International Council for
the Exploration of the Sea

C.M. 1976/ E : 14
Fisheries Improvement Committee

REPORT OF THE ICES WORKING GROUP ON MARICULTURE
(2nd Meeting)

A. Session on Methodology applied for the Development of Optimal Feeds for Fish Farming

1. Introduction

The Working Group met during 4-6th May with invited specialists to consider a special discussion topic, "the methodology applied for the development of optimal feeds for fish farming" in accordance with Council Resolution 1975/2:11. The list of / participants is given as App. 1.

The Chairman welcoming the group drew their attention to the problems in comparing the results of different experimenters due to lack of a standard reporting method. The inadequacy of much data was a considerable loss to mariculture especially when it was remembered that 40-60 % of the costs in such an enterprise might be apportioned to feed costs. After the adoption of the / agenda (app. 2) and appointment of Rapporteur (Mr. A.L.S. Munro was appointed Rapporteur), the Group proceeded with the / presentation of some 10 experience papers (app. 3). Discussion of them demonstrated that methods of reporting the results of feed trials were not all comparable. The rest of the meeting was devoted to a discussion of the experimental method and conditions necessary for conducting feedstuff trials and standardisation of the reporting of results.

2. Objectives

The following objectives were considered desirable in any overall programme however, individuals may emphasise a different order or include additional points as the list is not exhaustive:

1. Determination of the nutritional requirements of cultured fishes.
2. To develop knowledge of the interchangeability of raw feedstuff materials.
3. To minimise pollution loading through the development of feeds with high conversion efficiencies.
4. By evaluation of locally available materials replace imported feedstuff components.
5. To improve the flavour and appearance of the cultured fish product.
6. To obtain a cultured fish product suiting the higher demands of customers, such as physiologically healthy food.
7. To guarantee optimal health for the cultured fish.

3. Experimental Parameters

Those requiring definition and description were:

1. Provision of adequate numbers, it was suggested 60 as a minimum, 200 or more as optimal for each container.
2. The fish should be closely graded for size, and the experimenters consider whether stock from many families or a single family be used.
3. The numbers of fish escaping, dying or, removed by predators must be recorded.
4. The stocking density should be consistent with species preferences, type of enclosure and relevant to commercial practice.
5. The frequency of feeding the ration and any awareness procedures such as light or acoustic stimuli to warn the animal of impending feed ration.
6. The rate and frequency of handling such as for weighing.
7. Description of the environmental conditions and any deliberate change from natural conditions such as light or temperature regimes or natural change such as weed growth in net cages.
8. The intrusion of unwelcome wild species which may interfere with the experiment such as by eating the ration.

4. Design of Experiments

The following principles and alternatives were considered.

1. In defining the experimental questions not more than two questions should be asked of one experimental design.

2. The design will be determined by the questions asked but it should allow statistical evaluation of the results. The number of replicates cannot be categorically stated but depends on the size of the difference expected between control and experiment or comparisons. Where a big difference is expected duplication will suffice but where differences are small a greater number of replicates may be necessary. In statistical terms the number of replicates may assume greater importance than the number of fish in each experiment, provided that behavioural modifications resulting from using small numbers do not invalidate extrapolation of the results to commercial conditions.
3. Diets.
   a) The standard diet should guarantee to cover all known (and unknown) nutrient requirements of fish.
   b) The experimental diet should vary only one factor, all other nutrients should fulfill the requirement with a certain margin of safety.
   c) During the experiment there should be no change in the protein source or its "quality".
   d) Protein sources replacing the standard diet proteins should provide an isonitrogenous diet, or, supplement an otherwise complete but protein deficient diet.
   e) During the experiment there should be no change in the energy source or its "quality".
   f) The energy requirements may be met by feeding either isocaloric diets or isocaloric rations. Intermediate examples are where diets complete in all respects except energy content are supplemented by test energy sources.
4. The composition and chemical evaluation of the standard and experimental diets should be recorded.
5. The experimental period will depend on the experimental question.

5. Abiotic and biotic factors.

Information on the following was considered necessary.

1. The previous disease history of the fish. Preferably they should have a disease free history and come from an

establishment certified free of the major communicable diseases.

2. Prophylactic treatments given prior and during the experimental period.
3. A clear statement of any medication used during the experiment.
4. A general description of the abiotic conditions which will include the range of values of each major water quality factor such as oxygen, ammonia, pH, temperature, salinity and the container holding the fish.
5. Any major avoiding action which was necessary to maintain life or health of the fish.

6. Criteria to Measure Feed Efficiency and their Definition

1. Growth is measured as the weight gain at the start and end of the experiment and as the partial gains in each subperiod. It may be expressed as percentage of body weight or as percentage of body weight per unit of time. Growth may be measured also by length gain (at the start and end of the experiment). Measurement of both weight and length gain is preferred and the fishes Condition Factor expressed as: 100 x Weight (g) : Length^3 (cm).
2. The feed intake must be recorded for the experimental period and each sub period. The feeding ration may have to be altered to take account of mortality or stock loss.
3. Feed conversion. Several methods of presentation are possible, some may be preferred to others depending on experimental questions.
   a) The feed gain ratio may be expressed in 3 forms: feed/wet weight gain; dry weight of feed/wet weight gain; feed/gain, both on a dry matter basis. The latter is preferred but if a proximate analyses of the feed and body composition is carried out, none of the feed gain ratios are required. The reciprocal of any of the 3 forms, the gain feed ratio may be used but is not recommended.
   b) Feed protein value may be expressed in two forms: the protein efficiency ratio as gain/protein intake or, the productive protein value which is the ratio of nitrogen retained to that consumed.

c) The energy consumed per unit gain, or, its reciprocal the gain per unit of energy consumed.

d) The cost parameter which measures the cost of feed consumed per 1 kg gain produced. This parameter is of limited value as the costs only relate to the commodity prices prevailing at the time of purchase and to the particular conditions of tariff and subsidy of the country in question.

4. Body composition.
It was recommended that the crude fat, protein, moisture, ash and energy content be recorded from small numbers (approx. 5) of whole ground fish, before and after the feeding trial in order to determine the increments in fish body constituents and to relate these increments to the intake of the different feedstuff constituents. The number sampled can be quite small because of the lower variation in the standard deviation of the means of body composition parameters compared to the variations in the means of length and body weight.

5. Health status.
If mortalities on higher than 5 % specific comments are required. At the termination of the experiment examination of the gross external and internal appearance. Similarly histological examination of body tissues should be reported.

7. Principles of experimental diets and their chemical evaluation

1. Principles of composition of experimental diets.
Complete diets may be based on coventional or semipurified components. The diet may be simplified by using limited numbers of components or it may contain many components. Formulation is preferred on the basis of the nutrient content of components, such as the non-energy nutrients (vitamins and minerals) and the energy nutrients (Carbohydrates, fats including essential fatty acids, and proteins including amino acid composition) and a statement of their origin rather than formulation based on components only. The energy content of the diet must be known. In some experimental designs isonitrogenous or isocaloric rations may be necessary.

2. Preparation of experimental diets. Mixing may present special problems. The choice of components may assist in achieving homogenenous mixtures. Preparation of premixtures of microcomponents will facilitate their homogeneous distribution. The addition of preservatives and stabilisers is often necessary.
   The physical form of presentation will depend on the preferences in method of feeding of the experimental animal. The varied requirements for feed for crustaceans, eels, marine flatfish, molluscs and salmonids were noted. Some forms of presentation are: flakes, micro-granules, micro-encapsulated granules, granules which may sink or float, pellets, or as a solid mash. Dietary attractants imparting flavour may be important in achieving acceptability.
3. Physical and chemical evaluation of experimental diets.
   Physical evaluation of granules and pellets will record size, hardness, durability against breaking and crumbling, the dissolution in water and the sinking properties.
   Chemical evaluation of any diet is essential. Information on the following are indispensible:

   carbohydrate as crude fibre and nitrogen free extract (NfE)

   protein as crude protein and amino acid content

   fat as crude fat, free fatty acid, peroxide value, and melting point.

   Criteria of lesser importance are vitamin and mineral content, and the pesticide and carcinogen content. Biological evaluation is highly desirable, e.g. digestibility, nitrogen and energy retention (Section 6;4).

8. Clinical, chemical and organoleptic assessment of the farmed product.

1. Fish for human consumption. A clinical appraisal is required of gross and histological appearance (Section 6;5). A chemical assessment of the whole body as described (Section 6.4) and a similar assessment of edible tissues.
   Special tests may be necessary on occasion; amino acid composition, fatty acid pattern, vitamin content, residues of toxological relevance (organochlorines, PCB's) and

specific microbial pathogens (Clostridium botulinum, Salmonella, Vibrio parahaemolytica).

Organoleptic assessment may be necessary but it must be conducted in conjunction with a food technology laboratory. Tests include amount of edible tissue, distribution of body fat, colour and flavour of flesh, freshness, keepability, and wholesomeness for human consumption.

2. Fish for restocking or ocean ranching. It was concluded that adequate criteria could not be defined and for those listed suitable test procedures did not exist. Emphasis was placed on survival in the wild and ability to withstand stress. It was considered that significant body fat accumulations may assist in survival and that feeding diets rich in carbohydrate may be detrimental prior to release.

9. Interpretation, Statistical Analyses, Intercalibration

1. Interpretation and statistical analyses.
   It was concluded that all the necessary statistical methods for handling the data were available.
   Therefore at the planning stage statistical help should be sought in the experimental design. It was noted that the Range Test is better than the Distribution Test for handling data from group experiments. The difficulties of sub sampling at random during the course of an experiment were noted, in particular, that all fish in a cage are not independent of each other. However it is better to collect data periodically even if the whole population has to be sampled than risk an accident before the end. Caution was recommended in the world-wide use of the results of trials on growth and feed conversion because it was recognised they may not be valied in different geographical areas due to variation in biotic and abiotic factors.
2. Intercalibration.
   The nimimum requirements for intercalibration were listed as
   a) body weight range
   b) length distribution

c) length of experimental period
d) body composition as listed in Section 6,4 , i.e. crude fat protein, moisture, ash and energy content. (Failing this comprehensive analyses, feed/gain, both on a dry matter basis).

10. Further Research

It was considered that further work on the development of standard methods of evaluating feedstuffs was required. In general much further fundamental work is required on the nutrition of many species with the potential for mariculture.

11. Conclusions

1. Many published results are of little value because of failure to report the necessary critical criteria.
2. There must be a continuing search for new feedstuff components.
3. A list of species suitable for mariculture should be compiled along with their known nutritional requirements.
4. The design of experiments must be reported.
5. The abiotic and biotic factors influencing results must be reported.
6. To measure the feed efficiency a record of dry weight gain per unit of time in conjunction with whole body analyses is required. A co-operative programme with a nutrition laboratory may be the best approach if the analytical burdens are too great.
7. A statement of the chemical evaluation of the diet is essential.
8. Organo-leptic assessment of the product is necessary.
9. Criteria defining the qualities of fish for restocking or ocean ranching are inadequate.
10. Statistical methods are available for handling the experimental data. The number of replicates must be defined for each test.
11. It was agreed to present the papers discussed at the October Statutory Meeting of ICES.
12. Co-operative discussions with EIFAC and ICES should be held as a forum for nutritionalists to discuss the methodology for optimal feed development.

12. Recommendations

There should be a forum to include the extensive nutritional expertise of North America and Japan. This will act as a clearing house to ensure a common approach to the problems of methodology. After consultation and agreement ICES member countries should be recommended to adopt a common methodology for the development of optimal feeds for mariculture species.

B. Internal Session of the Working Group on Mariculture

The internal session of members of the Working Group was convened by Prof. Dr. K. Tiews on 5 May at Bundesforschungsanstalt für Fischerei in Hamburg.

1. Evaluation of the Meeting

It was concluded from the documents presented at the meeting and from subsequent discussion of them that there are numerous areas for standardisation in the presentation of results describing the use of experimental diets. The fact that terms were used in the papers which were not comparable supports this view. It is premature to have expected standardisation or the resolution of such problems without much fuller discussions which must consult the considerable expertise and experiences in North America and Japan. Because of the dangers of producing information which cannot be evaluated it is considered that researchers should not embark on work on this subject without considerable familiarity with it or co-operative assistance (or at least prior consultation) with a nutritional institute.

2. National reports and communications of research activites.

The regular updating of information on national programmes was regarded as essential to allow communication between groups with similar interests and also to avoid unnecessary duplication. Delegates were urged to ensure their national programmes were fully reported and brought up to date for annual recording by the ICES Mariculture Group. The communication of the results of papers of the Working Party to all relevant parties is the

responsibility of each country's national delegate. The attention of delegates was drawn to the US NOAA agency bibliography on aquaculture dating to 1970 details of which could be obtained from Mrs. Joan Mitchell, USA.
Delegates also learned of the formation and aims of the European Mariculture Group (affiliated to the World Mariculture Society).

3. Future Activities

It was decided that another meeting of the Working Party be held next year by invitation of the French delegate in Brest during 9 - 13 May to discuss "the methodology of rearing brood stock and the mass rearing of juveniles of mariculture species for controlled farming and for ocean ranching". The meeting will take the form of presentation and discussion of experience papers over 3 days and an additional day will be used for the demonstration of systems and techniques. It is essential that specialists in the subject are co-opted by their countries to attend and promote in depth discussion of the subject. In particular it is hoped that bioengineers will be represented at the meeting. Invitations will be extended to countries outside the ICES group with particular interests in mariculture, Japan in particular.
The attention of delegates was drawn to the recent number of patents relating to aquaculture, in particular those applying to biological processes, and their potential limiting effects noted. Discussion revealed that the ability to patent and the rights of patentees varied considerably in different member countries. In the belief that more information on the practices in different ICES member countries would assist the Council in making recommendations it was agreed that delegates be asked to report to the next Internal Session of the Working Group on the practices in their country relating to the patenting of biological processes.

4. Recommendations

1. It was recommended that at the special mariculture session between the Fisheries Improvement and the Shellfish and Benthos Committee, and the Fisheries Improvement and Anadromous and Catadromous Fish Committees at the 1977 Statutory Meeting the special topic should be as follows "the technology of mariculture systems with special reference to recycling and pollution control in salt water systems".
   As the EEC will have published its consultative document on the water quality criteria for the culture of shellfish and freshwater fish it was considered that it may be relevant to include a discussion of this paper on the agenda.

2. It was recommended that the subject for the subsequent (1978) Statutory Meeting sessions between the Fisheries Improvement and Benthos Committees and the Fisheries Improvement and Anadromous and Catadromous Fish Committee be as follows "to study how the knowledge gained from the various disciplines studying mariculture can be used for the better management of fishery resources".

C. Excursion

On 6 th of May an excursion was organized by the host to visit a fish feed manufacturer at Lindhorst and the experimental station of the Institut für Küsten- und Binnenfischerei at Emden where fish farming experiments in thermal effluents of a conventional power plant are being carried out (App. 4).

Appendix 1

2nd Meeting of the Working Group on Mariculture

List of participants

Belgium: Miss E. Jaspers, Laboratorium voor Biologisch Onderzoek van Milieuverontreiniging, Josef Plateaustraat, 22, B 9000 Gent

Canada : Dr. Castel, Fisheries Research Laboratory, Fisheries and Marine Service, Department of the Environment, P.O. Box 429, Halifax, Nova Scotia

Denmark: Mr. E. Hoffmann, Danmarks Fiskeri-og Havundersøgelser, Charlottenlund Slot, 2920 Charlottenlund

France : Mr. Gatesoupe, Institut National de la Recherche Agronomique

Mr. R. Metailler, Centre Océanologique de Bretagne

Prof. J. le Noan, Chef du Department "Ressources Vivantes", Centre National pour l'Exploitation des Oceans, 39, Avenue d'Iena, 75116 Paris

Germany, Federal Republic of:

Dr. H. Beck, Institut für Physiologie, Physiologische Chemie und Ernährungsphysiologie im Fachbereich Tiermedizin der Universität München, Veterinärstr. 13, 8000 München 22

Dr. J. Gropp, Sandoz Forschungsinstitut, Abteilung Tierernährung, Brunner Straße 59, A -1235, Wien

Dipl. Biol. H. Koops, Institut für Küsten- und Binnenfischerei der Bundesforschungsanstalt für Fischerei, Palmaille 9, 2000 Hamburg 50

Dr. H. Kuhlmann, Institut für Küsten- und Binnenfischerei der Bundesforschungsanstalt für Fischerei, Palmaille 9, 2000 Hamburg 50

Prof. Dr. K. Tiews (Chairman), Director, Institut für Küsten- und Binnenfischerei, Palmaille 9, 2000 Hamburg 50

Ireland: Dr. Alec Gibson, Department of Agriculture and Fisheries, Agriculture House, Dublin 2

Netherlands:

Dr. S.J. de Groot, Rijksinstituut voor Visserijonderzoek, Haringkade 1, IJmuiden

Prof.Dr.E.A. Huisman, Landbouwhogeschool, Duivendaal 5, Postbus 338, Wageningen

Drs. van Limborgh, Institute for Scientific in the Field of Animal Nutrition, Nijverheidsweg 2, Postbus 50, Putten (Gld.)

Norway : Dr. Dag Møller, Institute of Marine Research, P.O. Box 2906, 5011 Bergen

Portugal: Dr. R. Cachola, Secretaria de Estado das Pescas, Direccao-Geral da Investigacao en Proteccao dos Recursos, Vivos e do Ambiente Aquatico, Edificio da Capitania do Porto de Faro, Faro

Spain : Mr. H. Quiroga, Laboratorio Oceanográfico,Muelle de Animas, La Coruna

Sweden : Mr. Bo Holmberg, Director, Royal Board of Fisheries, Fack, S-403, 10 Göteborg 2

United Kingdom:

Mr. A.L.S. Munro (Rapporteur), Department of Agriculture and Fisheries for Scotland, Marine Laboratory, P.O. Box No. 101, Aberdeen

U.S.A. : Joan R. Mitchell, Assistant Program Manager for Environmental Quality, National Science Foundation, Office for the international decade of Ocean exploration, Washington, D.C. 20550

Observer : Mrs. Choo, Marine Fisheries Laboratory Glugor, Penang, Malaysia

Dr. V. Hilge, Institut für Küsten- und Binnenfischerei der Bundesforschungsanstalt für Fischerei, Außenstelle, Wulfsdorfer Weg, 2070 Ahrensburg

Dr. Lungershausen, Firma Hemo-Mohr KG Mischfutterwerke, Postfach 13, 3510 Hann.- Münden

Dipl. Biol. T. Neudecker, Institut für Küsten- und Binnenfischerei der Bundesforschungsanstalt für Fischerei, Palmaille 9, 2000 Hamburg 50

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Appendix 2

2nd Meeting of the Working Group on Mariculture

4 - 6 May 1976
(09.30 hrs)

at

Bundesforschungsanstalt für Fischerei, Palmaille 9, 2000 Hamburg

Special discussion topic:

Methodology applied for the development of optimal feeds for fish farming

A g e n d a

1. Welcome, opening remarks, adoption of Agenda.
2. Presentation of participants and appointment of Rapporteur.
3. Objectives of the meeting.
4. Introduction of papers and their general discussion.
5. Special discussion.
   - 5.1 Objectives for the development of optimal feeds.
   - 5.2 Experimental techniques for various species of fish, fish handlung and manupulation problems.
   - 5.3 Design of experiments.
   - 5.4 Abiotic and biotic factors influencing results.
   - 5.5 Criteria to mearuse feed efficiency and their definition (feed conversion, growth etc.).
   - 5.6 Preparation of experimental diets and their chemical evaluation.
   - 5.7 Clinical, chemical and organoleptic assessment of farming product.
   - 5.8 Interpretation, intercalibration and statistical analysis of data.
   - 5.9 Need for further research into the methodology for optimal feed development.
6. Conclusions.
7. Recommendations.

Internal Session of members of Working Group

8. Evaluation of scientific discussion on matters related to the development of optimal feeds for fish farming.
9. Updating of national reports on governmental and private research activities in the field of Mariculture (Ref. C.M. 1975/E:6)
10. Future activities of the Working Group.
11. Recommendations.

Appendix 3

2nd Meeting of the Working Group on Mariculture

List of documents

No. 1 Agenda

No. 2 List of participants

No. 3 List of documents

No. 4 K. Tiews, J. Gropp and H. Koops:
"On the Development of Optimal Rainbow Trout Pellet Feeds"

No. 5 J. Gropp, H. Koops, K. Tiews and H. Beck:
"Replacement of Fish Meal in Trout Feeds"

No. 6 E.A. Huismann:
"Food Conversion Efficiencies at Maintenance and Production Levels for Carp and Rainbow Trout"

No. 7 C.L. van Limborgh:
"Formula Feeds and Fish Nutrition"

No. 8 J.D. Castell and Jane F. Covey:
"Protein and Lipid Requirements in the Diet of Lobsters, Homarus americanus"

No. 9 S.P. Lall and F.J. Bishop:
"Utilization of Minerals by Atlantic Salmon (Salmo salar) in Seawater"

No. 10 R. Metailler:
"Résults récents des travaux francais de nutrition appliquée à l' aquaculture marine"

No. 11 R. Metailler and M. Girin:
"Croissance de jeunes soles (Solea solea) nées en laboratoire et conditionnées à l'aliment composé"

No. 12 F.J. Gatesoupe, C. Leger, R. Metailler, P. Luquet:
"Alimentation lipidique du turbot (Scophtalmus maximus L.). Influence de l'apport en acides gras de la série W 3"

No. 13 H. Kuhlmann:
"Fish Farming Experiments in Brackish Thermal Effluents of a Power Plant"

No. 14 Country Reports.

No. 15 Reference Agenda 5.1:
Objectives for the development of optimal feeds

No. 16 H. Koops and H. Kuhlmann:
"Preliminary note on the growth of the European Eel in a brackish thermal effluent"

No. 17 R. Meixner:
"Culture of Pacific Oysters (Crassostrea gigas) in containers in German coastal waters"

No. 18 : Excursion program

No. 19 Report of the ICES Working Group on Mariculture (1st Meeting)

No. 20 Reference Agenda 5.6: Preparation of experimental diets and their chemical evaluation

No. 21 Reference Agenda 5.3: Design of experiments

No. 22 Reference Agenda 5.5: Criteria to measure feed efficiency and their definition (feed conversion, growth etc.)

No. 23 Simpson, Wright, Fraser:
"Further observations on the use of anabolic steroids in the culture of salmonid fish"

Appendix 4

2nd Meeting of the Working Group on Mariculture

Excursion program

Thursday, 6. May 1976

07.15h	Meet at Bundesforschungsanstalt für Fischerei, Palmaille 9
07.30h	Departure of bus
08.30h	Arrival in Hemo Mohr KG, Mischfutterwerke, Lindhorst
09.30h	Departure Hemo Mohr KG for Emden
13.30h	Luncheon invitation by the Nordwestdeutsche Kraftwerke AG, Kraftwerk Emden
15.00h	Visit of experimental station Emden of the Institut für Küsten- und Binnenfischerei der Bundesforschungsanstalt für Fischerei
15.30h	Departure for Hamburg

Return to Hamburg between 19.00 and 20.00h

The bus tour will be free of charge upon the invitation of the Fachverband der Futtermittelindustrie e.V., Postfach 3063, 5300 Bonn