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C.M. 1990/B:29
Fish Capture Committee

Report of the Working Group on Fisheries Acoustics
Science and Technology
Ancona, Italy, 24-27 April, 1991

ICES FAST Working Group Meeting 24-27 April, 1991

Ancona, Italy

Agenda

Wednesday 24 April, 1991

0900

1. Opening of the meeting.
2. Welcome by Prof. Giovanni Bombace
3. Order of the day and appointment of rapporteur.
4. Current Acoustic Survey Design Practices
by Simmonds, J. (Chairman), F. Gerlotto, A. Aglen, and N.
Williamson

4.1 Introduction

4.2 Definitions

4.3 Definition of Survey Area

4.4 Track Design

4.4.1 Predetermined

4.4.2 Adaptive

Coffee Break 1100-1130

4.5 Interval for Averaging

4.6 Data Analysis

4.6.1 Species-Density Allocation

4.6.2 Spatial Averaging

Lunch 1300-1430

4.6.3 Spatial Errors

4.6.3.1 Repeat Surveys

4.6.3.2 Degree of Coverage

4.6.3.3 Bootstrapping

4.6.3.4 Transformations

4.6.3.5 Cluster Analysis

4.6.3.6 Geostatistics

4.6.3.7 Behaviour

4.6.4 Additional Errors

Coffee Break 1600-1630

4.7 Summary and Discussion

1800 Adjourn

Friday 26 April, 1991

0900

5. Presentation of papers

5.1 Survey problems near boundaries.

5.1.1 Birczinski, J. Different Applications of Acoustics: Monitoring of Riverine Fish and Assessment of Marine Zooplankton.

5.1.2 Gerlotto, F. and P. Freon. Near Boundary Problems during Echo Surveys in Coral Ecosystems around Tropical Islands.

5.1.3 Karp, W. Survey Problems Associated with Assessing Fish near the Bottom.

5.1.4 Nunnallee, E. An Investigation of the Avoidance Reactions of Pelagic Fish to Demersal and Midwater Trawl Gear.

5.2 Behavioural Considerations for Acoustic Surveys

5.2.1 Forbes, S. Fish Target Strength as a Function of Aspect Angle.

5.2.2 Simard, Y. Distribution Patterns of Small Pelagic Fish in Relation with the Oceanographic Features in the Gulf of St. Lawrence.

Coffee Break 1100-1130

5.3 Survey Considerations

- 5.3.1 Ona, E. Vessel Heave -- An Indicator for Air Bubble Attenuation?
- 5.3.2 Didier, D. and J. Cardenas. Acoustic Survey of an Hydroelectric Reservoir: An Original Example of a Boundary in Acoustic Detection.

5.5 Acoustic Applications to Plankton Surveys

- 5.5.1 Sprong, I. The Use of Echosounders in Marine Biological Research: Application of Equipment in the Study of the Distribution and Patchiness of Zooplankton and Micronekton.

Lunch 1300-1430

4. Current Acoustic Survey Design Practices (Continued)

Coffee Break 1600-1630

4. Current Acoustic Survey Design Practices (Continued)

6. Working Group Recommendations - Initial Discussions

1800 Adjourn

Saturday 27 April, 1991

0900

5.5 Acoustic Applications to Plankton Surveys (continued)

- 5.5.2 Holliday, V. Report of the Meeting of a Workshop on Globec Technology Requirements.

5.6 Fish School Recognition Studies

- 5.6.1 Weill, A. and N. Diner. Movies-B: A New Software for School Characterization.
- 5.6.2 Reid, D. and E. Simmonds. The Application of Image Analysis Techniques to the Study of Fish Shoal Structure using Acoustic Survey Data.

4. Current Acoustic Survey Design Practices (Continued)

6. Working Group Recommendations

1300 Adjourn

Report of the ICES Fisheries Acoustic Science and Technology (FAST)
Working Group Meeting 24-27 April 1991, Ancona, Italy

1. Participants and Terms of Reference.

A list is attached as Appendix A.

Terms of Reference:

In accordance with C. Res. 1989/2:9 the Working Group on Fisheries Acoustic Science and Technology (Chairman: Dr. J. Traynor) met in Ancona, Italy from 24-27 April 1991 to:

a) consider, under the chairmanship Dr. E.J. Simmonds (UK), the special topic: "Current Acoustic Survey Design Practices", in particular:

i) review acoustic survey practices and analysis procedures for abundance estimation;

ii) identify currently acceptable procedures and research needs;

iii) prepare a report on recommended acoustic survey procedures;

b) review acoustic survey problems associated with organisms near boundaries such as shallow water and near surface conditions.

2. Opening of the Meeting

Prof. Giovanni Bombace welcomed the participants and provided a brief description of the pelagic resources and scientific investigations in the Adriatic Sea.

3. Order of the Day and appointment of rapporteur.

The agenda was adopted. William Karp, Alaska Fisheries Science Center, National Marine Fisheries Service, Seattle, Washington, USA was appointed as rapporteur.

4. Current Acoustic Survey Design Practices
by Simmonds, J. (Chairman), F. Gerlotto, A. Aglen, and N. Williamson

The chairman opened the session and passed the chair to John Simmonds for discussion of the activities of the special working group. John Simmonds began by reviewing the terms of reference of the special

working group. The group was established to review the principles of abundance estimation by means of acoustics. Three areas of emphasis were defined:

- 1) Review of current practices
- 2) Recommendations
- 3) Definition of research needs

John began by discussing assessment requirements as presented in the draft documents. He emphasized the importance of understanding the implications of one's assumptions. Decisions made regarding survey design and analytical procedures define the assumptions being made about the stock. It is important that the assessment scientist be aware of these assumptions and the implications implicit.

John went on to discuss assumptions and definitions of terms. The concepts of dependence and independence were emphasized. The importance of taking dependence into account was explained. The concept of statistical stationarity and its implications was also emphasized.

Neal Williamson then proceeded with a discussion of survey areas and trackline designs. He emphasized the importance of understanding the ecology of the stock and of designing surveys to address clearly stated objectives. The concepts of isotropy and anisotropy were presented.

Williamson discussed the use of data collected during cross-transects and responded to questions regarding this topic. He stated that cross-transect data is only usable in certain circumstances and that some researchers may prefer not to use cross-transect information. Discussion of the use of cross-transect information followed but the question of appropriate use of this information remained open.

Yvan Simard pointed out that, regarding the use of spatial statistics, survey design depends on objectives but a uniform design is generally preferable. Regular sampling is advantageous for mapping auxiliary information.

Pierre Freon initiated a discussion of systematic sampling. In the case of a regular temporal cycle, systematic sampling is inappropriate. He expressed the opinion that systematic problems rarely exist in the spatial plane so that regular systematic sampling is generally reasonable.

John Simmonds cited the definition of systematic sampling according to Cochran. The definition incorporates a random starting point. This can lead to an index rather than an absolute estimate but, in general, randomly started uniform sampling is acceptable. Discussion of the relative merits of indices and absolute estimates followed. It was

emphasized that survey objectives are of prime importance in deciding whether results can be provided in the form of an index.

A discussion regarding transect line direction followed. Egil Ona reported that work by Pierre Petigas indicates that either perpendicular or parallel transects were acceptable. While John Simmonds suggested that perpendicular transect lines would provide lower resolution for geostatistical analysis, Yvan Simard and Pierre Freon indicated that perpendicular transects could be useful, especially for investigation of anisotropy. It was suggested that further discussions of this question also take transect spacing into account.

Yvan Simard pointed out that transects should be sampled in sequential rather than random order.

Bill Karp recalled that some authors had used zig and zag transects to construct replicate data sets. He asked if anyone could identify the cost associated with violating the assumption of independence. Neal Williamson responded that the approach was inappropriate but the "cost" was unknown. This gave rise to a brief discussion of the implications of violating assumptions in several contexts. It was felt that this concern should receive further consideration.

Egil Ona raised the issue of comparing between-year survey results. Should effort be similar from year-to-year if variance estimates are to be comparable (i.e. compared with each other)? How can this be accomplished if stratification considerations change? There followed a discussion of variance estimation procedures and the use of variance estimates in the assessment process. It was suggested that a suitable multi-year survey design would lend itself to within- and between-year comparisons but the issue of changing stratification criteria remains unresolved.

John Simmonds introduced the problems associated with surveying distributions that follow such features as the coastline or shelf edge.

Olav Rune Godo asked the question "Which is more important to address, accuracy or precision". Obviously, this will depend on the survey objectives; the index/absolute abundance issue being important in this context. Dan Miller reminded us that accuracy and precision are inter-related and should not be considered independently.

With respect to geostatistical considerations, Egil Ona pointed out that the work of Pierre Petigas indicates it is acceptable to re-allocate survey effort in high density areas. Pierre Freon concurred. This led into the discussion of adaptive survey design, introduced by John Simmonds.

The first issue of concern involved potential errors in estimation of surveyed areas. John Simmonds demonstrated the difficulty in determining correct area boundaries when transect spacing changes; he perceived that this process would always introduce bias. There was disagreement over this point. Jim Traynor and Olav Rune Godo felt that bias would be negligible in some situations.

Yvan Simard emphasized the point that the analytical technique would influence the adaptive approach. The selection of suitable ancillary variables during restratification may be useful. Strata with different transect spacing must be separated for analytical purposes.

Asegeir Aglen mentioned the "Pilot Survey" approach where a qualitative survey is used to provide information to design a subsequent quantitative survey. Good examples of this approach include Icelandic herring and capelin assessments.

John Simmonds next introduced the subject of selection of appropriate averaging intervals. There was discussion regarding diel differences in autocorrelation and recognition that ESDU selection would, to some extent, depend on the analytical technique to be employed. Yvan Simard suggested that the variogram shape could be used as an indication of appropriate ESDU length.

John Simmonds asked for suggestions regarding the lower unit size limit. Egil Ona suggested that sampling frequency should be sufficient to reproduce the "structure" of the data. Pierre Freon suggested that the lowest possible ESDU be selected initially and subsequent analysis could be based on regrouped data. Francois Gerlotto described the problem as one of scale; the ESDU should be homogenous - biological structure is the significant factor. Geostatistical procedures can be used to look for homogeneity.

Asegeir Aglen introduced the discussion of assignment of acoustic data to biological categories. The process of judgement or exclusion of non-fish targets. He stressed that a survey report should provide detailed information on the judgement procedures including the techniques for allocating trawl catch data.

A discussion of trawl sampling and use of catch information followed. Olav Rune Godo encouraged survey scientists to be aware of the biases inherent in trawl sampling. Data from trawl hauls should be combined but procedures for weighting have not been defined.

Francois Gerlotto initiated a discussion of spatial averaging. The concept of contour stratification was discussed at length. Pierre Freon pointed out that methods such as contour stratification, in which the data itself is used as the basis of stratification, is acceptable for determining means and distributions but cannot be used for

estimating variances. It was generally agreed that non-optimal stratification would lead to higher estimates of variance. Yvan Simard asked if contouring is different from geostatistics; he felt that Kriging was simply the best contour interpolation technique.

There followed an exchange of opinions regarding the differences between approaches for mapping distributions and those for appropriate stratification and variance estimation. Some scientists felt that the objectives of distributional mapping and variance estimation were mutually exclusive and could best be addressed by applying different analytical techniques to the same data set. Others felt that both objectives could be addressed simultaneously through the use of geostatistical techniques. The underlying factors which influence fish distribution were also considered in this context. The more we understand the mechanisms involved the more we can define strata objectively and consider distributional mapping from a statistical perspective.

Asegeir Aglen presented a summary of the section on survey repeatability. He made particular reference to table 8 in the draft cooperative report. Comparisons were based on global means. Very few comparative data sets are available. Discussions addressed the concept of degree of coverage, variance estimation for transect lengths, tests for transect independence, and techniques for determining the degree of sampling necessary for a given confidence limit. It was suggested that the title of section 4.5.3 should be generalized to incorporate the broader concept of allocation of biological characteristics. For example, errors associated with determining accurate size composition from trawl catches should be considered under this heading.

The use of bootstrapping to assess survey sampling error was discussed by John Simmonds. The approach should only be applied to stationary data but a stratified design can be used. He then went on to discuss transformations and stressed that those employing transformations must test the PDF to determine the underlying assumptions regarding distribution. Treatment of zeros should receive careful consideration.

Neal Williamson remarked that it is not necessary nor always appropriate to transform the data from each stratum in a survey in the same manner. Pierre Freon noted that bias can be introduced even if the required assumptions are satisfied.

Yvan Simard expressed concern regarding criteria for model selection. John Simmonds responded by reviewing the recommended procedure: test for the appropriate transforms. Compare transforms, the best transform will yield the lowest variance estimate.

Neal Williamson made reference to the lognormal distribution as cited by Jolly and Hampton. It was suggested that this procedure be more

fully discussed and referenced in the manuscript.

Neal Williamson then reviewed the cluster sampling approach. There was no further discussion of this topic.

Francois Gerlotto re-stated the 3 factors that are considered during geostatistical processing (according to Simard et al): geometry, absolute location, and relative location.

Fish behavior was the next area discussed. Francois Gerlotto introduced this topic. There was some discussion regarding the quantification of behavioral effects and a general consensus that a thorough knowledge of behavior, especially at the stock level, is an essential component of good survey design. Jim Traynor suggested that citations concerning behavior, especially with respect to target strength, should reference the species and size range.

Asegeir Aglen opened the discussion of additional sources of error. Siebren Venema and Kjell Olsen reminded the group that the positive aspects of acoustic surveys should be acknowledged; the document should take a balanced view.

Olav Rune Godo encouraged consideration of the conditions under which data is collected. Differences in weather conditions and other factors will influence consistency and comparability. This concern was generally endorsed, especially as it relates to the ability to analyze time series information.

In response to the question "should precisely the same transect tracks be repeated each year?", Yvan Simard responded in the affirmative, in order to avoid spatial interpretation problems. Francois Gerlotto felt that it would be acceptable to change survey procedures during a time series if an investigator felt sure of improvement. This led to an animated discussion of the relative merits of consistency in methodology and adoption of improvements. Each investigator must evaluate the advantages and disadvantages of change with respect to his or her research objectives. Kjell Olsen raised the concept of survey indices in this context. The choice between indices and absolute abundance estimates will depend on survey objectives and other considerations. Pierre Freon suggested that a pilot survey might always follow the same trackline and use consistent procedures while the detailed survey could incorporate differences in design and methodology.

Neal Williamson summarized the sources of error encountered during the various steps of abundance estimation by means of acoustic surveys.

Several delegates offered comments regarding the values presented in tables 10 and 11. The categorizations and ranges of magnitude

suggested for various sources of error are not based on objective criteria and this gave rise to a number of concerns. For example, the classification of "Diurnal behavior" in table 10 as being a source of random error but not systematic error, even with the footnote of explanation, may be confusing. It was suggested that classification of acoustic estimates according to biological characteristics be considered as a source of error in the estimation of abundance.

Under the terms of reference, the chairman next directed the working group to consider possible research needs. It was not considered appropriate to rank needs in order of priority because of national differences in research and survey objectives. It was agreed that the following topics should receive serious consideration.

- 1) Research regarding acoustic assessment near boundaries (eg near surface and near bottom).
- 2) Studies regarding the classification of acoustic assessments by means of fishing samples and other techniques. This would include:
 - i) Classification by acoustic methods (including multi-frequency approaches)
 - ii) Studies of gear/fish interactions with acoustic techniques
 - iii) Methods for excluding (or including) acoustic returns from plankton in survey biomass estimates
 - iv) Other aspects of echogram interpretation including image processing.
- 3) Continued research on the factors influencing target strength with particular emphasis on the development and documentation of in situ techniques for addressing TS related sources of survey error.
- 4) Consideration of appropriate methodology for adaptive survey design.
- 5) Studies of survey variability. Use of appropriate statistical procedures for comparing replicate surveys.
- 6) Development of techniques regarding the use of sonar in echo integration.
- 7) Studies of the interaction between stock density and environment (including depth).
- 8) Examination of techniques and development of methodology for calculation of spatial sampling confidence intervals.

The chairman provided each delegate with a copy of the draft manuscript and requested that anyone who wished to provide comments should do so by mid June. Suggestions will be considered for incorporation into a new manuscript which will be made available at the 1991 statutory meeting.

Overall, great appreciation was expressed to the authors, and to John Simmonds in particular, for the tremendous amount of work that had been required to prepare the manuscript. Even with so much of the work done, it was recognized that completion of the report is a daunting task.

5. Presentation of papers

5.1 Survey problems near boundaries.

5.1.1 Burczinski, J. Different Applications of Acoustics: Monitoring of Riverine Fish and Assessment of Marine Zooplankton.

This paper addressed two different areas of research involving the application of acoustic techniques. The author first presented a summary of fixed-location studies of salmonid migration being conducted on the Columbia River (Washington State, USA).

The Columbia River studies have been underway for about 10 years. Most of the research has been directed towards problems associated with the passage of juvenile salmon through hydroelectric dams as they migrate downstream. Because there are many such dams on the Columbia, cumulative mortality can be substantial. Since research has shown that mortality associated with passage through turbines is much greater than passage through spill (or, in some cases, through ice and trash sluiceways) acoustic techniques were originally developed to document the patterns of distribution of smolts as they approach and enter each dam, and the manner in which these patterns change under different operating conditions. Subsequently, the techniques were used to observe the effects of engineering and operational modifications that were designed to reduce mortality.

Most of the work has been conducted using 420 kHz systems, often with many transducers controlled through programmable multiplexers. Each transducer is mounted so as to maximize the insonified volume in the region of interest, and aimed so that direction of fish movement can be inferred from change-in-range measurements. In some situations, remote rotators are employed. Targets are generally spatially separate, so that counting and location information can be obtained by taking measurements from

the echograms. Initially, this was accomplished manually, and, later, by means of digitizing tablets and custom developed software. Now it is possible to track individual fish through a computer link to the echo sounder so data can be accumulated automatically and, in some cases, transferred to the laboratory by telemetry.

The studies of marine plankton have been reported in the literature (J.Acoust.Soc.Am.88(5):2346-2360.). The work has included in situ target strength measurement and studies of distribution and abundance. The in situ work was conducted using a dual-beam 420 kHz system in an enclosure filled with seawater moored to a dock. It was found that backscattering cross sections are proportional to volume. A three degree transducer was used for the TS measurements. Ranges up to 30 m were obtained in sparse density situations and 10-15 m in more densely populated situations.

Surveys were carried out using 120 and 200 kHz mobile systems. When areas of potential interest were encountered, they were surveyed by transecting vertically with 420 kHz and 1 mHz systems mounted on a submersible. The studies also included instrumentation of a Moccus sampling net and studies of seamounts and thermal vents.

Discussions considered possible problems of side aspect measurements, which were not considered serious by the author, early problems with transducer pressure dependency which have now been resolved, and limitations that occur when densities are not quite low.

5.1.2 Gerlotto, F. and P. Freon. Near Boundary Problems during Echo Surveys in Coral Ecosystems around Tropical Islands.

This work was conducted in shallow waters close to some small islands adjacent to Martinique. The water is very shallow, 10 cm - 20 m and only 3 - 15 m are actually samplable. The lagoons are protected from the ocean by a barrier reef. Low biomass densities are usual with larger demersal and smaller school pelagic species predominating.

Transect placement is determined totally by topography because of severe limitations in both vertical and horizontal planes. Survey design is not an issue in such situations and data collection is extremely difficult. All data collection takes place during moonless nights. The slope area is very narrow so sampling is difficult in this region. Analysis of results is complicated by

sampling limitations near horizontal and vertical boundaries and the need to obtain an overall assessment from many small sections of survey data. The authors believe that boundary problems and other assumptions severely limit the precision of their survey results.

There was heated discussion regarding the appropriateness of acoustic techniques in environments of this type. Some felt that it was very important that the limitations be stressed and that alternative techniques be recommended while others felt that, while the fundamental problems should not be ignored, some of the limitations should be addressed with suitable research.

5.1.3 Karp, W. Survey Problems Associated with Assessment of Fish near the Bottom.

The Alaska Fisheries Science Center conducts assessments of walleye pollock (Theragra chalcogramma) on the shelf and slope of the eastern Bering Sea. The species is semi-pelagic. The demersal portion is appraised by means of a stratified systematic bottom trawl survey designed to obtain biomass and distribution data for several species of fish and crabs. The midwater portion of the stock is assessed by echo integration-midwater trawl techniques. Overall age-specific pollock estimates are obtained by summing the demersal and midwater estimates, assuming that the effective height of the bottom trawl is 3 m. Concerns regarding the implications of this assumption, and the impact of gear-fish interactions on the survey results are now being investigated.

Techniques are being developed to permit the use of acoustic data for abundance assessment in the near bottom region so that overall biomass estimates can be made using the same technique. The problem of biological sampling remains, however, since it is clear that avoidance and herding effects occur and these are likely to be especially complex near the bottom.

The discussion included comments and questions regarding species identification, TS measurement, fish behavior in relation to sampling gear, and temporal and spatial aspects of stock distribution.

5.1.4 Nunnallee, E. An Investigation of the Avoidance Reactions of Pelagic Fish to Demersal and Midwater Trawl Gear.

This presentation concerns a study of the behavior of Pacific hake (Merluccius productus) in relation to demersal and pelagic trawls. Fish schools were observed acoustically from a separate vessel

before, during, and after passage of the trawls. Echograms presented illustrated disruption of fish layers during fishing operations conducted in daylight and darkness. The possible implications of this behavior on survey abundance estimates was discussed.

Questions and comments addressed the different size selectivities of demersal and pelagic trawls and, in particular, work that has documented the degree to which door spread influences catches of large fish. It was suggested that vessel avoidance in the absence of fishing gear be studied

5.2 Behavioural Considerations for Acoustic Surveys

5.2.1 Forbes, S. Fish Target Strength as a Function of Aspect Angle.

Results of cage experiments of the effect of tilt angle on free swimming herring were reported. Using a dual beam echo sounding system to measure target strength and a stereo camera assembly and wire grid to measure tilt angle, the relationship between tilt angle and target strength were measured between about -20 and +20 degrees around the horizontal axis of the fish. The author observed the unexpected result that there was no apparent directivity pattern over this range of angles, although there were large random variations. The author notes the discrepancy between the results reported here and those of numerous authors [e.g Nakken and Olsen (1977); Foote (1985)].

Many members of the audience expressed surprise at the lack of a relationship between tilt angle and target strength. Ona asked if one problem may have been the fact that the stereo cameras were below rather than beside the fish. Simmonds replied that the mathematics were such that the error is no different between the two stereo camera locations. Ona indicated that the use of split beam tracking will provide similar data and he encourage users to attempt to obtain such information.

5.2.2 Simard, Y. Distribution Patterns of Small Pelagic Fish in Relation with the Oceanographic Features in the Gulf of St. Lawrence.

Simard discussed the importance of considering how the distribution of acoustic targets is associated with environmental variables and suggested that every effort be made to simultaneously monitor environmental variables when conducting an acoustic survey. He reported the close link between the distribution of meso-pelagic fish distributions and temperature in the Gulf of St. Lawrence and suggested that the use of

environmental data will allow more efficient surveys to be carried out. In the future, he plans to obtain finer resolution data on the physical characteristics of the water masses in the area and develop a kriging model to use the environmental data for biomass and confidence interval estimation.

Godo indicated that, in the Barents Sea, it is not usual to find a direct correlation between temperature and fish. Many physical and biological covariates may be important in determining the distribution and density of the stock being surveyed. He indicated that he felt that a primary reason for collecting environmental data is that it may be useful for between-year comparisons in, for example, recruitment relationships.

5.3 Survey Considerations

5.3.1 Ona, E. Vessel Heave -- An Indicator for Air Bubble Attenuation?

In this presentation, the author suggests that vessel heave could be used as an indicator of air blocking for an echo integration system and reported preliminary results of measurements of vessel heave and its relationship to air blocking. Air blocking, which involves air being trapped beneath the vessel, presumably increases as vessel motion (heave) increases. Although he emphasized that the relationship will be vessel and speed dependent, the author suggested that vessel heave may be a stable indicator of attenuation due to air blocking. Also, he suggests that average vessel heave may be a useful, objective indicator of survey quality.

Discussions centered about the mechanism of air blocking. For example, the effect will be much different when traveling into or with the seas. It was generally agreed that it will be useful to examine the relationship between vessel heave and air blocking.

5.3.2 Didier, D. and J. Cardenas. Acoustic Survey of an Hydroelectric Reservoir: An Original Example of a Boundary in Acoustic Detection.

This paper describes the results of an exploratory survey of Guri lake, a recently (1986) impounded lake in Venezuela. The survey situation was complicated by the presence of submerged trees which caused significant problems with assessing fish populations in the areas of submerged vegetation. The authors report results of echo counting that provided estimates of the minimal abundance in these areas and suggest that acoustics may provide a useful tool to not only assess the abundance of fish, but also measure the decay in

the submerged vegetation. Preliminary estimates, derived acoustically were greater than 400 kg per hectare, over twice that estimated using exploratory fishing results.

5.5 Acoustic Applications to Plankton Surveys

- 5.5.1 Sprong, I. The Use of Echosounders in Marine Biological Research: Application of Equipment in the Study of the Distribution and Patchiness of Zooplankton and Micronekton.

This author presented a discussion of her use of acoustics to investigate small scale phenomena including biogeographic processes. The work reported here concerned Antarctic krill swarms.

Acoustic techniques were used to examine temporal changes in swarm dimensions although the effect of vessel speed was of concern. In spring and summer krill were observed in open water while in winter they were observed to be dispersed under ice floes. An extensive horizontal, northward migration was documented.

- 5.5.2 Holliday, V. Report of the Meeting of a Workshop on Globec Technology Requirements.

The Global Ocean Ecosystem Dynamics (Globec) initiative is a science component of the U.S. Global Climate Change Program. The aim of Globec is to attain an understanding of physical processes in the ocean environment influencing the success of individual animals in the sea through their feeding, reproduction and survival. Globec also attempts to address the relationship between the success of the individual organism and the dynamics of the population. A workshop was held during April 2-4, 1991. Four working groups were established to summarize technology needs for different components of Globec. These were: 1) Fisheries Acoustics, 2) Macrozooplankton / Micronekton Acoustics, 3) Small Zooplankton Acoustics, and 4) Acoustical and Optical Sensor Integration. Each group assessed research needs to accomplish Globec goals. Among other topics, the development and use of multi-frequency systems, the use of a variety of system deployment modes (i.e. towed, moored, etc.) and the integration of acoustic and optical information were discussed. The report of this meeting will be published and will be available from Dr. Holliday.

5.6 Fish School Recognition Studies

- 5.6.1 Weill, A. and N. Diner. Movies-B: A New Software for School Characterization.

This paper described a system that has been used for echo integration. The system differs from other echo integration systems in that it automatically segregates echo energy into specific schools of fish as well as to areas where schools are not present. A school is recognized only if it occurs (voltage above an input threshold) in the same depth region for a number of transmissions. Many parameters about the school (e.g. total energy, geometry, position in the water column) are stored for each detected school. The ultimate goal is automatic classification of schools which might allow segregation of echo integration data by species.

5.6.2 Reid, D. and E. Simmonds. The Application of Image Analysis Techniques to the Study of Fish Shoal Structure using Acoustic Survey Data.

The authors describe a new image analysis based processing system for use with acoustic fisheries data. Using a variety of image processing techniques, the authors process the acoustic data to improve the ability to 1) characterize schools and 2) separate bottom returns from fish returns. The authors argue that the technique allows better interpretation of school characteristics than available from visual inspection of echogram. In addition, the technique, provides a measure of echo energy as well as a variety of physical parameters related to each school. The authors concluded that inclusion of this type of information should improve the accuracy of some aspects of acoustic stock abundance estimation.

Discussions centered around the technical details of the image processing technique. Although the authors felt that the technique would add to our capacity to characterize the species contained in each school, they felt that much work was left to be done in this area.

6. Working Group Recommendations

The Working Group made the following recommendations regarding special topics for the 1992 Working Group Meetings:

- 1) The Working Group recommends that member countries be encouraged to provide documentation about the methodologies and results for in situ target strength measurements. The Working Group has long recognized the importance of in situ target strength measurements to improve the accuracy of survey results. Recent advances in technology have made the collection of this valuable data more readily available. It is important that methodologies be evaluated to ensure that the resulting estimates are accurate and comparable. The Working Group felt that 1992

would be an appropriate time to consider this important topic.

2) The working group recommends that member countries be encouraged to report results of species and pattern recognition studies using procedures for classifying acoustic signals. The Working Group believed that these types of analyses may play an important role in understanding the schooling characteristics of pelagic fish and also may be a useful tool for species identification.

The Working Group also affirmed their support for the special topic "Radiated Noise of Research Vessels" to be considered by a joint FTFB/FAST Working Group in 1992. Knowledge about the noise spectra of research vessels and fish reaction to the vessel noise is critical to assessing the accuracy of survey results. The FAST Working Group felt that it was entirely appropriate to consider this topic in a joint session since it falls under the terms of reference for both groups.

Finally, the FAST Working Group recommended that the 1992 meeting be held in Bergen, Norway immediately before or after the Symposium on Fish Behaviour in Relation to Fishing Operations.

7. National Progress Reports

7.1 Canada

Pacific Biological Station, Nanaimo, B. C.

A fishing and acoustic study of rockfish (Sebastes spp.) on untrawlable bottom identified distinct fish concentrations but encountered difficulties resolving fish from steep and rough bottom; a Simrad FS-3300 Trawl Sonar has been added to the existing trawl and acoustic survey tools and its use is being considered for rockfish behavioral studies; acoustic surveys continue to census fish populations in salmon nursery lakes; acoustics provided information on changes in distribution of adult salmon responding to deteriorating water quality in Alberni Inlet; a fifth annual acoustic estimate of herring in Hecate Strait was completed on two distinct overwintering locations, roughly about 30 km square, with survey activity concentrated around dusk and dawn to decrease variability due to diurnal migrations; an extended hydroacoustic assessment of summer feeding aggregations of Pacific hake was conducted; the problem of expanding transect surveys to cover an entire survey area is being addressed using a graphic information system; several algorithms can now be developed to objectively expand echo integration based on acoustic density measurements of the survey area and to combine them objectively with related fishing, bathometric and oceanographic data; a breakthrough in acoustic data processing has been achieved by using standard and customized image processing techniques to discriminate complex bottom and identify/analyze individual schools for better biomass estimates of demersal fishes and fish behaviour studies. Acoustic species recognition and specific acoustic estimates appear possible in the near future.

DFO Freshwater Institute, Winnipeg, Manitoba

A hydroacoustic (120 kHz) study of shrimp in eastern Hudson Strait (depth = 300 m), which was groundtruthed with a Bioness multistage plankton sampler and a bottom trawl, was completed. Shrimp were readily detectable near the bottom and within the water column. Diel vertical migration was extensive. Further study of Arctic cod schooling behaviour and marine mammal/sea bird predation in Lancaster Sound (Canadian Arctic archipelago) was also completed. A preliminary study of fish abundance/distribution in three lakes of the Red lake Climate Change study group was executed successfully, and three other lakes can now be evaluated. Work continues on the study of fish migration through hydroelectric diversion channels. Research was initiated in the Great Lakes Habitat Restoration Program (Thunder and Nipigon bays, Lake Superior): the response of fish populations to restoration

measures is being studied with acoustics and traditional fishery science techniques; this work established baseline conditions prior to implementation of restoration measures in order to allow their direct evaluation.

Institut Maurice-Lamontagne, Mt Joli, Quebec

The fisheries ecology study in the north-western Gulf of St-Lawrence continued to have a strong hydroacoustic component. The two-frequency (38 & 120 kHz) dual-beam Biosonics system was used along regularly-spaced parallel transects to map fisheries resources, aggregations of fin humpback and blue whales, and oceanographic characteristics. Acoustic traces were sampled with BIONESS, Issaacs-Kidd trawls and a seiner. A meso-scale upwelling/mixing front was located in Jacques-Cartier Strait, bordered by large-amplitude high-frequency internal-waves that were traced by vertical displacements of sound scattering layers. Secondary fronts and slicks were also present. Aggregations of fishes, including juvenile capelin and sandlance were found at or close to these fronts. An exceptionally-rich demersal scattering layer, dominated by the copepod Calanus hyperboreus, was detected at 120 Khz in a 200 m-deep basin, intensively fished for northern shrimp. Whales were more frequent in locations of dense fish schools and were sometimes associated with the frontal aggregations. Herring was surveyed on the west coast of Newfoundland, although most efforts were directed to developing the acoustic system, including a 120 kHz sounder, a DAT recording unit and the new FEMTO-HDPS 9001 menu-driven digital data acquisition and editing unit (Femto Electronics Ltd. Halifax).

DFO Scotia-Fundy Region Biological Sciences Branch

Recent research utilizing a multi-frequency acoustic system at 12, 50 and 200 Khz resulted in a new acoustic model for euphausiid target strength; recent sampling experiments using lights on a net sampler produced closer agreement between the net and acoustic euphausiid estimates than previously; a new 8 frequency (1 MHz-50kHz) acoustic system will be tested this fall with the first trials planned for 1992 - the system will be towed or vertically lowered to depths of 300m; acoustic abundance estimates of the NAFO Div. 4WX winter herring stock were again made from parallel transect surveys; an exploratory demersal first survey on Georges Bank showed that cod and haddock caught by bottom trawl were too close to bottom to be detected by the acoustic equipment - a higher frequency sounder and a long cable to tow the transducer closer to the bottom are being purchased to increase resolution near bottom; a new field method for deriving unbiased estimates of maximum dorsal aspect target strength of individual gadoid fish were developed for use with dual or split beam acoustic systems;

analysis of dual-beam acoustic data obtained from a concentration of spawning haddock has demonstrated that the high degree of mesoscale aggregation is body-size dependent.

DFO Newfoundland Region Biological Sciences Branch

Two inshore surveys estimated herring abundance off the southeast and northeast coasts of Newfoundland; offshore cruises comprised two capelin biomass surveys, one redfish biomass survey, one experimental survey evaluating procedures for estimating cod biomass during winter spawning aggregations, and one experimental cod survey to track a large cod aggregation during spring migrations; target strengths of net-enclosed herring at frequencies of both 38 kHz and 120 kHz were determined and a target strength/length relationship at 120kHz derived from the experimental data was used to estimate herring biomass; development activities included a preliminary design for a "standard target" calibration capability for the offshore acoustic data acquisition system; refinement and evaluation of the "standard hydrophone" calibration technique was continued; additional successful testing and trials for the towed body stern deployment and retrieval system for the R. V. Gadus Atlantica were carried out.

7.2 Denmark

Acoustic methods have been implemented in routine stock surveys in the North Sea and the western Baltic. Acoustic data with high resolution have furthermore served as a major input in a special study on spatial structure of biological targets in hydrographic fronts in the North Sea.

Development work on an echoanalyzer system (Echoann) has continued. The system is operational and has been used in above mentioned cruises. Further development work is mainly concerned with algorithm development for bottom tracking and inclusion of results from pattern recognition project.

A project concerning target classification is in the starting phase. Techniques within picture analysis and pattern recognition will be implemented with the goal of developing criteria for real time classification and sorting of signals.

7.3 Faroe Islands

Acoustics have been used to monitor the blue-withing stock for nearly 15 years. The last improvement in instrumentation was the installation of an EK-500 in august 1990 on the research vessel Magnus Heinason. The EK-500 is connected to an ES-380 (split-beam) transducer formerly used with an ES-400. The EK-500 was used on a blue-withing

survey on the feeding grounds north of Faroes in August 1990 (reported to Pelagic Fish Committee) and again in January 1991 on a survey on the spawning grounds south of Faroes. EK-500 used with the ES-380 transducer have not been satisfactory, mainly due to noise. The old single-beam DK-400 transducer (that have worked fairly noiselessly) will be connected to EK-500 to get a hint where to mount a new EK-500 transducer which is on order.

Acoustics have also been used on a herring survey in June 1990. To estimate the density of herring schools in the upper water layers, a side looking sounder in a towed body was used. This is reported to Pelagic Fish Committee.

7.4 France

Une nouvelle version du logiciel MOVIES de traitement de données sondeur par ordinateur compatible PC a été étudiée; ce logiciel reconnaît automatiquement des bancs de poissons et il est maintenant possible d'effectuer l'écho-intégration par banc et non plus uniquement par tranche d'eau.

Les premiers essais en mer d'un prototype de sondeur large-band (20-80kHz) ont été effectués à bord de la THALASSA. Sur le plan fréquentiel, des études sont entreprises pour déterminer le type de traitement le plus pertinent. La résolution en distance de ce sondeur s'est avérée remarquable.

Une étude sur la détermination de la nature des fonds sous-marins est en cours à partir de signaux émis par des sondeurs standard.

La gestion du stock d'anchois du Golfe de Gascogne a été poursuivie en collaboration avec l'Espagne, avec comme support une campagne d'écho-intégration effectuée en avril-mai.

Une deuxième campagne acoustique s'est déroulée en août dans le golfe de Gascogne avec pour objectif l'abondance et la distribution de ressources pélagiques potentielles pour des produits transformés type surimi.

Centre d'Océanologie de Marseille-Luminy

Les recherches en matière de détection de particules - plancton ou autre-avec pour objectif leur identification ont été poursuivies. Plusieurs fréquences d'émission sont utilisées simultanément - 20 à 200 kHz - monofréquence ou large-bande. Les échols échos réverbérés par des populations naturelles complexes ou expérimentales simplifiées sont enregistrées et font l'objet d'un traitement approprié du signal. L'élaboration d'un modèle

est en cours pour expliquer les accumulations de particules ainsi détectées.

Orstom

- Poursuite de la collaboration au programme d'évaluation des stocks pélagiques par campagnes d'écho-intégration au Sénégal.
- Observations précises de la répartition des concentrations de poissons et de leur évolution dans le temps dans le Golfe de Cariaco (Vénézuéla)
L'utilisation des méthodes géostatistiques a été développée.
- Propection acoustique des fonds de faible profondeur dans le Golfe de Batabano (Cuba) en collaboration avec l'Institut Océanographique de l'Académie des Sciences de ce pays; une méthodologie particulière a été développée.
- Aboutissement d'une premié phase dans les essais d'identification par spectroscopie ultra-sonore dans les bandes 50 à 145 kHz et 140 à 430 kHz, avec un taux de réussite de 80% environ pour deux espèces dans des conditions expérimentales.

7.5 Finland

Four combined hydroacoustic-trawl surveys were conducted in the northern Baltic in 1990. Surveys covered in ICES Division IIIId Sub-divisions 29 and 32. The dates of survey were:

1. January 09.01.-23.01. (Gulf of Finland; SD 32)
2. March-April 27.03.-06.04. (Gulf of Finland; SD 32)
3. July-August 24.07.-09.08. (Gulf of Finland and northern Baltic Proper: SD 32 and 29)
4. October 16.10.-27.10. (Gulf of Finland and northern Baltic Proper: SD 32 and 29)

The main aim of the surveys was to estimate seasonal changes of Baltic herring and sprat abundance in the northern Baltic and Baltic herring migration between SD 29 and 32. A total of 3871 nautical miles were echointegrated and 57 hauls with Larsen-type pelagic trawl made. Equipments used were EK-400 connected to SIORS-echointegrator and EK-500.

7.6 Iceland

Several acoustic surveys on the stock of the Icelandic capelin were carried out. The results were used for fisheries management purposes.

Separate surveys were carried out on the juvenile and adult stock of the Icelandic summer spawning herring.

The second acoustic survey on zooplankton was carried out in a sheltered fjord, using 38 and 120 kHz echo sounders. More extensive and reliable data were recorded at these two frequencies for purposes of comparison. Echo abundance figures were considerable lower at night than in daylight, which might be related to the orientation of the animals. A trial run of a new fishing-gear (BIOMASS) for zooplankton was made at the same time. An attempt at relating catches of krill to integrated echo sounder values was made, but more data are needed.

A pilot study of the possibility of doing acoustic abundance estimates of redfish in the area west and southwest of Iceland, was carried out in April 1990. This does not look promising at this time of the year due to mixing with other species. Another survey is planned in June 1991.

The acoustic instrument room onboard R/V Arni Fridriksson was enlarged and rebuilt, resulting in far better working conditions. A new echo sounder system (EK500) working at three frequencies (38, 120 and 200 kHz) will be installed in 1991, as well as the BI500 post processing system.

7.7 Norway

Abundance estimation of fish - deep-towed transducer

This project aims at improving acoustic estimates of the abundance of fish in deep water, exceeding 500 m depth and along steeply sloped bottoms, e.g. along the edge of the Continental Shelf.

A new towed body with split-beam transducer is being tested together with its hull-recessed launching system.

Sonar measurement of fish

The aim of this project is development of a sonar and method for abundance estimation of fish in near-surface schools. The system is being developed in collaboration with SIMRAD and SINTEF. As a foundation for specification of the measurement system, a dual system analysis has been undertaken by users and by engineers.

New measurements on mackerel schools and herring schools have been gathered in 1990.

Effect of seismological investigations on fish

As a consequence of injuries to farmed fish from light seismic work and mine detonations in a fjord, the Institute of Marine Research has become strongly engaged in the overall problem. To a considerable degree, the Institute has acted in a consulting role. It is also contributing to three projects in this area. These are: 1) Experimental study of the effect of seismic sources on egg and larvae, 2) In situ study of the effect of full scale seismic arrays on avoidance and mortality of larvae, and 3) In situ study of the effect on catch rates and abundance of large fish the the area of seismic activity.

The EK500/BEI echo sounder/echo integrator systems

These are now installed on all our vessels, and hardware/software are under continual revision. Significant improvements were made during 1990.

Absorption in high density layers/schools of herring

Measurements of the absorption of the acoustic energy in dense aggregations of herring have been continued and a model that corrects for this effect has been developed.

7.8 Spain

At present we use the equipment EK-500 with a split beam transducer, but we have a transceiver to work with single-beam transducers too.

Two surveys are carried out each year in the Mediterranean area, from Gibraltar as far as Marseille, and a second one in Atlantic area, in north and northwest coast of Spain. The objectives are to estimate abundance of sardine and anchovy in the Mediterranean and sardine and blue whiting in the Atlantic.

The survey is conducted with oblique transects separated by 15 miles. The total area is distributed in sectors and strata.

To estimate biomass by length classes, we use Nakken and Domasness method from fishing stations.

No optimal conditions have been detected to estimate TS for sardine, anchovy and blue whiting. We use valves from ICES working groups.

The conversion constants used are as follows:

Sardine: $C=1.448 \times 10^6 \times l^{-2}$

Blue Whiting: $C=1.448 \times 1^{-2.18} \times 10^6$, where l is
length

No statistical procedure is applied to estimate accuracy and precision.

7.9 Sweden

During 1990, two hydroacoustic surveys were carried out on herring and sprat. One survey covered the eastern part of the North Sea, Skagerak and Kattegat within the framework of ICES Planning Group for acoustic surveys in the North Sea, Skagerak and Kattegat. In the Baltic, an International survey was carried out in cooperation with GDR, Poland, USSR and Finland. Three intercalibrations were carried out:

- a) Swedish R/V Argos - Polish R/V Professor Siedlecki
- GDR R/V Ernst Haeckel
- b) R/V Argos - USSR R/V Issledovatel Baltiki
- USSR R/V Integral (chartered by the
Finnish Institute)
- c) R/V Argos - GDR R/V Ernst Haeckel

7.10 United Kingdom - Scotland

Surveys of herring were carried out: 1) in the Clyde; and 2) in the Orkney, Shetland and Buchan areas in July 1989. The latter survey was in conjunction with Norwegian, Danish and Dutch fisheries research laboratories. During these surveys data was collected in individual sample format for each transmission and with 0.5 depth definition at 38 and 120 kHz.

Analysis of photographic and dual beam target strength data from caged fish shows little relationship between target strength and tilt angle for herring at 38 kHz. This data has been examined with careful attention to detail in the analysis of errors. Over the range of angles observed during normal swimming behaviour in the cage no systematic relationship was found.

Work on the automatic identification and classification of shoals has developed considerably. The objective of the work is to aid extraction of shoal statistics to assist with understanding of stock distribution and species recognition. The echosounder output is treated as an image and loaded into a Unix based system using Imaging Technology high speed

image processing cards. Image processing techniques involving smoothing, edge enhancement, multiple binary thresholds, erosion and dilation are used to isolate and define the locations and shapes of fish shoals and the sea bed from the image. Timing is dominated by data recovery and the association of adjacent pixels into connected objects. Typical image recover and processing is less than 20 seconds for 512 acoustic transmissions.

7.11 U.S.A.

Alaska Fisheries Science Center, Seattle, Washington

Alaska Fisheries Science Center (AFSC) in Seattle has continued research on pollock (*Theragra chalcogramma*) and whiting (*Merluccius productus*) in the Northeast Pacific Ocean. During 1988 and 1989 and again in 1991, acoustic surveys of the spawning population of pollock have been carried out in January-March in the deep water portion (>1000 m) of the Bering Sea, and, in 1989 and 1991 including shelf waters of the eastern Bering Sea. Annual surveys of the Gulf of Alaska spawning stock in the Gulf of Alaska have continued through 1991. During the last two years, in the Gulf of Alaska, the AFSC has conducted survey operations with a Simrad EK500 echo sounder and Bergen echo integrator. During these surveys, the old echo sounding and echo integration system was run in parallel with the new Simrad system. Tests are now being conducted to compare the results from the two survey systems. Target strength studies of fish using the split beam technique continue and standard sphere calibration has become the primary calibration technique. Cooperative surveys of pollock in the Bering Sea with the Japanese Fisheries Agency have continued under the sponsorship of the International North Pacific Fisheries Commission (INPFC). The fifth in a series of triennial surveys of Pacific whiting off the west coast of the U.S.A. was completed in 1989.

Southwest Fisheries Center, La Jolla, California

The Southwest Fisheries Center (SWFC) in La Jolla, California, continues annual Antarctic krill investigations using acoustic and net techniques. The SWFC has acquired an EK500 echo sounder and Bergen Echo Integrator and used this system to conduct the 1991 Antarctic krill survey. Scientists at the SWFC are continuing studies to use commercial acoustic doppler current profilers to obtain quantitative data from zooplankton and micronekton.

Southeast Fisheries Center, Pascagoula, Mississippi

The Southeast Fisheries Center (SEFC) group has conducted acoustic surveys of midwater stocks in the Gulf of Mexico using a Biosonics system, operating at 38 and 120

kHz.

University of Southern California/Tracor Applied Sciences

A new two year research program has been initiated to develop several new acoustic tools for use in the study of zooplankton in the marine environment. This work, funded jointly by the National Science Foundation (NSF) and the Office of Naval Research (ONR), is focused on the development of several sensors appropriate for use on moorings. One of these sensors, a bi-frequency unit will measure volume scattering strengths at 100 kHz and at 1 mHz. A second sensor will combine volume scattering strength measurements with the collection of target strength distributions and echo envelope statistics. A third sensor will make measurements of volume scattering strengths at seven discrete frequencies between 100 kHz and 3 mHz. Two way telemetry will allow modifications in the nominal one half hour sampling protocol in response to observed changes in the environment and acoustical measurements.

Global Change Research Program

The global ocean ecosystem dynamics (GLOBEC) initiative is a science component of the U.S. Global Change Research Program. Planning efforts of this program are sponsored by the NSF with the additional participation by the National Oceanic and Atmospheric Administration (NOAA) and ONR. The GLOBEC concept involves gaining and understanding of how physical processes, both direct and indirect, influence the success of individual animals in the sea through their feeding, reproduction and survivorship. GLOBEC also addresses relationships between the success of the individual and the dynamics of the population. Activities to date have included the organization of a steering committee for the program, sponsorship of several workshops on new technology (including one on acoustic techniques; see below) and identification of a number of possible field studies, including one in the North Atlantic, one in southern ocean, one in the eastern Pacific and one in the Indian Ocean. In early April of 1991, a workshop was held in Woods Hole, Massachusetts, USA to discuss the application of acoustics to projects being planned under the GLOBEC. Four working groups (Fisheries Acoustics, zooplankton acoustics, Macro-zooplankton/micro-nekton, and Optic/acoustics) were established and recommendations were made by each group as to the most promising techniques to address research needs of GLOBEC. A report of this working group will be completed by May and is available from D. V. Holliday.

7.13

U.S.S.R.

VINRO (Moscow)

VNIRO has continued research of mackerel and horse mackerel in the South Pacific Ocean. Acoustic surveys for estimation of biomass distribution of these important commercial species have been carried out in the large area across the EEZ of Peru and Chile.

Experimental acoustic surveys of Baltic sprats and high-body pickrel of the Flemish Cup were conducted for testing of the technology of combining acoustic and catch data acquisition and processing to evaluate possible catch of commercial vessels.

Experiments with small sonar in parametric mode have been conducted in shallow waters (less than 15 m). They demonstrate a possibility to observe fish distribution and behavior of distances up to 100-120 m with ship stopped.

New results of fish reaction to ultrasound (frequency 125 kHz, sound pressure 0.1 Pa) and electromagnetic fields (up to 160 kHz) have been obtained in experiments with carp.

Acoustic activity of different water animals (crabs, crayfish, shrimps, spiny lobster, octopus, salmon, sturgeon, etc.) have been investigated and some proposals of implementation of these signals in fisheries and fish culture are now being tested.

PINRO (Murmansk).

Traditional echo-surveys of commercially important North Atlantic species (capelin, blue whiting, demersal fishes of the Newfoundland Bank and Irminger Sea, etc.) were conducted.

Experiments with underwater TV for increasing accuracy of acoustic density estimation of demersal fishes and designing of a combined acoustic-TV underwater device were continued in 1990.

Target strength of sea macrophytes was studied for acoustic estimation of its biomass.

A PC based system for processing acoustic data from SIMRAD ES400 and EK400 echo sounders was under design.

AtlantNIRO (Kaliningrad).

Five cruises on three vessels were conducted in accordance with international programs for acoustic surveying of different commercial fishes in the Central and South Atlantic and squids in the East Pacific Ocean. Design of acoustic surveys using satellite information was tested near the West Sahara coasts and in the Scotia Sea.