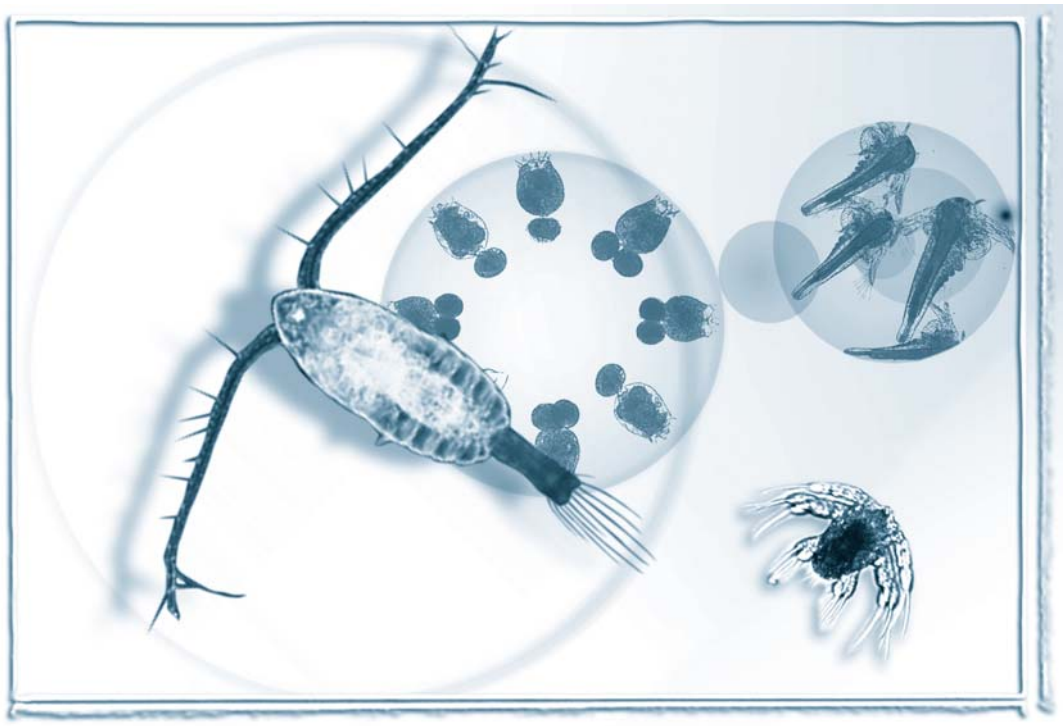
FRDC Project 2000/241

Hatchery Feeds Workshop

A. David McKinnon



AUSTRALIAN INSTITUTE OF MARINE SCIENCE

FISHERIES RESEARCH & DEVELOPMENT CORPORATION

TOWNSVILLE
2002

FRDC Project 2000/241

Hatchery Feeds Workshop

David McKinnon

Fisheries Research and Development Corporation

Hatchery Feeds Workshop

David McKinnon

Australian Institute of Marine Science,
PMB No 3
Townsville Qld 4810.

ISBN: 0 642 32229 5

CONTENTS

NON-TECHNICAL SUMMARY

2000/241	Hatchery Feeds Workshop

PRINCIPAL INVESTIGATOR: Dr A. David McKinnon

ADDRESS: Australian Institute of Marine Sciences
PMB No 3
Townsville QLD 4810
Telephone: (07) 4753 4444
Facsimile: (07) 4772 5852

OBJECTIVES:

1. To assess the status of hatchery feeds, including live and compounded feeds, and to identify research in progress.
2. To assess priorities for research and development needs in the area of hatchery feeds.
3. To identify constraints to the continued development of Australian aquaculture in the area of hatchery feeds.
4. To identify opportunities to enhance collaboration and information exchange amongst researchers and industry.
5. To develop a national R&D plan for hatchery feeds..

OUTCOMES ACHIEVED

A workshop was convened to facilitate communication between stakeholders interested in the development of hatchery feeds technology. Research priorities were identified and formulated into an R&D plan, and a mechanism for maintaining communication established via a web page and email discussion list.

KEYWORDS: Aquaculture, hatchery, hatchery feeds, rotifer, Artemia, copepod, diet.

With the expansion of aquaculture in Australia there is a need to improve coordination between and within both the R&D and industry sectors with regard to the study of hatchery feeds, and to identify opportunities and priorities for future research. The recent world shortage of the brine shrimp *Artemia* has precipitated a crisis situation in aquaculture hatcheries. Accordingly, in late 1999 FRDC commissioned a Hatchery Feeds R&D Plan, which was developed at a workshop held in Cairns, Queensland, on 9–10 March 2000.

The aquaculture community was widely polled to establish industry priorities for future research. A questionnaire was sent to all stakeholders, together with an invitation to attend the workshop, which was held in Cairns on 9-10 March 2000. Researchers were invited to present the results of work in progress, and industry needs were canvassed in open forums.

For convenience, the subject was divided into 5 main areas of research: microalgae, rotifers, brine shrimp, copepods and formulated diets. Status reviews were commissioned in each of these areas, and priorities in each defined in the workshop. In all areas, the need to benchmark best practice and to more efficiently transfer research results to industry were highlighted. In addition to these common priority areas, the following specific areas were identified as worthy of further research:

- Microalgal production systems
- The role of microalgae in green-water systems
- Assessment and production of Australian rotifer strains and alternative feeds
- Production of brine shrimp in Australia rather than depending on imported product
- Early weaning of larvae on to formulated feeds
- Scaling up existing systems for copepod production
- Development of a knowledge-base for copepod production
- Improvement of diets for copepod production
- Identification of appropriate copepods as food for individual species
- Development of local microdiets.

In recognition of the need to improve communication between researchers and industry in the field of hatchery feeds development, we have implemented an e-mail discussion group (hatchery-feeds@aims.gov.au) and have developed a web site detailing the outcomes of the Hatchery Feeds Workshop (https://web.archive.org/web/20090303235152/http:/www.aims.gov.au/pages/research/hatchery-feeds/hfa-01.html). Aquaculture conferences and workshops will be utilised for future meetings of researchers and industry involved in the development of hatchery feeds.

BACKGROUND

Nutrition during the early life stages is a major problem in intensive fish culture. Inadequate food sources, either in terms of quantity or quality, are a major cause of mortality. Live food (i.e. micro-algae, zooplankton) has been employed for culturing the early life stages of marine fish and is currently obligatory for successful culture past metamorphosis, when the fish are weaned onto dry formulated diets. Continuing research and development into production technology for a range of marine finfish species has consistently demonstrated the inadequacy of existing live prey organisms used for larviculture. Many R&D teams have identified the need to produce alternative feeds for feeding marine finfish larvae,. Numerous presentations at WAS 99 in Sydney reiterated the important role that live and dry feeds have in aquaculture, particularly of fish larvae.

Currently larval culture in Australia and around the world is heavily dependent on two main food organisms: the rotifer *Brachionus plicatilis* and the brine shrimp *Artemia*. These organisms present problems such as:

- Unsuitable size, especially with first feeding larvae such as groupers (*Epinephalis* spp.) and tropical snappers (*Lutjanus* spp.), which have a very small mouth gape.
- Inadequate nutritional content.
- Inconsistent nutritional profile.
- Inadequate digestibility. Tropical snapper and grouper larvae ingest rotifers, but are unable to digest them.
- Inconsistent supply. This is especially true of *Artemia*, with the decline in harvest from the Great Salt Lake, Utah USA (where 70% of the world's *Artemia* cysts originate).
- High production costs. The price of *Artemia* cysts doubled during the last year (to $150/kg) because of the shortage of cysts. Moreover, rotifer and *Artemia* production involves costly enrichment to enhance the nutritional profile. Live food production involves other costs such as, manpower, space (tanks, ponds), electricity (heaters, aeration etc.).

The main organism used as 'live food' in larviculture (especially in the later stages) is the brine shrimp *Artemia* sp. During the last twenty years intensive research has been conducted around the world to develop techniques of adapting *Artemia* to the aquaculture of both finfish and prawns. However, due to the dramatic ecological change in the Great Salt Lake, Utah USA, dramatic decline in harvest of cysts has caused a sharp increase in cost. Australia also has large salt fields that produce commercial amounts of *Artemia* cysts. This production relies on introduced strains of *Artemia* from San Francisco bay (*Artemia fransiscana*) to maintain high water clarity and reduce algal contamination. Production technology for this strain in semi-intensive ponds has been developed at a pilot scale at Dampier salt, WA. However, the suitability of this strain has not been adequately evaluated for marine finfish. These cysts may replace imported product and may develop into a reliable source for the international market.

Parartemia are native fairy shrimp (not related to *Artemia*). Considerable research on this organism has been undertaken through the University of Western Australia, which has formed the BioSaline Lake Reference Centre with additional financial support from the Wheatbelt Development Commission and Fisheries WA. Goals include commercial exploitation and biodiversity research and maintenance.

In Australia progress in copepod cultivation has been substantial in the last few years and there is good reason to be confident that this work has commercial applicability. For instance, Darwin, Cairns and Adelaide scientists have all been developing culture of the same genus of copepod, *Acartia*. In addition, the Perth group has developed an elegant automated system for culture of *Gladioferens*, supported by FRDC funding. This technology could be further developed and extended to other species. Current interest in the aquaculture of high value marine finfish (e.g. coral reef fish, groupers, tuna) by both industry and research sectors will require the development of copepod culture to be successful.

Dry diets for fish larvae present a viable alternative to live food. Advantages include 'off the shelf' availability, consistent nutritional profile, the ability to adjust to the specific nutritional requirements of specific fish species. Availability is especially important in remote places and in commercial hatcheries limited by budget, facilities and person power. However, to date microdiets have not matched the growth and survival demonstrated by fish larvae fed live feeds such as rotifers and *Artemia* nauplii. During

recent years, intensive research has been conducted by a number of research groups around the world, including Australia, to develop microdiets that can partially or fully replace the use of live food. Substantial advances have been developed especially in weaning diets and in shortening the live food period.

WAS 99 provided the opportunity for representatives from all the research groups working with larval feeds and larviculture to meet, and all concurred that a coordinated approach to the development live and dry feeds techniques and products for fish larvae would be the best way to optimise R&D resources. Willingness to cooperate was clearly expressed. It was agreed that the best way to initiate this would be to convene a workshop to facilitate communication between groups, and to identify areas of larvae feeds research requiring further scientific effort.

Need

There is already considerable Australian research commitment to the production of hatchery feeds and to the development of new feeds. Many research institutions have a proven track record in development of production technology, but with the expansion of aquaculture in Australia there is a clearly defined need to improve coordination between the research organisations in the area of fish larvae feeds, and to identify opportunities and priorities for future research.

In October 99, McKinnon acted on advice from QFIRAC and FRDC, and canvassed support for a live feeds workshop. All respondents indicated support, but indicated that such a workshop should encompass all aspects of hatchery feeds research. We therefore proposed that the workshop would focus on hatchery feeds for finfish, and would aim to summarise the current status of research within Australia, identify gaps in research effort, and prioritise research needed.

Objectives

1. To assess the status of hatchery feeds, including live and compounded feeds, and to identify research in progress.
2. To assess priorities for research and development needs in the area of hatchery feeds.
3. To identify constraints to the continued development of Australian aquaculture in the area of hatchery feeds.
4. To identify opportunities to enhance collaboration and information exchange amongst researchers and industry.
5. To develop a national R&D plan for hatchery feeds

Methods

A questionnaire (see Appendix 3) was circulated to all stakeholders in January 2000, together with an invitation to attend the workshop. The questionnaire requested input on relevance, feasibility, and current status of a wide range issues relevant to hatchery feeds, and allowed stakeholders to nominate issues they thought relevant.

The following researchers were approached to act as status reviewers in their areas of hatchery feeds research:

Malcolm Brown (CSIRO): Microalgae
Stewart Fielder (NSW Fisheries): Rotifers
Sagiv Kolkovski (Fisheries WA): *Artemia*
David McKinnon (AIMS): Copepods
Paul Southgate (JCU) & Sagiv Kolkovski: Formulated diets.

The workshop was held in Cairns on 9-10 March 2000. The first day comprised presentations, and the second for discussion of issues and formulation of a draft R&D plan (see Appendix 5). Forty-eight people attended the workshop, including 17 from industry. We employed an editor to record and collate discussion, and to produce the final report documents.

The status reviewers produced a literature review and status report on each area. All participants were invited to give a brief presentation on their research, and to submit an

extended abstract suitable for inclusion in the proceedings. Industry opinions were sought in an open session. The current status of R&D was then used as a baseline for development of a 5-year plan for hatchery feeds research. For convenience, this research was divided into four key areas: microalgae, rotifers & brine shrimp, copepods, and formulated diets. During the workshop, breakout groups were formed to discuss issues and research needs in each topic area. Chairs and reporters for each group were:

Topic	Chair	Reporter
Microalgae	Malcolm Brown	Frances D'Souza
Rotifers and brine shrimp	Stewart Fielder	Stephen Battaglene
Copepods	David McKinnon	Rob Rippingale
Formulated diets	Sagiv Kolkovski	Peter Appleford

Results and Discussion

SYNOPSIS OF OPINION EXPRESSED AT THE WORKSHOP

In today's economic climate a successful aquaculture industry needs to be extremely cost-efficient. Hatcheries need a reliable supply of high quality feeds suitable for the rearing of early life stages of aquaculture species. At present larval culture in Australia and around the world is heavily dependent on two main food organisms: the rotifer *Brachionus plicatilis* and the brine shrimp *Artemia*. Although easy to culture, these organisms can present problems such as:

1. Unsuitable size
2. Inadequate nutritional content
3. Inconsistent nutritional profile
4. Inadequate digestibility
5. Inconsistent supply
6. High production costs

In the short term the provision of alternative live prey items such as copepods may solve some of these problems. However, in the long term micro-particulate diets, which can be produced cheaply and made available 'off the shelf', provide the best solution. Existing industry sectors have less need for new feeds than emerging sectors, which require the development of new or alternative hatchery feeds. Extensive production techniques

provide an alternative to reliance on traditional live feeds, but seasonal limitations to the use of extensive systems, especially in temperate areas, mean that there is a need for further development.

Microalgae are the basis of all live feed production, but are often perceived as being difficult to grow reliably in quantity and therefore as expensive. Though some hatcheries find that microalgae are relatively easy to mass-culture most hatchery operators would prefer an off-the-shelf substitute. Mass production of micro-algae appears to be one area in which tested technology is available but where the extension and subsequent adoption of this technology is lacking. In addition, a larger suite of microalgal species and products (such as microalgal concentrates) would be available if import restrictions were less onerous. Existing quarantine procedures restrict progress in this regard and there is a need to involve AQIS in reassessing quarantine protocols.

Rotifers (*Brachionus* spp.) can be easily cultured at high density and have become the standard first feed organism for fish hatcheries. However, though rotifers can be easily enriched and are suitable for most fish currently used in aquaculture, developing industries are experiencing problems with existing larval rearing techniques. Larvae of groupers (*Epinephelus* spp.) and tropical snappers (*Lutjanus* spp.) have a very small mouth gape, and are therefore only capable of taking small food items. Though these fish can ingest small rotifers, some species are unable to digest them when rotifers are used as the sole food source.

The brine shrimp *Artemia* is the main organism used as 'live food' in the later stages of larviculture. However, the dramatic decline in harvest from the Great Salt Lake, Utah, USA, (where 70% of the world's *Artemia* cysts originate) caused the price to double during 1999, to $150/kg. The Australian *Artemia* market is currently around four tonnes, most of which is used in prawn hatcheries. In the short term, hatcheries need to improve the efficiency of use of *Artemia* to make the best of the existing supply. The worldwide *Artemia* shortage provides opportunities for Australian industry to produce brine shrimp, possibly from desalination projects, to take advantage of world demand and increasing prices. To date commercial production of brine shrimp in Australia relies on introduced strains of *Artemia* from San Francisco bay (*Artemia fransiscana)*. An alternative, native West Australian brine shrimp (*Parartemia spp.)* are expected to be commercially available in the near future.

Progress in copepod cultivation in Australia has been substantial in the last few years and there is good reason to be confident that this work has commercial applicability. For instance, Darwin, Cairns and Adelaide scientists have all been developing culture of the same genus of copepod, *Acartia*. Perth scientists have developed an elegant automated system for culture of *Gladioferens imparipes*, supported by FRDC funding. Current interest in the aquaculture of high value marine finfish (e.g. coral reef fish, groupers, tuna) by both industry and research sectors may require the development of copepod culture to be successful. Copepods provide a useful augmentation to, if not replacement for, *Artemia*. However, there remains a need for a production system which can be easily adopted by industry and which is suitable for a wide range of species.

Dry diets for fish larvae present a viable alternative to live food. Advantages include 'off-the-shelf' availability, consistent nutritional profile, and the ability to adjust this to the specific nutritional requirements of individual fish species. Availability is especially important in remote locations and in commercial hatcheries limited by inadequate budgets, facilities and staff. To date, however, microdiets have not matched the growth and survival demonstrated by fish larvae fed live feeds such as rotifers and *Artemia* nauplii. During recent years intensive research has been conducted by a number of research groups around the world to develop microdiets that can partially or fully replace the use of live food, especially *Artemia*. Substantial advances have been developed especially in weaning diets and in shortening the live food period. The limited local market has hampered progress in diet development in Australia.

Australia supports a substantial scientific community engaged in aquaculture research. Government and university researchers compete for funding from various agencies such as FRDC and the CRC for Aquaculture. However, in the ongoing competition for this funding technology transfer to industry is sometimes overlooked. In particular, on-the-ground extension work, such as hands-on workshops, is needed to efficiently transfer research results. It is also often the case that exchange of information is slow between aquaculture concerns, and there appears to be a need for more efficient avenues of communication such as meetings, workshops and electronic media. Whereas scientists often have the opportunity to visit overseas installations to learn of new developments, these opportunities are seldom available to hatchery managers or technicians. At present there is no clear way for hatcheries to gain access to overseas experience to increase the

range of live food and to shortcut research. One means of achieving this would be to institute a mechanism by which exchange programs for industry technicians could occur.

Post-graduate degrees are a cheap way of funding research. Masters degrees are often more productive in that they provide more industry-relevant information in a shorter time frame than PhD degrees, which tend to take longer and be more academic. However, a gap in infrastructure remains in extending technology from research scale to commercial production scale.

More research is needed on the widespread problem of land salinity (inland-based marine aquaculture). This is being addressed through several Inland Saline Aquaculture projects, funded by FRDC, ACIAR, RIRDC and the CRC Aquaculture.

Our vision is for a strong Australian aquaculture industry, with a broad base. In order to achieve this goal we need to be better develop our resources, and we need ways to assess the economics of new systems and/or technologies. It is generally acknowledged that there is not enough research funding to go around, but if we can improve collaboration between researchers, industry and funding agencies we can improve the efficiency with which existing funds are used. Dedicated business units are one option by which the economics of new systems could be assessed. Indeed, a recurrent theme through the Hatchery Feed workshop was the need for the aquaculture community to promote best practice by benchmarking the most cost-effective hatchery feeds procedures.

PRIORITY AREAS FOR FURTHER RESEARCH

In all areas, the need to benchmark best practice and to more efficiently transfer research results to industry were highlighted. In addition to these common priority areas, the following specific areas were identified as worthy of further research:

- Microalgal production systems
- The role of microalgae in green-water systems
- Assessment and production of Australian rotifer strains and alternative feeds
- Production of brine shrimp in Australia rather than depending on imported product
- Early weaning of larvae on to formulated feeds

- Scaling up existing systems for copepod production
- Development of a knowledge-base for copepod production
- Improvement of diets for copepod production
- Identification of appropriate copepods as food for individual species
- Development of local microdiets.

COMMUNICATION STRATEGIES

In recognition of the need to improve communication between researchers and industry in the field of hatchery feeds development, we have implemented an e-mail discussion group (hatchery-feeds@aims.gov.au) and a web site (http://www.aims.gov.au/hatchery-feeds) (website no longer active). Aquaculture conferences and workshops will be utilised for future meetings of researchers and industry involved in the development of hatchery feeds.

OUTPUT DOCUMENTS

The *Hatchery Feeds Research & Development Plan 2000-2005* and a companion document, *Proceedings of a Hatchery Feeds Workshop, Cairns 9-10 March 2000* containing extended abstracts of presentations from the workshop are available at https://web.archive.org/web/20090303235152/http:/www.aims.gov.au/pages/research/hatchery-feeds/hfa-01.html and https://web.archive.org/web/20090304224536/http://www.aims.gov.au/pages/research/hatchery-feeds/hfa-04.html .
The contents of these documents are listed in Appendix 6 and 7.

Benefits

The *Hatchery Feeds Research & Development Plan 2000-2005* is a larger document than originally envisaged, but includes status reviews in the five major areas of hatchery feeds research. It therefore provides a clear statement of "the state of the art" as well as a map of the road ahead.

Further Development

The *Hatchery Feeds Research & Development Plan 2000-2005* includes sections on review and communication strategies, which ought to provide a mechanism for update and revision. Participants in the workshop agreed to meet approximately annually, where possible at other national meetings.

We trust that FRDC will adopt the R&D plan as a guide for allocating support to future research proposals on hatchery feeds.

Conclusion

Attendance at the workshop surpassed expectations, and the workshop was successful in gaining consensus on where further R&D effort should be placed. In addition, the draft documents were published on the web page and comment invited from stakeholders unable to attend. The major output of the workshop, the *Hatchery Feeds Research & Development Plan 2000-2005,* therefore ought to express a national body of opinion.

Appendix 1: Intellectual Property

Intellectual Property from the workshop is in the public domain.

Appendix 2: Staff

Principal Investigator	David McKinnon Australian Institute of Marine Science P.M.B. No. 3 Townsville MC Qld 4810 Tel: (07) 4753 4292 Fax: (07) 4753 4429 email: d.mckinnon@aims.gov.au
Co-investigator	Mike Rimmer Qld Department of Primary Industries Northern Fisheries Centre P.O. Box 5396 Cairns Qld 4870 Tel: (07) 4035 0109 Fax: (07) 4035 1401 email: rimmerm@dpi.qld.gov.au
Co-investigator	Sagiv Kolkovski c/- Fremantle Maritime Centre 1 Fleet Street Fremantle WA 6160 Tel: (08) 9239 8102 Fax: (08) 9239 8105 email: skolkovski@fish.wa.gov.au
Workshop editor	Merv Littmann (Workshop Editor) 75 Cracknell Rd Annerley Qld 4103 Tel: (07) 3892 5756; Second telephone line: (07) 3848 1539 Mobile: 04 1257 3594 Fax: (07) 3892 5756 email: mervynn@ozemail.com.au

Appendix 3: Questionnaire

14 January 2000

Dear Aquaculture Stakeholder

Invitation to contribute to a Hatchery Feeds R&D Plan 2000/02 – 2005/06

There is a considerable Australian research commitment to the production of hatchery feeds and to the development of new feeds. However, with the expansion of aquaculture in Australia there is a need to improve coordination between the research organisations in the area of fish larvae feeds, and to identify opportunities and priorities for future research. The Fisheries R&D Corporation (FRDC) has recognised the need to adopt a more strategic approach to investing in research on this topic. Accordingly, FRDC has requested us to prepare a strategic R&D plan to more appropriately match the needs of industry. Such a plan will emphasise national R&D priorities for aquaculture hatchery feeds and will engage all relevant stakeholders including industry, government and researchers. The principal focus is to be on finfish aquaculture, but we welcome submissions relevant to other aquaculture sectors.

In formulating the R&D plan, we propose to:

1. Assess the status of hatchery feeds, including live and compounded feeds, and to identify research in progress
2. Prioritise research and development needs for hatchery feeds
3. Identify constraints to the continued development of Australian aquaculture in the area of hatchery feeds
4. Identify opportunities to enhance collaboration and information exchange amongst researchers and industry.

- You are invited to complete the following questionnaire and to participate in a workshop to develop an R&D plan for hatchery feeds in aquaculture for the period 2000/01-2005/06

The Questionnaire: Please complete and return all or part of this document to David McKinnon **by 29 February 2000** together with an indication of your intention whether or not to attend the workshop. Feel free to further consult on the content of your submission within your own immediate network of contacts. Submissions can be either hard copy, with hand-written comments marked directly on the document, or electronic. We ask you to make your comments from your own perspective, on the understanding that expertise, jurisdictional and geographic based differences will be adequately captured in the cross section of respondents. The Project Topics included in the questionnaire are a guide only, and are not intended to be all-inclusive. Please include any additional project topics in the row labelled "other". A comments section at the bottom of each page covers other contingencies. The Plan is for a five-year period from 2000/01 to 2005/6, and key issues and associated project topics should be prioritised within this timeframe ie. what can/should be done within the next five years. Anonymous submissions will be welcomed, should issues of propriety be involved.

- *The Workshop:* The workshop will be held in Cairns on 9-10 March 2000.The workshop will include status reviews of the five main areas of hatchery feeds research: microalgae, rotifers, *Artemia*, copepods, and compounded larval diets. We invite all stakeholders to participate, and to give a brief presentation on their research/industry needs. Presentations should be accompanied by the submission of an extended abstract (2-3 pages), which will be published as workshop proceedings in Acrobat format on the World Wide Web. We will include an inspection of the aquaculture facilities at the Qld. DPI Northern Fisheries Centre, including a demonstration of the development of hatchery feeds (microalgae, rotifers, *Artemia* and copepods) being undertaken at that facility. The main business of the workshop will be to consolidate and further refine all completed submissions into a draft R&D plan. Further details on the program and venue will be circulated in a following correspondence.

However, we realise that for reasons of time and money many stakeholders may not be able to attend, but we encourage those people to send us completed questionnaires so that we may be able to include their viewpoints. Those who would like to attend the workshop should contact David McKinnon directly as soon as possible, but no later than 29 February 2000.

The final draft Strategy is expected to be forwarded to FRDC for endorsement by the end of March, and made available to all stakeholders by the end of June, in good time for pre-proposals to be submitted to the FRABS for consideration for the 2001 funding cycle.

If you have any queries on these matters please feel free to contact us.

Dr David McKinnon Research Scientist Australian Institute of Marine Science PMB No 3 Townsville MC Qld 4810 Ph: (07) 4753 4292 Fax: (07) 4753 4429 d.mckinnon@aims.gov.au	Dr Mike Rimmer Principal Fisheries Biologist Northern Fisheries Centre Queensland Department of Primary Industries PO Box 5396 Cairns Qld 4870 Ph: (07) 4035 0100 Fax: (07) 4035 1401 rimmerm@dpi.qld.gov.au	Dr Sagiv Kolkovski Lead Scientist Mariculture Research and Advisory Group Fisheries WA Fremantle Maritime Centre 1 Fleet Street Fremantle WA 616- Ph: (08) 9239 8102 Fax: (08) 9239 8105 skolkovski@fish.wa.gov.au

Issues	Project topics	State/Region	Technology/ Experience	Research in Progress	Research needed (priority)
1. Microalgae Microalgal culture is the basis for all live hatchery feeds. What resources are available to aquaculture hatcheries, and how may these be improved?	Reference collections (e.g. CSIRO Hobart, NT Uni.)				
	Characterisation (e.g. Fatty acids. sugars, vitamins)				
	Concentration and preservation (e.g. centrifugation, flocculation, preservation)				
	Other				

General comments

Issues	Project topics	State/Region	Technology/ Experience	Research in Progress	Research needed (priority)
2. Rotifers Rotifers are the most widely used live feeds for first-feeding larval finfish. Size, nutritional profile and digestibility are problems, especially for fish such as groupers and tropical snappers, which have a very small mouth gape	Strains: L-strain (*Brachionus plicatilis*) S-strain (*Brachionus rotundiformis*) SS-strain (*B. rotundiformis*)				
	Selective breeding.				
	Resting egg production.				
	Nutritional composition, enhancement products				

2. Rotifers (cont.)	Other				

General Comments

Issues	Project topics	State/Region	Technology/ Experience	Research in Progress	Research needed (priority)
3. Brine Shrimp *Artemia* is the main live food in larviculture, especially in the later stages. As for rotifers, size, nutritional profile and digestibility are problems, but are compounded by supply problems, causing increases in the cost of *Artemia* cysts.	Nutritional composition, enhancement products.				
	Artemia replacements – *Parartemia*, local *Artemia* cysts				
	Other				

General Comments:

Issues	Project topics	State/Region	Technology/ Experience	Research in Progress	Research needed (priority)
4. Copepods Though research into copepod cultivation has been substantial, it has yet to be commercially viable. Current interest in high value marine finfish appears to require the development of copepod culture to improve larval survival.	Species: *Gladioferens, Tisbe, Acartia,* other?				
	Nutritional composition.				
	Production technology: Diet (quantity, microalgal species), Resting egg production.				
	Commercial-scale production				

4. Copepods (cont.)	Other				

General Comments:

Issues	Project topics	State/Region	Technology/ Experience	Research in Progress	Research needed (priority)
5. Enhancement products Spray dried products used in combination with live microalgae have shown enhanced growth of shellfish.	Commercially available: lipid emulsions, spray dried Schizochytrium				
	Developmental, e.g. Thraustochytrids				
	Other				

General Comments:

Issues	Project topics	State/Region	Technology/ Experience	Research in Progress	Research needed (priority)
6. Compounded / inert diets Advantages such as "off the shelf" availability, consistent nutritional profile and adaptability are outweighed by sub-optimal growth and survival of fish larvae. Advances have been made in weaning diets and in shortening the live food period.	Types, preparation methods				
	Additives (enzymes, hormones)				
	Feed attractants				
	Ingestion, assimilation				

6. Compounded / inert diets (cont.)	Nutritional value, ingredients				
	Other				

General Comments:

Appendix 4: Workshop Program

DAY 1 : 9 MARCH

Session 1 : Introduction

(CHAIR: DAVE MCKINNON

0830-0845 Opening Remarks, Housekeeping, *Dave McKinnon*
0845-0900 FRDC Perspective, Expected Outcomes, *Patrick Hone*

Session 2 : Review of Hatchery Feeds Technology

(CHAIR: MIKE RIMMER)

0900-0930 Review: microalgal culture, *Malcolm Brown*
0930-1000 Microalgal production system, *John Bayes*
1000-1030 Review: rotifer culture, *Stewart Fielder*

1030-1100 MORNING TEA

1100-1130 Review: *Artemia* culture, *Sagiv Kolkovski*
1130-1200 Review: copepod culture, *Dave McKinnon*
1200-1230 Review: artificial feeds, *Paul Southgate & Sagiv Kolkovski*

1230-1330 LUNCH (BLUE MANGO TERRACE)

Session 3 : Research in Progress

(CHAIR: SAGIV KOLKOVSKI)

1330-1350 CSIRO, *Malcolm Brown / Frances D'Souza*
1350-1410 Qld Department of Primary Industries, *Richard Knuckey / David Mann*
1410-1430 James Cook University, *Paul Southgate*
1430-1450 WA Fisheries, Fremantle Maritime Centre, *Sagiv Kolkovski / Mick Payne*
1450-1510 Curtin University, *Rob Rippingale*
1510-1530 Tasmanian Aquaculture & Fisheries Institute, *Stephen Battaglene / John Purser*

1530-1600 AFTERNOON TEA

1600-1620 University of Tasmania, *Tom Lewis*
1620-1640 South Australian Research & Development Institute, *Wayne Hutchinson*
1640-1700 Marine & Freshwater Resources Institute, *Lachlan McKinnon*
1700-1720 Flinders University, *Jian Qin*
1720-1740 University of Western Australia (*Parartemia*), *Brenton Knott*
1740-1800 Primo Aquaculture, *Liz Evans*

1900 DINNER – FISHLIPS (228 SHERIDAN STREET)

DAY 2 : 10 MARCH

Session 4 : Industry Perspectives

(CHAIR: MIKE RIMMER REPORTER: RICHARD KNUCKEY)

0830-0930 Discussion, tabulation of industry needs

Session 5 : Hatchery Feeds Survey

(CHAIR: SAGIV KOLKOVSKI)

0930-1000 Presentation of results of Hatchery Feeds Survey, *Dave McKinnon*

1000-1030 MORNING TEA

1030-1100 General discussion, filling in any gaps in Hatchery Feeds Survey.

Session 6: Discussion: Identification of Issues and Research Needs

1100-1200 Break-out groups in each of the following areas, with status reviewers as chairs:

MICROALGAE	Malcolm Brown (Chair), Frances D'Souza (Reporter)
ROTIFERS & *ARTEMIA*	Stewart Fielder (Chair), Wayne Hutchinson (Reporter)
COPEPODS	Dave McKinnon (Chair), Rob Rippingale (Reporter)
ARTIFICIAL FEEDS	Sagiv Kolkovski (Chair), Peter Appleford (Reporter)

Session 7: Prioritisation of Research Needs

(CHAIR: PATRICK HONE)

1200-1300 Reporters and session chairs summarise results of break-out sessions. This will provide a list of needs / topics in each area.
Prioritise topics for Hatchery Feeds Research [High / Medium / Low]

1230-1330 LUNCH (BLUE MANGO TERRACE)

1330-1430 Session 7 continued

Session 8: Wrap Up

(CHAIR: DAVE MCKINNON)

1500-1530 Where from here?
Communication strategies
Finalisation of R&D Plan

1530-1700 FIELD TRIP TO NORTHERN FISHERIES CENTRE

Appendix 5: Workshop Participants

Colin Adams
Wheatbelt Development Commission
P.O. Box 250
Northam WA 6401
Ph: (08) 9622 7222.
Fax: (08) 9622 7406

Peter Appleford
Department of Aquaculture
School of Marine Biology and Aquaculture
James Cook University
Townsville Qld 4811
Phone: (+61) 07-47815346
Fax: (+61) 07-47814585
Email: Peter.Appleford@jcu.edu.au

John Bayes
SeaSalter Shellfish (Whitstable) Ltd
The Hatchery
Old Roman Oyster Beds
Reculver, Kent CT6 6SX
United Kingdom
Ph 01227 363359, 01227 272003
Fax 01227 740518
email: seasalter@compuserve.com

Stephen Battaglene
Tasmania Aquaculture and Fisheries Institute
University of Tasmania
Marine Research Laboratories
Taroona Tas 7053
Ph: 03 6227 7268
Fax: 03 6227 7298
email: Stephen.Battaglene@dpiwe.tas.gov.au

Sue Blackburn
CSIRO Microalgae Research Centre (CMARC)
CSIRO Marine Research
GPO Box 1538
Hobart Tas 7001
Phone: 61 (0)3 6232 5307
Fax: 61 (0)3 6232 5000
email: Susan.Blackburn@marine.csiro.au

David Borgelt
Bluewater Barramundi
PO Box 4
Mourilyan Qld 4858
Phone: (07) 4063 2455
Fax: (07) 4063 2377

Malcolm Brown
CSIRO Marine Research
GPO Box 1538
Hobart Tas 7001
Ph: +61 3 6232 5037
Fax: +61 3 6232 5125
email: Malcolm.Brown@marine.csiro.au

Michael Burke
Department of Primary Industries, Queensland
Bribie Island Aquaculture Research Centre
P.O. Box 2066
Bribie Island Qld 4507
Ph: 07 3400 2051
Fax: 07 3408 3535
email: burkem@dpi.qld.gov.au

Liz Cox
Qld Department of Primary Industries
Northern Fisheries Centre
P.O. Box 5396
Cairns Qld 4870
Ph: 07 4035 0100
Fax: 07 4035 1401
email: CoxE@prose.dpi.qld.gov.au

Frances D'Souza
CSIRO Marine Research
PO Box 120
Cleveland Qld 4163
Ph: +61 7 3826 7290
Fax: +61 7 3826 7222
email: Frances.D'Souza@marine.csiro.au

Samantha Duggan
Australian Institute of Marine Science
P.M.B. No. 3
Townsville MC Qld 4810
Ph: 07 4753 4272
Fax: 07 4753 4429
email: s.duggan@aims.gov.au

Liz Evans
Primo Aquaculture Pty Ltd
PO Box 8007 MC
Coffs Harbour NSW 2450
Ph: 02 6655 4463
Fax: 02 6655 4463
email: primaqa@midcoast.com.au

Stewart Fielder
Marine Fish Breeding
NSW Fisheries
Port Stephens Research Centre
Taylors Beach, NSW , 2316
Ph: 02 4982 1232
Fax: 02 4982 1107
email: fielders@fisheries.nsw.gov.au

Andrew Fogarty
Tropical North Queensland Institute of TAFE
PO Box 1453
Innisfail Qld 4860
Ph: (07) 4043 8671
Fax:(07) 4061 4847
email: andrewfogarty@hotmail.com

Rod Grove-Jones
The South Australian Oyster Hatchery
PO Box 1579
Port Lincoln SA 5606
Ph: (08) 86 846115
Fax: (08) 86 846156
email: grofish@dove.net.au

Patrick Hone
Fisheries Research and Development Corp
PO Box 222
Deakin West ACT 2600
Ph: 02 6285 0412
Fax: 02 6285 4421
email: honep@frdc.com.au

Wayne Hutchinson
Coastal Finfish Aquaculture
South Australian Research and Development Institute (SARDI)
PO Box 120
Henley Beach SA 5022
Ph: 08 8200 2444 Mobile: 0417 018 933
Fax: 08 200 2481
E-mail hutchinson.wayne@saugov.sa.gov.au

Kevin Kane
SeaFood OnLine.Com Ltd.
P.O. Box 150
Hyde Park Qld 4812
Ph: 07 47 21 1599
Fax: 07 4721 1283
email: abbotbay@bigpond.com

Clive Keenan
Qld Department of Primary Industries
Bribie Island Aquaculture Research Centre
Bribie Island Qld 4507
email: keenanc@dpi.qld.gov.au

Matt Kenway
Australian Institute of Marine Science
P.M.B. No. 3
Townsville MC Qld 4810
Ph: 07 4753 4405
Fax: 07 4772 5852
email: m.kenway@aims.gov.au

Brenton Knott
Department of Zoology
The University of Western Australia
Nedlands WA 6970
Ph: (08) 9380 2223 (office) (08) 9380 3970 (lab)
Fax: (08) 9380 1029
e-mail: bknott@cyllene.uwa.edu.au

Richard Knuckey
DPI Northern Fisheries Centre
PO Box 5396
Cairns Qld 4870
Phone: (07) 4035 0103
Fax: (07) 4035 1401
E-mail: knucker@dpi.qld.gov.au

Sagiv Kolkovski
c/- Fremantle Maritime Centre
1 Fleet Street
Fremantle WA 6160
Ph: 08 9239 8102
Fax: 08 9239 8105
email: skolkovski@fish.wa.gov.au

Tom Lewis
School of Agricultural Science
University of Tasmania
GPO Box 252–54
Hobart Tas 7001
Mobile: 0417 537 806
Fax: (03) 6226 2642
email: Tom.Lewis@utas.edu.au

John Lindsay
Pisces Marine Aquaculture Pty Ltd
PO Box 80
Maclean NSW 2463
Ph: 02 66 467033
Fax: 02 6646 7061
email: hmgr@ozemail.com.au

Merv Littmann (Workshop Editor)
75 Cracknell Rd
Annerley Qld 4103
Phone: (07) 3892 5756; Mobile: 04 1257 3594
Second phone line: (07) 3848 1539
Fax: (07) 3892 5756
email: mervynn@ozemail.com.au

David McKinnon
Australian Institute of Marine Science
P.M.B. No. 3
Townsville MC Qld 4810
Ph: 07 4753 4292
Fax: 07 4753 4429
email: d.mckinnon@aims.gov.au

Lachlan McKinnon
Marine and Freshwater Resources Institute
PO Box 114,
Queenscliff VIC 3225
Phone: (03) 52580212; Mobile: 0407987011
Fax: (03) 52580270
email: lachlan.mckinnon@nre.vic.gov.au

Rod McNeal
Aquamats
303 Kerr Dam Road
PO Box 876
Polson
Montana USA 59860
Ph: 0011 +1 40 6883 8590

Dave Mann
Qld Department of Primary Industries
Bribie Island Aquaculture Research Centre
Bribie Island Qld 4507
email: mannd@dpi.qld.gov.au

Adam Maskew
Oceanwest Fisheries
PERTH OFFICE
Lot 103 Jade St
Maddington 6109
Ph: (08) 9493 2353
Fax: (08) 9493 2453
HATCHERY SITE
C/- GiraliaStation
Burkett Rd
Via Carnavon
Ph: (08) 9942 5962; Mobile: 0419 19 8161
Fax: (08) 9942 5972
email: oceanwest@nwc.net.au

Steve Mawer
Morefish
10 Bruce St
Morphett Vale SA 5162
Mobile: 0408 809 251
email: smawer@powercom.com.au

Antonio Mozqueira
Ocean Wave Seafoods
Dandos Road (P.O. Box 190)
Lara Vic 3212
Ph: 03 5282 5350
Fax: 03 5282 5354
email: abalone@austasia.net

Mick Payne
c/- Fremantle Maritime Centre
1 Fleet Street
Fremantle WA 6160
Ph: 08 9239 8000
Fax: 08 9239 8080
email: epayne2@cc.curtin.edu.au

Doug Pearson
ProAqua
PO Box 929
Hamilton Qld 4007
Ph: (07) 3268 2727; Mobile: 0408 735 185
Fax: (07) 3268 2999
email: dougpearson@bigpond.com

John Purser
Tasmania Aquaculture and Fisheries Institute
University of Tasmania
PO Box 1214
Launceston Tas 7250
Ph: 03 6324 3820
Fax: 03 6324 3804
email: John.Purser@utas.edu.au

Jian Qin
School of Biological Sciences
Flinders University
GPO Box 2100
Adelaide SA 5001
Ph: 61 8 8201 3045
Fax: 61 8 8201 3015
email: jian.qin@flinders.edu.au

Ramon Ramos
SeaFood OnLine.Com Ltd.
P.O. Box 150, Hyde Park
Townsville Qld 4812
Ph: 07 47 21 1599
Fax: 07 4721 1283
email: abbotbay@bigpond.com

Bob Richards
Australian Barramundi Culture P/L
PO Box 73
Sanderson NT 0812
Ph: (08) 89 272426. Farm (08) 89 88121
Fax: (08) 89 272010

Mike Rimmer
Qld Department of Primary Industries
Northern Fisheries Centre
P.O. Box 5396
Cairns Qld 4870
Ph: 07 4035 0109
Fax: 07 4035 1401
email: rimmerm@dpi.qld.gov.au

Rob Rippingale
Environmental Biology
Curtin University
Bentley WA 6102
Ph: 08 9266 9266
email: R.Rippingale@info.curtin.edu.au

Gale Semmens
Qld Department of Primary Industries
Northern Fisheries Centre
P.O. Box 5396
Cairns Qld 4870
Ph (07) 4035-0160
Fax: 07 4035 1401
email: SemmenG@prose.dpi.qld.gov.au

Alex Sobluski
Harvest Home Holdings
PO Box 3
Mount Molloy Qld 4871
Ph: (07) 4060 2101
Fax: (07) 4060 2109

Paul Southgate
School of Marine Biology and Aquaculture
James Cook University
Townsville Qld 4811
Phone: (+61) 07-47815737
Fax: (+61) 07-47814585
email: Paul.Southgate@jcu.edu.au

Brendan Spillman
Clean Seas Aquaculture SA
PO Box 80
Arno Bay SA 5603
Ph: 08 8628 0220
Fax: 08 8628 0221
email: martloip@epc.net.au

Cameron Talbot
Pacific Reef Fisheries Pty Ltd
Lot 1 Trent Street
Ayr Qld 4807
Phone: (07) 4783 6068.
Fax: (07) 4783 606

Appendix 6: Contents of *'The Hatchery Feeds Research and Development Plan 2000-2005'*

Appendix 7: Contents of '*The Proceedings of a Hatchery Feeds Workshop, Cairns 9-10 March 2000*'

Research in Progress

Stephen Battaglene, John Purser, Piers Hart and David Morehead. Priorities for live feed production and research in Tasmania.

Susan Blackburn, Cathy Johnston and Dion Frampton. CSIRO Microalgae Research Centre – microalgae for aquaculture, biotechnology and the environment.

Malcolm Brown, Graeme Dunstan, Piers Hart and Arthur Ritar. Polyunsaturated Fatty Acid and Ascorbic Acid Enrichment of Zooplankton.

Michael Burke. Marine fingerling production at the Bribie Island Aquaculture Research Centre. Intensive green water culture – a historical perspective.

Frances D'Souza. Optimising penaeid larvae growth and nutrition: Methods for Artemia, copepods and rotifers.

Wayne Hutchinson. Live feed production in South Australian aquaculture.

Brenton Knott and Colin Adams. The *Parartemia* Working Group.

Richard Knuckey, Gale Semmens and Bernard Della-Rodolfa. Live Prey Research Unit, QDPI Northern Fisheries Centre, Cairns.

Tom Lewis, Peter Nichols and Tom McMeekin. Production of polyunsaturated fatty acids by Australian thraustochytrids: aquaculture applications.

David L. Mann, Tom Asakawa, Morris Pizzutto, Clive P. Keenan and Ian J. Brock. Hatchery feeds for the mud crab *Scylla serrata*: Towards a nutritionally complete diet.

Lachlan McKinnon and Brett Ingram. Victorian hatchery feed production and development.

M. F. Payne. Cultured copepods as live food for fish.

Jian G. Qin and Troy Hillier. Live Food and Feeding Ecology of Larval Snapper (*Pagrus auratus*).

R.J. Rippingale. Intensive cultivation of a calanoid copepod.

Paul Southgate and Sagiv Kolkovski. Development of artificial diets for fish larvae.

Industry Perspectives

John Bayes. Latest developments in low cost, low impact phytoplankton production for feeding molluscs and zooplankton for the shrimp and fish farming industry, or: How to produce it?

Liz Evans. Artemia, The Turning Point: Industry research priorities in a world short of *Artemia*.

Rodney Grove Jones. Production of live microalgal feed.

Adam Maskew. A synopsis of aquaculture in WA.

Antonio Mozqueira. Ocean Wave Seafoods.

Mike Rimmer. Issues raised in general discussion at the Hatchery Feeds Workshop, Cairns 9-10 March 2000.

Brendan Spillman. Clean Seas Aquaculture Pty. Ltd.