International Council for the
Exploration of the Sea

C.M.1992/L:5

Report of the ICES Study Group on Zooplankton Production

Bergen, Norway - March 23-26 1992

Quotes from the meeting:

"The 1990s will be the decade of Zooplankton" (Peter Wiebe)

"It is biomass that is eaten but individuals that are dying" (Jarl Giske)

CONTENT:

I. Opening

The meeting was held at the Institute of Marine Research in Bergen and was opened at 0930 on Monday 23 March 1992. The meeting was addressed by the Director Odd Nakken who emphasized the importance of zooplankton and their study as a prerequisite to progress in fisheries oceanography. The chairman Hein Rune Skjoldal noted that several participants had cancelled their participation due to lack of funding, and that this put a greater burden of responsibility on those that had the oportunity to attend the meeting.

The list of participants to the meeting is given as Annex I.

II. Adoption of agenda

The proposed agenda for the meeting was adopted. The agenda is given in Annex II.

III. Terms of reference

The Study Group adopted the Terms of Reference given in C. Res. 1991/2:45, as follows:

a) Review existing methods for measuring biomass and production processes;
b) Make proposals for improvement and standardization of methods, and prepare a methodological manual;
c) Consider the need for laboratory and sea-going workshops to intercalibrate experimental methods and evaluate new technology;
d) Report on the progress in the scientific and commercial development of new sampling techniques.

The Study Group will report progress to the Biological Oceanography Committee at the 1992 Statutory Meeting.

IV. Study Group membership

Members listed in CM 1991/L:32 were acknowledged with additional members nominated from Germany (Elbrächter, Greve, Hirche, Schneider), USA (Davis, Rothschild), Spain (Varela) and Norway (Aksnes, Giske) (Annex III).

It was noted that nominees would be encouraged from other nations, e.g. Belgium, Denmark, France, the Netherlands, Poland and Sweden.

V. Scientific issues

The Study Group took note of the following background documents as being pertinent to its proceedings:

1. Marine Zooplankton Colloquium 1 (1989). Future marine zooplankton research - a perspective. Marine Ecology Progress Series, 55:197-206.

2. An International Program for Global Ocean Ecosystems Research (GLOBEC). Report of the SCOR/IOC meeting, Solomon's, Maryland, USA, April 29-May 3, 1991.

3. Anon. 1991. Meeting report from ad hoc committee on Large Marine Ecosystems. Unesco, Paris, France, 22-23 March 1991.

4. Skjoldal, H.R., H. Gjøsæter, H. Loeng (In Press) The Barents Sea ecosystem in the 1980s: Ocean climate, plankton and capelin growth. Proceedings of the Russian-Norwegian Symposium, Murmansk, August 1991.

5. Kimmerer, W.J. (1987). The theory of secondary production calculations for continuously reproducing populations. Limnology and Oceanography, 32:1-13.

It was acknowledged that there have been major changes in the understanding of zooplankton productivity in the past two decades. The most important of these is the recognition that zooplankton population dynamics must be viewed in the context of the fluid dynamic environment. Secondly, behavior must be taken into account, particularly among the macrozooplankton and micronekton, which have the ability to aggregate voluntarily and to otherwise control their position in the water. Thus, any attempt to estimate secondary production must include consideration of both local physics and zooplankton behavior.

Major current issues include fish recruitment and climate. The effect of zooplankton production on year-class strength has been recognized for almost a century, but our ability to estimate it accurately may now be more possible than ever before. The issue of density-dependence remains to be resolved. With respect to climate, zooplankton are now recognized to be an important component of the biological carbon pump, influencing vertical transport of marine particulates. Of great interest also is the effect of climatic change on zooplankton population dynamics - a phenomenon that is poorly understood. In this context the problem of ecological tolerance ranges were noted in relation to the ability of organisms to adapt to changing conditions.

In this general context, the group acknowledged the importance of the following approaches. New methods and technology need to be used to assess biomass and distribution of zooplankton. Studies of secondary production must be done in conjunction with studies of physical circulation. Advice should be provided on design of survey strategy. Observations should be made at higher resolution in time and space, as it is likely these would reveal behaviors and phenomena that are as yet unknown or poorly understood, yet will strongly influence trophic transfers and production processes. A need for long-term monitoring of marine ecosystems was also acknowledged.

VI. Review of existing methods

A. Experimental

Five different methods have been used in estimating zooplankton production, none of them being *a priori* superior as a general method.

The **calculation method** (Boysen-Jensen 1919) sums up the total biomass increase and the biomass of dead individuals during the defined period.

The **growth-rate method** sums up the product of individual growth and abundance, integrated over the whole population (Greze, 1978). This method is especially valid for a population with distinct cohorts and specific mathematical population dynamical models may be adopted on such data. Direct experimentally determined data on individual growth rate may also be used, but the growth of individuals dying off during the period must then be included.

The **egg-number method** is especially usable for populations with continous reproduction and it makes use of the fact that the number of eggs in a population and the egg-development rate define the potential population increase, whereas the difference between the potential and actual population size gives the mortality (Edmondson, 1960).

The **Production/Biomass ratio method** is commonly used as a crude estimate of production. It is based on empirical data which typically are taken from other areas, species and situations, making the estimates unpresice. A further refinement and modification of this method is to use mean individual life span or age (Allen, 1971), mean individual body mass at maturity (Banse & Mosher, 1980) or mean individual weight (Båmstedt, 1981) as an independent variable that determines the P/B ratio.

The **physiological method** is in fact a number of experimental methods, which all are related to the balance equation at the individual level:

Growth (G) = Ingestion (I) - Faeces (F) - Metabolism (T)

where growth is either directly measured or estimated from measurements on one or several of the variables I, F, T. Production is then estimated by extrapolating to the population level, taking into account the population structure and using age/stage-specific growth calculations. When converting to the population level, production by the lost part of the population (mortality) must be considered. If only one of the right-hand variables is measured it might be possible to estimate individual growth by assuming a constant numeric relationship with growth. Commonly an empirical growth efficiency is used in order to calculate growth from quantitative information on ingestion or assimilation and individual growth is then calculated from the gross (K_1) or net (K_2) growth efficiency:

$$G = I * K_1 \quad \text{or} \quad G = (I - F) * K_2$$

However, when a high degree of accuracy is essential there is no shortcut method and one has to measure all the components in the balance budget, using as natural conditions as possible in the experiments. Even then one has to use a critical attitude when extrapolating the experimental results to the natural population, which is made up of individuals with their individual physiological state and behaviour, interacting with the spatial and temporal variability in abundance and the variable physical environment. Thus, we will never be able to eliminate uncertainties in the production estimation, but by adopting a standardization of the procedures being used, we will maximize the comparability of the results, making estimates all over the world as homogenous as possible.

Table 1 refers to experimental methods currently in use. We recommend production to be expressed in terms of carbon, and conversion factors from other units need to be evaluated as a basis for recommendation of standard factors.

Table 1. Overview of experimental methods used for estimating zooplankton production.

Ingestion (I)

- Food balance methods
  - (a) Closed chamber
  - (b) Flow-through system
- *In situ* methods
  - (a) Gut fluorescence method
  - (b) Microscopic gut content analysis
  - (c) Gut fullness
- Biochemical indices
  - (a) Activity of digestive enzymes
- Respiration change methods
  - (a) Decrease in respiration rate of field collected animals in starvation (SDA)

Assimilation (A) and Egestion (F)

- Gravimetric method
- Inert ratio methods
  - (a) Natural foods
    - (1) Ash ratio method
    - (2) Silica ratio method
    - (3) Pigment ratio method
  - (b) Prepared foods
    - (1) Cromium ratio method
- Radiotracer methods
  - (a) Quantitative recovery
  - (b) Ratio principle

Metabolism (T)

- Component balance methods (oxygen, ammonium, urea, total nitrogen)
  - (a) Closed chamber
  - (b) Flow-through chamber
- Radiotracer methods
- Biochemical indices (ETS, GDH)

Growth (G)

- Direct growth observations
- Egg production methods
- Molting rate methods
- Radiotracer methods
- Biochemical indices
  - (a) RNA/DNA ratio
  - (b) Rate of synthesis of RNA and DNA
  - (c) DNA polymerase
  - (d) Guanosine/ATP ratio
  - (e) ATC activity

VI.B Biomass

For more than 100 years efforts have been spent to improve sampling methods for sampling zooplankton. During the past 15 years there have been major advances in our ability to sample the vertical distribution of zooplankton with the development of multiple net systems which are operated on conducting cable. The use of conducting cable has also enabled other physical and biological sensors to be mounted on these systems and data to be obtained from them concurrently with the collection of zooplankton. On the horizon, there are acoustical and optical sensors and methods which promise additional advances.

Organism size is a most important parameter because it is a primary factor in the determination of food relationships in the sea. Distinguishable are two major trophic structures, the microbial loop and the classical food web, which exist throughout the oceans. The former, composed of bacteria, picophytoplankton, and protists, recirculate energy with little loss out of the photic zone. The microbial loop contributes to the classical food chain largely through the ciliate protists. The classical food web provides the energy for higer levels in the food chain and is very important for the vertical flux of carbon. Because the linkage between the two webs is mainly by ciliates, the consideration of zooplankton biomass measurement techniques should begin with the microzooplankton with a lower limit of approximately 20 µm.

By definition sub-categories of zooplankton are the following:

20 - 200 µm	= Microzooplankton
0,2 - 20 mm	= Mesozooplankton
2 - 20 cm	= Macrozooplankton

Micro- and some mesozooplankton are so abundant that small sample volumes are sufficient to collect enough of them for study. In contrast, macrozooplankton must be collected with large, high speed gear to be effectively captured. Thus, sampling methods must be adjusted according to the abundance and behavior of the different types of zooplankton. The point was also made that a collecting bottle provides point source sample which is advantagous in that the exact volume and all small organisms present are in the sample. With nets, there is more integration over space and sampling is biased to some degree by filtration efficiency and avoidance. Thus, net samples only provide information on a portion of the size spectrum. How sampling gear is deployed depends upon the purpose of the sampling. Particular care must be taken if the organisms are destined for rate measurements or physiological studies.

Ideally, continuous recording of plankton biomass is desired that is analagous to the way that chlorophyll fluorescence is measured.Several new methodologies are available or being developed which offer this measurement ideal. These involve both acoustical and optical techniques. Regarding the latter, J. Lenz provided the group with a copy of his recent ICES paper describing a new video plankton recorder.

Table 2 gives an overview of different methods of sample processing for obtaining zooplankton biomass.

Table 2. Overview of sample processing for determination of zooplankton biomass

Direct Measurement

1) Displacement volume
2) Wet weight
3) Dry weight
4) Ashfree dry weight
5) Carbon

Indirect Measurement

1) Single Beam Acoustic - echo integration
   Integrated target strength => volume

<u>Biomass by size frequency</u>

Direct Measurement

1) length - Microscope micrometer measurements
   length/weight regression => Biomass
2) length - Microscope/digitizing pad measurements
   length/weight regression =>Biomass
3) length - Silhouette photography/digitizing pad/microcomputer
   length/weight regrèssion =>Biomass
4) length - Video Image Analysis
   length/weight => Biomass

Indirect Measurement

1) Particle Volume - Coulter Counter (eletric field)
   Voltage Change =>volume
2) Particle Volume - HIAC Counter, Optical plankton counter
   (light field). Light Blockage => Voltage Change => area => volume
3) Particle Volume - dual beam/split-beam/multifrequency acoustics
   Target strength => Geometric area => volume

<u>Size frequency by taxa or species</u>

Direct Measurement

1) Sort taxa into groups and weigh

Indirect Measurement

1) length - Microscope micrometer measurements
   lenght/weight regression => Biomass
2)length - Microscope/digitizing pad measurements
   length/weight regression => Biomass
3) length - Silhouette photography/digitizing pad/microcomputer
   length/weight regression => Biomass
4) length - Video Image analysis
   length/weight regression => Biomass

Included in the list are classical methods or techniques which have been in practice for years, and newer methods utilizing optical or electronic measurements. Discussion in the group focussed on new techniques for measuring biomass, and the tools available to make the measurements. The silhouette technique was described. By measuring the lengths of individuals of specific taxa on the silhouette photograph, this semi-automated technique provides estimates of the biomass in terms of wet weight, dry weight, or carbon in size specific categories of each taxa.

Table 3 gives an overview of zooplankton sampling gears. Information is also given on resolving scales and operating ranges for the various gears.

Table 3. Overview of Zooplankton sampling gear

Sampling gear	Kind of sampling	Size fraction	Resolving scale		Typical operating range	
A.CONVENTIONAL METHODS			Vertical	Horizontal	Vertical	Horizontal
Water bottles	Discrete samples	Micro/Meso	0.1-1 m	-	4000 m	-
Small nets	Vertically integrating	"	5-100 m	-	500 m	-
Large nets	Vertically, obliquely, horizontally integrating	Meso/Macro	5-1000 m	50-5000 m	1000 m	10 km
High-speed samplers	Obliquely, horizontally integrating	Meso/Macro	5-200 m	500-5000 m	200 m	10 km
Pumps	Discrete samples, vertically integrating	Micro/Meso	0.1-100 m	-	200 m	-
B. MULTIPLE NET SYSTEMS						
Continuous Plankton Recorder	Horizontally integrating	Meso	10-100 m	10-100 m	100 m	1000 km
Longhurst-Hardy Plankton Recorder	Obliquely, horizontally integrating	"	5-20 m	15-100 m	1000 m	10 km
MOCNESS	Obliquely, horizontally integrating	Meso/Macro	1-200 m	100-2000 m	5000 m	20 km
BIONESS	"	"				
RMT	"	"				
C. ELECTRONIC, OPTICAL, OR ACOUSTICAL SYSTEMS						
Electronic Plankton Counter	High resolution in the horizont./vertical plane	Meso	0.5-1 m	5-1000 m	300 m	100's km
In situ Silhouette camera Net system	"	"	"	"	1000 m	10 km
Optical Plankton Counter	"	"	0.5-1 m	"	300 m	100's km
Video Plankton Recorder	"	"	0.01-1 m	"	200 m	100's km
Ichtyoplankter Recorder	"	"	0,1-1 m	"	200 m	10 km
Multifrequency Acoustic Profiler System	"	Meso/Macro	0.5-1 m	"	100 m	10 km
Dual-beam Acoustic Profiler	"	Meso/Macro	"	1-1000 m	800 m	100's km
Split-beam Acoustic Profiler	"	"	"	1-1000 m	1000 m	100's km
ADCP	"	"	10 m	5-500 m	500 m	100's km

Most vertical nets are hauled at a speed of 0,5-1 m s^{-1}. Normal speed for horizontal tows are ~ 2 kts (1 m s^{-1}) and for high speed samplers ~ 5 kts (2.6 m s^{-1}). For further categorization of pumping systems which are used by a number of investigators, reference is made to the review paper by Miller and Judkins (1981).

Acoustical techniques now provide the means of estimating biomass down to the microplankton size range (~60-100 µm). The MAPS system using a set of transducers operating at different frequencies is one system providing that capability. Multi-frequency systems can also provide estimates of the size frequency distribution of individuals contributing to the total biomass. Dual-beam and split-beam systems can also provide this information directly. Most systems now available to make these kinds of measurements are not off-the-shelf and are not easily operated by biologists. The availability of general use instrumentation was identified as a specific need. Also identified as a major problem impeding the application of acoustical techniques for biomass estimation was the difficulty of calibrating the systems. This problem area can be subdivided into the problem of hardware calibration and the problem of signal interpretation. For the latter, the need for data and information about the acoustic characteristics of individuals as a function of size and orientation on a species by species and taxa by taxa basis was recognized. Standardized, easily applied, and inexpensive calibrating schemes need to be developed. With the newer dual-beam and split-beam technology, additional information such as behavior and swimming speed are products of the processing software which result from the ability to do target tracking.

Discussion focused on the development of a comprehensive table of measurements and techniques. Questions concerning what should be considered as standard methods and whether this group would be able to reommend specific nets or net systems were raised. Different objectives for sampling with nets were recognized. These include biochemical measurements, identification of species and taxa, verification of acoustical measurements, and quantification of numbers and biomass. The problem of avoidance of nets especially by the larger macrozooplankton and micronekton was recognized as an especially important problem that needed to be addressed. It was generally agreed that the problem was most acute for visually orienting animals where mechanisms of avoidance was mediated by vision.There is a need for comparisons of different gear and development of new sensors to measure the mechanical aspects of the gear performance (i.e. better flow sensors and acoustic scanners to measure net capture efficiency). At the same time it was recognized that the multiple net systems which are able to measure a variety of other environmental parameters represent a major increase in sampling capability.

The need to advance the technology through the construction of integrated sampling systems in which nets, acoustical sensors and video imaging technology is combined, was recognized.

VI.C. Population dynamics approach to estimation of copepod production

Production in animals are commonly assessed indirectly by estimating numbers of recruits and rates of mortality and individual growth (i.e. individual weight increments). Copepods are grouped by stages rather than by age. This complicates estimation of recruitment and mortality. Development times (or stage durations) have to be known in order to obtain estimates of the others. The several estimation procedures that have been proposed for stage frequency data (including insects, freshwater copepods and marine copepods) differ primarily in the way development time is estimated. Two possibilities exist:

i) to estimate development time from stage frequency data by assumptions (such as assuming constant mortality between stages),

ii) using laboratory derived measurements of stage durations.

When continuous reproduction is prevalent the second approach is preferable. Extensive experiments with laboratory rearing, but also short time incubation of newly collected individuals may be performed in order to measure development times. Although estimates of stage specific mortalities and recruitments are sensitive to estimates of development times, estimates of total production are not that sensitive. Thus having stage frequency data and measurements of individual weights (and development times), relatively robust estimates of total production may be obtained by several calculation procedures published the last decades. These estimation procedures may account for production lost in the moulting process etc. by the inclusion of such measurements.

VII. Review of new developments

There is no sharp distinction between existing methods and new developments. Several of the methods and sampling gears listed in section VI are in various stages of development and are being further improved. The discussion at this point of the agenda was to highlight some of the more promising method developments.

In the last few years novel techniques for the study of zooplankton production have appeared as a result of the present need for reliable methods. Most of them fall into two categories. On one hand there are biochemical methods based on relationships between processes in the cell and physiological parameters related to the energy balance equation. On the other hand there are methods based on new technology now becoming available.

A list of such new developments is given in Table 4. Growth rate measurement using artificial cohort is a promising method if used with modern technology (as video systems) and good relationship between length (or area) and carbon biomass per individual. A major problem and disadvantage is the need for long incubation periods (at least 24 hours in warm water). The use of a biochemical index would be one way to avoid the incubation problem, but there is a strong need for evaluation and calibration. The same apply for metabolic rate determination using classical methods (which need to be standardized) and biochemical indices.

Table 4. Overview of new developments of zooplankton methods.

A. Methods for determination of zooplankton rates

1. Ingestion
    - Tracers for herbivory: pigments, lipids
    - Tracers for carnivory: astaxantin, chitin
    - Video imaging for determination of feeding behaviour
    - Video imaging for quantification of feeding activity

2. Metabolism (energy producing)
    - Pyruvate kinase (PK)
    - Lactate dehydrogenase (LDH) (?)
    - Citrate synthase (CS)

3. Growth
    - Direct measure of growth using laboratory raised artificial cohorts.
        * Silhouette photography
        * Video images
        * Acoustics
    - Biochemical methods involved in protein synthesis
        * rRNA
        * Malate dehydrogenase (MDH) (lipids to protein)
        * Aspartate transcarbamylase (ATC)
        * Reproducing and molting hormone activities

B. Technological methods for determination of zooplankton biomass

1. Optical methods
    - Video plankton recorders, high speed video recording
    - Holography: three dimensional images

2. Acoustical methods
    - Multifrequency Acoustic Profiler System (MAPS)
    - Dual-beam and split-beam systems

(Table 4 continued)

- Acoustic Doppler Current Profiler (ADCP)

3. Zooplankton collection gear.
   - Combination of nets, acoustics and video imaging

Improvements in software, echo integration, target strength measurements, three dimensional imaging, calibration techniques and signal transfer are needed in acoustic methods. Optical methods are also lacking very high speed software, data storage etc. Improvements are presently under study and development.

With regard to quantitative zooplankton collection there are two important needs. The first is the ability to quantify animal avoidance. Acoustic and video systems would be useful tools in defining the problem and additional knowledge about animal vision and behaviour is needed to effect solutions. The second need is an improved ability to characterize and quantify filtration and water flow through nets.

For the purpose of monitoring large marine ecosystems, the Continuous Plankton Recorder should be improved using currently available technology. Suggestions for additional zooplankton parameters to be measured are needed.

VIII. Practical workshops for intercomparison and evaluation of methods

The Study Group has been given the task to consider the need for laboratory and sea-going workshops to intercalibrate experimental methods and evaluate new technology. There was broad agreement in the Study Group that there is a strong need for such workshops. It was considered necessary to have a better and more direct and objective basis for evaluating methods and recommend standardization. This would be one major purpose for the workshops. A second purpose is to explore combinations of instruments and experimental approaches in order to recommend improvements in how to most effectively measure zooplankton production.

The Study Group took notice of proposed activities in the US and in Europe to conduct intercomparison of experimental methods. While these initiatives underline the need and importance of such exercises, there is considerable uncertainty as to the realization, content and extent of these planned intercomparisons. In view of this the Study Group recommends that practical workshops be organized and conducted as part of the Study Groups activities aiming towards methods evaluation and preparation of a manual.

The Study Group agreed to organize seagoing and laboratory workshops to be carried out in 1993. The group recommends that these seagoing and laboratory workshops be conducted in close connection with the GLOBEC initiative, which has a strong emphasis on zooplankton population dynamics and production. These workshops should compare:

- sampling gears (including Continuous Plankton Recorder)
- acoustical and optical methods
- plankton counts,

and experimental methods, to measure:

- population dynamics
- P/B ratios
- ingestion/grazing
- metabolism, etc.

A principal objective is to characterize and evaluate the performance of gear and techniques and ensure that their strengths and limitations in different habitats and geographical regions are well known and understood. Regions selected for intercomparisons are:

- fjords, shelf, and offshore areas off Norway, where the Mare Cognitum program initiated by Norway will be carried out as a regional component of GLOBEC, with links to WOCE and JGOFS
- at the Georges Bank, where the US/Canadian GLOBEC Georges Bank Study is being implemented. This study includes also intercomparisons of acoustical and optical methods for plankton detection, and plankton nets and pumps.
- off/at Hawaii where intercalibration workshop on zooplankton biomass, growth and production measurements in tropical, oligotrophic waters near Hawaii is proposed as part of the US GLOBEC.

The experimental methods should be compared additionally during laboratory workshops at the University of Bergen/Norway and off/at Hawaii. A core of people should participate at all these activities, which should be carried out in 1993 according to the following tentative time schedule:

- in March/April off/at Hawaii,
- in May during the US/Canadian GLOBEC Georges Bank Study, and
- in June/July in the Norwegian waters.

Dr. HUNTLEY agreed to be responsible for the activities off/at Hawaii,
Dr. WIEBE for those on the Georges Bank,
Dr. SKJOLDAL for the seagoing exercise off Norway and
Prof. BÅMSTEDT for those in the Laboratories at University of Bergen.
Further details concerning the proposed workshops are contained in Annex IV.

IX. Zooplankton methodology manual

The study group noted that although there exist several methodology manuals for zooplankton research and for determination of secondary production, these were published more than 10 years ago. There have been several important developments regarding methods and sampling gears since the publication of the existing manuals. The study group concluded that there is need for a new manual and that this would serve an important and timely contribution to international programs such as GLOBEC.

The study group agreed on the general format of the manual with a general part containing overviews and discussions of methods and methodological issues, and a handbook part containing descriptions of methods and standardized procedures.

The manual will be edited by Hein Rune Skjoldal, Mark Huntley and Jürgen Lenz. The co-editors Huntley and Lenz will take particular responsibility for methods for determining growth and physiological processes and biomass and distribution, respectively.

In discussing the content of the manual, it was noted that there was a need to emphasize the role of physical advection and animal behaviour as additional terms to growth and mortality in population dynamical consideration. It was also noted that growth rates can be estimated either from direct rate measurements or indirectly from changes in biomass or abundance data.

A suggested outline for the content of the manual is given as Annex V. It was agreed that the various sections or chapters should be authored by a small number of experts from both within and outside the study group. The editors will produce a more detailed table of content for the manual and suggest and approach potential contributing authors for the various sections or chapters. The study group will be asked to review drafts and approve the final version of chapters as part of their work with review of methods and recommendations of improvments and standardization.

The study group supported a suggestion that the handbook part of the manual could be supplemented by video sequences describing details of experimental techniques. It was felt that this would be particularly useful in showing how to handle zooplankton for experimental purposes. The study group noted with interest an interactive taxonomic information system for phytoplankton, LINNEUS, developed at the Institute of Marine Research in Bergen by Dr. K. Estep and F. Rey, and published with support from UNESCO. It would be possible to use this system as a base for developing a CD (compact disc) version of the handbook which could include video sequences.

Publication of the manual was briefly discussed. It was felt that in order to increase its authoritative status, it would be useful to have the manual published with support from IOC/SCOR and UNESCO. The chairman will approach IOC and UNESCO to receive their advice in this matter.

X. Future plans and meeting of the study group.

The study Group discussed its future plans and made a time table of activities to reach the main goal which is to conclude its work on methods evaluation and standardization by publishing the methodology manual. The aim is to have this done in 1994 and present its final report to the Statutory Meeting in the autumn of 1994.

The Study Group recommends that it should held its second meeting in February 1993 with the following main tasks:

1) Continue the review of methods and new developments
2) Review plans for the practical workshops
3) Review plans and contributions to the Zooplankton methodology manual
4) Consider plans and contributions to a proposed Symposium on Zooplankton production in 1994.

Dr. Santiago Hernández-León offered kindly to host the meeting at the University of Las Palmas, Canary Islands, Spain.

A third meeting of the study group is planned early in 1994. The main tasks at this meeting will be to:
- review results from the practical workshops
- finalize the methods evaluation
- review and recommend selected standard methods and standardized procedures
- review and approve contributions to the methodology manual
- discuss contributions to the proposed Symposium on Zooplankton production.

The work in the study group will be organized along a main division into methods for rate determination and methods for biomass determination. Dr. Mark Huntley and Dr. Jürgen Lenz have kindly agreed to assist the chairman in the work of reviewing these two categories of methods. It would be advantageous for the progress of the work to arrange ad hoc meetings of subgroups during the intersessional periods. This will be attempted when practically possible, for instance in connection with statutory meetings and the planned workshops.

The preparation of the methodology manual will be done in parallel with the methods evaluation by the study group, with the following time table:

- October 1992: Detailed outline and author list finalized by editors.
- February 1993: Progress and first draft contributions reviewed by 2nd SGZP meeting
- September 1993: First draft version of part A finalized and circulated for SGZP members
- February 1994: Second draft version of part A reviewed and approved by 3rd SGZP meeting. First draft version reviewed and final decision on detailed content of part B (which methods and procedures to be included as recommended standards) reached by 3rd SGZP meeting.
- May 1994: Second draft version of part B finalized and circulated to SGZP members
- October 1994: Final version of manual completed.

The Study Group discussed a proposal from Dr. John Steele for ICES to sponsor a Symposium on Zooplankton Production in 1994 (Annex VI). The Study Group strongly endorsed the proposal and recommends that ICES should take the initiative to convene a Symposium on Zooplankton Production.

ICES SGZP, Bergen, 23-26 March 1992

List of participants:

Hein Rune Skjoldal (chairman), Norway

Ulf Båmstedt, Norway

Jarl Giske, Norway

Eilif Gaard, The Faroes Isles

Santiago Hernández-León, Spain

Mark Huntley, USA

Jürgen Lenz, Germany

Egil Ona, Norway

Lutz Postel, Germany

Svein Sundby, Norway

Kurt Tande, Norway

Peter Wiebe, USA

AGENDA

I. Opening

II. Adoption of agenda

III. Terms of reference

IV. Study group membership.

V. Scientific issues/concepts - methodology
- Establishing a framework for our study group work.
- Identification of major issues and concepts concerning zooplankton in larger programmes (IGOFS, GLOBEC, fish recruitment, multispecies, eutrophication, climate, etc.)
- Identifying demands as a basis for making priority choices and recommendations concerning methods and instrumentation.

VI. Review of existing methods
A) Experimental
B) Technological
a) Overwiew and categorizing of methods.
b) Consider needs and possilities for improvements and standardization.
c) Evaluation of methods - identification of strengths and weaknesses.

VII. Review of new developments.

VIII. Practical workshops for intercomparison and evaluation of methods
a) Inventory of ongoing or planned activities.
b) Need for workshops
c) Planning of eventual workshops
A. Experimental
B. Technological

IX. Zooplankton methodology manual.
a) General format
b) Outline of content
c) Identification of contributors
d) Publication

X. Future plans and meeting of the study group

XI. Any other business

XII. Closing of the meeting

Members or potential members of the study group:

Dr. O. S. Asttorsson	Marine Research Institute P.o.box 1390, Skulagata 4, 121 Reykjavik, Island Fax: 354 (1) 623 790
Dr. Keith Brander	Fisheries Laboratory Lowestoft, NR33 OHT Suffolk, U. K. Fax: 44 (502) 513 865
Prof. Ulf Båmstedt	Inst. Fiskeri- og Marinbiologi Thor Møhlensgt. 55, 5008 Bergen, Norway 47 (5) 544 400 Fax: 47 (5) 544 450
Dr. C. Davis	Woods Hole Oceanographic Institution Woods Hole, 02543 Ma., USA 1 (508) 548 1400 Fax: 1 (508) 457 2169
Dr. Elbrächter	Biologische Anstalt Helgoland, Aussenstelle, 2282 List, Germany
Dr. Franz	Nederland. Inst. Oceanograf. und Zeevorsch. Texel, Nederland 31 (2220) 69 300 Fax: 31 (2220) 19 674
Dr. John C. Gamble	Plymouth Marine Laboratory Prospect Place, The Hoe, PL1 3DH Plymouth, U. K. 44 (752) 222 772 Fax: 44 (752) 670 637
A. Gislason	Marine Research Institute P.o.box 1390, Skulagata 4, 121 Reykjavik, Island 354 (1) 623 790
Dr. W. Greve	Biologische Anstalt Helgoland Notkestrasse 31, 2000 Hamburg 52, Germany
Eilif Gaard	Fiskirannsóknarstovan Noatun, FR 100 Torshavn, Færøyene 298 - 15 092 Fax: 298 - 18 264
Dr. Roger Harris	Plymouth Marine Laboratory Prospect Pl., The Hoe, PL1 3DH Plymouth, U. K. 44 (752) 222 772 Fax: 44 (752) 670 637
Dr. S. Hay	Marine Laboratory P.o. box 101, Victoria Rd., AB9 8DB Aberdeen, Scotland Fax: 44 (224) 295 511
Santiago Hernández-León	Facultad de Ciencias del Mar Apartado 550, 35017 Las Palmas de Gran Canaria, Canary Islands 34 (28) 452 907 Fax: 34 (28) 452 922
Dr. Hans-Jürgen Hirche	Alfred-Wegener-Institut Columbus Center 2850 Bremerhafen, Germany 49 (471) 597 3865Fax: 49 (431) 565 876
Dr. Mark Huntley	Marine Biology Research Div. Scripps Inst. of Oceanography, 92093 Ca, La Jolla, USA 1 (619) 534 3417 Fax: 1 (619) 534 0701 OMNET: M.Huntley
Dr. Thomas Kiørboe	Danmarks Fiskeri og Havstyrelse Charlottenlund Slot DK-2920 Charlottenlund, Danmark 45 (33) 963 300 Fax: 45 (33) 963 333

Members or potential members of the study group:

Prof. J. Lenz	Institut für Meereskunde, Universität Kiel Dunsterbrooker Weg 20, W-2300 Kiel, Germany 49 (431 597 386 Fax: 49 (431) 565 876
Dr. D. Malley	Dept. of Fisheries & Oceans 501 University Avenue, R3T 2NG Manitoba, Win., Canada 1 (204) 983 5000 Fax: 1 (204) 984 2403
Egil Ona	Institute of Marine Research P.o. box 1870 - Nordnes, 5024 Bergen, Norway 47 (5) 238 455 Fax: 47 (5) 238485 Internet: egilo@imr.no
Dr. M. Paranjape	Dept. of Fisheries & Oceans P.o. box 5667, A1C 5X1 Nfld, St. John's, Canada Fax: 1 (709) 772 4347
Dr. Lutz Postel	Institut für Ostseeforschung Seestrasse 15, D-02530 Warnemünde, Germany 37 (81) 58 282 Fax: 37 (81) 58 336
Dr. M. Reeve	Ocean Scientific Research National Science Foundation, 20550 Washington DC, USA Fax: 1 (202) 357 7621
Prof. B. Rothschild	Chesapeake Biol. Lab., Univ. Maryland P.o.box 38, 20688 MD, Solomons, USA
Jeff Runge	M. Lamontagne Inst., Fish. & Oceans P.o. box 1000, Mont-Joli, G5H 3Z4 Quebec, Canada 1 (418) 775 0500 Fax: 1 (418) 775 0542
Dr. D. Sameoto,	Bedford Institute of Oceanography P.o. box 1006, NS B2Y 4A2 Dartmouth, Canada Fax: 1 (902) 426 7827
Dr. G. Schneider	Biologische Anstalt Helgoland Aussenstelle, 2282 List, Germany
Hein Rune Skjoldal	Institute of Marine Research Po. box 1870 - Nordnes, 5024 Bergen, Norway 47 (5) 238 500 Fax: 47 (5) 238584 Internet: heinrune@imr.no
Dr. Barbara K. Sullivan	Graduate Sch.Oceanography, University RI. Narragansett Bay Campus, 02882-1197 RI, Narragansett, USA 1 (401) 792 1000 Fax: 1 (401) 792 6160
Svein Sundby	Institute of Marine Research P.o. box 1870 - Nordnes, 5024 Bergen, Norway 47 (5) 238 468 Fax: 47 (5) 238584 Internet: sveins@imr.no
Kurt Tande	Norges Fiskerihøgskole 9000 Tromsø, Norway 47 (83) 440 000 Fax: 47 (5) 544 450
Mr. M. Varela	Centro Oceanografico Aptdo 130, 15080 La Coruna, Spain
Dr. Peter Wiebe	Woods Hole Oceanographic Institution Woods Hole, 02543 Ma., USA 1 (508) 548 1400 Fax: 1 (508) 457 2169 OMNET: P.Wiebe

ICES SGZP, Bergen, 23-26 March 1992

Recommendations for Sea-going and Laboratory Workshops on Standardization and Intercalibration of Methods

BACKGROUND

A major international program, Global Ocean Ecosystems Dynamics (GLOBEC), will soon be focussing its attention on rates of production of marine zooplankton. Field studies will begin in the mid-1990s in the North Atlantic Ocean, the Indian Ocean and the Southern Ocean. It is important that there be agreement on approaches for measuring biomass and turnover rates to assess zooplankton production before such field studies begin in earnest.

Many new developments have taken place in the past 15 years, both in terms of new sampling technology and new experimental methods for assessing physiological rates. However, the last comprehensive guides for measuring the components of zooplankton production were published more than 15 years ago (Omori and Ikeda 1976; UNESCO, 1968; Edmondson and Winberg 1971).

A new handbook needs to be produced that reflects these recent developments. The handbook will differ in one very important aspect from those previously available. It will include a formal guide to studying how the physical fluid dynamic environment and animal behaviour affects distribution and production of marine zooplankton populations. As a basis for methods evaluation and recommendations of standardized procedures to be included in the handbook, there is a need for workshops for intercomparison of methods.

RECOMMENDATION

It is recommended that

1) a series of three sea-going and laboratory workshops be held in early 1993 for the purpose of standardizing and intercalibrating methods for measuring the biomass and production of zooplankton;
2) workshops be held in waters of Norway, Georges Bank and Hawaii;
3) results from the workshops be coordinated with the writing of a comprehensive handbook for measuring zooplankton production, to be published in 1994.

WORKSHOP GOALS

It is the goal of these sea-going and laboratory workshops to provide

1) a basis for evaluating the performance of a variety of methods; and
2) explore combinations of instruments and experimental approaches that can most effectively be used to measure zooplankton production.

To satisfy these goals, various technologies and physiological rate measurements techniques were suggested for comparison in practice. The motivation was to suggest technologies and methods that are in common use, methods in limited use, and methods that have only recently been developed. There is a strong need to describe and intercompare these.

Examples suggested:

<u>TECHNOLOGY:</u>

A. NET SYSTEMS

1. WP-2 net
2. Bongo net
3. MOCNESS (1 sq m and 10 sq m)
4. LOCNESS
5. BIONESS
6. Hydrobios Multinet
7. LHPR
8. CPR
9. Gulf-3 high-speed sampler

B. ACOUSTIC SYSTEMS

1. Dual beam
2. Split beam
3. Multifrequency acoustic profiling system (MAPS)
4. ADCP

C. OPTICAL SYSTEMS

1. Optical Plankton Counter
2. Video Plankton Recorder
3. Ichthyoplankton Plankton Recorder
4. In situ Silhouette Camera
5. Holography

PHYSIOLOGICAL METHODS

A. FEEDING

1. Incubation balance method (carbon, nitrogen, pigment)
2. In situ method (gut evacuation)
3. High speed cinematography
4. Methods for measuring carnivory
5. Feeding indices (digestive enzymes)

B. ASSIMILATION EFFICIENCY (& EGESTION)

1. Pigment tracer method
2. Silica tracer method
3. Radiolabel tracer method
4. Ash-ratio method
5. Gravimetric method

C. RESPIRATION

1. Microwinkler method
2. Cartesian diver method
3. Microelectrode method
4. Respiration indices (pyruvate kinase, citrate synthase, ETS)

D. EXCRETION

1. Ammonia
2. Urea
3. Amines
4. Phosphorous all by various methods
5. Excretion indices (GDH)

E. GROWTH

1. Egg production method
2. Development (molting) rate method
3. Cohort analysis
4. Artificial cohorts
5. Growth indices (rRNA, ATC)

APPROACH

A. Technology

Sampling technologies will be compared from aboard 7-10 day cruises at three sites: (a) a Norwegian fjord and coastal waters, (b) Georges Bank, and (c) Station ALOHA in the North Pacific Ocean. These sites will provide a relatively stable environment with assurances of sampling the same population (the fjord), a productive temperate zone environment rich in biomass (fjord and Georges Bank), and a dilute oligotrophic warm-water environment more representative of the open ocean (North Pacific).

A key problem to be addressed is the magnitude of animal avoidance behavior of physical collecting gear. The technology to evaluate this problem is available and requires comparison of various multinet systems, with acoustical and optical systems. A central goal will be the development of new counter-measures to reduce or eliminate avoidance, thus leading to better biomass assessments. Ship time will be provided by appropriate host institutions or programs (University of Bergen, WHOI, UH/HOTS program), with Dr. Skjoldal as host in Bergen, Dr. Wiebe as host at WHOI, and Dr. Huntley host at UH.

B. Physiological Methods

Physiological methods will be compared on populations of copepods reared in the laboratories at University of Bergen and University of Hawaii. Populations will be reared as recognizable cohorts, and then, at the same time, the entire spectrum of physiological methods will be carried out. The physiological balance results will be compared amongst themselves, and then to the direct method of measuring growth by cohort analysis. Routine rearing of marine copepods will be underway at both University of Bergen (Dr. Båmstedt) and at University of Hawaii (Dr. Huntley). Each workshop will require approximately two weeks.

PROPOSED SCHEDULE

March/April, 1993: University of Hawaii

May, 1993: Georges Bank

June/July, 1993: University of Bergen

ICES SGZP, Bergen, 23-26 March 1992

Zooplankton Methodology Manual

METHODS FOR DETERMINING ZOOPLANKTON PRODUCTION

Editors: H.R. Skjoldal, M. Huntley and J. Lenz

Part I **General**
Part II **Handbook**

Sections:

Part I

A. Introduction
Overview of zooplankton
Populations, distribution and behaviour
Production ecology

B. Biomass and distribution
Feeding, metabolism and growth
Population dynamical methods
Behaviour and advection
Modelling
Sampling strategy and design

Part II

Procedures
(Also on CD format with video (Macintosh QuickTime) sequences included)

ICES SGZP, Bergen, 23-26 March 1992

Proposal for Symposium on Zooplankton Production

It is proposed that ICES sponsor a Symposium on zooplankton Production in 1994 with SCOR/IOC as possible cosponsors.

Suggested convenors are H.R. Skjoldal and M. Reeve with J. Gamble and R. Harris as local co-convenors.

It is further suggested that a suitable location for the Symposium would be Plymouth, England.

Justification:

(1) Recent advances in technology have revolutionised our ability to measure plankton at a wide range of scales.

(2) Theoretical developments are focussed on plankton in terms of agestructured populations and their recruitment processes.

(3) ICES has supported activity and initiated developments through the Study Group on Zooplankton Production.

(4) There are obvious links with the broader aims of the Cod & Climate Change initiative and with the initial aims of international SCOR/GLOBEC