Biofloc Research Extension Project

Final Report 2012/729

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AUSTRALIAN SEAFOOD COOPERATIVE RESEARCH CENTRE

May 2015

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ISBN 978–0–9942147–5-1

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ACRONYMS

ABFA	Australian Barramundi Farmers Association
APF	Australian Prawn Farms
APFA	Australian Prawn Farmers Association
BFT	Biofloc Technology
CRC	Cooperative Research Centre
DEEWR	Department of Education, Employment and Workplace
DERM	Department of Environment and Resource Management (QLD)
FRDC	Fisheries Research and Development Corporation
GBRMPA	Great Barrier Reef Marine Park Authority
SEWPAC	Department of Sustainability, Environment, Water, Population and Communities

ACKNOWLEDGEMENTS

Graham Mair	Seafood CRC
Matt West	Australian Prawn Farms
John Moloney	Pacific Reef Fisheries
David Mann	QLD Department of Agriculture and Fisheries
Mark Oliver	Aquaculture Support Services
Helen Jenkins	Australian Prawn Farmers Association
Nyan Taw	Blue Archipelago Berhad
Michelle Burford	Griffith University
Yoram Avnimelech	Technion. Israel Institute of Technology
Madeleine Burke	Hyphen IT
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Gustaaf Hallegraef	University of Tasmania

Special acknowledgement must be made to Emily Mantilla of the Seafood CRC for her patience and belief in the project and for the provision of sound guidance throughout, for without her unwavering support the project would certainly not have succeeded.

1.0 NON-TECHNICAL SUMMARY

Biofloc Research Extension Project 2012/729

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1.1 OBJECTIVES

The objectives of this project were to design, develop and deliver a targeted series of extension activities on the mechanisms, methodology and management of low-water exchange, microbial floc prawn production for Australian prawn farmers. This was in support of the research into low water exchange, microbial floc production carried out by Smith and West 2009 (Seafood CRC Project No 2009/748), which demonstrated significant potential benefits from the implementation of biofloc technology for Australian farmed prawn production.

1.2 EXECUTIVE SUMMARY

The Smith and West 2009 biofloc research (Seafood CRC Project No 2009/748) is considered to have significant implications for the Australian prawn industry. Smith and West demonstrated that a low water-exchange, microbial floc system *can* work and *can* deliver increased productivity and other benefits for *Penaeus monodon* production under Australian conditions.

Their research highlighted the potential for biofloc technology to be applied effectively in Australian *P. monodon* production. What the research did not (and, due to the site specific methodology of biofloc technology, could not) deliver was a set of rules or guidelines that all Australian prawn farmers could follow in order to implement their own biofloc technology systems. A generic, one size fits all, biofloc technology management system is not feasible due to the variable nature and complexity of the processes involved in biofloc system methodology and the differences in climate, site soil conditions, infrastructure and other influencing factors between farms. However, the Seafood CRC identified the importance of Smith and Wests' work for the Australian Prawn farming industry and determined that there was a distinct need for further extension of their research.

To ensure that the Seafood CRC extension initiative delivered the largest possible benefit for industry, the Seafood CRC agreed to facilitate a detailed consultation with Australian prawn farming industry stakeholders to identify concepts for biofloc research extension activities. The results of the consultation indicated that development of an appropriate extension program required a dual approach; firstly to raise industry awareness of the potential of biofloc technology through delivery of its underpinning principles. This would form the foundation from which individual operators could validate biofloc as a viable production system and determine the feasibility of integrating such an approach within their existing business structure. Secondly, extension activities would need to facilitate operator access to biofloc management information resources to enable successful on-farm trials to be confidently and sustainably up-scaled and incorporated into existing farm management protocols.

The consultation identified a critical need for the development of targeted training and information resources to address the identified gaps in operator knowledge and skill level regarding biofloc system mechanics, risks, benefits and implementation. This would provide operators with the right level of knowledge, skill and understanding of biofloc system dynamics needed for them to be able to develop and implement their own BFT management systems if and where appropriate.

The following range of extension activities were developed directly from the feedback gained from Australian prawn farming industry operators and associated stakeholders. Three phases of extension activities were planned, with Phase 2 and 3 only getting the green light if there was a significant commitment by industry. Phase 1 was extended to all Australian prawn farming association members. However, before the next phase of extension activities could proceed, industry members were encouraged to demonstrate commitment to the extension program (now dubbed the Floc Program) and industry stakeholders were offered access to the full range of Floc Program activities for a small fee per farm of $500. The stop/ go criterion at this point was to get over 50% of farmers on board with the Floc Program – which was subsequently achieved.

Phase 1

- A summary of the Smith and West 2009 research results for dissemination to industry.
- Development of a generic 'Start-Up' guide to *P. monodon* biofloc implementation.

Phase 2 (Floc Program)

- Development and facilitation of a 2-day Advanced Pond Management training course incorporating critical water chemistry elements and associated biofloc dynamics.
- Development of a webinar support series for industry to provide targeted information on biofloc technology implementation.

Phase 3 (Floc Program)

- Development of a Unit of Competency on biofloc for inclusion in the VET system.
- Development of an online directory to host information on algal species, behaviour and management.

The Seafood CRC biofloc research extension project has concluded with a diverse series of strategically developed activities designed and delivered in consultation with the Australian prawn farming industry to provide maximum benefit to industry.

While it is not yet feasible to *quantify* the benefits that these extension activities have had or are having on Australian farmed prawn production, we can propose in the conclusion how these extension activities will serve to leave a lasting Seafood CRC legacy for the Australian farmed prawn industry.

2.0 BIOFLOC RESEARCH BACKGROUND

Low water exchange, microbial floc shrimp production technology, or ***'biofloc technology' (BFT)*** as it is now termed, was first applied commercially in the Americas in the 1990's as an alternative pond management method to conventional flow-through shrimp culture systems.

The underlying principle of a BFT system is the promotion of a bacteria-dominated, stable ecological pond environment, instead of a phytoplankton-dominated system, which can be highly unstable. The concept behind a BFT system is that the pond is controlled as an integrated system and that water quality, shrimp production and disease are managed collectively.

Any nutrients that are added to the system that are not retained as shrimp biomass, are recycled through microbial processes within the pond and form a flocculation of bacteria, algae, protozoa and zooplankton. These flocs provide an additional nutrient source for the shrimp that would otherwise have been discharged from a conventional flow-through system. A BFT system, at its core, is a clever in-pond adaptation of a mixed bed bio-reactor.

BFT systems have several advantages over conventional flow-through culture systems. A BFT system provides a stable culture environment in which shrimp thrive under and survival rates are high. Higher stocking densities are possible using BFT. Biosecurity levels are increased. Shrimp graze on the bacterial floc that accumulates in a BFT system, thereby allowing better feed utilization. Discharge volumes are reduced due to the low water exchange requirements, thereby lessening environmental impact. (Avnimelech, 2009).

BFT has been successfully applied in the Americas, China, Indonesia and Thailand for the commercial production of Pacific white shrimp (*Litopenaeus vannamei*). Belize Aquaculture Ltd in Central America was one of the pioneers of this technology and remains the most well known commercial producer of shrimp under biofloc conditions, so much so that many in the industry still refer to biofloc shrimp production methodology as the "Belize" system. The overall benefit from the application of BFT systems in shrimp production has been the significant increase in pond productivity. Belize Aquaculture Ltd achieved 15mt/*L. vannamei*/ha very early on after first implementing BFT, and P.T. Central Pertiwi Bahari, C. P. Indonesia have been able to achieve average production volumes of over 20mt/*L. vannamei*/ha in later years using BFT systems. (Nyan Taw, 2010). In comparison, the Australian industry average for prawn production of *P. Monodon* is currently 8mt/ha utilizing conventional flow-through systems. (Jenkins, 2011).

The economic viability of the Australian prawn farming industry is threatened by significant increases in south-east Asian farmed prawn production volumes and a resulting decrease in global prawn prices. There is a pressing need for Australian prawn farmers to develop production technology for black tiger prawns that will facilitate increased production efficiencies in order to counter the growing problems of rising production costs and cheaper overseas imports. The Australian industry is also under increasing pressure from environmental regulators to reduce the scale and impacts of sediment and nutrient discharges from prawn farms (Smith and West 2009).

In late 2005, Australian Prawn Farms Pty Ltd (APF) began to investigate the potential for the application of low water exchange, microbial floc production methodology for farming of black tiger prawns, *Penaeus monodon*, under Australian conditions.

After researching BFT production systems used for *L. vannamei*, APF concluded that this type of system would not suit the culture of *P. monodon* under Australian conditions and would not be compatible with the APF business model. Therefore a direct transfer of the BFT methodology used in *L. vannamei* production was not possible. APF trialled a less intensive method, using lower stocking densities and consequently lower feed and nutrient inputs, which resulted in a lower biofloc density than is commonly attained in BFT systems used for *L. vannamei*.

In the 2005/6 season, APF successfully reared and harvested a crop of *P. monodon* from six, low water exchange ponds, and in some cases were able to increase the productivity of the ponds. However, there was some uncertainty about the manipulation of finer elements of the system in order to ensure that this success could be repeated again the following season. It was clear that to make further progress, there was a need for broader and more extensive research than could be done by APF alone. (Smith & West, 2009)

A research project was commenced by principle investigator Dr David Smith (CSIRO Marine and Atmospheric Research), and Matt West (Australian Prawn Farms). The project was funded through the Seafood CRC program and addressed the key issues stated in Challenge 1 of the FRDC Research and Development Plan (2005-2010):

Increasing the profitability of *Penaeus monodon* farms via the use of low-water exchange, microbial floc production systems at Australian Prawn Farms. David M. Smith and Matt West. Project No. 2009/748

The results of the project were significant as the research at Australian Prawn Farms demonstrated that the effective co-management of algal and bacterial communities for control of water quality ***can*** deliver increased productivity and other benefits for *P. monodon* production and that this production method represents a viable alternative management technique for *Penaeus monodon* production under Australian conditions. *See Appendix 6.3 for a summary of these results.*

2.1 POTENTIAL INDUSTRY BENEFITS AND ADOPTION OF BIOFLOC

2.1.1 SHORT TERM BENEFITS:

APF has been able to utilize the research findings to develop and advance its existing pond management systems and operational procedures to incorporate low water-exchange, microbial floc production methodology across its entire operations.

Benefits to Australian Prawn Farms include:

Increased productivity by 50% from 8 tonnes/ha to 12 tonnes/ha giving an increased production value of approximately $65,000 per pond.

Reduction of nitrogen discharge into the environment by 77%

Reduction of water exchange by 70%

Reduction in feed costs per unit weight of production by 30%

Two other farms within the Australia prawn farming industry have adopted a low water-exchange, microbial floc pond management system, either fully (Eimeo) or in a hybrid form with a view to increasing integration of this system into its operations (Pacific Reef).

2.1.2 MEDIUM TERM BENEFITS:

The Australian prawn farming community is noting with interest the productivity outcomes accomplished by APF by their adoption of low water-exchange, microbial floc technology production systems. The Smith and West 2009 biofloc research will not result in a set of operational protocols to instruct Australian *P. monodon* farmers on how to adopt low water-exchange, microbial floc production systems. Rather it will provide farmers with information to assist them in determining whether this type of production system is viable for their operations, and if so, will then help them to identify key parameters that will need to be monitored and incorporated into their pond management systems.

2.1.3 LONG TERM BENEFITS:

Within any agricultural sector, innovative developments towards farming methods that lead to a reduction in nutrient discharge levels into coastal waters will benefit the environment and therefore the wider Australian community. From a prawn farming industry perspective, low water-exchange production technology, *if properly incorporated and managed*, could lead to better opportunities for industry viability and expansion as a result of reduced environmental impact and an improved perception of the industry by regulators.

2.2 EXTENSION ACTIVITIES CARRIED OUT PRIOR TO THIS PROJECT

In late 2009, Matt West of Australian Prawn Farms prepared a list of the basic requirements operators require to run a biofloc system. This list was circulated to Australian Prawn Farmers Association members along with an invitation for expressions of interest to attend a workshop about the system. 18 individuals from 5 farms confirmed their interest in attending a workshop.

In May 2010, Stuart Whitney of Sunshine Coast Institute of TAFE and Matt West of Australian Prawn Farms ran a strategic planning workshop pitched at prawn farm managers and owners. The aim was to give farmers an overview of the prerequisite management and infrastructure requirements that are needed in order to implement a viable low-water exchange biofloc pond management system.

The participants were funded under the Farm Ready grant program and the workshop was framed under the unit titled RTE6903A Develop and Review a Strategic Plan, which is an Advanced Diploma level competency within the Seafood Industry Training Package (Aquaculture).

Matt West (APF), who covered the principle requirements of a low-water exchange biofloc pond management system, delivered the first day of the workshop. The second day was delivered by Stuart Whitney (SC TAFE) who covered the steps of strategic business planning in context with implementing a low-water exchange biofloc pond management system.

The participants were awarded a certificate of attendance and thereafter had the option of completing the assessment for the unit that encompassed creating a strategic plan for biofloc implementation for their farm. This assessment covered basic principles of developing a strategic plan / business plan and covered areas such as expenditure / budgeting / up-skilling / infrastructure and would have been a valuable exercise from a business perspective for the farmers committed to changing their production management methods.

No farmers completed the strategic planning assessment, however several of the participants have gone on to trial some form of low-water exchange methodology in-situ at their farms.

David Smith took the opportunity to attend the APFA / ABFA conference in 2010, to speak with several prawn farmers in attendance to gauge their interest in adopting low-water exchange, microbial floc technology as a pond management tool. The feedback that David received was that there were currently not many prawn farmers with the essential combination of business incentive / infrastructure / staffing capacity / staff acumen to warrant a move towards adopting biofloc technology wholeheartedly as a pond management system. However there were several farmers who were aware of the significance and potential advantages of biofloc technology as a production tool and who were keen to gain a greater level of understanding on the subject.

In July 2010, David sent a concept plan to the Seafood CRC proposing the idea of delivering a Masterclass for prawn farmers on the principles of running a low-water exchange, microbial floc system. The pre-requisite for the attendees would have been an understanding of basic water chemistry and microalgal identification. David would then have gone through the *driving parameters* of a low-water exchange, microbial floc system.

However, David began to have concerns about possible ramifications of accountability and the liability involved in delivering expert “how to” instruction on a pond management methodology that can easily be misinterpreted in its implementation with potentially ruinous consequences. These concerns, coupled with the demands on David’s time from his own consultancy business, lead David to reconsider his preparedness to commit to ensuing project extension activities.

3.0 IDENTIFICATION OF BIOFLOC RESEARCH EXTENSION PROJECT ACTIVITIES

In August 2010, the Seafood CRC introduced its Seafood Highway Extension program with the aim of identifying pertinent research results, developing concept plans and delivering effective and relevant training and productivity outcomes to industry.

It was determined that there was still extension work that needed to be done from the Smith and West 2009 biofloc research as it has such significant implications for the Australian prawn industry. To ensure that a Seafood CRC biofloc extension initiative delivered the largest possible benefit for industry, the Seafood CRC agreed to facilitate a detailed consultation with Australian prawn farming industry stakeholders to identify concepts for biofloc research extension activities.

The consultation with Australian prawn farming industry stakeholders was designed to extract the following information:

- The current status of biofloc technology uptake within the Australian prawn farming industries. (NB The Australian Barramundi Farmers Association was also included in the consultation process).
- The primary motivators for adoption or rejection of biofloc technology systems.
- The problems encountered during implementation of biofloc technology.
- The measurable benefits gained through adoption of biofloc technology.
- The resources / information / training that could assist with adoption and implementation.

The key findings from the consultation were as follows:

- At the time of the consultation, 16% of prawn farm operators (n=3) had committed to incorporating biofloc technology as a production method in full or in a hybrid form. Another 26% (n=5) were trialling biofloc technology whilst the remaining 58% (n=11) of operators were not incorporating or trialling biofloc systems.
- Small-scale trials of biofloc technology had been conducted by saltwater Barramundi farm operators but without success. Further investigation are still required before any conclusion can be made as to the potential for application of biofloc systems in barramundi culture.

- The principle motivator (42% of responses) behind biofloc technology adoption for prawn farmers is to *maintain pond water stability to increase survival rates.*

- The main problems encountered during implementation of biofloc technology are associated with *algal blooms and floc stability* (68% of responses) and *cost of implementation* (16% of responses)

- Of those farms incorporating biofloc technology, Australian Prawn Farms is, to date, the only prawn farm that has been able to *quantify* the benefits gained from biofloc technology implementation. The biofloc system at Australian Prawn Farms has demonstrated an increase in production value by an estimated $65,000 / ha

- The principle motivator (33% of responses) behind not incorporating biofloc technology is a *lack of operator / staff knowledge*.

- It is not possible to develop a generic series of *formulaic* biofloc production management protocols due to the array of influencing farm and pond specific variables that affect the viability of a biofloc system, however a generic 'start-up' guide to implementation may be possible to develop.

- All stakeholders contacted were interested in gaining a better understanding about biofloc technology systems and the dynamics involved.

- Industry expressed that further biofloc extension activities be focussed on three main areas: *information on algal triggers; general information on biofloc dynamics;* and *advanced pond management / water chemistry training*

This consultation with the Australian prawn farming industry and associated stakeholders concluded that there was a **distinct need for targeted extension** to the Smith and West 2009 biofloc research.

Despite its successful adoption by Australian Prawn Farms and the reported benefits to farm productivity most Australian prawn farmers regarded biofloc technology with reserved interest as a prospective but complex, potentially costly and as yet unproven production tool.

The consultation determined that the Australian prawn farming industry has the capacity to develop the technical resources and appropriate infrastructure required for biofloc technology system adoption. However it revealed that over a third of industry operators do not yet feel that they have enough understanding of biofloc dynamics to confidently commit the financial and operational resources required for system trials and subsequent adoption.

It was clear that any extension process to the Smith and West 2009 research should begin by increasing operator knowledge of the fundamentals of BFT dynamics to give operators the skill level and confidence to initiate or build upon their own on-farm trials.

Industry uptake of biofloc technology will need to begin at the individual operator level starting with a management commitment to invest in the right infrastructure and human resources / staff training required for effective system implementation. Operators can be provided with a list of infrastructure requirements and training and information on the principles of biofloc dynamics but a turnkey "one size fits all" package on how to run a biofloc system is not feasible due to the many influencing variables that affect the viability of a biofloc system.

The consultation identified a critical need for the development of targeted training and information resources to address the identified gaps in operator knowledge and skill level regarding biofloc system mechanics, risks, benefits and implementation. This would provide operators with the right level of knowledge, skill and understanding of biofloc system dynamics needed for them to be able to develop and implement their own BFT management systems if and where appropriate.

The following range of extension activities were developed directly from the feedback gained from Australian prawn farming industry operators and associated stakeholders. Three phases of extension activities were planned, with Phase 2 and 3 only getting the green light if there was a significant commitment by industry. Phase 1 was extended to all Australian prawn farming association members. However, before the next phase of extension activities could proceed, industry members were encouraged to demonstrate commitment to the extension program (now dubbed the Floc Program) and industry stakeholders were offered access to the full range of Floc Program activities for a small fee per farm of $500. The stop/ go criterion at this point was to get over 50% of farmers on board with the Floc Program – which was subsequently achieved.

Phase 1

- A summary of the Smith and West 2009 research results for dissemination to industry.
- Development of a generic 'Start-Up' guide to *P. monodon* biofloc implementation.
- Short presentation of the results of the biofloc extension consultation and opportunity to pitch Phases 2 and 3 of the extension program to industry at the ABFA/APFA conference held in Cairns 1-3 August 2012

Phase 2 (Floc Program)

- Development and facilitation of a 2-day Advanced Pond Management training course incorporating critical water chemistry elements and associated biofloc dynamics.

- Development of a webinar support series for industry to provide targeted information on biofloc technology implementation.

Phase 3 (Floc Program)

- Development of a Unit of Competency on biofloc for inclusion in the VET system.

- Development of an online directory to host information on algal species, behaviour and management.

A detailed description of each activity, the rational for the activity and the outcome achieved from each extension activity is described below.

4.0 BIOFLOC RESEARCH EXTENSION PROJECT ACTIVITIES AND OUTCOMES

4.1 Summarise the Smith and West 2009 research results and disseminate to industry.

RATIONALE:

Most operators consulted had not read the Smith and West 2009 paper although they were familiar with the research and its outcomes. It was suggested that the research results be summarised and presented from a farmers perspective, focussing on the practical findings and resultant benefits to productivity for Australian Prawn Farms, and then forwarded to prawn farm industry operators and associated stakeholders.

OUTCOME:

The Smith and West 2009 paper was summarised in an 8-page document that was appended at the back of the document "Application of low water exchange microbial floc technology for production of *Penaeus monodon* under Australian conditions. Start Up Guide. Seafood CRC. 2012/729. 2013" and was distributed to all Australian Prawn Farm Association members.

4.2 Develop a generic 'Start-Up' guide to *P. monodon* biofloc implementation.

RATIONALE:

Although it is not currently feasible to develop a generic *formulaic* series of management protocols for biofloc implementation on Australian *P. monodon* farms, there was scope to develop a 'Start-Up' guide to biofloc technology implementation. This would be in the form of a guide containing a *basic* series of parameters that are non-formulaic but that, in practical language, encompass essential prerequisites to successful biofloc system implementation such as infrastructure requirements, nutrient conditions and management tips.

OUTCOME:

The document "Application of low water exchange microbial floc technology for production of Penaeus monodon under Australian conditions - A Start-Up Guide" was developed in consultation with Australian Prawn Farms and Pacific Reef Fisheries in addition to the use of research literature on biofloc technology, with significant information extracted from

"Biofloc Technology, A Practical Guidebook by Yoram Avnimelech" - still the leading text on biofloc technology.

This start-up guide contained important recommendations and advice for Australian prawn farmers who were considering the adoption of a low water exchange, microbial floc production system for use within their farming operations.

The guide covered the principles of traditional "Biofloc Technology" but aimed to dispel some of the myths of what Australian prawn farmers until now had understood "Biofloc Technology" to be and re-position the science within the Australian prawn-farming context in order to accurately explain the low water exchange, microbial floc methodology that is currently being utilised within the Australian prawn farming industry.

The guide was not written as a "how to" for farmers wanting to learn the practical methods of implementing a low water exchange, microbial floc production system because this is a relatively new area of pond management and more research is required into the application of this technology for intensive commercial black tiger / banana prawn farming under the range of variable Australian conditions before a "how to" manual can begin to be considered. Rather, the guide was aimed at providing farmers with an overview on what they need to know and what steps they will need to take before adapting a low water exchange, microbial floc approach for their production.

The guide also recommended research papers, books and other publications that have been written on the subject of biofloc technology, water chemistry and the behaviour and ecology of microbial communities within aquatic systems, that farmers may find useful when researching implementation methods and management strategies.

Copies of the Start-Up Guide were distributed to all Australian Prawn Farming Association members.

4.3 Gain commitment from >50% of farmers to take part in the Floc Program

RATIONALE:

In order to get industry buy-in and commitment to the Biofloc Extension Project it was determined that each farm should be prepared to pay a small fee to take part in Phase 2 and 3 of the extension initiative. The invitation was open to all prawn industry stakeholders including not only farmers but also, for example, academic institutions and feed companies. The next two phases of the extension initiative were collectively named the "Floc Program" and stakeholders were asked to contribute a nominal $500 per company / institution, to take part in the initiative. This was a stop / go point for the biofloc extension project and the aim at this stage was to continue with the initiative only if more than 50% of Australian Prawn Farmers signed up to take part.

OUTCOME:

The response was very good with 9 out of 15 prawn farms joining the Floc Program. (See participant list of Advanced Pond Management Training Initiative below).

4.4 Develop and facilitate a 2-day Advanced Pond Management training course that incorporates critical water chemistry elements and associated biofloc dynamics.

RATIONALE:

The concept behind the advanced pond management training course was for a learning experience for those prawn farmers who wanted to gain a greater understanding of the complex dynamics of a microbial floc based production system and how these systems can be successfully managed.

During the biofloc extension consultation process it was found that the principle motivator for operators choosing *not* to incorporate biofloc technology in their operations was the lack of knowledge held by them and their staff. Operators recognise that to manage a biofloc system successfully requires a good understanding of water chemistry and pond dynamics. The feedback from operators suggests that personnel with the necessary knowledge of water chemistry and pond dynamics to understand and properly manage a biofloc technology system are in short supply in the prawn farming industry. Responses indicate that even graduates from university aquaculture programs do not often possess a high enough level of knowledge of water chemistry and pond dynamics and must first undergo several years of in-situ training before they have the expertise to become effective pond managers.

It was determined that farmers wanted a course to be led by an industry expert in the field of biofloc technology who had hands on in situ experience of the application of biofloc in prawn production. They wanted the course to focus particularly on algal behavior, water chemistry, bacterial populations, wastewater management and business management.

OUTCOME:

FLOC Program and Advanced Pond Management Workshop 29th – 30th July 2013, Palm Cove, QLD.

A two-day Advanced Pond Management workshop was held at Palm Cove, QLD just prior to the Australian Prawn and Barramundi Farmers Conference 2013.

The workshop facilitator was Dr Nyan Taw who at the time was the Senior Technical Advisor / General Manager of Blue Archipelago; an integrated shrimp company in Malaysia, and who has over 30 years experience in global shrimp farming. Nyan had made a significant contribution to the global shrimp industry through the development and commercial application of microbial floc technology and has had hands-on experience with the application of microbial floc technology for both *P. monodon* and *L. vannamei.* Nyan is therefore one of only a handful of experts on microbial floc prawn production worldwide suitably qualified to undertake the training.

The workshop was open to all Floc Program participants and other stakeholders that wanted to attend could do so upon becoming a Floc Program member. The workshop participants were:

Ying Lii	Ausfarm
Steve Lii	Ausfarm
Matt West	Australian Prawn Farms
Nyan Taw	Blue Archipelago
Ten (Had Ming)	Coral Sea Farms
David Mann	DAFF
Luke Rossman	GI Rural
Geoff Rossman	GI Rural
Julii Tyson	Humpty Doo Barramundi
Bob Richards	Humpty Doo Barramundi
Greg Smith	IMAS
Mark Oliver	LMC Training
Glen Wormald	Pacific Reef Fisheries
Marcus Pyne	Pacific Reef Fisheries
John Moloney	Pacific Reef Fisheries
Brad Callcott	Pacific Reef Fisheries
Wayne Di Bartolo	Pacific Reef Fisheries
Kristian Just	Ridley Agriproducts
Paul Skordas	SARDI
James Tyrer	Seafarm
Andrew Crole	Seafarm
Anni Conn	Seafood CRC
Matt Briggs	Shrimp Doctor

The training was held on the 29th and 30th July 2013 at the Novotel, Palm Cove, QLD and consisted of presentations from Nyan followed by group discussions. The workshop covered the following topics:

- Prawn growth and effect on water quality / chemistry
- The nitrogen cycle / nitrogen removal pathways and other toxic residues.
- Algal and bacterial growth / species and effect on water quality / chemistry
- Additives / inputs and effect on the pond ecosystem / water quality / chemistry
- Water exchange and weather events and effect on water quality / water chemistry
- Benefits / risks of a biofloc based production system
- Infrastructure / staffing / resources
- Floc pond development – what happens and how
- Floc pond management strategies / essentials
- Floc production problems / risks / critical considerations (including environmental)
- Monitoring / testing and response
- Practical floc pond management scenarios

The aim of the workshop was not to provide a step by step "how to" for the culture of prawns in a microbial floc system as this would depend on the particular circumstances of each farm; in addition to technical capacity there are many variables that can impact such as infrastructure, human resources, climate, water quality, soil quality, discharge management systems etc. The workshop was instead designed to arm participants with as much information as possible on the technical and infrastructure requirements and biological and chemical parameters of a biofloc system so that participants could later apply this knowledge on their own systems. The workshop was also intended to provide a forum through which farmers and other industry stakeholders could exchange information and experiences of microbial floc methodology in the Australian context.

The workshop was a mixed success in that the focus by Dr Taw was very much on his experience with *vannamei* species production in zero exchange biofloc systems, which require quite a different management approach to that of the low-water exchange, microbial floc system demonstrated for *P. monodon* by Smith and West. However there were many in-depth discussions between the participants on the implementation of microbial floc processes for *monodon* and *merguiensis* species and all participants seemed to take away something useful from the conversations that took place.

The workshop not only proved a useful capacity building exercise but it provided an opportunity discuss the limitations that farmers currently face in applying the microbial floc production systems here in Australia. In addition it also served to highlight the future possibilities of microbial floc production systems for the Australian aquaculture industry.

Australian farmers will be the true pioneers of the science of microbial floc production for *P.* monodon in earthen ponds. The workshop identified how the science is applied to *Vannamei spp.* with the question being how microbial floc techniques currently employed for commercial *L. vannamei* production can be modified for use in commercial *P. monodon* farming. Limitations were identified such as the high stocking density required to achieve a critical biomass to thus support a dense heterotrophic bacterial population and therefore a zero exchange system.

Of great interest to all the participants was how Dr Taw advocated microbial floc systems as a biosecurity measure. There was much discussion about EMS and its rapid spread through Asia and biosecurity was heavily discussed in terms of the increasing need to apply a zero exchange system or spend money treating inlet water for potentially damaging microbial pathogens before use.

4.5 Development of a webinar support series for industry to provide targeted information on biofloc technology implementation.

RATIONALE:

The concept was to follow on from the Advanced Pond Management workshop with a webinar support series for the participants of the Floc Program. The topics for the webinars were to be identified at the workshop and delivered by an expert in that particular field. The idea was that the webinars be run 'live' with the opportunity for Floc Program participants to take part in a question and answer session after each webinar for personalised support on queries and issues regarding biofloc system implementation and management.

OUTCOME:

The Floc Program participants identified that a 'live' webinar would not be the best format for them, preferring instead to be able to view an information session or presentation in their own time and then email the host with queries or issues.

The Floc Program participants identified two main areas where they would like more support or information; firstly algae and algal bloom management and secondly, the science and dynamics of a microbial floc system.

Two leading experts were identified as ideal to develop the information sessions; Professor Michele Burford and Professor Yoram Avnimelech.

Michele Burford Profile.

Professor Burford has a PhD in nutrient cycling. She has studied ecological processes,

including water quality, in rivers, reservoirs, estuaries and marine systems, and published extensively in this area. She also has research expertise in Algal ecology, Nutrient cycling and Food web dynamics of Aquaculture Systems – with a particular focus on biofloc systems.
Contact: Prof Michele Burford, Executive Deputy Director, Australian Rivers Institute, Griffith University, Kessels Rd, Nathan QLD 4111, Australia. Ph: + 61 7 3735 6723. Email: m.burford@griffith.edu.au

Yoram Avnimelech Profile.
Professor (Emeritus) Yoram Avnimelech from the Israel Institute of Technology is one of the pioneers of zero or minimal water exchange aquaculture systems. He heads the International Working Group on Biofloc Technology (BFT) and is a member of the Board of Directors of The Aquaculture Engineering Society, USA. Professor Avnimelech has published more than 100 papers in refereed scientific journals, has edited 4 books and has supervised 34 graduate students towards master and doctorate degrees.
Contact: Yoram Avnimelech (Prof. EM), Civil & Environmental Eng. Technion. Israel, Inst of Technology, Haifa, 32000 Israel. Tel + 972 (0) 3 7522406. Mobile 972 0523 511702. Email: agyoram@technion.ac.il

Professors Burford and Avnimelech each developed two x 30 minute information sessions with live video / voiceover for dissemination to the Floc Program participants. Both experts were / are happy to receive and answer email queries from Floc Program participants on the presentations provided. The presentations were developed to provide targeted information to Floc Program participants with a specific focus on the implementation of biofloc as a production system for Australian prawn farmers and researchers.

Michele's presentations covered the fundamentals of managing water quality in both flow through and low water exchange prawn ponds with a focus on algal bloom management. Yoram's presentations focused on simplifying the biofloc process and the key control measures in a biofloc system. He also covered the future of biofloc technology and the exciting opportunities that biofloc production techniques may present for the aquaculture industry. Yoram also included a copy of the latest edition of his book "**Biofloc Technology – A Practical Guidebook, Third Edition, Yoram Avnimelech 2015 which** is the updated and expanded 3rd Edition of Professor Avnimelech's technical biofloc handbook that gives a practical and scientific review of the management and status of biofloc technology in aquaculture systems. Yoram also included a letter for the Floc Program participants recommending the chapters in his book that specifically cover biofloc implementation.

The presentations were designed to be viewed in the Floc Program participants' own time with both Michele and Yoram prepared to talk with farmers or technicians by either phone or email about any questions that they may subsequently have had regarding the subjects covered.

Michele and Yorams presentations were disseminated to Floc Program participants on a USB drive as part of an electronic information package containing:

Video Presentations:

- Michele Burford – Water Quality and Algae 1
- Michele Burford – Water Quality and Algae 2
- Yoram Avnimelech – Biofloc Technology – It's Not So Difficult
- Yoram Avnimelech – Biofloc Technology – Science Fiction or a New Reality?
- Supporting Letter to Australian Farmers and Researchers – Yoram Avnimelech

Guides:

- Start - Up Guide to Low Water Exchange Floc Production, Seafood CRC, 2013.
- Biofloc Technology – A Practical Guidebook, Third Edition, Yoram Avnimelech 2015

Articles:

The following articles containing information on a range of subjects relating to prawn production in biofloc systems were also included in the information package.

- To Lime or Not to Lime (Shrimp News International, Feb 6, 2012)
- Questions About Biofloc Shrimp and Semi Intensive Ponds (Shrimp News Int., Apr 16, 2010)
- Molasses, Salinities, Bioflocs and Semi Intensive Ponds (Shrimp News Int., Feb 13, 2009)
- Controlling Phosphate and pH in Biofloc Ponds (Shrimp News Int. Sep 3, 2010)
- Future of Biofloc Technology (Shrimp News Int. Jul 26, 2011)
- Water Reuse in a Biofloc System (Shrimp News Int. Apr 23, 2010)
- Biofloc Technology for Shrimp Farming – Basic Information for Field Operations (Taw, N)
- Recent Developments in Biofloc Technology – Biosecure Systems Improve Economics and Sustainability (Taw, N. Global Aquaculture Advocate. Sep/Oct 2012. p 32)
- Malaysia Shrimp Farm Redesign Successfully Combines Biosecurity and Biofloc Technology (Taw, N. Global Aquaculture Advocate. Mar/Apr 2011. p 74)
- Malaysia Shrimp Project Scales up for Production in Biosecure Biofloc Modules (Taw, N. Global Aquaculture Advocate. Jan/Feb 2013. p 40)
- Biofloc Technology Expanding at White Shrimp Farms (Taw, N. Global Aquaculture Advocate. May/June 2010. p 20)
- Partial Harvest Biofloc System Promising for Pacific White Shrimp (Taw, N. Global Aquaculture Advocate. Sep/Oct 2008. p 84)

4.6 Algal identification and information exchange directory

RATIONALE:

During the extension consultation process, 68% of responses established that the main difficulty of an integrated bacterial / phytoplankton, low stocking density, low water exchange, microbial floc system implementation is that associated with establishing blooms of preferred algal species, maintenance of established blooms and the recovery of flocs after unfavourable algal blooms. Establishment of a good floc system depends largely on the dominance of particular algal species such as those belonging to the Diatom group of phytoplankton. There seems to be a great deal of variability of algal species dominance between different geographic locations, farm sites and even between individual ponds on the same farm site. Operators are not sure of the algal triggers that cause dominance of one algal species over another.

Blooms of unfavourable algal species such as dinoflagellates and cyanobacteria (blue-green algae) can be detrimental to the establishment of and on-going stability of flocs. Once an unfavourable bloom has become dominant, it can take a considerable amount of time and resources to recover from this and improve bloom type and pond conditions so that a floc can be re-established. Operators often have difficulty eradicating unfavourable algal species once they have become established without resorting to using water exchange.

Farmers tend to monitor their algae species according to whether the type is favourable or unfavourable and then according to dominance of that algal type. Few farms go to the lengths of screening for and identifying particular algal *species*, although they will identify to genus level if possible. Floc Program participants, particularly during the Advance Pond Management Training workshop, identified a gap in available resources for Australian prawn and barramundi farmers on marine algae and algal behaviour and management in Australian green water aquaculture ponds.

The prawn and barramundi industry has, for many years, used the following publication for identification of marine algae in their ponds; *A Guide to Phytoplankton, Stafford. C, 1999, The State of Queensland, Department of Primary Industries.* This data and images within this guide still remains the most comprehensive resource available to date.

After consultation with the Floc Program participants, it was determined that an up to date online directory of algae would be a valuable resource for prawn farmers. The concept described was that of an online database of known algal genera and species found in Australian marine green water aquaculture ponds. The directory would enable farmers to search for individual algal groups, genera and species to help to identify the particular algae that they were seeing in their ponds. Farmers also expressed a need for the directory to act as a forum where information about algal behaviour and management could be shared.

OUTCOME:

It was deemed feasible, within the limitations of the biofloc extension project budget, to develop an online algal directory using existing information and images on marine algae found in Australian prawn ponds. The directory was designed around an 'Image based key' concept so farmers can quickly scroll through collections of images belonging to algal groups and select a group and subsequently a genera that most closely matches the algae they have collected from their pond/s. Hyphen IT were contracted to build the directory.

The bulk of the information and images for the directory was sourced with copyright approval from the publication: *A Guide to Phytoplankton, Stafford. C, 1999, The State of Queensland, Department of Primary Industries.* Online marine algae data sources were researched to provide additional information in support of the Stafford data on genera and species. Gustaaf Hallegraeff of the University of Tasmania was consulted on the content and provided information in his publication; *Aquaculturists' Guide to Harmful Australian Microalgae. 2002.*

Additional data and images are expected to be provided by David Mann of the Queensland Department of Agriculture and Fisheries in association with the Fisheries Research and Development Corporation Harmful Algal Bloom Project 2013/231. Significantly, Australian prawn farmers are expected to make contributions to the directory so that over time, the information and images of favourable and unfavourable marine algal genera and species are updated to reflect the populations currently found in Australian marine prawn ponds.

The algal directory will be linked to the Australian Prawn Farmers Association website and provide an up to date, easy to access, reference on the common pond algae found in Australian prawn ponds. In addition it provides a portal through which farmers can exchange, with other farmers, their experiences and challenges with pond algae behaviour and management relating to production and pond performance.

The key information exchange feature of the directory means that farmers can submit information, images and video on notable harmful or beneficial algae, which will then be validated and incorporated into the directory for the benefit of other farmers. Farmers can also submit enquiries should they encounter an algal bloom or algal species that they are unfamiliar with and upload information, images and videos that may assist with the identification of the alga / algae in question.

The directory provides a valuable tool for Australian prawn farmers to assist with the identification of pond phytoplankton in order to facilitate more informed bloom management decisions. The directory will initially be administered and managed by the

Queensland State Department of Agriculture and Fisheries in association with the Fisheries Research and Development Corporation Harmful Algal Bloom Project 2013/231. Data and images from this project will be captured within the directory. It is expected that upon the completion of the Harmful Algal Bloom Project 2013/231 the directory will be administered and managed by the Australian Prawn Farmers Association on an on-going basis.

The directory can be grown and populated with additional data and farmers can add their input and experiences with algal behaviour and management. It is a tool with great potential to be further developed by the farmers themselves. Many farms now have light microscopes on site and have the capacity to take electronic images of algae collected and submit these to the directory for identification. This information and images or video can subsequently be added to the directory once verified. The directory has been designed to be a platform that can now be built upon. How industry maximises its usefulness from here is up to industry.

4.7 Develop a unit of competency on biofloc for inclusion in the Australian Vocational Education and Training system

RATIONALE:

The Australian seafood industry relies heavily on a skilled workforce that displays competence in their abilities to undertake specific work related activities. As the seafood industry evolves, the suite of skills needed to stay commercially competitive increases both in commercial facilities and indeed research institutions. From management to new industry entrants, the adoption and utilisation of successful modern techniques in all sectors is vital for the industries long-term growth. Within Australia there are now benchmark packages available that capture these skills and develop mechanisms that can assist in disseminating this information as well as training and assessing ones competence within these techniques. The Seafood Industry Training Package is an integrated set of nationally endorsed competency standards, assessment guidelines and qualifications and is by far the most relevant package for all sectors of the seafood industry.

The Seafood CRC biofloc extension program falls within the range of skills training areas outlined in the Seafood Industry Training Package. The implementation of biofloc technology on Australia prawn farms is an example of the application of innovative techniques, practices and procedures with the potential to enhance the productivity of the Australian prawn and barramundi farming industries.

Advances such as this are fundamental to the continuous improvement process of the Seafood Industry Training Package. The package goes through regular review processes where new skills and knowledge are added. Having these new skills and knowledge areas available for training institutions and industry will ensure that the range of skills and knowledge areas obtained through the Seafood CRC biofloc research will be passed on to future members of the seafood industry which will greatly influence both their work practices and sector wide productivity.

It was determined that a unit of competency derived from the Seafood CRC biofloc research be developed and incorporated into the Seafood Industry Training Package. The objectives were:

- To analyse and capture relevant new skill sets and techniques developed from the Seafood CRC Smith and West 2009 biofloc research.
- To incorporate these skill sets and techniques into a new unit to be included in the Seafood Industry Training Package.

OUTCOME:

A new vocational training unit of competency entitled “Implementing Low Water Exchange Microbial Floc Technologies” was developed by Mark Oliver of Aquaculture Support Services in conjunction with the ‘Seafood CRC skills audit and articulation into the National Seafood Industry Training Package Project No. 2010/779’.

The draft unit was reviewed by key industry stakeholders and was subsequently uploaded to the Agrifood Skills Australia Continuous improvement register, which will then be disseminated for wider industry comment prior to adding the units in the SFITP during its next review.

The unit is a highly technical unit that focuses its application on *P. monodon* farming. Other marine pond based sectors such as the barramundi industry have also showed an interest in implementing biofloc technology.

A stretch goal for this unit would be for it to be adopted overseas in particular Asia where biofloc is widely used throughout the shrimp farming and finfish industries. To the best of Mark Oliver’s knowledge there are no institutions within the region that have developed curriculum for the implementation of biofloc technologies. This brings opportunities for this unit to be used not only in Australia but also internationally.

5.0 CONCLUSION

The Seafood CRC biofloc research extension project has concluded with a diverse series of strategically developed activities designed and delivered in consultation with the Australian prawn farming industry to provide maximum benefit to industry.

While it is not yet feasible to *quantify* the benefits that these extension activities have had or are having on Australian farmed prawn production, we can propose how these extension activities will serve to leave a lasting Seafood CRC legacy for the Australian farmed prawn industry.

Industry contacts

The development of industry resources and the capacity building that has occurred has only been possible through collaboration with some of the worlds most prominent authorities on biofloc technology such as Professor Yoram Avnimelech, Professor Michele Burford and Dr Nyan Taw. Australian prawn farmers have taken part in the Floc Program now have personal links and direct access to each of these people who are willing to continue to support the Australian industry in the development of its capacity for biofloc system production.

Capacity building and on-going learning

The extension process has centred on the development of information resources to enable the Australian prawn farming industry to better understand the science, application, implementation, challenges and limitations of biofloc technology. One of the most important aspects of this process has been to dispel some of the myths of biofloc technology in the Australian context by underlining the fundamental differences between the zero exchange full biofloc production methods used for and applied in *L. vannamei* and Tilapia farming and the low water exchange, microbial floc system, (a hybrid algal / bacteria system) applicable in *P. monodon* farming in Australia.

The "Start Up Guide" and the "Advanced Pond Management training course" have provided Australian farmers with information on the core principles of biofloc technology. Importantly however the focus has also been on why these core principles cannot be directly applied in *P. monodon* production under Australian conditions. A generic "how to" manual has not been a viable outcome from this extension project due to the species specific, environmental and geographical variables involved, but instead farmers have been given the information they need to be able to start doing their own on farm trials in order to develop their own microbial floc production system processes and procedures.

The "Webinar Series" focussed on practical considerations and microbial floc system implementation with the aim of drilling further down into the areas where Floc Program participants continued to have questions. These were areas such as, for example, algal behaviour and management, and floc development and maintenance. Hearing directly from Professor Avnimelech in his webinars was insightful as he underlined that the science of biofloc is still relatively new and is still developing and that many of the dynamics of a biofloc system are still poorly understood. As the pioneer of the science of biofloc technology, it was noteworthy that Professor Avnimelech emphasised that the evolution of the science is in the hands of farmers, such as within the Australian context with *P. monodon,* and that the future potential for its application in aquaculture systems is exciting and highly significant.

The development of a unit of competency on "Low water exchange, microbial floc technology" for the Seafood Industry Training Package has cemented biofloc technology as a valid production method and ensures future vocational skills training in this area. This is a significant legacy for the Seafood CRC to leave for the Australian prawn farming industry.

Industry resources

The extension project has delivered a host of information resources to industry, ranging from the "Start-Up Guide", which contains comprehensive information on biofloc technology and systems in addition to numerous citations and references, to the information contained in the "Webinars" and information pack attached that included video presentations and noteworthy papers and discussion notes. Each Floc Program participant received a copy of the 2014 revised 3rd edition of "Biofloc Technology – A Practical Handbook" by Yoram Avnimelech which is the worlds most comprehensive text on biofloc production.

The development of an online algal species and information exchange directory will provide farmers with the platform to build on and to create a directly relevant, comprehensive and up to date database of notable prawn pond algae and associated behaviours and management recommendations. The keys to the success of this directory will be the level of industry input and how industry utilises it. The more industry puts in to the directory, the more valuable a tool it will become for industry. The Australia prawn farmers' algal directory has the potential to be one of the longest standing and highly beneficial legacy resources to come out of the Seafood CRC. Future work to enhance this resource and with subsequent implications for biofloc production of *P. monodon* could include specific projects to analyse and capture data on Australian prawn farm algal populations, behaviour and management.

In conclusion, the biofloc research extension project has delivered targeted extension initiatives that the Australian prawn farming industry can utilise and build upon as farms look to incorporate the science of low water exchange, microbial floc production systems into their operations. There is a level of in situ trialling that farms must go through themselves before further extension assistance could be provided in the form of more strategic on-farm guidance. The dynamic nature of a living system such as a prawn production floc system means that each farm and farmer will get different results from the application of the science. Farmers may be reluctant to lose existing production area to trial floc methodologies but innovative technology such as this carries an element of risk that farmers must be prepared to accept in order to determine whether such a system will work for them.

Future research into the behaviour and management of algal blooms in floc based *P. monodon* production systems would be very beneficial as this appears to be the key to the control of a hybrid bacteria / algal marine prawn microbial floc production system.

6.0 APPENDIX

6.1 DETAILS OF STAKEHOLDERS CONSULTED

Name	Affiliation	Location	Contact Details
Alistair Dick	Pacific Reef Fisheries Pty Ltd	Ayr, Qld	(07) 4783 6068
Catherine Chen & David Lin	Monagold Pty Ltd	Ilbilbie, Qld	(07) 4950 3028
David Smith	AquaNutrition Services Pty Ltd	Queensland	(07) 3286 2105
David Symons	Eimeo Prawn Farm	Mackay, Qld	(07) 4956 7111
David Yang	Fortune Prawn Farm	Mission Beach, Qld	(07) 4068 7407
Ewan Colquhoun	Ridge Partners	Milton, Qld	(07) 3369 4222
Frank Roberts	Tru Blu Prawn Farms	Palmers Island, NSW	(02) 6646 0196
Geoff Rossman	GI Rural Pty Ltd	Stapylton, Qld	(07) 5546 2131
Geoffrey Tsai	Prosperity Enterprises	Proserpine, Qld	(07) 4947 1800
Helen Jenkins	Australian Prawn Farmers Association	Brisbane, Qld	(07) 3262 9015
Joe Tu	Bundaberg Prawn Farm Pty Ltd	Bundaberg, Qld	(07) 4159 6988
John Maloney	Coral Sea Farms Pty Ltd	Ingham, Qld	(07) 4777 2797
John Rossman	Rossman Pty Ltd	Alberton, Qld	(07) 5546 2341
Joseph Chen	Mackay Prawn Farm	Mackay, Qld	(07) 4956 309
Mark Oliver	LMC Training Pty Ltd	Wurthulla, Qld	(07) 5456 1173
Marty Phillips	Pejo Barramundi	Innisfail, Qld	0408 835 447
Matt West	Australian Prawn Farms Pty Ltd	Ilbilbie, Qld	(07) 3290 2816
Murray Zipf	Rocky Point Prawn Farm	Woongoolba, Qld	(07) 5546 1588
Nick Moore	Gold Coast Marine Aquaculture Pty Ltd	Woongoolba, Qld	(07) 5546 1361
Rick Hobson	Prawns North Pty Ltd	Thuringowa, Qld	(07) 4773 3333
Stephen Andrijevic	Melivan Pty Ltd	Kurrimine Beach, Qld	(07) 4065 6048
Stephen Lii	Ausfarm Aquaculture Pty Ltd	Palmers Island, NSW	(02) 6646 0239
Stuart Whitney	Sunshine Coast Institute of TAFE	Nambour, Qld	0419 767 837
Ting Chou Ko	Sunrise Seafood Pty Ltd	Rosedale, Qld	(07) 4156 6686
Trevor Anderson	Seafarm Pty Ltd	Cardwell, Qld	(07) 4066 4400
Warren Truloff	TPF Management Pty Ltd	Cardwell, Qld	(07) 5546 1771

6.2 REFERENCES

Avnimelech, Y. 2009. *Biofloc Technology – A Practical Guide Book*. The World Aquaculture Society, Baton Rouge, Louisiana, US.

Jenkins, H. 2011. *Personal Communication.* Executive Officer. Australian Prawn Farmers Association.

Nyan Taw. *Biofloc Technology Expanding at White Shrimp Farms.* Global Aquaculture Advocate. May 2010.

Smith, D. H; & West, M. 2009. *Increasing the profitability of Penaeus monodon farms via the use of low-water exchange, microbial floc production systems at Australian Prawn Farms.* Australian Seafood CRC. Project No. 2009/748

6.3 SUMMARY OF SMITH AND WESTS (2009) RESEARCH RESULTS

RESEARCH PAPER SUMMARY

Increasing the profitability of Penaeus monodon farms via the use of low-water exchange, microbial floc production systems at Australian Prawn Farms. David M. Smith and Matt West. Seafood CRC Project No. 2009/748

BACKGROUND

During their 2005/06 season, Australian Prawn Farms (APF) successfully cultured black tiger prawns, *Penaeus monodon*, via a low water exchange, microbial floc production culture system (Smith and West, 2011). However, the reason for the success of the trial 2005/06 season was not well understood, and thus, required further investigation in order to repeat the successful harvest of this season. In 2008, a three-year study funded through the Seafood CRC program was commenced by APF and Dr. David Smith (CSIRO) in an attempt to better understand the successful harvest of *P. monodon* during the 2005/06 season. The key objective of the study was to determine how varying nutrient concentrations, carbon source, and water exchange affect the formation, composition, and persistence of a microbial floc (Smith and West, 2011). Also of interest was the effectiveness of different carbon sources in the formation of a microbial floc, the nutritional benefits provided to *P. monodon* by microbial flocs and consequently the reduction in feed expenses, and ultimately the environmental and economical benefits that can be reaped via utilization of a low water exchange, microbial floc production system.

METHODS

The research approach adopted was to intensively monitor the nutrients, microalgal population and biofloc density over a three year period in five production ponds at APF that were being managed according to the farms established low-water exchange protocol.

Five production ponds at APF were filled at the beginning of each season, and fertiliser was added as per Australian Prawn Farms protocol until either a dense microalgal bloom was established, or the Total Ammonia Nitrogen (TAN) surpassed 1 mg/L (usually after approximately 4 weeks). Two different types of fertilisers were used for the sake of comparison in this study. During the first two seasons, the fertiliser used was urea, while during the third season Easy N was used. Easy N is a liquid fertiliser consisting of a mixture of urea and ammonium nitrate with a 1:1 nitrogen ratio.

During the 2008/09 and 2009/10 seasons, sodium silicate (waterglass, 35% sodium silicate solution) was added to the ponds in several doses during the first two weeks after filling to provide approximately 0.5 mg/L of reactive silica to the pond.

Stocking density ranged from 35, 45 and 60 PL's per m^2 in 2007/08 (two, two and one pond respectively) to 50 PL's per m^2 in 2008/09 and 2009/10 (all five ponds).

Sampling of the ponds was carried out for 120 days, until harvesting preparation began. The main parameters analysed were; Temperature, pH, Dissolved Oxygen, Total Ammonium Nitrate (TAN), Biofloc Volume, Salinity, Total Alkalinity. Total Nitrogen, Total Kjeldahl Nitrogen, Reactive Silicate, Nitrate and Nitrite, Total Phosphorus, Filterable Reactive Phosphorus, Total Inorganic Carbon, Total Organic Carbon, Microalgal Species and Microalgal Density

Fertiliser Comparison Trial

After experimental difficulties encountered during the study in situ at APF, a more rigorous fertiliser comparison trial was conducted during the 2009/10 season at CSIRO, Cleveland using 2.5 tonne fiberglass tanks in a controlled environment facility.

26 tanks were filled with seawater, well aerated and maintained at an ambient temperature of 30oC. 13 tanks were fertilized with urea and 13 tanks were fertilized with Easy N. The dosage rate was calculated so all tanks received the same amount of total Nitrogen. Sodium silicate was also added to the tanks. Water quality and

microalgal density was analysed daily and dominant algal species were identified three times per week. The experiment ran for four weeks.

RESULTS

The purpose of sampling was to monitor nutrient concentrations in the ponds, microalgal populations, and biofloc density. Of the nutrients monitored throughout the course of the study, the measurement of those nutrient forms categorized as reactive nutrients (TAN, reactive silica, and filterable reactive phosphorus (FRP)) were found to be most useful as these are the nutrient forms available to bacteria and microalgae. As a consequence the focus in the discussion is on the reactive nutrients.

Biofloc Formation

The results showed a significant positive relationship between diatom bloom density and the establishment of a biofloc of > 0.1 mg/L. A strong bloom of blue green algae was also found to favor the formation of a biofloc, though this floc tended to be weaker and thus less stable than the biofloc following a diatom bloom.

Total Organic Carbon

Total Organic Carbon (TOC) measurements were used as an indicator of microalgal biomass in the ponds and there appeared to be a positive correlation between the TOC concentration and diatom dominance. TOC levels are a useful indicator in pond management intervention to preempt and prevent a microalgal crash or to minimize its magnitude.

Total Ammonium Nitrogen

TAN, the sum of the ammonia (NH_3) and ammonium ion (NH_4^+) concentrations, was measured. Peaks in TAN were found to be significantly related to diatom blooms. The peak in TAN that occurred 30 to 45 days after filling the pond appeared necessary for the development of a strong bloom of large diatoms within the following 30 to 40 days. The lack of a TAN peak renders it unlikely that a medium or strong bloom of large diatoms will occur and consequently, makes the formation of a biofloc of adequate density (> 0.1ml/L) unlikely as well.

In the 2009/10 season a TAN peak of > 0.9mg/L did not occur in the first 45 days and consequently a medium or strong bloom of large diatoms didn't become established until late in the season and hence a good biofloc failed to develop. The lack of a TAN peak in 2009/10 was considered due to the use of Easy N fertiliser. It appears that Easy N assisted the establishment of a pioneering species of algae – typically chlorella – that has exceptional stability and maintained dominance. The peaks in TAN later in the 2009/10 season were due to very overcast conditions.

pH and Ammonia

Prawn ponds are usually maintained at a pH between 7.6 and 8.6, as at higher pH values, a greater proportion of TAN exists in the form of ammonia, which is toxic to prawns at elevated concentrations.

pH was observed to increase over the first 20 days from about pH 8.3 to a maximum of > 9 as the microalgal bloom became denser and reduced the dissolved CO_2 concentrations in the water. Thereafter the pH tended to decline as the prawn biomass increased and the amount of respired CO_2 increased. As the season progressed, sodium carbonate or hydrated lime were occasionally used to increase pond pH following events such as microalgal crashes or a period of cloudy weather during which the rate of photosynthesis was reduced.

At APF the pond managers accept TAN concentrations of up to 1.5 mg/L for a few days when the pH is between 9.0 and 9.5, in the early weeks after stocking. Whereas many microalgal species do not tolerate high pH (pH > 9) very well, certain species of diatom dominate in environments of high pH. It is suggested that the early peaks in TAN developed as a result of the increased pH causing less tolerant microalgal species to die off, which would result in less uptake of TAN and more TAN being released due to decomposition of the dead microalgae. The appearance of large diatoms following this event reaffirmed the fact that certain species of diatom are more tolerant of high pH.

It was therefore concluded that because most conventionally managed prawn farms would not be willing to allow the pH of the ponds to reach 9.0, nor would they willingly let the TAN in ponds increase to the levels seen at APF, they would not see the development of blooms of large diatoms and the development of biofloc.

Total Inorganic Carbon

Total inorganic carbon (TIC) is the sum of dissolved CO_2, bicarbonate (HCO_3^-) and carbonate (CO_3^-) and therefore is closely related to Total Alkalinity. TIC declined in all ponds in the first 20 – 30 days after filling as the dissolved CO_2 was used by the microalgae and some of the bicarbonate was taken up by the litho-chemoautotrophic bacteria. Thereafter TIC concentration was variable but TIC and alkalinity were maintained within defined limits (60 – 120 mg/L) by the addition of sodium bicarbonate.

Silica and Silicate

While silica is not required for other microalgal species it is an essential nutrient for diatoms. Silica is poorly soluble in water at pH < 9.0 but becomes increasingly soluble as the pH becomes more alkaline, markedly increasing in solubility when the pH increases above 9.0. Because strong diatom blooms were found to lead to the formation of a large biofloc, sodium silicate was added to the ponds in order to support a diatom bloom.

All the five study ponds were dosed with sodium silicate but as a result, without any control ponds to compare against it was not possible to rigorously test the effect of silica. However, higher concentrations of silica were measured in the study ponds in the 2009/10 season in the period between 40 to 80 days when diatoms were *not* the dominant species in comparison to seasons 2008/09 and 2007/08 when diatoms *were* the dominant microalgal species. This suggests that the silica was being taken up and utilised by diatom microalgae when the diatom species were dominant and silica was available in the pond.

Filterable Reactive Phosphorus

Statistical analysis demonstrated a significant inverse relationship between diatom density and FRP concentrations.

Nitrate and Nitrite

The combined concentration of nitrate-nitrogen and nitrite-nitrogen (NOX) found in all the ponds was very low which indicated that toxic nitrite was not a problem and suggests that de-nitrification of nitrate was occurring.

Molasses, Bicarbonate, and Biofloc

When a strong biofloc was present (> 0.1ml/L), the total alkalinity of the ponds was found to progressively decrease, suggesting the utilization of bicarbonate by the bacterial community in the pond. Thus, sodium bicarbonate was added to the ponds in order to keep the alkalinity between 80 and 120 mg/L. If a strong biofloc was not present, molasses was added to the ponds in order to manage the microalgal bloom and the TAN by encouraging the productivity of heterotrophic bacteria. Under these conditions Total Alkalinity does not decrease markedly. Statistical analyses found a weak relationship between the amounts of molasses or bicarbonate added to the ponds and the presence of a strong biofloc but with only 15 sets of data there was not enough information available to detect a significant correlation.

Fertiliser Comparison Trial Results

Water Quality

There was no significant difference in water salinity levels, dissolved oxygen, water temperature, pH, total alkalinity, TAN and nitrate levels between the two treatments with water quality parameter levels remaining constant across all tanks.

Microalgae

Measurements of the density of microalgae were highly variable with time and were not found to differ significantly with the use of urea versus Easy N fertilizer. Fertilizer type was also not found to have a significant effect on the microalgal species composition. These results differ from observations made at APF where ponds fertilized with Easy N had exceptionally stable microalgal blooms and ponds fertilized with urea appeared to have a slower response in the establishment of a bloom.

Discussion of fertiliser comparison trial results

The key observations that can be gathered from the fertiliser comparison study are as follows:

1. The use of Easy N fertilizer as opposed to urea was found to have no significant effect on the establishment and growth of microalgal populations (in contrast to the stable Chlorella blooms observed after using Easy N at APF).
2. All measurements of TAN throughout this study were less than 0.1 mg/L. The fate of the nitrogen added to the tanks throughout the course of the study remains uncertain. One possible explanation is that the nitrogen was taken up by heterotrophic bacteria and by benthic or epiphytic algae growing on the bottom of the tanks.
3. pH was found to increase progressively at the start of the experiment, with periodic decreases correlated to culture longevity and conditions of the microalgal bloom.

4. Different types of microalgal species were dominant at different times throughout each season of the study. For the first week moderate densities of diatoms were frequent, while from day 3 – 14, dinoflagellates reached a peak, and finally either diatoms or blue green algae became more prevalent.

CONCLUSIONS

The Effect of Nutrient Conditions on Establishing Biofloc

Throughout the course of this study, it was determined that a bloom of large diatoms of moderate to high density is significantly correlated to the establishment of a satisfactory biofloc (> 0.1 mg/L). The large peak in TAN (> 0.9 mg/L) that is produced within 50 days of filling the ponds is well correlated to the establishment of the bloom of large diatoms, generally about 30 days after the TAN peak.

Although data from the test ponds did not show that the establishment of a bloom of large diatoms was dependent upon having reactive silica and FRP concentrations considered necessary for diatom growth (0.5 mg/L and 0.1mg/L respectively), the data were heavily skewed in favour of adequate levels of these nutrients. Observations from other ponds at APF and information in the literature suggest that it would be beneficial for the establishment of a strong bloom of large diatoms if the concentration of reactive silica was in the order of 0.5 mg/L and that the FRP concentration be at least 0.1mg/L at about the same time as the TAN peak .

Observations at APF indicate that a better and more stable biofloc occurs in ponds with stocking densities > 35 prawns per m2. The current APF stocking protocol is for ponds to be stocked with 50 PL/m^2.

Weekly chaining of pond bottoms was a vital method for pond management. By dragging the long loop of chain across the bottom of the pond with the exception of the middle, material that had settled to the bottom was resuspended, keeping the bottom free of anaerobic sludge. Once the organic material is resuspended, it is available for oxidation by aerobic bacteria.

Peaks in TAN also occur after microalgal crashes and during overcast conditions when photosynthetic activity is reduced. During these periods action may need to be taken to minimize the impact of the high TAN levels. One strategy for the management of TAN is the addition of molasses as an energy source for heterotrophic bacteria production. During the process of heterotrophic bacterial growth some of the TAN from the water is used for synthesis of amino acids, protein and nucleic acids thereby reducing the ammonia concentration in the water.

Another benefit of reducing TAN concentrations is that it results in less ammonium being available for microalgal productivity, which provides a management strategy to control an unsustainable increase in density of the microalgal blooms. This is considered by APF to be the most important application for the addition of molasses to prawn ponds.

Effectiveness of Different Carbon Sources

Carbon sources are added to the ponds in order to supply a complementary nutrient or energy source for the bacteria. The benefit of adding a carbon source to the pond is twofold: by encouraging bacterial growth, excess ammonia is removed from the pond via bacterial metabolic processes. Secondly, while it was assumed prior to this study that only *organic* carbon sources such as molasses or bagasse would be of use in the low water exchange production system, it was observed that *inorganic* carbon, in the form of bicarbonate, is also important as it is required by both microalgae and litho chemoautotrophic bacteria as their carbon source.

Large diatoms such as *Bellerochia* and *Helicothica spp* associated with the establishment of a stable biofloc appear also to be associated with lithoautotrophic bacteria. These lithoautotrophic bacteria appear dominant in the biofloc and, along with the microalgae, use the bicarbonate in the water. Sodium bicarbonate is the preferred inorganic carbon source to replenish the bicarbonate and hence increase the Total Alkalinity if the pH does not need to be changed. If both Total Alkalinity and pH are too low, the application of sodium carbonate will raise both of these parameters. It should be noted that whilst hydrated lime will increase both pH and Total Alkalinity, it won't add any inorganic carbon (or bicarbonate).

Organic carbon sources compared in this study were molasses and bagasse. The degradation rate of bagasse was determined to be far too slow for effective uptake by heterotrophic bacteria, leaving molasses as the organic carbon source of choice. Molasses is also very cost effective and a practical carbon source as it is easily applied to the ponds.

The approach at APF is to use molasses primarily to control fluctuations in microalgal density, rather than trying to reduce TAN concentration. The objective is to control the algae growing on this ammonia by stimulating bacterial growth with the molasses. The addition of molasses to a pond is generally required when there is a weak or poor biofloc present. Under these situations, the large diatoms such as *Bellerochia spp* and *Heliothica spp* are either absent or present at low density.

Nutritional Benefits of Bioflocs and Reduction in Feed Costs

While the main purpose of establishing a biofloc is to manage water quality in the ponds, the flocs may also provide a secondary source of nutrition for the prawns. It is also believed that the stable environment created by the biofloc contributes to improved growth and better feed-conversion ratios. During the 2007/08 season, ponds in which a good biofloc had been established produced a 10 tonne harvest 10 days earlier than those with a poor biofloc. These good biofloc ponds also returned an FCR of 1.2 – 1.3 compared with an FCR of 1.5 – 1.6 from the poor biofloc ponds. Thus, the presence of a good biofloc was calculated to have saved 3 tonnes of feed or about $6,000 per pond, equivalent to 20% of the total feed cost.

Environmental Benefits and Effects on Farm Profitability

As compared to the conventional flow-through system of prawn farming, the low water exchange production system used in this study reduced water usage by 68%, 69%, and 73% in the first, second and third year of this study. Furthermore, total nitrogen discharge was decreased by 77%.

Perhaps the most enticing benefit to the low water exchange production system is the increase in production from the ponds. In 2003/04 a harvest of 6.7 t/pond was obtained using the conventional flow-through system. In comparison, in the 2008/09 season, a harvest of 12 t/pond was obtained from ponds in which a biofloc was established. Overall, reductions in power usage, feed costs, and labor combined with the increase in prawn production using the biofloc system equate to an estimated $65,000 increase in production per pond.