square kilometre, specifying mesh size and mean carapace length. Also, efforts should be increased to obtain more extensive temperature data in an attempt to closely monitor changes in environmental conditions over time.

3. Studies should be initiated to determine the possibility of immigration into certain stock areas. In many areas there are refugia, unfishable grounds where it is not known what the shrimp densities are or how and if they contribute to the fishable stock. The use of cluster analysis to describe the biogeography and investigate the possibility of immigration is encouraged.

4. Research should be directed towards finding an independent method of determining the age of shrimp. Growth in weight, variations in isotopes or enzymes over time and age pigment were discussed as possibilities and these should be investigated further.

5. Future Meetings

Although no formal proposals were made for a future meeting in terms of mandate and location, all participants agreed that the present meeting was extremely beneficial and that any new initiatives, either through NAFO or local institutions, should be communicated to all participants. It was also noted that there was no representation from the USSR or Japan and it was agreed that any future meeting should try to attract attendance from those countries, as well.