WORLD AQUACULTURE

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YELLOW CATFISH IN INDIA


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WORLD AQUACULTURE

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Cover: *Yellow catfish* Horabagrus brachysoma *is cultured as an ornamental fish in India. See article on page 52.*

WORLD AQUACULTURE MAGAZINE

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As I write this, Christmas decorations are starting to appear in the gardens of Adelaide and what looks like being a long dry summer is about to descend on us as the year spins by. South Australia is the driest state in Australia and yet, along with Tasmania, has the greatest aquaculture activity. It's somewhat counterintuitive to think of aquaculture expanding in dry areas but here at WAS we are seeing a significant growth of interest in aquaculture in arid areas, particularly in the Middle East. A reliable source of quality water is a pre-requisite for any aquaculture operation and a basic fact is that our animals live in water. Thus, as aquaculturists, we treasure that water and invest heavily in conserving it and maintaining a quality conducive to profitable production. Aquaculture is actually one of the most drought-resistant forms of primary production!

The Asia-Pacific Chapter organized an Aridland Aquaculture Symposium and Workshops last year. Also, our immediate Past President Michael Schwarz is heavily involved and formally representing WAS in the Global Forum for International Agriculture (GFIA) initiative, which is emphasizing climate-smart agriculture with a focus on the Middle East and Africa, and also in the upcoming Middle East Aquaculture Forum (MEAF). The second GFIA meeting is being held next year on March 9-10 in Abu Dhabi and the first MEAF meeting follows in Dubai April 5-6. These are meetings towards which WAS is contributing and sponsoring and, in the case of GFIA, ensuring that aquaculture has a profile as an important component of climate-smart agriculture.

Shifting attention farther south, and a development that I am following closely, we are moving forward in the planning and organization of our first WAS conference in Africa. This will be held in Cape Town, South Africa from June 26-30, 2017. I signed the agreement for this conference with Roger Krohn of the Aquaculture Association of Southern Africa during the conference in Adelaide earlier this year and the first steering committee meeting was held last month in Cape Town. The conference in South Africa will represent an exciting opportunity to bring together the global aquaculture community with aquaculturists throughout Africa to discuss the latest technologies and opportunities for aquaculture development. The conference theme is Sustainable Aquaculture - New Frontiers for Economic Growth. My personal interest comes from having spent some considerable time in the region working on an aquaculture development project with the University of Stellenbosch in the late 1990s. In addition to the interest around this being our first meeting in the region, this happens also to be a spectacularly beautiful part of the world with plenty to interest delegates outside of aquaculture. Nonetheless, the conference will have a significant challenge in encouraging and supporting participation from aquaculturists throughout the sub-continent, in particular, which includes some countries that remain among the least economically developed in the world.

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SOCIETY

Editor's Note

Strengthening Aquaculture for Food Security

The UN's Universal Declaration of Human Rights recognizes food security as a social, economic and cultural right; there is a Right to Food. Food security is defined operationally by the FAO as when "all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life."

Although the number has been declining, there are currently about 870 million people with chronic hunger, or 1 in 8 of the global population. Although less visible, many more are malnourished. The UN estimates that more than 2 billion people do not consume adequate amounts of vitamins and minerals, the so-called "hidden hunger." The WHO estimates that 1 in 3 living in developing countries suffer from vitamin and mineral deficiencies, lacking vitamin A, iron and iodine. Micronutrient deficiencies are most severe throughout Sub-Saharan Africa but are also very high in India.

Fish provides high-quality protein, vitamins and essential fatty acids. Compared to other foods, there has been little attention given to the role of fish in providing food security, despite its potential importance in addressing malnutrition. Although the focus of health benefits is on protein consumption, fish is arguably more important as a source of micronutrients and fatty acids.

There are a number of well-known nutritional and health benefits of fish consumption. In developed countries, the link between fish consumption and human health emphasizes the effect of consuming heart-healthy polyunsaturated fatty acids. In developing countries, it is focused on malnutrition or unequal access to food for women and children.

The phenomenal growth of aquaculture — about 6 percent per year over the last decade — has expanded the global supply of fish. Aggregate demand for fish has been increasing with human population and with wealth, especially in China and India. Aquaculture provides food security by supplying high-quality animal protein and providing employment, income and livelihood opportunities, especially for poor people.

According to the FAO, fish from aquaculture and capture fisheries provides 3 billion people with 20 percent of their average intake of animal protein and an additional 1.5 billion people with about 15 percent of their animal protein intake. Fish provides 50 to 60 percent of protein in human diets in countries with significant aquaculture production, such as Bangladesh and Indonesia. Most nations where fish represents a significant proportion of animal protein consumption are low-income developing countries.

Aquaculture is an economic activity that provides food security through employment, income and livelihood opportunities, particularly for poor people in developing countries. The FAO estimates that 660 to 820 million people depend to some degree on fisheries, aquaculture and related activities as a source of income. These include 19 million working directly in production as fish farmers, most (70 to 80 percent) at a small scale, nearly all of which (90 percent) are in Asia. An additional 19 million are employed in other parts of the value chain, including support activities (feeds, hatcheries), production, processing, transportation and marketing.

Recently published studies have demonstrated unequivocally that small-scale aquaculture can reduce poverty and improve food security in Asia. However, small-scale aquaculture does not necessarily equate to food security, at least in Africa, where the focus of development efforts has shifted to larger-scale, commercially-oriented operations to improve food security outcomes. Fish produced in small-scale aquaculture are often more important as a cash crop than direct use as food in these households.

Food security and nutrition outcomes are strongly determined by gender, class and ethnicity. Access to resources and way those resources are distributed within countries, along value chains and within households is gendered, with women having a subordinate role. Men dominate the workforce in aquaculture production, with women generally more prominent in processing and marketing. Food security through aquaculture can be improved by addressing gender inequality in the value chain.

Food security through aquaculture is threatened by environmental problems, including the availability of freshwater, land degradation that affects production of commodity grains used in feeds and water pollution from industrial activities, among others. It is also threatened by the spread of diseases, early mortality syndrome being a recent example.

Food security through aquaculture will depend on the ability of small-scale producers to adapt to climate change. Climate change represents a challenge to food security through the availability of fresh water, sea-level rise and increased incidence of extreme weather such as droughts and floods. Food security will be affected by uncertainty in the fish supply from aquaculture as well as the vulnerability of fish farmers to the effects of climate change. Vulnerability to climate change is very high in coastal areas and river floodplains, areas where most of the world's aquaculture production occurs.

Fish is one of the most globally traded foods and is the most traded form of animal protein. The evidence that global trade in fish from aquaculture is beneficial to producers in developing countries is equivocal. Most benefits tend to accrue to processors and brokers rather than producers. Local or regional trade, especially for low-value species, is likely to have better outcomes relative to employment and food security.

To realize the full potential of aquaculture to contribute to food security, research and development related to genetic improvement (such as the GIFT program), production system efficiency, fishmeal replacement, health management and the domestication of new species is needed. In short, improving the productivity and sustainability of aquaculture can improve food security and nutrition outcomes. Food security goals and strategies need to be an integral and explicit part of policies and governance of the aquaculture sector.

— John A. Hargreaves, Editor-in-Chief

U.S. Aquaculture Society

Thank It is the time of year to give thanks and to reflect on who we are and where we going. First, I truly appreciate the time and dedication of my fellow current volunteer USAS Board Members. They have endured many a frantic "blonde moment" with me this year. Thanks to each of you for your enduring patience and good sense of humor.

I also want to recognize and thank our old and new sponsors for the USAS student awards. Because of their support and commitment, in partnership with USAS, we will award over $17,000 to students for travel and presentation excellence. Through our combined efforts, we intend to have a positive and lasting impact on the next generation of aquaculture scientists among us.

The 2015 USAS Student Award Sponsors are: American Fisheries Society, Fish Culture Section; Aqualogic; Drs. Ebeling and Timmons; Merck Animal Health; Pentair Aquatic Eco-Systems; Sea Grant, National Sea Grant College Program; Soy Aquaculture Alliance; Tyson Foods, Inc.

In addition to these sponsors, Alltech. USAS and Alltech have partnered to create an exciting opportunity for USAS students presenting at Aquaculture America 2015 (AA15) in New Orleans, LA, from February 19-22, 2015. The USAS student (graduate or undergraduate) receiving the USAS Merck Best Presentation Award will be eligible to advance to the Alltech Young Scientist (AYS) competition at the regional level for North America, where they will compete with other AYS country/affiliation winners. The top three winners in each of the regional phases will be an AYS Finalist and invited to compete (all expenses paid) in the Global Competition held at the Alltech Annual Symposium in Lexington, KY in May, 2015. The USAS AYS winner and their mentor will receive AYS Affiliation Awards (trophies, medals and certificates). Regional and Global Competition winners will receive certificates and cash awards. For USAS student winners to compete in the AYS North American Regional Competition, they will need to prepare and submit an aquaculture science-related paper following the AYS paper submission requirements (3,500 words for undergraduate and 5,000 words for graduate). For more information on the Alltech Young Scientist Program and requirements go to www.alltech.com/education/alltech-young-scientist/about.

Thanks to all who stepped up to be judges for the USAS student abstracts for AA15. Your time is appreciated. Students, it is not too late to submit an application for some of these awards. You can visit the USAS website (www.was.org/USAS/) or contact me for more information. Deadlines are in early December 2014.

Another thank you to Hayward Industries for their support and making possible our student field trips and activities at AA15. Hayward – you delivered when we needed it most!

USAS has exciting news from the Publications Committee. The USAS Board has approved sponsorship of the new book by Drs. Boyd and Tucker, Handbook for Aquaculture Water Quality. (See review this issue. – Ed.) The book will be sold through the WAS online store (www.was.org/Shopping/). The USAS appreciates Drs. Boyd and Tucker for thinking of the USAS and our membership.

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Asian Pacific Chapter

Year by year more people in Asia rely on aquaculture for food and as a source of income but disease and poor management threaten the industry. According to the FAO, fish farming holds tremendous opportunities in responding to the increasing demand for food, which is taking place due to global population growth. Asia – including South Asia, Southeast Asia, China and Japan – is projected to represent 70 percent of global fish consumption by 2030.

Asia is the largest producer of farmed shrimp but, in recent years, growth in some countries has declined significantly due to diseases. Since 2012, shrimp production in China, Thailand, Vietnam and Malaysia has declined due to early mortality syndrome (EMS). Other countries, including Indonesia and India, have not been impacted by EMS and their shrimp farming sectors are on the rise. Vietnam is having a promising recovery from the EMS outbreak. However, Thailand remains in doubt, with an estimated shrimp production of less than 250,000 t for 2014, which is 50 percent less than its normal production.

As promised in my previous column, we have started working on the new website for the APC Chapter and expect it to be ready to launch by the first quarter of 2015. We are also finalizing the employment of an APC secretariat with a qualified candidate. Two small symposia have been confirmed, one in India in January 2015 and the other in Iran, both related to shrimp farming. The Iran symposium is pending for final confirmation from government authorities.

The first steering committee meeting for the APC meeting in Surabaya, Indonesia in 2016 will be held on December 8 and there is great support from the government and private sector.

Finally I would like to congratulate our new President-Elect, Dr. Enday from Indonesia and two new board members, Brett Glencross and Jenny Cobcroft as Directors. Welcome on board.

— Farshad Shishehchian, President

Korean Chapter

The Korea-Japan Joint Symposium on Aquaculture, which is held biannually in Korea and Japan, was held on October 31, 2014 in Kunsan National University, Korea. It was co-organized by the Aquaculture Division of the Korean Society of Fisheries and Aquatic Science (KOSFAS). The symposium provided a rich variety of information to more than 80 participants, with 10 oral and 57 poster presentations by scientists from various institutions and academia.

There were four invited lectures given by distinguished speakers: Dr. J. Higano (Director, Fisheries Research Agency) Suspended Culture of Asari Clam, Ruditapes philippinarum, Utilizing Natural Seeds"; Dr. Park Kwan-Ha (Kunsan National University) on "Current Concept on Aquaculture Farm Water Quality Regulation and Aquaculture Product Safety"; Dr. T. Yoshimatsu (Mie University) on "Climate Change and Its Impact on Aquaculture in Shallow Seas"; and Dr. Yoo Jin-Hyung (Bari Cooperative Co.) on "Monitoring Causes Affecting the Productivity of Flounder in Jeju Island, Korea."

Along with the symposium, the Annual Conference of KOSFAS, including three divisions — Fish Farming, Processing and Utilization of Seafood, and Biological Engineering — was held. The conference provided not only great opportunities to share knowledge and new ideas, but also to meet new scientific collaborators, old friends and fellow researchers.

— Albert Kwang-Sik Choi, President

LEFT. *Participants of the 2014 Korea-Japan Joint Symposium on Aquaculture.*

Latin American and Caribbean Chapter

From 4-7 November, our second LACQUA event took place in Guadalajara, Mexico, one of the most beautiful cities in the region. LACQUA 14 had the participation of around 600 professionals from around the globe, which is a sign that more people are paying attention to what it is happening in the Latin America and the Caribbean region. This event was historic for our chapter for three reasons. First, it consolidated the Latin American and Caribbean Chapter (LACC) of the World Aquaculture Society as the second largest chapter in the Society. Second, the conference had increased participation from the Caribbean area, one of our main objectives for the chapter. Third, and most important, it confirmed that having our regional meeting in Spanish and/or Portuguese is the best way to attract producers and decision-makers to our conference. When we started with this idea, many doubted that this strategy would succeed. However, the current board envisioned that this was the only way of achieving our main goal, which was to bring together academia, producers and decision-makers under one umbrella – our chapter.

During the event, more than 150 oral presentations and 50 posters were made. The commercial exposition, which attracted 700 visitors in addition to the participants of the conference, had the participation of 65 vendors. Knowledge was shared, businesses were celebrated, friends were made — LACQUA14 was a great success!

Our next LACQUA conference will take place in Brazil next year. LACQUA15 will take place in the Convention Center in Fortaleza, Ceará, from 16-20 November, in coordination with FENACAM 2015. This will conclude our first three-year conference cycle, which started in Villavicencio, Colombia, last year. It will also be the time to change our board, so keep your eyes open if you want to participate as a board member for 2015-2017. I am sure that our organization will continue to grow along with our events. Our commitment to the chapter membership is to keep improving our services and contribute as much as we can to aquaculture development in the Latin American and Caribbean region and worldwide.

It is also time for a new challenge. Our first regional workshop will take place from 9-12 December in Coquimbo, Chile. It will be the First Arid Land Aquaculture Workshop sponsored by the LACC and in partnership with the Fifth Congress of Aquaculture and the Fifth Congress of Aquaponics in Chile. These series of events will support the creation of a "Centro de Investigación Mundial para el Desarrollo de una Acuicultura Sustentable en Zonas Áridas," which will function to promote sustainable arid-land aquaculture worldwide. We are sure that LACC will be deeply involved with this center and that it will make a great contribution to achieve food security in the region. I hope to see you there.

— Antonio Garza de Yta, President

Handbook for Aquaculture Water Quality by Claude E. Boyd and Craig S. Tucker

Water quality in warmwater fish ponds, first published in 1979, was my initial introduction to the science of water chemistry as applied to aquaculture ponds, given to me as a young and idealistic Peace Corps volunteer and aspiring aquaculturist. My copy of that book bristles with post-it notes that mark sections I found particularly useful and annotated in the margins. The blue cover is scuffed from use but in otherwise good condition. The second version of this book, *Water Quality in Ponds for Aquaculture*, was published in 1990, and it too is marked with multi-color tabs, although the rather poor binding meant that large chunks of pages became detached and are now loosely stuffed into place. Now, the third version of this book, *Handbook for Aquaculture Water Quality* has been published, co-authored with Craig Tucker. The books are of identical size (15 × 23 cm) and stack one on top of the other neatly.

The progression of these books tells the story of the evolution of water quality in aquaculture as an area of scientific inquiry. It also tracks the evolution of the career of Claude Boyd as the pre-eminent scientist working in this area of aquaculture science. The first version of the book had three main parts: principles of water quality, water quality management and measurement of water quality. The second version of the book did away with the laboratory measurement and methods section, which was published separately, and included the original principles and management sections, expanded to include much more information about water quality in marine shrimp ponds. The new book, as the title suggests, discusses water quality independent of the pond aquaculture production system, although water quality in ponds remains the major theme.

The new book has been completely reorganized and revised, with the big change being a general coupling of principle with management. For example, the discussion about dissolved oxygen dynamics is paired with a chapter about aeration. The reorganization has also resulted in much more succinct and salient discussions of topics than in previous versions; the page count has decreased from 482 to 439 from the 1990 version to the current book, despite the expanded scope. Nearly all chapters include excellent summaries of the physiological effects of particular water quality variables on cultured animals, indicating one of the many contributions of the second author to the book. A section on measurement of a particular water quality variable concludes most chapters.

Overall, the illustrations, graphs and figures are better quality than in previous versions, although there are some digital photographs that were distorted when placed. The list of references at the end of each chapter are not exhaustive, emphasizing publications of the first author, but representing key references for deeper investigation into a topic. The authors selected the less-useful and awkward convention of numbering citations in the text, rather than providing author names.

The book begins with chapters on the fundamentals of water science, with a good discussion of hydrology that is based on the terms in water budgets for aquaculture production systems. Then, a new chapter to this book on ecological principles is provided, including an excellent discussion of the role of life support, culture system intensity and the footprint of aquaculture. A chapter on water sources and culture systems follows, emphasizing ponds but including flow-through systems, cages, recirculating systems, shellfish and seaweeds – all indicating the expanded scope of the book.

The ordering of the water chemistry chapters has shifted, giving prominence to those water quality variables in order of priority. In general, the ordering of chapters flows much more logically than in the previous two versions. After the introductory chapters, two chapters discuss dissolved ions and salinity and then alkalinity and hardness. Given the importance of alkalinity in buffering pH changes, chapters on carbon dioxide, pH and liming follow. There is interesting organization of this topic by describing the processes that affect pH in aquaculture production systems. The section on liming in previous versions of the book has become a subsection of a more comprehensive “managing pH” section. Here too a new passage on managing high pH in aquaculture ponds is provided.

Chapters on fertilization and feeds and water quality follow. The chapter on fertilization has been significantly modified from previous versions of the book, with a much more cogent and concise summary of the topic provided, although incorporating more of the work of the Pond Dynamics and Aquaculture CRSP on this topic would have been welcome.

The next group of chapters starts with a new chapter on thermal stratification and mixing, a topic that was only a subsection of a chapter in previous versions of the book. Again, a phenomenon (stratification) is linked with a management approach (mixing). Chapters on dissolved oxygen and aeration follows. These chapters are considerably revised and updated from previous versions of the book and are much more succinct, organized from the perspective of the terms in pond dissolved oxygen budgets. There is new information about aeration rate and aerator placement. A new chapter on gas supersaturation, important in hatcheries and flow-through systems in particular, has been added to this version of the book.

A chapter on solids, turbidity and color follows, including a discussion of sedimentation basins and effluent treatment. Next is a chapter on nitrogen, with a particularly good discussion of the forms of nitrogen in ponds and the toxicity of ammonia and nitrite. A new chapter on hydrogen sulfide has been added, a topic that was covered in only a couple of pages in previous versions of the book.

A new chapter on toxic algae and off-flavor provides a particularly deep treatment of the topic, indicating the contribution of Craig Tucker. The aquatic plant management chapter has been completely re-worked.

The chemistry chapters of the book conclude with a chapter on trace elements, emphasizing the importance of iron in groundwater. This chapter combined several chapters from previous versions of the book. A chapter on miscellaneous treatments follows, including discussion of biological amendments, microbial and plant extracts, oxidants and disinfectants, therapeutants and other substances. Despite their widespread use, particularly in marine shrimp farming, the authors are rather dismissive of probiotics, although admittedly the evidence for their efficacy is equivocal. There is a new chapter on water quality in low-salinity aquaculture, particularly applicable to the farming of shrimp in inland areas heretofore underutilized for this form of aquaculture. A chapter on pond bottom soil management has been re-worked and is considerably shortened from the previous version of the book. Interestingly there is no discussion of phosphorus dynamics here. On the whole, the discussion of phosphorus is minimal and scattered throughout the book. Phosphorus deserves its own chapter, given its importance to primary productivity and environmental impact (i.e. eutrophication).

The Handbook then moves into a group of chapters describing the particular water quality issues associated with various culture systems, including partitioned ponds, lined ponds (including biofloc systems), flow-through systems, cage culture and recirculating systems. A last chapter on effluents provides information on strategies for effluent reduction and summarizes the Best Management Practices available to minimize the volume and impact of effluents.

The book concludes with a section on volume measurement and calculations. This section is organized according to the water inflow and loss terms of a water balance and provides good information on measuring water flow. The section also includes information on calculating the proper dose of chemical treatments of culture systems. As in the other books, a helpful reference of commonly-used conversion factors is included.

This book will have broad appeal to fish and shrimp producers, students and scientists. It is an essential reference for anyone working in the field of water quality, although the book also represents a key reference for aquaculture scientists working in sub-fields such as nutrition, reproduction, diseases, engineering, etc. The price point of this book makes it affordable to growers, students and scientists in the developing world. As with previous versions, the book is, at its core, a practical manual for managing water quality in aquaculture production systems.

— John A. Hargreaves

Editor's Note: ***Handbook for Aquaculture Water Quality*** *is available through the on-line store at the WAS website. The book is also available in the US for $49.50 per copy (including shipping by US mail media rate) by ordering from P. Boyd, P.O. Box 3074, Auburn, Alabama 36831. For international shipping costs or other questions, contact claudee39@gmail.com.*

President, continued from page 2

Shifting gears, many of you may have heard of predatory publishing, where journals, usually new open-access journals, will approach academics seeking submission of manuscripts, which often turn out to have significant page or publication charges and lack the editorial and publishing services associated with quality, legitimate journals. A regularly updated on-line report lists nearly 500 such journals and it is inevitable that one or more will encompass the field of aquaculture.

I recently became aware of a similar phenomenon of predatory conferencing, with organizations seeking to organize fee-paying conferences, principally for income generation. This is different from the scams many of us are aware of with invitations to bogus conferences that never actually occur. (Most of the invitations that I receive seem to arise from China). These predatory conferences may actually take place if sufficient interest is garnered but are likely to turn out to be something less than they are made out to be.

A common practice of predatory conferencing is to seek endorsements from well-known people in the field, who are often not aware that their interest in the conference is being used to promote the event. Senior figures in WAS are prime targets for such practice. So, when these tempting invitations drop into your inbox, it pays to do a bit of due diligence. Things to look out for that might set alarm bells ringing include a lack of any obvious cooperation with local organizations and a lack of organizational endorsement rather than individual endorsement. Fortunately the brand and reputation of WAS is such that, as an organization, our participation in or endorsement of an event can be seen as a measure of its authenticity and legitimacy.

I mentioned in my last column about the two important decisions taken by the Board in Adelaide to reinvigorate the journal and to support the development of chapter home offices for the APC and LACC. On the journal, our first step is to recruit an Executive Editor. This process is travelling a bit slower than hoped but we have a number of promising candidates for the position and will soon be shortlisting. Hopefully I will be able to provide an update in my next column.

We have made better progress on the development of chapter home offices, with appointments made for both executive officers, who will take up their positions this December. Further details will be provided by the chapters but I would like to welcome Pornnatcha Klinsorn (Genie) and Nashieli Rodriguez (Nash) to the WAS executive team representing the APC and LACC respectively. Genie will be based in Bangkok and will be working full time with the APC while Nash will be based in La Paz, Mexico and will initially be working on a part-time basis. These appointments will enable those chapters to be more proactive and to engage more effectively with their members. Hopefully these executive officers will gain a better understanding of the most effective value proposition of WAS membership in their respective regions, enabling us to better tailor and adapt membership features and services to deliver better value from membership.

I would like to end by wishing all WAS members an enjoyable and productive festive season, which here in Australia is a key time of year for the seafood industry, with a major peak in consumption.

— Graham Mair, President


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Milkfish culture in cages at SEAFDEC/AQD, Igang marine station, Guimaras, Philippines. Photo by J.A. Ragaza.

A Fish Farmer's Role in Sustainable Aquaculture: An Overview of Philippine Aquaculture

Jonni Fay C. Teves and Janice A. Ragaza

The expansion of Philippine aquaculture is essential to addressing poverty and food insecurity in the midst of a seemingly irreversible decline in national capture fisheries. Concomitant with its rise, however, are compounding environmental problems caused by climate change, lackluster governance and irresponsible farming practices. It is equally important to ensure aquaculture sustainability so that fish demand from a rapidly growing population is continually met and that fish farmers' socioeconomic well-being is secured. As such, programs have been developed that aim to enjoin the government and private sectors with fishing communities to realize this goal.

Contribution of the Fishery Sector to the Philippine Economy

The Philippines is a tropical, archipelagic country comprised of 7,107 islands located in Southeast Asia. Surrounded by the Pacific Ocean on the east, the Celebes Sea and Bornean waters on the south and the South China Sea on the west and north (Bautista 2009), it has a total territorial water area of 2,200,00 km^2 while the total land area covers only about 300,000 km^2. Its 17,460 km coastline spans marine areas that include coral reefs, seagrass and algal beds. In the interior of landmasses are freshwater and brackishwater

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Fish pens using bamboo poles for enclosure at SEAFDEC/AQD, Binangonan Freshwater station, Rizal, Philippines. Photo by J.A. Ragaza.

Lake-based cages at SEAFDEC/AQD, Binangonan Freshwater station, Rizal, Philippines. Photo by J.A. Ragaza.

swamplands, fishponds, lakes, rivers and reservoirs (Yap 1999, BFAR 2011).

With its extensive aquatic resources, the country was the fifth top fish producer in the world in 2010. However, total production has decreased at a rate of 3.6 percent, from 5.16 million t in 2010 to 4.97 million t in 2011. Nonetheless, total export value was US$ 871 million while import value was US $217 million, leaving a positive trade balance of US$ 654 million. Overall, the fishery sector contributed 1.9 percent (US$ 4.23 billion) and 2.2 percent (US$ 3.02 billion) at current and constant prices respectively of the country's GDP (US$ 224.79 billion at current prices and US$ 136.79 billion at constant prices) (BFAR 2010a, BFAR 2011).

Annual performance of Philippine fisheries is attributed to three subsectors: municipal (small-scale) fisheries, commercial fisheries and aquaculture. Municipal and commercial sectors are distinguished by fishing location and vessel capacity—the municipal sector involves capture operations in inland and coastal areas with or without the use of a vessel not exceeding 3 gross t, while commercial fisheries is done in offshore waters using vessels of at least 3 gross t. Aquaculture is defined as the cultivation and farming of aquatic plants and animals in inland, coastal and marine areas (FAO 2001).

Among the three subsectors, aquaculture made the greatest contribution to fish production in 2011, with 52.4 percent (2.61 million t), followed by the municipal sector with 26.8 percent (1.33 million t) and commercial sector with 20.8 percent (1.03 million t) (BFAR 2011).

Status of Philippine Aquaculture

Philippine aquaculture can be traced to the fourteenth century, starting with the use of traditional, low-density pond culture of milkfish (Lopez 2006). Only in the 1940s was aquaculture recognized as an important industry, with 20,000 t of production, and since then has grown rapidly (Yap 1999). Total aquaculture production has increased from 0.29 million t in 1980 to 2.54 million t in 2012 (CountrySTAT Philippines 2012), comprising 42.5 percent of total fisheries output in 2013. Its steady growth, together with increased commercial fishery production, allowed the fishery sector to recover from a contraction in growth the previous year (BAS 2014). It has had an average annual growth rate in production volume of 8.6 percent from 1997 to 2008, and the production value is now nearly triple the amount in 1996 (BAS 2014, CountrySTAT Philippines 2012).

Philippine aquaculture involves many species and farming systems. As of 2007, there are 16 reported aquaculture species, among which four are considered most important: seaweeds, milkfish *Chanos chanos*, Nile tilapia *Oreochromis niloticus* and tiger shrimp *Penaeus monodon* (BFAR 2011, Sumagsay-Chavoso 2007). In 2011, seaweed was the greatest contributor to production at 70.6 percent (1.84 million t); followed by milkfish, 14.3 percent (372,580 t); tilapia, 9.9 percent (257,385 t); shrimps and prawns, 1.9 percent (50,159 t); and others, 3.3 percent (87,162 t) (BFAR 2011).

Seaweeds. There are two groups of farmed seaweeds in the Philippines, those which are extracted for industrial chemicals, such as *Eucheuma* spp., and edible species, mainly *Caulerpa* spp. Research on new seaweed strains (*Kappaphycus* spp.) has been undertaken in 2008 to generate fast-growing, disease-resistant seaweeds for commercial farming (SEAFDEC/AQD 2008). The Philippines is the world's largest producer of farmed *Eucheuma* (BFAR-PHILMINAQ 2007).

Milkfish. Locally known as bangus, milkfish is the country's national fish, having a high level of consumer acceptance and the largest share of farmed foodfish production. In 2001-2005, the Philippines was consistently the top milkfish producer in the world, and has increased growth rate over the recent years (BFAR 2008). Meanwhile, milkfish processing is a growing industry in the country. Fish are deboned before they undergo marinating or smoking to make them more palatable to the current younger generation, who are often deterred by its bony features. "Boneless bangus," as it is called, is a uniquely popular Philippine product (Yap *et al*. 2007).

Tilapia. Tilapia (*Oreochromis mossambicus*) was first introduced to the Philippines from Thailand in 1950. Nile tilapia (*O. niloticus*) was first introduced in 1972 and has since gained wide acceptance among farmers and consumers (Yap 1999). It is the main tilapia species cultured in the Philippines and in 2013 the country

Seahorse hatchery at SEAFDEC/AQD, Tigbauan, Iloilo, Philippines. Photo by J.A. Ragaza.

Rearing tanks for giant freshwater prawn at SEAFDEC/AQD, Binangonan Freshwater station, Rizal, Philippines. Photo by J.A. Ragaza.

maintained its rank as the fourth top tilapia producer, contributing 8 percent to global tilapia production (SunStar 2013).

Shrimp/prawns. In the early 1990s, the Philippines ranked as the third top shrimp producing country in the world, specifically based on the culture of the black tiger shrimp *P. monodon*, locally known as sugpo. However, high stocking densities in pursuit of high production have led to the spread of bacteria diseases. Although initially mitigated by antibiotics, the causative bacteria developed resistance, causing the collapse of shrimp farms (Yap 1999). Culture of black tiger shrimp then waned, clearing the way for the culture of Pacific white shrimp *P. vannamei*, the species of current interest. Despite opposition by local NGOs and producers fearful of another disease outbreak, Pacific white shrimp are preferred for ease of culture, better survival and lower protein requirement in feeds, together leading to cheaper shrimp in the market (Sulit *et al*. 2005).

Culture environments. Species are cultivated in fish pens, cages and ponds in marine, brackishwater, and freshwater environments. Open coastal water is the largest culture environment, mainly as a result of the seaweed industry. Mariculture began in the 1930s with oysters, followed by the culture of mussels 20 years later. However, it progressed only with the start of carrageenophyte seaweed farming in the 1970s (Yap 1999).

Brackishwater areas, such as mangrove swamps and estuarine areas, is the second largest culture environment. The two main brackishwater species cultured are milkfish and black tiger shrimp; others include mudcrabs *Scylla serrata*, grouper *Epinephelus* spp., seabass *Lates calcarifer* and other penaeid shrimps.

Freshwater aquaculture started with the introduction of Mozambique tilapia in 1950 and the subsequent spread of backyard tilapia culture throughout the country. Freshwater aquaculture came to prominence in the mid-1970s with the discovery that milkfish could be reared without feeding at commercial levels in Laguna de Bay fish pens. Thereafter, tilapia were successfully cultured in cages, initially in Laguna de Bay and then in other lakes, dams and reservoirs. Commonly cultured freshwater species aside from tilapia are bighead carp *Aristichthys nobilis* and common carp *Cyprinus carpio*, African catfish *Clarias gariepinus*, snakehead *Channa striata*, euryhaline milkfish and most recently the freshwater prawn *Macrobrachium rosenbergii* (Garcia and Sumalde 2013, BFAR-PHILMINAQ 2007, Lopez 2006).

Aquaculture, Food Security and Poverty Alleviation

Aquaculture has steadily contributed to the fish supply, a panacea for dwindling fish stocks from overfishing and habitat degradation. The importance of aquaculture is underscored inasmuch as fish remains the major essential protein source for the poor majority, with a 42.5 percent share of total animal protein consumption (Kawarazuka and Béné 2011) as well as the greater food insecurity experienced in rural compared to urban areas (Ravanera and Emata 2012). Pressure on the fish supply has been intensified by the impacts of climate change, as evinced by erratic weather patterns and the increasingly powerful and frequent typhoons that ravage the country. Fish farmers are highly vulnerable to loss of food and income. This was keenly felt when Typhoon Haiyan (known locally as Yolanda) wreaked havoc in the major aquaculture and fisheries producing regions in the Visayas in November 2013, leaving most small-scale fish and seaweed farmers displaced. Dependence of poor fish farmers on the fish supply is augmented by the fact that families in the lowest income groups spend more on fish products for food compared to the average Filipino household (Worldfish Center 2008).

Sustainability in Aquaculture

The rise of aquaculture has negatively impacted ecosystems. Proliferation of fish pens and cages has led to fish kills because of oxygen depletion, accumulation of pollutant toxins and diseases. Species have become threatened and endangered. Mangrove areas were converted to fishponds, a practice that has compromised natural filtration and has added up to water pollution (Bergquist 2007, BFAR-PHILMINAQ 2007).

The Philippine government's Mid Term Development Program (2004-2010) has identified aquaculture as a subsector that will generate new jobs and ensure food security geared toward the country's goal of economic development (Nagothu and Ortiz 2007).

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Mud crab rearing tanks at Institute of Aquaculture, College of Fisheries and Ocean Sciences, University of the Philippines-Visayas, Miagao, Iloilo, Philippines. Photo by J.A. Ragaza.

Rotifer culture, as feed for fish larvae at Institute of Aquaculture, College of Fisheries and Ocean Sciences, University of the Philippines-Visayas, Miagao, Iloilo, Philippines. Photo by J.A. Ragaza.

If aquaculture is aimed toward positive development, sustainability programs must integrate the following factors: technical (feeding practices, aeration, broodstock quality); physical (temperature, salinity); institutional (legislation, externalities); and socioeconomic (poverty, farmers' management abilities) (Bergquist 2007).

Technical factors. The search for potential plant-based proteins, including water hyacinth and white cowpea as alternatives for fishmeal in aquafeeds, has gained importance to reduce dependence on depleted marine fish stocks (SEAFDEC/AQD 2008). This also calls for a shift toward cultivating herbivorous and omnivorous fishes, such as milkfish, tilapia and catfish.

Studies have also been conducted that aim to improve the living standards of fish farmers and consumers, provide avenues for employment and ensure food security throughout the country. These include the genetic improvement of tilapia and, more recently, the project of identifying tilapia "super strains" (Worldfish 2013), improving technologies for breeding new aquaculture species of high economic value, such as snubnose pompano *Trachinotus blochii*, scat *Scatophagus argus* and Napoleon wrasse *Cheilinus undulatus*, among others (SEAFDEC/AQD 2010).

Innovative studies for resource enhancement to increase species stocks also have helped sustain the aquaculture industry. Low survival of seahorses *Hippocampus comes* in hatcheries has been a problem until the recent discovery of disinfecting its live food (copepods) with low doses of disinfecting chemicals in Guimaras, West Central Visayas. This technique has increased seahorse survival, which could enable mass production and consequently rehabilitation of depleted stocks (SEAFDEC/AQD 2014).

Physical factors. Studies on how climate change can affect the aquaculture industry have been conducted to aid fish farmers in adapting to this change. For example, effects of elevated water temperatures and acidity on performance of important cultured fishes, such as milkfish and seabass, have been assessed. Search and identification of species that can be used for integrated multi-trophic aquaculture (IMTA), an approach that promotes waste management and minimizes environmental impacts of aquaculture, is also being examined (SEAFDFEC/AQD 2011).

Recently completed research in Dagupan on saline tilapia called "mollibicus," which can be reared in coastal areas, proves to be promising in the face of increasingly frequent fishkills in brackishwater environments (The Fish Site 2014a). These studies can help provide preparatory and mitigation measures that can ultimately cushion the impacts of climate change on food supply and livelihood of fisherfolk communities.

Institutional factors. The Bureau of Fisheries and Aquatic Resources (BFAR) is the leading fishery organization in the Philippine government that has a mandate under the Republic Act (RA) 8550 of 1998 to conserve, protect and use fishery and aquatic resources sustainably, alleviate poverty and provide supplementary livelihoods for Filipinos (Lopez 2006). Other research organizations include the Aquaculture Department of Southeast Asian Fisheries Development Center (SEAFDEC/AQD), Worldfish Center, Food and Agriculture Organization (FAO) and the Asian Development Bank (ADB), among others (Lopez 2006).

At present, fisheries researchers have been collaborating with private sector fish farmers and policy makers from the national and local government through forums on enforcing limits on aquaculture operations and other environmental concerns (BFAR 2010b). This is to ensure the fair allocation of coastal resources; otherwise externalities (indirect costs to aquaculture) are incurred. Externalities include reduction in natural fish productivity and increased vulnerability to natural disasters, such as typhoons and tsunamis, resulting in loss of natural coastal protection (as provided by mangroves).

Government institutions are also strongly encouraged to mobilize funds for the benefit of fish farmers. For example, the Quezon provincial state government has been providing free materials for milkfish cage construction, such as bamboo poles, nets, ropes and fingerlings to fishermen, thereby paving the way for aquaculture development in the region (The Fish Site 2013b). Similarly, BFAR has allocated US$ 737,000 to the local government of Cebu to help rehabilitate fish cages, seaweed farms, fish pens and coral reefs damaged by Typhoon Yolanda (The Fish Site 2014b). As the country has been facing shortages in the supply of seaweed, the

Checking water quality in milkfish culture ponds at Institute of Aquaculture, College of Fisheries and Ocean Sciences, University of the Philippines-Visayas, Miagao, Iloilo, Philippines. Photo by J.A. Ragaza.

Outdoor circular fish tanks at Institute of Aquaculture, College of Fisheries and Ocean Sciences, University of the Philippines-Visayas, Miagao, Iloilo, Philippines. Photo by J.A. Ragaza.

government also increased the budget from US$ 924,000 in 2011 to US$ 6.275 million in 2012 to develop the seaweed industry. This could help farmers supply more seaweeds to avoid importing from Indonesia, and eventually retrieve the country's position as the top seaweed industry in the world (Dagooc 2012).

Socioeconomic factors. The capacity of fish farmers to run aquaculture operations sustainably depends on their economic standing, education and empowerment, inasmuch as these can provide farmers with access to the latest aquaculture information and technologies. Access to this information is normally limited to local elites, who are more capable of acquiring institutional and natural resources, thus placing poor and unskilled laborers at a great disadvantage (Bergquist 2007). To address this, the Philippine government has adopted a shift in its policy program from aquaculture development to aquaculture for rural development, a 'pro-poor' program that promotes livelihood projects in rural communities (Lopez 2006). Government and private sectors also have been conducting a series of workshops and skills training throughout the country. These aim to educate fishing communities on the importance of aquaculture resources, impacts of climate change and adoption of the latest environment-friendly technologies (SEAFDEC/AQD 2011). For example, the Misamis Occidental Project has trained fishers on improved grouper cage culture technology so they can operate cage farms in the province (SEAFDEC/AQD 2010). Skills training for farm operations is positively correlated with income, emphasizing how the lack of proper skills and access to technology remain among the main constraints to aquaculture development in the country (Nagothu and Ortiz 2007).

Outlook

The Philippines is endowed with a tropical climate and vast aquatic resources conducive for aquaculture expansion. However, it also faces an overarching problem—climate change—parried only by an equally potent solution through integrated sustainability programs. While anchored in research and development of new environment-friendly technologies, government and private sectors alike must take on the task of bringing these to the industry's real major stakeholders, the poor majority. Given a substantial dependence on aquaculture for food and income, their wide and active participation would provide for their needs and also sustain the fast-paced growth of aquaculture in the Philippines.

Notes

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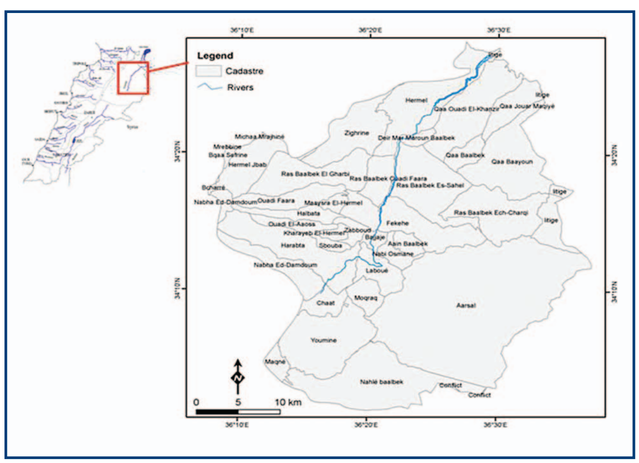
Environmental Impact of Trout Aquaculture on the Lebanon Portion of the Assi River

Nadim Farajalla, Yara Daou, I.P. Saoud

Global rainbow trout *Oncorhynchus mykiss* aquaculture production reached 732,432 t in 2009, with a value of more than US$ 3.4 billion (FAO 2011b). The most important nations producing rainbow trout in 2008 were Chile (149,411 t), followed by Norway (75,316 t) and Iran (62,630 t). Rainbow trout was introduced into Lebanon in 1958 (FAO 2011a).

Aquaculture in Lebanon started as subsistence food production in the 1930s (FAO 2011a). Commercial-scale aquaculture in Lebanon started in the 1990s, after the civil war. Development, technical expertise and a greater demand for seafood products were provided by investors and tourists who returned after armed conflicts ended (Lebbos and Saoud 2006).

More than 90 percent of aquaculture production in Lebanon is rainbow trout. The remaining 10 percent includes small quantities of carp, catfish, penaeid shrimp and tilapia. Rainbow trout production in the country in 2002 was estimated by the Ministry of Agriculture to be 600 t or by trout farmers to be 1,000 t (Lebbos and Saoud 2006). A 2011 article published in the Lebanese daily newspaper, *Al-Akhbar* (Al-Akhbar.com), suggested that rainbow trout production may have reached 1,700 t yearly. There are reportedly 150 fish farms in Lebanon, most of them small, family-owned businesses (FAO 2011a).



TOP, FIGURE 1. *A rainbow trout farm along the Lebanon portion of the Assi River.* MIDDLE, FIGURE 2. *Aerial view of trout ponds on the Assi River near the town of Hermel, Lebanon.* BOTTOM, FIGURE 3. *The Assi (Orontes) River and its watershed in northern Lebanon.*

Most (70 percent) aquaculture in Lebanon takes place along the Assi (Orontes) River (Lebbos and Saoud 2006), near the northern border with Syria, in earthen and concrete raceways (Figs. 1 and 2). The Assi River is a perennial stream located in northern Lebanon, a few kilometers northeast of the Litani River source (Fig. 3). The Orontes River Valley region is arid, mainly because the mountain range on the west side of the Bekaa Valley deprives the valley of rainfall. Annual precipitation averages 250 mm (El Moussaoui and Yazigi 2005) and temperatures vary between an average of 5.5 C in January to 32 C in August (El Moussaoui 2001). The Lebanese portion of the Assi River, which flows north into Syria, is 46 km long. The annual flow rate of the Lebanese part of the Assi River is 480 million m^3 (Ministry of Environment 2001).

The Assi River has excellent water quality for trout aquaculture. It has the clear, cool, oxygenated, fast-flowing waters necessary to meet the water quality requirements of rainbow trout (Table 1). However, these water quality attributes also make the river desirable for municipal uses, traditional irrigation and recreational activities. It is imperative that aquaculture not pollute the water, making it unsuitable for other uses.

Fish farmers along the Assi River near the town of Hermel use earthen or concrete raceways supplied with constantly-flowing water diverted from the river. This has environmental consequences that depend on farm size, number of surrounding farms, load of fish in each farm, intensity of feeding, flushing capacity of the aquatic environment, bacteriology and biodiversity of the milieu and land use around aquaculture farms

(Boaventura *et al*. 1997). Fish on the downstream part of the river live in effluent from farms located upstream.

Water quality is not the only factor affecting rainbow trout health. Crowding, improper handling, grading, pond cleaning and other routine activities are additional factors that stress fish and can lead to increased susceptibility to pathogens (Pickering 1992). In many countries, fish farmers are assisted in the management of water quality and environmental parameters by government and academic institutes and extension agents, but this is not the case for the trout farmers of Lebanon.

Aquaculture has generated massive enthusiasm in the past two decades, with some viewing its development as a 'blue revolution' with tremendous potential for food security, economic growth in rural areas and poverty alleviation. However, growth in fish farming, as with all farming activities, has environmental impacts, which must be managed if production is to be sustainable.

Other than the flow rate of the Assi River, very little is known about water quality and no studies of the impact of trout aquaculture on the Lebanon portion of the stream are available. Here we describe a study performed on the river to assess levels of pollution, effects of aquaculture on river water quality and local stakeholder perceptions of aquaculture and the environment.

Study Survey

A survey of trout farmers along the length of the Assi River in Lebanon was done in 2012. Farms were identified and a list of 49 farmers who fully or partially own ponds along the Assi River was established. Geographic coordinates of each farm were estimated using Google Earth imagery. Survey results cover 199 ponds from the source of the Assi River to the last accessible point before the Lebanon-Syria border. Every trout farm owner or manager along the river was interviewed and informal conversations with the mayor of Hermel, recreational activity (e.g. rafting and camping) organizers and restaurant owners bordering the river, were recorded.

A detailed questionnaire was prepared in English and translated to Arabic. It included questions related to land and ponds, fish production, feeding and environmental practices and the farmers' personal opinion about the state of aquaculture in the river valley. Questions were posed at random and in no specific order. The veracity of some answers was controlled by asking some farmers if the information given by other farmers was correct.

TOP, FIGURE 4. *Earthen raceways along the Assi River, Lebanon.*
BOTTOM, FIGURE 5. *Concrete raceways along the Assi River, Lebanon.*

Raceway Design and Construction

The design and construction of ponds and raceways on fish farms of the Assi River valley is diverse. Only earthen raceways (Fig. 4) are used by 43 percent of farmers, both earthen and concrete raceways are used by 34 percent and only concrete raceways (Fig. 5) are used by 23 percent. In general, those with concrete raceways thought they were better and those with earthen raceways defended their use.

There are two main reasons to explain the prevalence of earthen raceways along the Assi River. First, earthen raceways are less expensive to build than concrete raceways. Trout farmers who believe that concrete raceways are better often lack the funds to transform their earthen raceways to concrete. Some trout farmers who rent raceways perceive the expense of transforming earthen raceways to concrete raceways as unnecessary, inasmuch as they will not benefit from the investment over time because they do not own them.

The other reason to explain the prevalence of earthen raceways is that many farmers assert that trout reared in earthen raceways are healthier, more colorful and a better-quality product. Thirty-eight percent of farmers believe that earthen raceways are better for trout health and welfare than concrete raceways. Some of the reasons given were that fish feed on small plants growing in the soil and hence obtain more nutrients and grow faster. Also, some believe the soil acts as a filter, cleaning the water in which trout are grown.

A majority (53 percent) of trout farmers thought yields from earthen raceways were better than from concrete raceways. Another 13 percent believe that rearing rainbow trout in earthen or concrete raceways gives similar results and therefore deem the additional expense of building a concrete raceway unnecessary. Piper *et al*. (1982) also reported that some trout farmers stand by their opinion with respect to high yields from earthen raceways. Survival of rainbow trout does not seem to depend on the type of the raceway, earthen or concrete.

Thirty four percent believed that concrete tanks were better because, in contrast to earthen tanks, they can be totally cleaned of waste. Furthermore, no aquatic animal can dig into them and allow fish to escape. They are difficult for pests or predators (e.g. snakes, rats or frogs) to enter and prey upon trout fingerlings. Eleven percent of farmers stated that they were certain that concrete raceways helped reduce fingerling mortality and offered better population control. Fish and water quality in concrete raceways are much easier to manage than in earthen raceways (Piper *et al*. 1982, Hinshaw 2000, Dunning and Sloan 2001).

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We believe that rainbow trout aquaculture in earthen raceways along the Assi River is not sustainable. Earthen raceways are more difficult to clean and sediments accumulate, leading to anaerobic conditions. Earthen raceways are subject to resuspension and accumulation of solids, which could harbor pathogens. Furthermore, earthen raceways are prone to erosion and caving in of embankments, resulting in irregular widths and depths that disrupt water flow patterns (Piper *et al*. 1982). Finally, earthen ponds are difficult to sterilize between harvests.

Feeds and Feeding

All rainbow trout farmers along the Assi River use manufactured fish feed, purchasing any brand available. Most farmers knew some of the major ingredients in the pelleted feed but do not know their proportions. Only 11 percent were willing to state the composition of the feed used.

Nearly all farmers (96 percent) offer fish only aquafeeds. The price of aquafeed and fishmeal is a very important factor in deciding whether to feed fish a manufactured diet or chicken processing wastes. Trout farmers occasionally replace fish feed with poultry byproducts because they cannot always afford to purchase fish feed and because they do not fear legal penalties, inasmuch as the government does not control their practices.

If chicken processing wastes are used as substitutes for aquafeed, the water quality of the Assi River may be at risk. Even if poultry byproduct is added to aquafeeds as a substitute for fishmeal, it performs worse in terms of pollution loadings (Wu 1995). Also, poultry byproducts do not always contain the necessary nutrients required for healthy growth (Riche and Brown 1996).

Very few farmers are aware that fingerlings need feed with a greater protein level than larger rainbow trout. However, because the majority of farmers purchase their feed at the correct pellet size for their fish and the feed manufacturers know the required feed composition at various sizes, the fish receive the correct feed composition and size for each development stage. This is not a problem because most farms along the Assi River stock fish at the same time and have similar-size animals.

Healthy fish growth depends on appropriate feeding rates. When asked stocking densities, farmers gave such different answers that it almost was impossible to sort responses into categories. For most trout farms along the Assi River, the biomass of fish per tank is not known with certainty and, without this estimate, the proper quantity of feed as a function of body weight cannot be determined. Most farmers offer feed to apparent satiation as instructed by feed salesmen but do not weigh the feed given. Some farmers do not feed fish for days if they do not have the money to purchase feed.

We are uncertain that actual feeding practices match responses to the survey. Trout farmers do not keep records of water quality, mortalities and fish growth, despite this information being essential to determining feeding quantities. Repercussions of feeding in excess of what fish are able to metabolize include increases in production costs, deterioration of water quality and outbreaks of diseases (Cain and Garling 1993, Dunning and Sloan 2001). Very few farmers realize uneaten food is a pollutant.

TABLE 1. Water quality requirements for rainbow trout culture.

Parameter	Range	Reference
Optimal temperature	13 – 18	Dunning and Sloan 2001
	7 – 18	Cain and Garling 1993
	12 – 21	FAO 2011c
	10 – 15	IDEQ 1998
Optimal pH range	6.5 – 7	Hinshaw 2000
	6.5 – 8	Cain and Garling 1993
	6.7 – 8.5	Klontz 1991
	6.5 – 8.5	FAO 2011b
Alkalinity (mg/L as CaCO3)	10 – 400	Cain and Garlin 1993; IDEQ 1998, FAO 2011b
	30 – 200	Klontz 1991
Hardness (mg/L as CaCO3)	10 – 400	IDEQ 1998
Minimum dissolved oxygen (mg/L)	6	Hinshaw 2000
	5	Piper *et al.* 1982;
	7	IDEQ 1998
Phosphorus (mg/L)	0.01 – 3	IDEQ 1998
Ammonia-N (mg/L)	< 0.03	Klontz 1991
	0.0125 – 0.025	IDEQ 1998
Nitrate (mg/L)	< 0.55	Klontz 1991
	< 0.1 in soft water	
	< 0.2 in hard water	IDEQ 1998

TABLE 2. Range of water quality parameters along the Lebanese portion of the Assi River during August, September and October of 2012.

WATER PARAMETER	*RANGE*
Conductivity (µs/cm)	303 – 368
Temperature (C)	15.1 – 16.2
Oxygen (mg/L)	7.72 – 9.78
pH	8.0 – 8.2
Alkalinity (mg/L)	200
Hardness (mg/L)	200
Ammonia-N (mg/L)	0.02 – 0.35
Nitrite-N (mg/L)	0.0
Nitrate-N (mg/L)	0.37 – 0.84
Phosphorus (mg/L)	0.06 – 0.18

Sludge Management

The perception of most farmers (64 percent) is that sludge does not accumulate in raceways because it is carried out with the flowing water. Thirty two percent of surveyed farmers declared that they remove sludge from their tanks and dispose of it. Two said that they simply dump it in the river. One farmer collects sludge and uses it to fertilize agricultural crops.

Farmers allow sludge to accumulate in raceways and discharge it all at once because this is the least labor and time consuming method. Most farmers lower raceway water level after harvesting, increase water flow rate and allow sludge to exit ponds and raceways and flow into the Assi River. Nearly all (96 percent) of farmers do not gauge the flow rate of water that runs through their raceways. Continual sludge removal of sludge is better because sludge accumulation can cause stress in fish and poor water quality (Cripps and Bergheim 2000). Continual removal of sludge was performed by only 32 percent of surveyed farmers.

Use of Chemicals and Therapeutants

Nearly all (96 percent) of surveyed farmers stated they clean and sterilize tanks between crops. Potassium permanganate ($KMnO_4$) was mentioned most often (by 79 percent of farmers) as a sterilization chemical. Most trout farmers apply potassium permanganate to their tanks when they lower water levels after harvesting. Salt and quicklime are other products applied to raceways between crops. Salt was mentioned by 47 percent of farmers and 23 percent say they use quicklime for their ponds. Many farmers do not know the difference between permanganate, salt or quicklime as therapeutants.

To clarify, farmers use chemicals if they thought there was a need, but generally do not use them. They followed cleaning and sterilizing protocols mainly because other farmers do so. Some farmers even use potassium permanganate as a drug and apply it while fish are cultured. Such a treatment is an approved parasiticide used elsewhere but flow rate and drug concentration are managed strictly. Excessive use of potassium permanganate can harm fish and low dosages are inconsequential to the parasites. In addition, farmers often treat sick fish with permanganate without knowing if the disease is viral, bacterial or parasitic.

Drugs used to treat the fish included Avytril (enrofloxacin, fluorquinolone) and tetracycline, each used by 19 percent of the farmers. However, those 38 percent are not the only farmers giving drugs to their fish. Farmers generally do not know the names of the medicines they use and some declare that they receive drugs them with no label on the bottles.

A potential catastrophe in the making is farmers treating all diseases with antibiotics (namely enrofloxacin and oxytetracycline), without knowing if the disease was bacterial and with disregard to the possible environmental harm of antibiotics. For instance, enrofloxacin is not approved by the United States Food and Drug Administration (Koc *et al*. 2009) and oxytetracycline inhibits nitrification, a necessary detoxifying process in natural waters (Klaver and Matthews 1994). Also, oxytetracycline was found to be "so stable that a half-life cannot be determined" (Shao 2001). Thus, antibacterial drug residues may remain in ponds and can be transferred from raceway to raceway and into the Assi River. Antibiotic residues in cultured fish could adversely affect consumer health, and indiscriminant antibiotic use can promote the development of drug-resistant bacteria that may also affect humans (Grave *et al*. 1990, Wu 1995, Beardmore *et al*. 1997, Shao 2001, Zhang *et al*. 2010).

"Knowing how to deal with disease outbreaks can mean the difference between a successful business or going broke," stated Cain and Garling (1993). Farm managers rarely ask for technical assistance from experts when there is a disease outbreak. Farm managers along the Assi River mainly copy practices from other farmers, without trying to find the scientific explanations behind them. For instance, when NGOs provided farmers with non-labeled drug bottles, farmers used those for any symptoms they noticed on rainbow trout, irrespective of the drug. They know that these treatments are ineffective and possibly harmful and thus hide the medications they use. We were unable to obtain a list of drugs distributed to trout farmers by the local NGO.

An Estimate of Aggregate Ammonia Loading from Trout Farms

In addition to the farming skills a trout farmer should have, he/she should also understand the environment. The farmer must be a biologist and ecologist. He should understand the relationship between the position of the farm on a stream and water quality entering the raceways. Aquaculture, similar to any agriculture practice, can be environmentally unfriendly if not properly managed.

The carrying capacity of any system should be estimated and production levels of an industry controlled accordingly. There are no estimates of sustainable trout production quantities for the Lebanese portion of the Assi River so a preliminary estimate was made. The estimate is based on farmers' expectations of overall rainbow trout production for the 2010 season (2,196 t). Assuming a FCR of 1.3, then 2,196 t of fish requires 2,855 t of feed. The feed used by fish farmers contains 45 percent protein. For fish feeds containing a high level of protein, the net protein utilization (NPU) is 40 percent. Hence, total ammonia nitrogen (TAN) released into the Assi River from 2,855 t of aquafeed would be:

$$TAN = (1.0 - NPU) \times (protein / 6.25) \times 1000$$

$$TAN = (1.0 - 0.4) \times (0.45 \times 2{,}854.93 / 6.25) \times 1000 = 123{,}300 \text{ g}$$

(CONTINUED ON PAGE 22)

Assuming that the average monthly feeding rate is the same in each month of a year, then the mass loading of TAN released each month is 10,275 g. At the lowest flow rate of the river (11.5 m^3/s, or 29,808,000 m^3/mo), the total concentration of TAN is (10,275 g × 1000 g/kg) / (29,808,000 m^3 × 1000 L/m^3) = 3.4×10^{-4} mg/L. This value is much lower than the 0.05 mg/L ammonia-N considered toxic to rainbow trout (Table 1). Hence, additional production of trout along the Assi River is possible without substantial environmental impact with respect to ammonia concentration. The analysis is based on the fact that there is no other source of chemical pollution because there are no other industrial facilities along the river.

Water Quality in the Assi River

Waters samples were collected at eight locations along the river and key water quality variables were measured in the field. Sampling locations included the source of the river, the final dam on the river before the border with Syria, ponds in farm 45 before feeding the fish, ponds in farm 45 after feeding the fish, farm 21 upstream from a group of several juxtaposed farms, farm 28 downstream from the same group of farms before feeding and farm 28 downstream from the same group of farms two hours after feeding.

Conductivity, temperature and oxygen were measured with a YSI Model 85 meter (YSI Inc., Yellowstone, OH). A hand-held pH tester (Oakton Model 10) was used to measure pH. Alkalinity and hardness were determined using a LaMotte freshwater aquaculture test kit. Ammonia-N, nitrite-N, nitrate-N and phosphorus were determined using a field spectrophotometer (Hach DR/2400).

Water quality parameters did not vary significantly between river and raceways or before and after feeding. The pH varied from 8.0 to 8.2. Alkalinity and hardness averaged 200 mg/L as $CaCO_3$, with minimal variation. Dissolved oxygen concentration averaged 7.93 mg/L at the source, 7.72 mg/L at the outfall from raceways and 9.45 mg/L at the last point on the river. Water at the source contained some ammonia and varied among samples between 0.02 and 0.21 mg/L as N. Ammonia-N concentration increased downriver, reaching 0.35 mg/L. Nitrite was below detectable limits in all samples. Nitrate concentrations increased from the source of the river to downstream, reaching 0.84 mg/L in one sample. Phosphorus concentration was greater at the source (0.15 mg/L) than downstream at the last point on the Lebanese portion of the river (0.06 mg/L).

Many farmers attribute low survival of rainbow trout to the degraded quality of Assi River water. However, based on analysis of samples of river water, all water quality variables measured were within the range of no harmful effect to rainbow trout (Table 2).

Calculation of ammonia loading showed that, even in the most intensive aquaculture scenario, ammonia was not being released at a concentration beyond the no-harmful effect concentration. Agriculture fertilizers used around the Assi River were not likely to be the cause of ammonia levels in the river for two main reasons: 1) samples did not reveal high nitrate levels, which normally would result from agricultural fertilizers ending up in the stream, along with ammonia and 2) the small quantity and low intensity of precipitation in the Assi River watershed was not likely to cause significant runoff of agricultural fertilizers.

Municipal runoff and sewers are likely the main sources of ammonia. A municipal wastewater treatment facility was not operational and wastewater just flowed through to the river. Additionally, most houses and businesses around the river were not connected to the sewer system and dumped directly or had septic tanks that leaked into the river.

Recommendations for Regulation of Trout Farming

An appropriate legislative framework for aquaculture development and environmental regulations has not been established by the government (Lebbos and Saoud 2006). No license is required from the Ministry of Agriculture. Establishment of a fish farm is subject to regulation by municipal authorities and is considered industry rather than agriculture. Furthermore, although the Ministry of Environment requires an environmental impact assessment (EIA) for any business bordering a river, there are no environmental standards for aquaculture effluents to support EIAs.

Based on the principle that the Assi River is a public resource and that access to clean water is a basic right for all citizens, the Ministry of Agriculture must, as a first step, install a licensing system that would 1) acknowledge the existence of the current trout farms near Hermel, 2) give farm owners a grace period to ensure the transition of their facilities to meet established environmental and public health standards and, 3) regulate the establishment of new facilities on the banks of the Assi River.

The Ministry of Environment should develop effluent quality criteria for the Hermel trout farmers with the aim of minimizing the discharge of specific pollutants and banning feeding regimes based on animal wastes, even if their current overall concentration is not harmful to the fish or the environment. Those criteria must not only take into consideration the effluents of individual farms but the additive effects of all the farms on the Assi River.

Results of the present study suggest that additional loading of ammonia is possible without adverse effects but continuous monitoring is imperative. Also, pollutant sources other than aquaculture should be identified and discontinued.

In conclusion, trout farming along the Lebanese portion of the Assi River does not pollute the river with ammonia beyond its assimilative capacity. Education of all stakeholders is necessary to improve farm management protocols to ensure growth of the industry, while maintaining environmental quality.

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Notes

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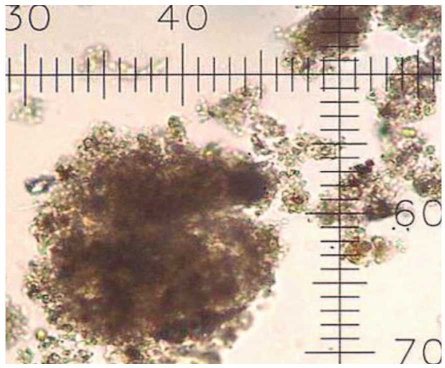
Shrimp Farming with Biofloc Technology: Commercial Experience and Approaches to Disease Control

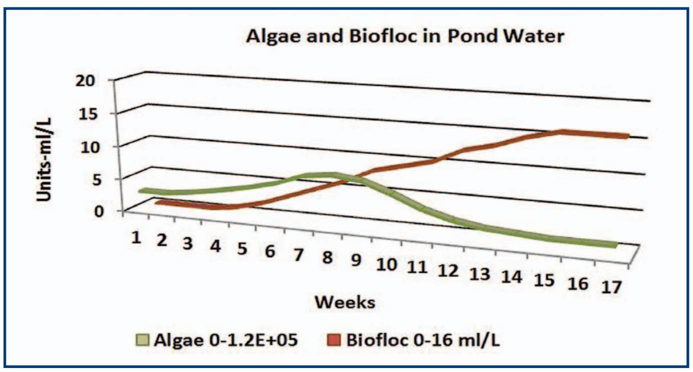
Nyan Taw

Biofloc systems—a recent technology—offer a promise of stable and sustainable production, inasmuch as the system is operated without water exchange and so has an enhanced capacity for nitrification within the culture ponds (Avnimelech *et al*. 2012). The main economic advantages of biofloc technology over greenwater (algae-based) systems are higher growth rate, lower FCR and sustainable production (Table 2).

Bioflocs are macroaggregates – diatoms, macroalgae, fecal pellets, exoskeletons, remains of dead organisms, bacteria, and invertebrates – suspended in the water column (Fig. 1). Biofloc can be used as a single-cell protein source for shrimp and fish. The crude protein content of biofloc ranges from 35 to 50 percent, and the crude lipid content is 0.6 to 12.0 percent by volume. Biofloc can be slightly deficient in arginine, lysine and methionine. The ash content ranges between 21 and 32 percent.

In biofloc systems, algae develop first, then a transition period with foam formation and finally a brown biofloc develops (Fig. 2 and 3). This may take a few weeks or longer, depending on the biomass of shrimp or fish in the pond. The transition occurs earlier with tilapia, later with shrimp. Basically the systems starts with an algae bloom and the biofloc community develops thereafter.





TOP, FIGURE 1. *A biofloc macroaggregate.* MIDDLE, FIGURE 2. *Changes in the importance of algae and biofloc in a production cycle for shrimp. Algae is more important in the first half and biofloc dominates in the second half in response to high feed loading.* BOTTOM, FIGURE 3. *The transition from algae dominance to biofloc dominance in biofloc shrimp ponds is indicated by the presence of abundant foam.*

Advantages and Disadvantages

One of the main advantages of biofloc technology is high biosecurity. To date, white spot syndrome virus has not been a factor in biofloc systems. Production and carrying capacity are typically 5-10 percent greater than in typical culture systems with no water exchange. Shrimp grow larger and reflect feed conversion ratios between 1.0 and 1.3. Production costs can be 15 to 20 percent lower.

A main disadvantage is the high energy input for aeration. Power failures of more than one hour in duration can be critical. Biofloc ponds need to be lined. The more advanced technology also demands better training of technicians.

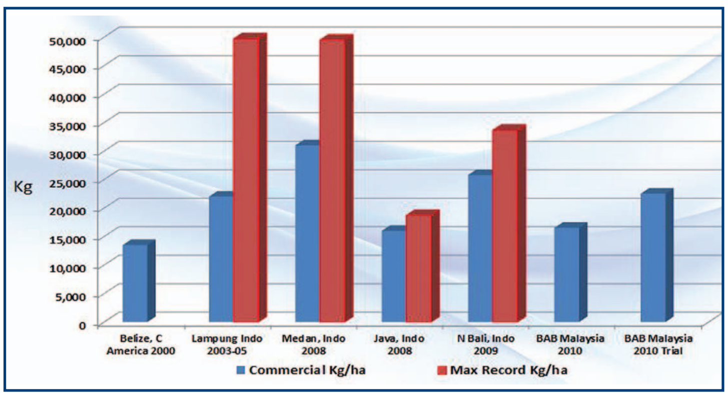
Brief Operating Protocol for Shrimp Farming

Biofloc technology for shrimp culture on a commercial scale and in large ponds is simple and yet, in a way, complex. Basic conventional procedures, depending on location and situation of the farm, need to be followed. The procedure must be adjusted with changes in culture water environment and shrimp behavior, such as health and growth (Table 1). For optimized, sustainable commercial biofloc shrimp culture, HDPE- or concrete-lined ponds are basic requirements. Only specific pathogen-free post-larvae are stocked.

When ponds are stocked, a major factor to be controlled is biofloc volume. Using Imhoff cones for assessment, biofloc volumes must be maintained below 10 mL/L for full biofloc and 5 mL/L for semi-biofloc systems (Fig. 4). A sample must be taken concurrently from each of two locations below the water surface. Green or brown water is acceptable, but black water is an indicator of abnormal conditions. Suspended biofloc must be available as food for shrimp.

Shrimp can be fed high protein (35-40 percent) or low protein

(29-30 percent) feed. Grain pellets and molasses supply carbon as needed to sustain carbon-to-nitrogen ratios greater than 15. Generally grain pellet applications vary from 15 to 20 percent of the total feed used during operations. Molasses can be applied two or three times weekly at 15-20 kg/ha. Water stability of grain pellets is between 15 and 20 minutes. This provides an inexpensive organic substrate for biofloc to develop, in addition to increasing the C:N ratio.



TOP, FIGURE 4. *About 5 mL/L of settled biofloc in an Imhoff cone. Moderate floc densities are preferable.* MIDDLE, FIGURE 5. *Biofloc shrimp culture ponds must be well aerated. Note number and positioning of aerators.* BOTTOM, FIGURE 6. *Shrimp production in commercial-scale biofloc systems.*

Grain pellets are a mixture of ground wheat, corn and occasionally soy, with a protein level around 14-18 percent. Animal-grade ground wheat flour must be used. Using grain pellets from wheat flour as a carbon source results in better yield, survival and FCR of green tiger shrimp *Penaeus semisulcatus* (Megahed 2010).

In addition to typical chemicals such as dolomite and lime, kaolin is required in the preparation of pond water and during operation. Kaolin is the mineral kaolinite, a hydrous aluminum silicate, also known as China clay. It is distinguished from other industrial clays on the basis of its fine particle size and pure color. Its ability to disperse in water makes it an ideal pigment. Fine particles of kaolin suspended in pond water are thought to become nuclei of bioflocs in pond water. Kaolin is applied at 50-100 kg/ha.

Aerators help suspend bioflocs continuously in the pond water, a main requirement for maximizing the potential of microbial processes in shrimp culture ponds (Fig. 5). Especially in biofloc systems, aerators need to be constantly monitored for malfunctions and repaired or replaced without delay. Paddlewheel aerators keep dissolved oxygen levels high. Dissolved oxygen levels must be monitored frequently to keep levels greater than 4 mg/L. Water quality should be managed within the limits indicated in Table 2.

Paddlewheel aerators need to be in the correct position to promote accumulation of sludge in central areas of ponds. Accumulated sludge at the pond center needs to be siphoned or drained out periodically as needed. The required energy input (horsepower of aerators) needs to be correlated to stocking density. High stocking densities of 130-150 post-larvae/m^2 and high aeration rates of 28-32 hp/ha are also essential for expected production of over 20 t/ha. Aeration energy efficiency is 680 kg/hp and can be as high as 1,000 kg/hp if partial harvesting is implemented.

Performance of Biofloc Systems in Commercial Shrimp Farming

The technology has been successfully applied commercially with shrimp *(L. vannamei)* by Belize Aquaculture (McIntosh 2001). Heterotrophic bacterial communities facilitate the production of high yields (~15 t/ha per cycle) in ponds with no water exchange. It has also been applied with success in commercial shrimp farming in Indonesia, achieving a production of nearly 50 t/ha in small research and development ponds, and over 20 t/ha from commercial ponds, with feed conversion ratios between 0.98 and 1.30 (Table 3; Kopot and Taw 2004, Taw 2005, Taw 2010).

A combination of two technologies, partial harvesting and biofloc, has been studied in northern Sumatra, Indonesia (Taw *et al*. 2008). Production performance using partial harvest with biofloc technology was greater than expected. One 2,500-m^2 pond produced 12.4 t (49.5 t/ha) through six partial harvests, with a feed conversion ratio of 1.11. The technology was successfully commercialized in Malaysia (Taw *et al*. 2011). For ponds lined on dikes only, the shrimp farm averaged over 12 t/ha; for fully-lined ponds with a semi-biofloc system, the average was over 16.2 t/ha. Two ponds with biofloc systems averaged over 22.5 t/ha with an average shrimp size of approximately 18 g. The outstanding achievement was in a biofloc system with a stocking density of 130 post-larvae/m^2, where shrimp reached over 18.8 g in just over 90 days of culture, with a production of over 22.5 t/ha (Taw *et al*. 2011). A similar performance with a semi-biofloc system was recorded at the iSHARP project in Malaysia (Taw *et al*. 2013, Fig. 6).

The small, family-owned Ndaru Luat Setio shrimp farm

(CONTINUED ON PAGE 26)

TABLE 1. Basic management concepts in shrimp culture.

	BIOFLOC BASIC MANAGEMENT CONCEPTS FOR SHRIMP CULTURE
1	Semi-biofloc to Full biofloc system feasible
2	Use treated water only
3	Zero water exchange (only topping up)
4	Earthen to HDPE full or semi-lined ponds
5	Aerators to have pond water (biofloc) in suspension (22-24 hrs)
6	Correct aerators' position and number very important
7	Excess sludge need to be removed –specially for full biofloc
8	Biofloc volume control (<10 ml/L)
9	Control C/N ratio to above >15
10	Molasses & Grain pellet required (Carbon source)
11	Operate in accordance with Carrying capacity of pond essential (species/stocking density/pond type/operating system)

TABLE 2. Desired concentrations of select water quality variables in biofloc systems applied to commercial shrimp farming.

VARIABLE	*VALUE*	*NOTE*
Salinity	20-35 ppt	
Temperature	25-30 C	
DO	> 4.0 mg/L	
pH	7.3-8.4	
Alkalinity	> 70 mg/L as $CaCO_3$	tends to reduce with duration of culture period
TAN	< 1.5 ppm	higher than autotrophic system
NH3-N	< 0.1 ppm	higher than autotrophic system
Nitrate (NO_3)	< 5.0 ppm	higher than autotrophic system
PO_4-P	< 2.0 ppm	

TABLE 3. Comparative performance and technical features of intensive biofloc and greenwater systems for shrimp.

ECONOMICS

Shrimp farmers' view – Saving is profit also

	BIOFLOC	AUTOTROPHIC	REMARKS
Production (MT)	22 MT/ Ha	21 MT/ha	Increase in production = more profit
Growth (gms/day)	0.16 to 2.1	0.13 to 0.16	Larger shrimp size = better price
FCR	1.1 to 1.3	1.5 to 1.7	Lower FCR = lesser feed cost. FCR 0.1 = 4% of feed cost (approximately).
DoC (Days of Culture)	90-100 days	110-120 days	Less DoC = increase production cycles (eg from 2 to 2.5 cycles/ year. More revenue.
Energy Efficiency (HP)	680 – 1,100 Kg/HP	400 - 600 Kg/HP	More efficiency = less energy cost
Shrimp color (red)	Salmon scale > 28	Salmon scale < 24	Strong red = Better price
Stability	CV < 25 %	CV > 25 %	Lower CV = More productivity
Sustainability	Flush out < 1.5%	Flush out > 10 %	More sustainability = Higher production
Water exchange	Zero water exchange	Minimum or flow through	Energy saving in water pumping
Gross profit	> 35 %	< 30 %	The more the profit the better
Production Cost	< 15-20 % than Autotrophic	Standard Autotrophic	Less production cost = more profit
Feed Mill - production	Less sale but more sustainable sale	Normal sale	Feed mill should include grain pellet for biofloc with which sustainable sales could be secured.

TABLE 4. Biosecurity attributes of biofloc systems.

	BIOFLOC SYSTEM	BIOSECURITY
1.	Zero water exchange (topping up only for water lost due to siphoning & evaporation)	Low risk of virus entering culture ponds through water source
2.	Use treated water only – through reservoirs	Modular system
3.	Aeration full 22-24 hours in accordance with pond carry capacity (full or semi-biofloc) to have biofloc suspended in pond water.	Stable dissolved Oxygen (DO). Healthier shrimps
4.	Phytoplankton (algae) bloom & crash non-existent as biofloc does not depend on sun light for photosynthesis.	Stable environment. Low stress for shrimps – healthier shrimps
5.	Stable culture water environment – DO and pH.	Stable environment. Low stress for shrimps – healthier shrimps
6.	Extra natural live feed – biofloc with unicellular protein (protein 30 -50%)	Extra nutritious natural feed
7.	More than 2,000 bacterial species were found in well-developed biofloc water	Possibly a probiotic affect
8.	Biofloc contains six immune related genes	May enhance immune activity in shrimps

located in Kubu, Bali raises specific pathogen-free *L. vannamei* in ponds, applying basic biofloc technology with no water exchange. Ample aeration and well-controlled dissolved oxygen concentration maintained good water quality in the culture environment. The farm has produced 45-55 t/cycle since 2009 in a stable and sustainable way from 12 small concrete ponds with a total surface area of 2 ha (Taw and Setio 2014). The technology also has been applied in super-intensive raceways production as high as 9.9 kg/m^2 (Samocha *et al*. 2012) and 7.5 kg/m^3 (Otoshi *et al*. 2006).

The technology was applied for other species of shrimp, such as *P. monodon* in Australia by CSIRO in 2008 and freshwater prawn *Macrobrachium* in India. It has also been applied in blue shrimp *L. stylirostris* broodstock production (Cardona *et al*. 2014). That study compared two culture systems, clearwater and biofloc, and confirmed that biofloc is beneficial to the reproductive performance of blue shrimp broodstock and larval quality.

Biofloc Technology and Biosecurity

With emerging viral problems and rising costs for energy, biosecurity with biofloc technology appears to be an answer for sustainable production (Table 4). Large shrimp farms, which initiated biofloc technology in Sumatra, Indonesia from late 2002 to 2007, have not experienced any WSSV outbreaks (Taw 2010).

As at other farms in the vicinity, Arca Biru shrimp farm, Blue Archipelago Berhad was faced with serious outbreaks from white spot syndrome virus (WSSV) before the redesign. During its first new cycle, viral incidents were common in the vicinity. On one occasion, dead WSSV positive shrimp were found within the main supply canal. Despite this, the production cycle was a success, without viral outbreaks (Taw *et al*. 2011)

A large-scale "integrated shrimp aquaculture park" (iSHARP) project started by Blue Archipelago Berhad in Malaysia in 2009 had a goal to complete over 600 ponds and reservoirs for raising Pacific white shrimp on 1,000 ha of land at Setiu, in the state of Terengganu, northeast of Kuala Lumpur. The first stocking was initiated in October 2011. A total of 144 ponds were in operation by mid-November 2012. No incidents of white spot syndrome (WSSV) or early mortality syndrome (EMS) have been reported at the facility (Taw *et al*. 2013) (Fig. 6).

The small family-owned shrimp farm located in Bali referred to previously has produced shrimp continuously since 2009 in a stable and sustainable way without WSSV and IMNV outbreaks (Taw and Setio 2014).

Biofloc systems—a recent technology—offer a promise of stable and sustainable production, inasmuch as the system is operated without water exchange and so has an enhanced capacity for nitrification within the culture ponds.

Biofloc and Shrimp Immunity

Kim *et al*. (2013) studied the effect of biofloc on growth and immune activity of Pacific white shrimp post-larvae and found dense microbial population associated with bioflocs induces a trigger toward the development and maintenance of the shrimp immune system. More than 2,000 bacterial species have been found in well-developed biofloc water. Bioflocs enhance the non-specific immune system of shrimp, based on mRNA expression of six immune-related genes: ProPO1, proPO2, PPAE, ran, mas and SP1. This mechanism may be an important means to protect shrimp against drastic disease outbreaks, which often lead to collapse of shrimp production systems and huge losses.

A study at Bogor University, Indonesia and Ghent University, Belgium revealed that the biofloc system contributes to the enhancement of immune response and survival after IMNV challenge, regardless of carbon source. The application of biofloc technology brings about beneficial effect in disease control and management in shrimp culture.[1]

A workshop on biofloc technology and shrimp diseases was held in Ho Chi Minh City from December 9-10, 2013. Ekasari[1] reported higher phenoloxidase activity (an immune indicator) in response to carbon loading in a biofloc system. Avnimelech[1] showed significantly lower infection of tilapia by *Streptococcus* in biofloc compared to clear water system. Wasielesky[1] showed that biofloc can be successful in preventing WSSV in southern Brazil. Taw[1] presented on possible use of biofloc system as biosecurity in preventing diseases in shrimp culture (Table 3).

In summary, the main attributes of biofloc systems that reduce the risk of shrimp disease are:

- Low rates of water exchange improve pathogen exclusion (biosecurity).
- Continuous aeration provides stable water quality (DO and pH).
- A diverse and stable microbial community stimulates the non-specific immune system and limits development of opportunistic species like *Vibrio*.
- Regular removal of accumulated sludge controls biofloc concentration to moderate levels.

Notes

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[1] Presentations at 'Workshop on biofloc technology and shrimp diseases' held on 9-10 December 2013 in Ho Chi Min City, Vietnam.

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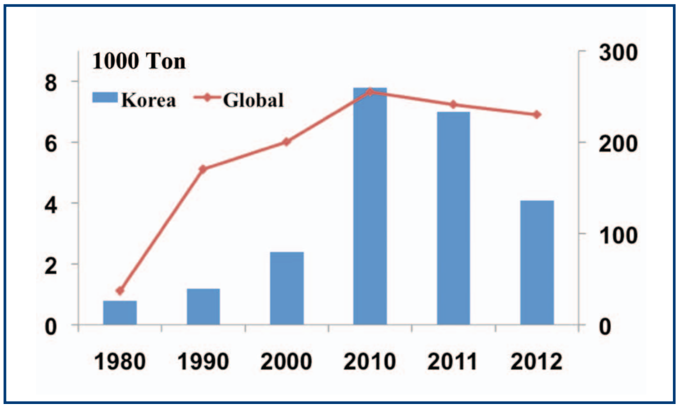
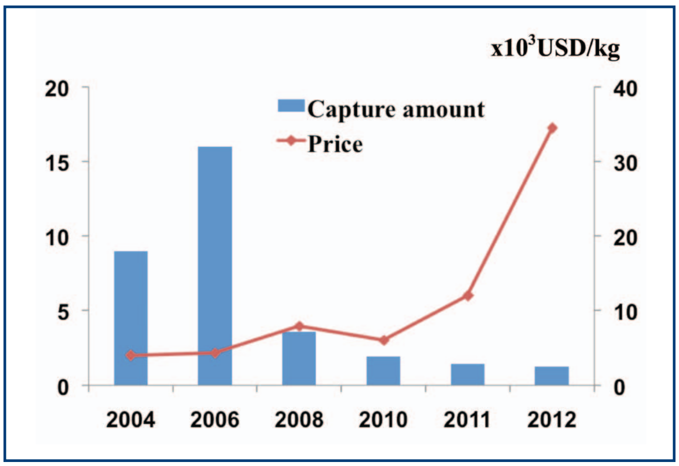
Dietary Requirements for Ascorbic Acid, α-Tocopheryl Acetate and Arachidonic Acid in Japanese Eel, *Anguilla japonica*

Sungchul C. Bai, Kumar Katya and Hyeonho Yun

The continuous decline in eel production from wild capture fisheries has become a formidable issue globally. Most eel populations have already been declared to be threatened or close to extinction. However, eel demand for human consumption continues to grow, particularly in Asia. Consequently, because of limited glass eel supply from the wild and unsuccessful commercial glass eel production technology, the glass eel price has surged to a historic high. As a result, eel production has become one of the most difficult and challenging aquaculture industries in the world.

Despite three decades of phenomenal research advances, the scientific community has not been able to develop the complete package for eel farming on a commercial scale. At present, Japan is the only country to have developed a complete eel production technology but the production of seedlings is insufficient to meet international demand.





TOP, FIGURE 1. *Eel production trend in Korea and the world.* BOTTOM, FIGURE 2. *Trend in glass eel capture and price.*

The continuous decline in eel production from wild capture fisheries has become a formidable issue globally. Most eel populations have already been declared to be threatened or close to extinction. However, eel demand for human consumption continues to grow, particularly in Asia.

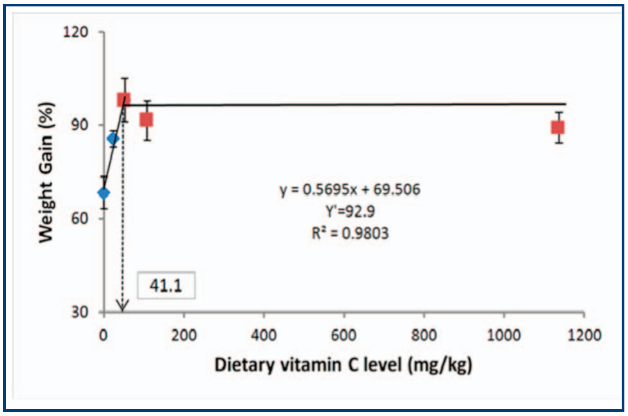
Eel Aquaculture in Korea

In Korea, Pukyong National University initiated research on the Japanese eel *Anguilla japonica* in 2002 and achieved success in fertilizing eggs. In 2006, a majority of the eel research moved to the country's largest fisheries research institution, the National Fisheries Research & Development Institute (NFRDI). Subsequently Korea's government policy was targeted to develop complete aquafarming technology for eel in the near future. After a decade of research efforts, Korea has finally produced two individual glass eels for aquaculture. Korea should soon have a complete aquafarming package for eels and begin to play a greater role in global eel production (Bai *et. al*. 2012).

Not surprisingly, despite the lack of a comprehensive technical package for eel aquafarming and complete dependence on nature for glass eels, aquaculture production has developed impressively in Korea. Japanese eel production accounts for 27 percent of freshwater aquaculture in Korea, due to historical high demand in domestic and international markets, especially in Japan. Production of eel increased from a negligible value of 500 t in 1980 to 4,257 t in 2012 (Fig. 1). However, aquaculture production of eels peaked in 2010 and then declined in the next two years. Every year, 10 to 20 t of 0.2-g wild captured glass eel are stocked and grown to 200-g marketable size within one year. However, in 2012, only 2 t of glass eel were captured domestically and 7-8 t were imported from different countries. The current market price for glass eels is around $7 per individual ($35,000/kg) while market-size eel fetches a premium price of around $50-70/kg at the farm gate (Fig. 2, Bai *et. al*. 2012).

Favorable government support that spurred research and the growing experience of farmers based on trial and error have established a strong foundation for eel aquaculture. Consistent

(continued on page 30)



TOP, FIGURE 3. *Broken-line analysis of vitamin C requirement of Japanese eel based on weight gain.*

increasing production mirrors regional skills in capturing glass eels and transporting them with minimum stress to aquaculture farms and in stocking and feeding for maximum yield, which has advanced greatly.

A government policy to protect freshwater resources in 1997 directed the majority of inland farms to terminate eel aquaculture and subsequently production moved to indoor systems. A total of 236 farms covering about 133 ha comprising 202 flow-through systems and 34 recirculating system farms in the Jeon-nam area were exclusively designed and adopted for eel aquaculture (KSNO 2009). Indoor systems for eel farming have always been under scrutiny for improvement of quality, with the view to increase the overall efficiency of farms. Flow-through systems with concrete bottoms have been replaced by polypropylene polymer-bottom circular tanks. Circular tanks ranging from 30-50 m^2 up to 200-300 m^2 are used, based on eel life-stage.

The Need to Establish Nutrient Requirements

There are a number of constraints that need to be resolved to develop a complete technology package for eel aquaculture. Poor understanding of nutrient requirements and the availability of balanced diets are major barriers to further expansion of eel aquaculture. The greatest mortality at eel farms has been reported during the weaning period and the adaptation period to dry feed.

Inasmuch as it is unlikely capture production will increase further, studies have been conducted to boost aquaculture production to meet the ever-increasing demand for this species (Lee and Bai 1997, Okorie *et al*. 2007, Bae *et al*. 2008). Our research center (FF-NRC) has been conducting a series of experiments with different age groups of Japanese eel to reevaluate the nutrient requirements, the efficiency of various dietary ingredients and additives and the body composition of wild and cultured eel. Here we present some important micronutrient requirements, namely those for vitamin C, vitamin E and arachidonic acid, in Japanese eel.

Vitamin C Requirement

Most marine and freshwater teleosts are unable to synthesize vitamin C (ascorbic acid / AA) from D glucose because of the lack of an enzyme, L-gulonolactone oxidase, that is responsible for the synthesis of vitamin C *de novo* (Dabrowski 1990, Fracalossi *et al*. 2001, Wilson 1973). In general, marine and freshwater teleosts depend fully on a dietary supply of ascorbic acid.

Many general physiological functions of L-ascorbic acid (AA) are well defined, the most important among them being its capacity to act as a co-factor in the hydroxylation of proline to hydroxyproline, critical for the helical structure of collagen. L-ascorbic acid is also the most powerful reducing agent available to cells, losing two hydrogen atoms to become dehydroascorbic acid, and is of general importance as an antioxidant because of its high reducing potential (Bai 2001).

The standard reference for aquatic species nutrition, *Nutrient Requirements of Fish and Shrimp* (NRC 2011), has documented the studies devoted to evaluating AA requirements in economically important species. The previous edition (NRC 1993) listed only a few economically important species in the vitamin C section, but the current edition covers the majority of commercially important species.

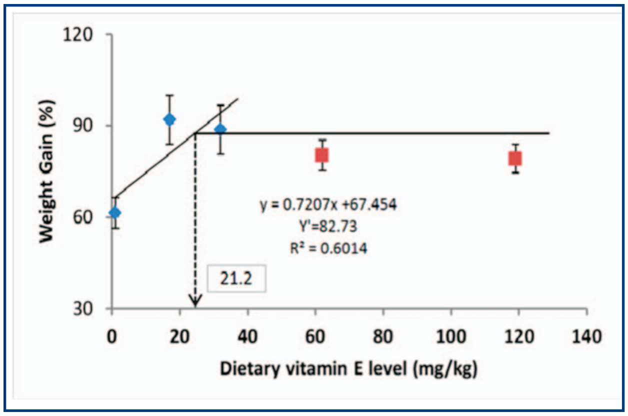
A number of symptoms linked to vitamin C deficiency, such as impaired collagen formation, spinal deformation, haemorrhaging, retarded growth and depressed immunity (Ai *et al*. 2006, Al-Amoudi *et al*. 1992, Gouillou-Coustans *et al*. 1998, Halver *et al*. 1969) were formerly common problems encountered at aquaculture farms. Knowledge of vitamin C requirements has advanced substantially. As a result, fish producers have been relieved of severe economic losses linked to high and frequent incidence of malformed fish and subsequent mortality.

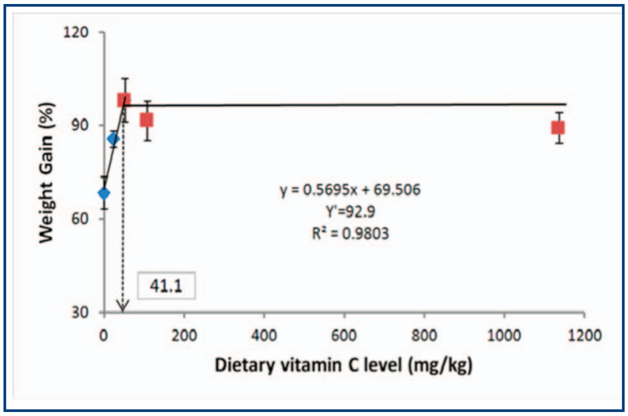
Large discrepancies in quantitative requirements of vitamin C in and between fish species are a result of differences in species, size and methodological approaches and experimental conditions (NRC 1993). The dietary source of AA used in different experiments is another major and fundamental difference, which makes it complex to oversimplify the quantitative requirement of vitamin C. L-ascorbic acid is the traditionally used vitamin C source in fish and shrimp feeds, but it is thermolabile, unstable and easily oxidized to an inactive form during feed processing and storage. Various derivatives of AA, including L-ascorbyl-2-sulfate (C2S), L-ascorbyl-2-monophosphate-Mg (C2MP-Mg), L-ascorbyl-2-monophosphate-Ca (C2MP-Ca), L-ascorbyl-2-polyphosphate (C2PP) and ascorbate-2-glucose (C2D), are more stable than the parent compound and provide antiscorbutic activity in fish and shrimp.

The dietary vitamin C requirement of Japanese eel has been estimated using L-ascorbic acid Ca as the source of vitamin C (Ren *et al*. 2005). In an experiment to reevaluate the vitamin C requirement in juvenile eel using L-ascorbyl-2-monophosphate (AMP) as the vitamin C source, survival of eels fed the AMP-supplemented diets was significantly greater than those of fish that did not receive vitamin C supplementation. No vitamin C could be detected in the whole body of fish fed AMP0 diet. The vitamin C level in fish fed AMP108 diet was significantly greater than that of eels fed AMP24 and AMP52. The vitamin C level of fish fed the AMP1137 diet was significantly greater than those in fish fed all other diets.

Dietary vitamin C in juvenile eel is essential. However, there seems to be no benefit of increasing vitamin C supplementation in diets beyond 24 mg AMP/kg diet, inasmuch as fish fed any of the vitamin C supplemented diets had similar growth performance. The requirement based on broken-line analysis of weight gain (Fig. 3) is comparable to values obtained in common carp *Cyprinus carpio*

(45 mg AA/kg diet) (Gouillo-Coustan *et al*. 1998). Ren *et al*. (2005) reported the optimum dietary level of AA for Japanese eel juvenile growth to be more than 27 mg AA/kg diet without stating an upper limit. Although no significant differences were recorded above this minimum level, specific growth rate continued to increase up to the maximum supplementation level. Any differences in the minimum requirement can be attributed to differences in the vitamin C source. Furthermore, no vitamin C deficiency signs, such as anorexia, abnormal swimming, and hemorrhagic areas under the skin, could be observed in our study, in contrast to the study of Ren *et al*. (2005). Therefore, the dietary vitamin C requirement of juvenile eel is equal to or greater than 41.1 mg/kg diet.





TOP, FIGURE 4. *Broken-line analysis of vitamin E requirement of Japanese eel based on weight gain.* BOTTOM, FIGURE 5. *Broken-line analysis of arachidonic acid requirement of Japanese eel based on weight gain.*

There are a number of constraints that need to be resolved to develop a complete technology package for eel aquaculture. Poor understanding of nutrient requirements and the availability of balanced diets are major barriers to further expansion of eel aquaculture. The greatest mortality at eel farms has been reported during the weaning period and the adaptation period to dry feed.

Vitamin E Requirement

Vitamin E (tocopheryl) is a fat-soluble antioxidant that stops the production of reactive oxygen species that are formed when fat undergoes oxidation. It is an indispensable nutrient required to maintain flesh quality, immunity, normal resistance of red blood corpuscles to hemolysis, capillary permeability and heart muscle (Halver 2002). Vitamin E has several naturally occurring forms, with α-tocopherol having the highest vitamin E activity (NRC 1993). Tocopheryl acetates do not act as antioxidants but are hydrolyzed by digestive enzymes prior to absorption into the body (Hung *et al*. 1982, Sau *et al*. 2004).

Vitamin E functions as a lipid-soluble antioxidant, protecting biological membranes and lipoproteins against oxidation; it is an essential dietary nutrient for all fish species studied (NRC 1993). Its main function is to protect unsaturated fatty acids against free radical-mediated oxidation (Hamre *et al*. 1998). The level and state of oxidation of polyunsaturated fatty acids in the diet and the presence of other antioxidants and selenium may affect the dietary vitamin E requirements of fish (Murai and Andrews 1974, Poston *et al*. 1976, Watanabe *et al*. 1977, Hung *et al*. 1981, Cowey *et al*. 1983, Lovell *et al*. 1984, Gatlin *et al*. 1986). Until recently, there was no quantitative estimation of the dietary vitamin E requirement for Japanese eel (Bae *et*. *al*. 2012).

In our experiment, inclusion of vitamin E did not affect whole body composition of Japanese eel. Similar results were reported by Gatta *et al*. (2000) and Sau *et al*. (2004), who found no differences in lipid, ash or moisture contents after feeding graded levels of vitamin E to rohu fry. The growth performance of fish fed vitamin E-supplemented diets improved to a supplementation level of 16.5 mg TA/kg diet and then dropped at higher levels. Based on these observations, the dietary vitamin E requirement of the juvenile Japanese eel is >21.2 but <21.6 mg/kg diet, as assessed by broken-line regression analysis of weight gain (Fig. 4), specific growth rate, feed efficiency and protein efficiency ratio. DL-α-tocopheryl acetate was used as the dietary vitamin E source under the experimental conditions in our laboratory.

Arachidonic Acid Requirement

Among *n*-6 HUFA, arachidonic acid (ARA, 20:4*n*-6) is the main fatty acid precursor of eicosanoids in fish (Henderson and Sargent 1985, Henderson *et al*. 1985, Bell *et al*. 1994). Arachidonic acid in fish tissues is located almost exclusively in the 2-position of the glycerol of the inositiol phospholipids, which have critical roles in many areas of cellular signal transduction (Sargent *et al*. 1989). Arachidonic acid produces eicosanoids with high biological activity, namely 2-series prostanoids and 4-series leukotrienes, while eicosanoids derived from EPA, namely 3-series prostanoids and 5-series leukotrienes, are less biologically active (Tocher *et al*. 2003). The relative abundance of the two fatty acids, subsequently, determines eicosanoid potency and mode of action.

In fishes, eicosanoids are responsible for a range of physiological functions, such as modulating immune and neural function and osmoregulation, and controlling the stress response (Mustafa and Srivastava 1989, Sargent *et al*. 1999, Koven *et al*. 2001b, Tocher *et al*. 2003). Elevated dietary ARA increases overall survival (Bessonart *et al*. 1999) and improves resistance to handling stress in larval gilthead seabream *Sparus aurata* (Koven *et al*. 2001). An optimal concentration of dietary ARA maximizes stress resistance to a hypersaline challenge in larval summer flounder

(CONTINUED ON PAGE 32)

(Willey *et al*. 2003) and striped bass *Morone saxitilis* (Harel *et al*. 2001).

The essential fatty acid requirements for optimal growth of the Japanese eel were satisfied by *n*-3 and *n*-6 PUFA (Takeuchi *et al*. 1980). Additionally, we investigated the optimum levels of dietary *n*-3 or *n*-6 fatty acids and the availability of AA in elver and juvenile stages of Japanese eel (Bae 2003, Bae *et al*. 2004).

In our experiment, the WG, FE and SGR of fish were significantly influenced by dietary ARA level. WG and FE of fish fed ARA0.8 and ARA1.2 diets were significantly greater than that of fish fed ARA0.07, ARA0.22 and ARA0.43 diets; there were no significant differences among fish fed ARA0.6, ARA0.8 and ARA1.2 diets.

Castell *et al*. (1994) and Bell *et al*. (1995) demonstrated that dietary ARA promotes growth of juvenile turbot and concluded that ARA is an essential fatty acid for juvenile turbot. These studies provided the first evidence that ARA is an essential fatty acid for normal growth, development and survival of juvenile marine fish. In addition, Koven *et al*. (2001) suggested the importance of dietary ARA for improving resistance to handling stress in gilthead sea bream larvae. The authors proposed that increased prostaglandin E2 (PGE2) production in the ARA supplemented fish was responsible for up-regulation of cortisol synthesis through the hypothalamus-pituitary interrenal axis, resulting in improved response to acute stress (Bell and Sargent 2003). On the other hand, it has been reported that high levels of ARA in the diet negatively affect growth and survival of the larvae of cod (Zheng *et al*. 1996), Japanese flounder (Furuita *et al*. 1998) and yellowtail (Ishizaki *et al*. 1998). Likewise, in our study, the best growth and feed utilization effects were observed in the fish fed an optimum ARA level in the diet. In the present study, the dietary arachidonic acid (ARA) requirement for the juvenile eel, *A. japonica* based on WG and SGR was 0.69-0.71 percent of the diet (Fig. 5).

Conclusion

As it is unlikely that capture fisheries production of Japanese eel will increase further, substantial investment and multilateral efforts are warranted to boost aquaculture production to meet the ever-increasing demand for this species. A clear understanding of the optimum level of macro- and micro-nutrients is imperative to formulate nutritionally balanced and cost-effective diets for Japanese eel. Based on a series of experiments conducted in our laboratory with different age groups, vitamin C requirement is equal to or greater than 41.1 mg/kg diet, vitamin E requirement is >21.2 but <21.6 mg/kg diet and arachidonic acid requirement is 0.69-0.71 percent of the diet.

Notes

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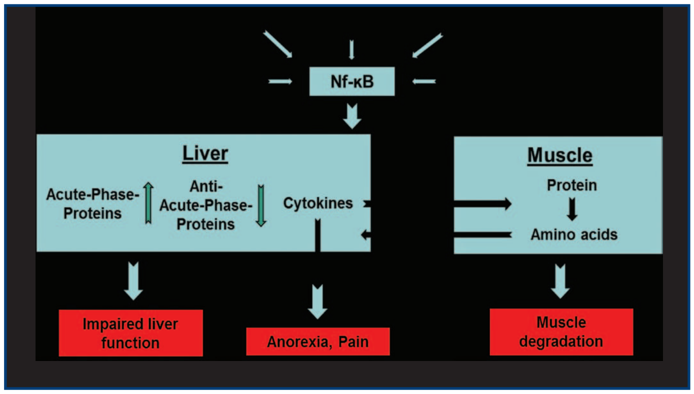
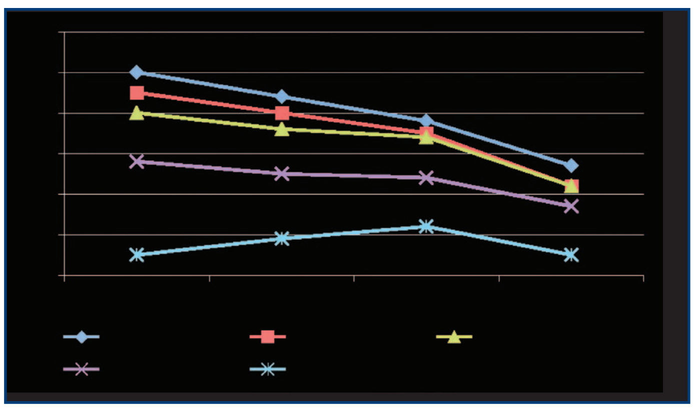
Controlling Inflammation with Flavanoids—An Option for Future Aquafeeds

Malte Lohölter, Susanne Kirwan and Bernhard Eckel

With annual growth rates of approximately 10 percent throughout the last five decades, the global aquaculture sector is the fastest growing food-producing industry in the world (Pettersson 2010). Despite great past and present success, aquaculture is facing diverse challenges, including a need for increased productivity and efficiency while simultaneously implementing further replacement of traditional feed ingredients derived from marine fisheries. Achieving these apparently opposite targets will be ambitious and likely to have unexpected side-effects that need to be taken into account in expedient diet formulation.

Current research indicates processes subsumed as inflammation may be among these detrimental side-effects, leading to suboptimal feed efficiency, animal growth and eventually affecting profitability of the production system. The present article summarizes current knowledge, providing a glimpse at the potential future impact of inflammation on cultured aquatic species, while discussing existing and conceivable solutions.





TOP, FIGURE 1. *Physiological effects related to inflammation.* BOTTOM, FIGURE 2. *Dietary inclusion of fishmeal in aquafeeds from 1995 to 2010 (Redrawn from Tacon* et al. *2011).*

Impacts of Inflammation

Inflammation is often imprecisely considered a synonym for infection but should be understood as a complex stereotypic response of the body to damage of its tissues or undesired chemical (reactive oxidants, acids, lyes, toxins), physical (foreign objects, radiation, heat, cold) and biological (viruses, bacteria) stimuli (Weiss 2008). The main objective of the processes subsumed as inflammation is to eliminate the damage, stop the spread of injury and restore the functionality of the affected regions.

The body responds to the onset of inflammation with molecular changes in gene expression and diverse reactions of the immune system. In the initial reaction, affected tissues are subjected to an increased blood flow, followed by altered concentrations of different plasma proteins and white blood cells. The liver responds with increased production of specific proteins (so-called acute-phase proteins) that are capable of destroying or inhibiting microbes and subsequently giving a negative feedback to the inflammatory response to down-regulate the physiological response to the stimuli. At the molecular level, inflammatory processes are regulated by a protein complex, NF-κB, which is found in its inactive form in the liquid phase of cells. As summarized in Figure 1, inflammation can ultimately lead to impaired liver function, anorexia, pain and muscle degradation.

But what happens if the defense mechanisms of the organism are not able to fully limit the inflammation to its transient acute form (lack of healing)? So-called chronic inflammation can occur and lead to the development of a variety of disorders. In contrast to acute inflammation, which is typically characterized by the five signs of pain, heat, redness, swelling and loss of function, chronic inflammation is often less visible and can affect apparently healthy animals, which are well supplied with all required nutrients, according to current recommendations. In humans, chronic inflammation is known to be related to cancer, allergic reactions, atherosclerosis and myopathies. As a general consequence of inflammation, the physiological priority is shifted toward healing and cell protection, meaning that a considerable amount of dietary energy and protein is used to control these processes and is no longer available for tissue and muscle growth. Thus, animals are no longer able to reach their genetic potential and farmers are likely to experience economic losses.

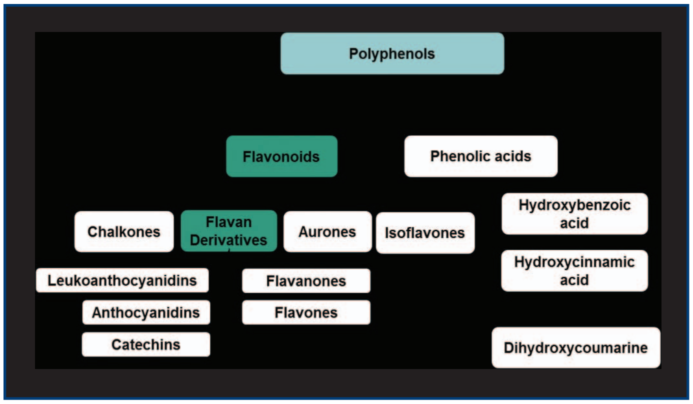
The Future Situation

Production losses associated with inflammation are likely to increase in future aquaculture. Although knowledge and awareness of the issue is growing among nutritionists, two inevitable developments might aggravate the risk of inflammatory disorders in cultured fish.

Raw material availability. Diets rich in fish oil have strong anti-inflammatory properties but these benefits are less likely to be found in future aquafeeds. Enabling further double-digit growth rates of aquaculture will require ongoing reductions in the incorporation of fish oil in aquafeed formulation, as has already been observed in recent years (Fig. 2). Fish oil is mainly produced from small pelagic fish species and the global capture of these species has increased 7-fold since the 1950s but has stabilized at approximately 20-25 million t within the last two decades. Future increases in aquaculture production will evidently require efficient replacement of fish oil, if high-energy diets with current lipid contents of up to 40 percent in salmonid feeds are to be produced (Pettersson 2010).

Fish oil is an excellent source of polyunsaturated fatty acids (PUFA), key substances that reduce intestinal inflammation. Although substitution by vegetable oils might improve the bottleneck of oil availability and generate benefits in aquaculture sustainability, the fatty acid concentrations of both oil sources are different. Many oils of plant origin are rich in linoleic acid (18:2n-6), oleic acid (18:1n-9) and partially α-linoleic acid (18:3n-3). However, they lack the highly unsaturated fatty acids (HUFA), fatty acids with ≥ 20 C20 and ≥ 3 double bonds (Sargent *et al*. 1989).

Breeding and improved genetics. Enhanced growth performance is linked to increased metabolic formation of reactive oxygen compounds that can induce oxidative stress and lead to the development of chronic inflammation. Compared to many land-based livestock, a number of the most important cultured aquatic species have been domesticated during the last decades or only relatively recently included in breeding programs. Atlantic salmon breeders can already look back on some decades of successful work, with a gradual inclusion of functional traits, such as disease resistance (furunculosis, infectious salmon anaemia), fat content and fat distribution or body shape. Further genetic improvement with higher growth performance or feed efficiency can be expected for most cultured aquatic species (Gjøen and Bentsen 1997, Ponzoni *et al*. 2008).



TOP, FIGURE 3. *Sub-groups of polyphenols.* MIDDLE, FIGURE 4. *Red grapes, a good source of flavonoids (Photos: Susanne Kirwan).* BOTTOM, FIGURE 5. *Sturgeon used for commercial caviar production (Photos: Susanne Kirwan).*

The electron transport chain, a central part of the process of making dietary energy available to the organism, is an important source of free radicals, such as reactive oxygen. Increases in energy metabolism, resulting in faster growth rates, are closely related to an elevated production of these reactive oxidants, which will increase the development of inflammatory effects.

Potential of Anti-inflammatory Additives

One promising approach to controlling the frequent chronic form of inflammation—and thus to improving nutrition, performance and health of fish—is the inclusion of special plant-derived ingredients with strong anti-inflammatory properties in diets of animals. Although future research must close some gaps in knowledge, such as absorption and bioavailability of the substances, a growing number of *in vitro* and *in vivo* trials have shown the benefits of such additives.

Flavonoids, secondary plant metabolites found in nearly all higher plants, are an interesting group of naturally active substances. The compounds consist of two aromatic and one heterocyclic ring and can be divided in different sub-classes wherein flavan derivatives exhibit strong anti-inflammatory properties (Fig. 3). The sub-classes differ in the functional group of the ring system. The main effect of flavonoids is an inhibition of the activation of the protein complex NF-κB, which is considered a central regulator of inflammation at the cellular level. Other mechanisms might contribute to the amelioration of inflammatory actions, inasmuch as flavonoids also are related to a reduced metabolic production of reactive oxidants. Flavonoids have good processing properties because they are relatively heat stable during practical aquafeed manufacturing (Wuerzbach *et al*. 2014).

The anti-inflammatory effects of flavonoids have been demonstrated repeatedly in studies investigating a variety of samples, such as immune, blood or intestinal cells (Gonzales *et al*. 2011). So far, most information is available on the benefits of flavonoids derived from green tea and red grapes (Fig. 4) and most flavonoid

(CONTINUED ON PAGE 38)

research has focused on monogastric land-based livestock. Current publications describe improvements in inflammatory processes and intestinal health of swine and poultry. For example, a recent study conducted at the Institute of Animal Nutrition and Nutrition Physiology at University of Gießen, Germany, investigated the effects of supplementation with a grape seed and grape marc meal extract1 on performance characteristics and gut health of pigs (Gessner *et al*. 2013). The tested additive might provide a useful strategy to prevent inflammation in the gut, inasmuch as different parameters involved in inflammation, such as NF-κB, were improved markedly. Interestingly weight gain increased by 6.6 percent and feed conversion improved by 4.5 percent. It needs to be elucidated whether or not these benefits were directly linked to saving energy and protein, which were no longer needed for counteracting chronic inflammation. However, it could also be concluded that the animals were apparently healthy and fed according to current recommendations.

Available research performed on effects of flavonoids on aquatic species is scarce but promising. Decaffeinated green tea extract improves anti-oxidant status and egg quality of rainbow trout (Asadpour *et al*. 2012). Malondialdehyde, a marker for oxidative stress, was lower in trout eggs and related to green tea intake, an observation that confirmed previous experiments. In fish, reactive oxidants are produced not only during basal metabolism but can be generated by cold water temperatures or exposure to the factors shown in Figure 1. Inasmuch as the anti-oxidant system of the liver is not activated before late embryonic development, early protection of eggs via an enhanced anti-oxidant system is of particular importance to ensure high reproductive performance. Reduced malondialdehyde content was measured in chicken meat produced from animals fed on diets supplemented with grape pomace rich in flavonoids.

This transfer of anti-oxidative effects from feed additives to food products might represent a profitable approach for niche markets, such as aquaculture caviar production, where the application of flavonoids might increase the durability of final products (Fig. 5). However, more information is required and future research needs to focus on the best flavonoid combinations and dosages to improve such valuable food products. In this context, it is crucial to choose the best processing technique of herbal raw materials. For example, Cho *et al*. (2007) demonstrated that the addition of green tea extract to diets of juvenile flounder had better effects on growth and feed utilization than raw leaves, dry leaves or a tea by-product.

Conclusions

Future aquaculture will likely face the need to adapt to a reduced availability of valuable feed ingredients, such as fish oil, and to improved genetics with faster and more efficiently growing species. These developments likely will generate a greater risk of inflammatory damage, which can prevent farmers from fully exploiting the production potential of their stocks because controlling inflammation requires energy and protein that will no longer be available for tissue growth. Secondary plant metabolites, such as flavonoids, exhibit strong anti-inflammatory properties and improved anti-oxidant status, production parameters and product quality of terrestrial livestock and aquatic species. More research is required to fully understand the underlying mechanisms and interactions with production factors, such as water temperature and salinity in different production systems. Feed additives based on green tea and grape products are available sources of flavonoids and can contribute to optimized present and future aquafeed formulations.

Notes

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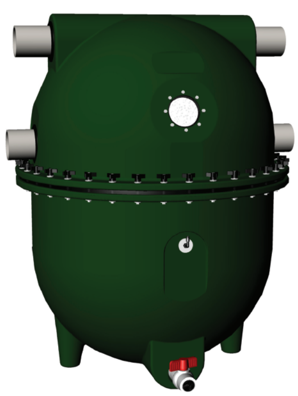

The Impact of Net Density on Oceanic Aquaculture Pens

Benjamin Levy, Heide Friedrich, John Cater, Richard Clarke and James P. Denier

Since the early 1980s, there has been an exponential growth in the quantity of seafood produced by aquaculture and, in the near future, this production will account for half the world's global harvest of fish. With ever-growing demand, fish farms are trying to expand. Countering this expansion is growing concern, globally, on the potential environmental impact of larger aquaculture farms. As a result, many governments are becoming reticent to grant new concessions to aquaculture developments in coastal waters. Consequently commercial producers of marine finfish have been seeking alternative locations to coastal bays, fjords or other areas to locate larger net-pen farms. Moving further offshore appears to be the logical alternative, making farms invisible from the coast, reducing their ecological and environmental impact on coastal marine life and also enabling the installation of wider and deeper pens.

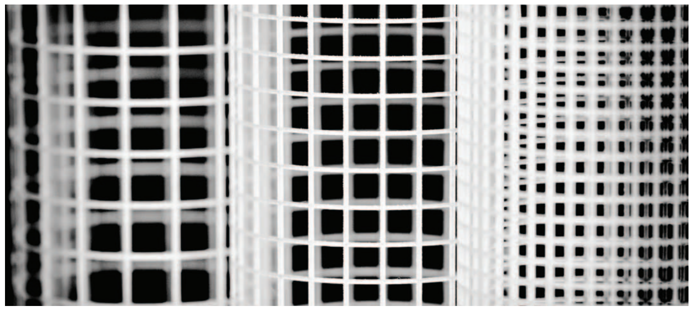

FIGURE 1. *Three net-pen models with varying mesh and twine dimensions.*

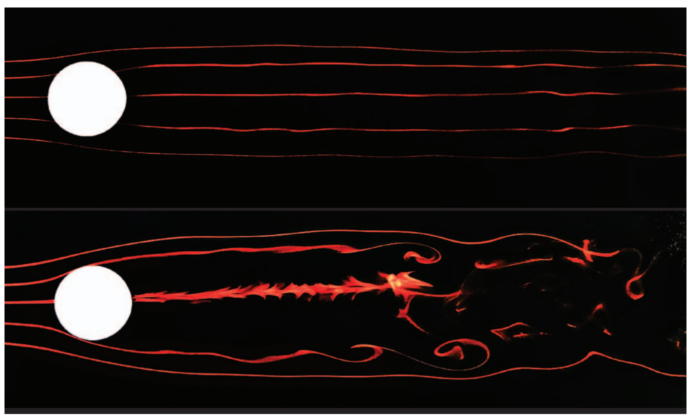

FIGURE 2. *Flow regimes obtained from two models with the same mesh void size but differing twine thickness. The increase in twine thickness reduces the bleed flow velocity which results in greater velocity gradients that evolve into an unstable wake (lower image).*

Inevitably this expansion raises a number of new requirements: increased operating costs, on-site maintenance personnel, energy use and net-pen design. Existing pens may be unsuitable for the harsher conditions found in the open ocean, where mooring lines must resist large fluctuating forces and high induced drag generated by waves and currents. Exploiting wave action to provide autonomous wave-powered energy system for aquaculture farms is being explored currently (Meggitt 2014). Failure of mooring lines caused by overloading often leads to net loss, resulting in 'ghost nets' that can pose a threat to marine life and a navigation hazard. Furthermore, an increase in climatic variability seems likely to lead to an increase in ocean wave states.

Considering future changes in environmental conditions, the compounding problems of increasing pen size and the lack of natural shelter in the open ocean, new farms must increase their capabilities to withstand degradation and major mechanical fatigue. The interaction of the net with water flow from waves and currents govern the resulting forces. This is an area where efforts can be made toward optimizing the net structure (mesh/twine composition or 'weave') and the relative location of a pen within a concession.

In addition to the mechanical action of water flow, there is the associated problem of bio-fouling, which can serve to reduce net porosity by over 50 percent, with direct consequences for fish health through a reduction in the rate of oxygen supply. Another major impact of biofouling is the resulting drastic increase of drag forces on the structure, increasing tension in mooring lines or towing cables.

These combined factors have motivated a deeper study of aquaculture net drag and how it may be minimized. The considerations presented here must be taken together with certain practical issues such as the constraint of the mesh void size in relation to fish size and the need of the twine thickness of the mesh to support mechanical stress.

Technical Aspects

Within the Faculty of Engineering at the University of Auckland, we are undertaking a study of the impact of net density on flow dynamics and drag, where variations in the mesh void (i.e. the space between two consecutive twines) and twine thickness are being investigated. To better quantify the effects of design changes, a small-scale experimental investigation was conducted within our Fluid Mechanics Laboratory, where changes can be evaluated under well-defined and controlled flow conditions.

Experimental data were acquired using a recirculating flume with a measured turbulence intensity of less than 3 percent. The flume cross-sectional area is 0.4 m by 0.4 m, with a length of 4 m and an operational flow rate between 2 and 50 cm/s. Under these controlled conditions, it has been possible to obtain detailed measurements of the flow dynamics for a range of models with varying mesh and twine dimensions.

Rather than studying a section of a net, we manufactured small-scale models mimicking a simplified aquaculture net pen. The models were manufactured using the low-cost, rapid prototyping capabilities offered by modern 3D-printing technology, capable of a spatial resolution of 20 μm. This method guarantees precision and regularity of twines and mesh, allowing us to modify the geometry by microns. Thirty circular pen models, with a surface porosity varying from 0.56 to 0.90, were manufactured (Fig. 1). As a point of reference, typical aquaculture nets have a porosity of about 0.80. Data were acquired using dye visualization, Particle Image Velocimetry and unidirectional load cell measurements.

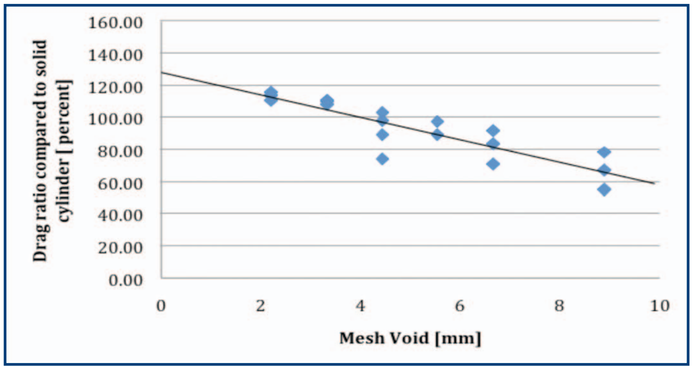

FIGURE 3. *Drag of various net models as a function of the mesh void.*

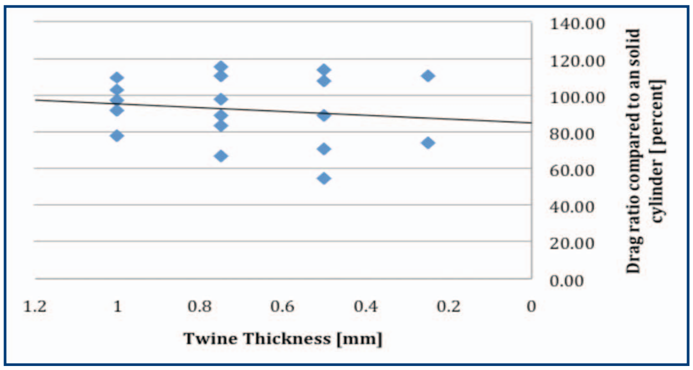

FIGURE 4. *Drag of various net models as a function of the twine thickness.*

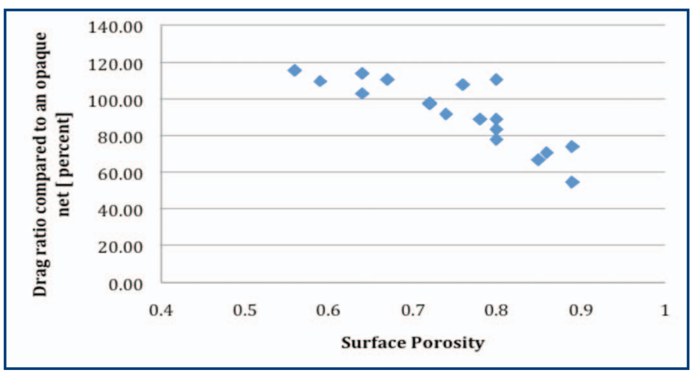

FIGURE 5. *Drag of various net models as a function of the surface porosity E.*

Observations

Despite using a small-scale model at low inflow velocity, the observed flow behavior was in good agreement with larger-scale experiments and numerical simulations (Klebert 2013). Varying the net-pen porosity serves to vary the bleed flow velocity (Wood 1967), designated as U_1, which is the reduced velocity flow in the wake of the model as a result of the flow through the porous surface at the back side of the obstruction. Our models are able to recreate the types of flow expected in the wake of this kind of geometry:

- Regime 1 flows - A laminar steady wake with a bleed flow velocity (U_1) that is close to the free flow velocity (U_∞).
- Regime 2 flows - A steady wake of finite length that evolves into an oscillating shear layer and subsequent vortex shedding.
- Regime 3 flows - The bleed flow velocity is a small fraction of the free flow velocity, resulting in high velocity gradients and a shear layer developing into the classic von Kármán vortex shedding pattern (Williamson 1996).

The mechanism for generation of a particular flow regime is related to the porosity of the net pen. A very porous pen will have regime 1 flow (Fig. 2 top) and a nearly solid pen will generate a regime 3 flow (Fig. 2 bottom). However, porosity is not the only parameter determining the wake, as two net-pen models of identical porosity but different twine/mesh ratio can produce different flow dynamics and significantly different drag.

Environmental Aspects

The netting density of a pen, usually imposed by the need to retain fish of a specified size, plays an important role in the operation of a net pen. It dictates the oxygen supply rate to the pen from inflowing water and the rate that wastes are flushed through the pen. The dispersion of biosolids is directly related to the flow regime and the magnitude of the bleeding flow. Net-pen models with the first flow regime have the fastest diffusion time, whereas models with the third flow regime tend to trap particles in their wake for an extended period. To consider the issue of waste, this may have an impact on fish health, as in the case of waste returning to a net pen with a turning tide, which is not preferable.

Impact on Drag

We conducted multiple experiments, each varying only one parameter: twine thickness, the mesh void or porosity. The results indicate the following trends:

- An increase in the mesh void tends to result in a reduction of drag. However, a void that is too small induces more drag than a completely opaque net (Fig. 3).
- A reduction of twine thickness does not necessarily lead to a reduction of drag. Regardless of twine thickness, it is always possible to identify a net-pen model porosity with a greater drag than an opaque net (Fig. 4).
- An increase in net porosity does not necessarily induce less drag. The same drag was obtained with models of surface porosity varying by over 40 percent (Fig. 5).

Based on these results, we infer that the induced drag on a net pen produced by the net cannot be determined by the surface porosity parameter alone. Although mesh void is the dominant parameter driving the mechanism, generating drag, the effect of twine thickness cannot be overlooked.

We are currently revising the mathematical model which, if verified on a larger-scale aquaculture net-pen model, could

(CONTINUED ON PAGE 42)

help optimize aquaculture netting used in future applications. Extrapolating our small-scale results to a 20-m diameter net pen in open-ocean conditions, a 10-mm increase of the mesh void can lead to a 0.4 GN reduction in the drag force.

Conclusions

With net-pen farms increasingly situated farther offshore, it has become even more important to understand flow dynamics around aquaculture pens to predict the load forces applied to the net and to optimise the farm environment. We have observed that a change in surface porosity can result in drastically different flow dynamics and changed dispersion rates of particulate matter through nets.[1]

A change in surface porosity has an impact on the drag force, as expected. However, porosity alone is not the main factor in determining the level of drag, but that it is primarily imposed by the mesh void size and to some lesser extent by twine thickness.

These results provide a better understanding of the fluid-structure interaction on a porous structure similar to those used in commercial net-pen aquaculture and provide a starting point for net-pen design optimization.

Acknowledgments

The experiments spanned a one-year period and are part of an ongoing research project on nets of aquaculture pens. This work is supported by a Faculty of Engineering Faculty Research Development Fund at the University of Auckland, New Zealand.

Notes

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KEEP UP WITH NEW DISCOVERIES IN AQUACULTURE


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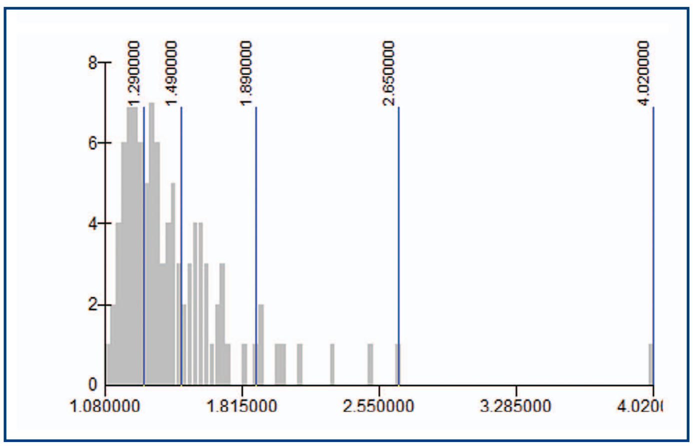
Land to Water Surface Area Ratio in Pond Aquaculture

Lauren N. Jescovitch, Philip Chaney and Claude E. Boyd

Requirements for pond aquaculture include land for pond construction, soil with suitable properties for constructing stable embankments, sufficient water availability and an enabling socioeconomic environment (Giap *et al*. 2005). Data reported by national aquaculture agencies to the FAO Fisheries and Aquaculture Department for compiling country-level aquaculture production statistics[1] are based on pond water surface area. However, additional land on farms is necessary to support the pond culture system, including embankments, canals, roads, storage areas, buildings and parking lots, as illustrated in the image of a farm in Figure 1. This land is needed for farms to operate and usually cannot be used for other purposes.



TOP, FIGURE 1. *A typical farm, located in Malaysia, that was evaluated in this study. Screenshot by Lauren Jescovitch.* BOTTOM, FIGURE 2. *Natural breaks in the distribution of land to water surface area ratios were determined from a sample of 100 farms by Jenks Optimization.*

The average ratio of total land area to pond water surface area was 1.48, with a range of 1.08 to 4.02. Most farms had land to water ratios less than 1.89. As average pond size increased, the ratio decreased, stabilizing at about 1.25 beyond a pond water surface area of 3 ha. A ratio <1.29 can be recommended as a standard for improved land use efficiency in pond aquaculture.

Since the middle of the 20th century, aquaculture production has increased sharply in response to increasing demand for foodfish. Farmers reacted by establishing more farms and by intensifying production on existing farms to meet this demand. This phenomenon is continuing in the 21st century. Intensifying a system requires a greater stocking density; use of feeds, antibiotics, pesticides and disinfectants; and a greater amount of mechanical aeration (Sapkota *et al*. 2008). On intensive farms, ponds tend to be smaller than on extensive and semi-intensive farms, and this means a relatively greater area for roads and canals on intensive farms. The intensity of pond aquaculture has been increasing as better management practices were developed and implemented. For example, channel catfish production in the southern USA averaged less than 2 t/ha in the late 1960s, but is over 5 t/ha today (Boyd *et al*. 2013).

Measuring the Area of Aquaculture Ponds

Based on 2005 data, there were about 11.1 million ha of water surface area of ponds in the world, including freshwater and saltwater areas (Verdegem and Bosma 2009). This number possibly has increased to around 16.7 million ha, based on 2011 aquaculture production data from FAO, assuming no increase in production intensity during the intervening 6 years. This area is very likely an underestimate of the total amount of land dedicated to aquaculture use.

The most accurate way of measuring water and land areas is with conventional surveying and mapping techniques (Boyd and Shelton 1984). This technique requires surveying instruments and knowledge of their use and is time-consuming and tedious. Considering the alternatives, estimation of areas using satellite imagery was considered appropriate for the objectives of this study.

Remote sensing and GIS allow the acquisition of a series of synoptic data for large geographic areas, uniformly in space and time, and without the need for exhaustive field surveys (Green *et al*. 1996). This permits prediction of impacts to the local environment of food production around the globe. Aquaculture competes for resources with other economic activities, and should be evaluated for the sustainability of land management (Alonso-Perez *et al*. 2003). The satellite imaging approach requires current and accurate thematic information to make precise estimations and data available to the public are often a few years behind.

The Ratio of Land Area to Water Surface Area

A study was conducted to estimate the total area of land used globally for pond aquaculture: the water surface area of aquaculture ponds plus land area needed to support production in ponds. Data were collected for 100 farms in 26 countries using Google Earth Pro. Ponds ranged from 0.1 to 26 ha. Ponds were divided into five categories, with 20 farms in each category, based on average pond size for farms: <0.5, 0.5-1, 1-5, 5-10 and >10 ha.

These farms contained 2,783 individual ponds with a total water surface of 10,923 ha, placed on 14,091 ha of land, or 1.48 ha of land for each hectare of water surface. This sample represents approximately 0.1 percent of the total water surface area of aquaculture ponds globally. Despite the small sample size compared to the total area of aquaculture ponds, the results of the current pond survey should be helpful in framing land use considerations.

Data were analyzed based on ratios of farm land area to water surface area. Farms with smaller pond size had a greater average but a more variable land to water surface area ratio. The ratio exponentially decreased as the average pond size on farms increased. The larger the pond the less additional land needed per unit surface area of water. As average pond size increased, the change in the ratio with respect to water surface area decreased, stabilizing at about 1.25 beyond a pond water surface area of 3 ha.

The average ratio of total land area to pond water surface area for all farms was 1.48, with a range of 1.08 to 4.02. Jenks Optimization (Goodness of Variance Fit) classified breaks in the data based on distribution of the ratios (Fig. 2). Jenks Optimization reduces variance within groups while maximizing variance between groups. The natural break points for these data were at ratios of 1.29, 1.49, 1.89, 2.65, and 4.02. Jenks Optimization determined that most farms had land to water ratios less than 1.89. Using Jenks Optimization, a ratio <1.29 can be recommended as a standard for improved land use efficiency in pond aquaculture.

TOP. *Farms can be highly concentrated in an area, causing difficulty in discerning boundaries between adjoining farms through satellite imaging, as at this site in Malaysia. Screenshot by Lauren Jescovitch.* MIDDLE. *These small-pond farms in Asia emphasizes the importance of aquaculture in certain regions. Screenshot by Lauren Jescovitch.* BOTTOM. *This photo illustrates how land can be developed as an agriculture and aquaculture farm. Photo by Lisa Bott.*

Land Area Needed to Grow Crops for Feed Ingredients

Based on the mean land to water surface area ratio of 1.48, the total global land area devoted to pond aquaculture farms might be around 24.8 million ha. This area underestimates the total land area required for aquaculture because land is needed to grow plants as ingredients included in aquaculture feeds. The area for plant production is difficult to calculate because statistics for aquaculture feed use are not separated by the culture system in which they are used. In addition, not all species are grown only in ponds and not all ponds are supplied with feed.

The total land area needed for plant meals was estimated by using average world yield of crop plants[2] and typical feed ingredients for some common aquaculture species as suggested by Boyd and Polioudakis (2006); the average land use was 0.274 ha/t feed. Production per unit area of water surface area is reduced in systems that are more intensive or in which there is more than one crop per year. This reasoning does not apply to land requirements for feed.

The total amount of land needed for aquaculture feed ingredients can be estimated by making a few assumptions. According to Alltech's 2013 Global Feed Summary[3], 34.4 million t of aquaculture feed were produced globally in 2011. To estimate the total amount of feed produced for pond aquaculture, feed production

(CONTINUED ON PAGE 46)

On intensive farms, ponds tend to be smaller than on extensive and semi-intensive farms, and this means a relatively greater area for roads and canals on intensive farms. The intensity of pond aquaculture has been increasing as better management practices were developed and implemented.

for salmonids, diadromous fish and cage culture was subtracted. Assuming an average feed conversion ratio (FCR) for salmonids and other diadromous fishes of 1.2 (Marine Harvest 2013) and that the production of these fish totaled 3.73 million t (FAO 2011), 4.48 million t of feed were consumed by these species. Cage culture production was 3.4 million t in 2005 (Tacon and Halwart 2007), but this production included salmonids and diadromous fish. Thus, cage culture production of other species probably was around 1.1 million t. At a typical FCR of 1.75 (Beveridge 1993), 1.92 million t of feed were consumed by fish in cages. Subtracting the total feed used for salmonids, diadromous fishes, and other cage culture species (6.3 t) is from the total aquaculture feed production, suggests that 27.6 t were used for pond aquaculture. Multiplying the amount of feed used in pond aquaculture by the average land area required for plant meals for feed (0.274 ha/t), around 7.6 million ha of land were used for producing plant-based feed ingredients for feed applied to aquaculture ponds.

Adding the land for plant crop production (7.6 million ha) to the adjusted water surface area and support area required for farms estimated above (24.8 million ha), indicates that about 32.4 million ha of land are dedicated to pond aquaculture. The production of non-pond fish that was removed before calculating land use for plant feed ingredients for pond aquaculture also requires land for feed. Even cage culture in natural lakes requires land to support production in cages.

Global Implications

The estimates of pond water surface (Verdegem and Bosma 2009) and the land to water ratios and area needed for plant ingredients are subject to considerable uncertainty. However, even if estimates are 25 to 50 percent too low, aquaculture still uses a very small area of land compared to world agriculture usage of 4,920 million ha (Boyd *et al*. 2013). Although aquaculture is probably not a major land use in any country, it can bring significant changes to the landscape, redirect other land uses and cause ecological problems. As aquaculture production increases in the coming years, so will production from terrestrial agriculture. Thus, despite having a small impact of total land use at present and in the future compared to terrestrial agriculture, pond aquaculture is and will continue to be of vital importance to the food security of many developing countries, and an important component of the world food system.

Ecolabel certification is becoming more popular among farmers as the demand for such products increases. These certification programs have specific standards intended to avoid negative environmental impacts, but they also are used to make farms more efficient in feed, energy, and water use (Boyd *et al*. 2013). Certification standards could be extended to include a standard related to the maximum allowable land to water surface area ratio. The standards for ecolabel certification typically require farmers to improve on current management practices. The standard for land to water surface area ratio would no doubt be less than the average found by this survey.

Notes

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[1] www.fao.org/fishery/statistics/en
[2] faostat.fao.org
[3] www.alltech.com/sites/default/files/2013-feed-tonnage-report.pdf

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Farming of Giant Freshwater Prawn in China

Yang Ming

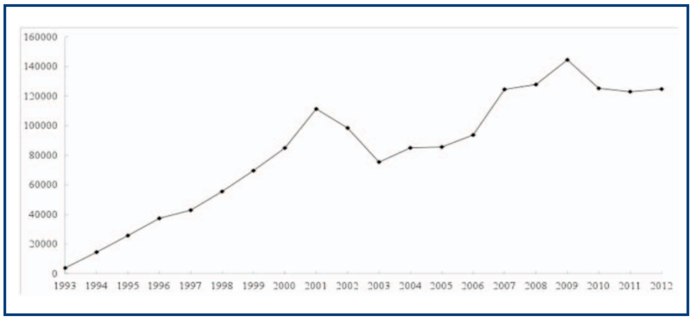

FIGURE 1. *Production (t) of farmed giant freshwater prawn* Macrobrachium rosenbergii *in China.*

The start-up phase for giant freshwater prawn development in China extended from 1976 to 1992. Many regions in other provinces carried out farming and breeding experiments after obtaining initial seed from Guangdong. Because breakthroughs in artificial breeding were first made in Guangdong Province and, combined with suitable temperatures there, the farming of the giant freshwater prawn was initially concentrated in the Zhujiang Delta.

A Brief History of Prawn Farming in China

There are more than 35 species of the genus *Macrobrachium* present in China (Li *et al*. 2007) but the two main species cultured commercially in China are the giant freshwater prawn *Macrobrachium rosenbergii* and the oriental river prawn *Macrobrachium nipponense*. As one of the most commercially important farmed crustaceans, the giant freshwater prawn is cultured in many regions of China. As an exotic species, *M. rosenbergii* was first introduced into mainland China from Japan in August 1976 (Cai and Chen 1995). During this process, the Guangdong Province Fisheries Research Institute (now Pearl River Fisheries Institute, Chinese Academic of Fisheries Science) led propagation research and achieved success in 1977. Postlarvae produced in that year (79,600) were distributed to 14 provinces. Giant freshwater prawn farming first started in southern China and thereafter gradually spread to other coastal provinces and even to northern and inland areas.

The start-up phase for giant freshwater prawn development in China extended from 1976 to 1992. Many regions in other provinces carried out farming and breeding experiments after obtaining initial seed from Guangdong. Because breakthroughs in artificial breeding were first made in Guangdong Province and, combined with suitable temperatures there, the farming of the giant freshwater prawn was initially concentrated in the Zhujiang Delta. The culture area in Guangdong Province was 276 ha in 1991, increasing to 520 ha in 1992, with production reaching 598 t (Liao 1994).

Beginning in 1993, the giant freshwater prawn farming industry entered a new phase of development, obtaining splendid achievements. The prospect of greater profits attracted many more farmers to giant freshwater prawn farming. Another reason is related to the contagious disease of penaeid shrimp caused by white spot syndrome virus (WSSV), which spread throughout China in 1993. White spot syndrome virus outbreaks caused the farmed production of marine penaeid shrimp to drop dramatically in 1993 as a result of mass mortalities of native cultured species *Fenneropenaeus chinensis*. As a result, many shrimp farmers began culturing giant freshwater prawn as an alternative species. The farming area reached 1,533 ha in Guangdong Province with a production of 2,601 t in 1993, which was 2.9 times the area and 4.3 times the production of 1992. The phenomenal growth in farming area and production enabled Guangdong Province to rank first in the nation. Earthen pond culture was commonly used during this period and the yield was between 1,500-3,000 kg/ha, with a mean net profit of US$ 6,410-9,615/ha. Profitability was twice as much as traditional fish farming and this greatly stimulated the giant freshwater prawn farming industry.

Prawn culture has expanded at a tremendous rate. Giant freshwater prawn production in China increased by 13,000 t every year from 1993 to 2001, reaching an average annual growth rate of 65 percent (Fig. 1). China became the largest global producer of giant freshwater prawn in the middle of 1994. Prawn production in China rose to a peak of 111,282 t in 2001, representing 65 percent of global production.

Production declined in 2002 and 2003 as a result of outbreaks of white tail disease (WTD). The pathogen was first found in prawn seed imported from Thailand to Guangdong Province in 1996 (Qian *et al*. 2006 b). Thereafter, the disease spread rapidly to most hatcheries and culture farms throughout the country, causing widespread losses. The causative agent of WTD has been identified as *Macrobrachium rosenbergii* nodavirus (MrNV) and extra small virus (XSV) (Qian *et al*. 2003 b). Diagnostic techniques for WTD use reverse transcriptase-PCR (Widada *et al*. 2003) and TAS-ELISA (Qian *et al*. 2006 a) methods. The development of specific pathogen (SPF) free seed production technologies has effectively prevented WTD epidemics.

Since then, aquaculture production of giant freshwater prawn recovered gradually. Guangdong Province was the country's main producing region from 1976 to 2002. In 2003, for the first time, the production of farmed giant freshwater prawn in Jiangsu Province exceeded that in Guangdong Province. Since then, Jiangsu has replaced Guangdong as the province with the greatest prawn production in China. Another popular farmed species, *Litopenaeus* *vannamei*, was cultured at a large scale in Guangdong Province, with the farming area expanding quickly at that time. Although thought of as a marine penaeid shrimp, *L. vannamei* can also be cultured in fresh water, so it soon outgrew *M. rosenbergii* and became the most popular culture species with the farmers of Guangdong Province.

Freshwater prawn farming had another period of rapid development from 2004 to 2009. The production of cultured freshwater prawn increased rapidly with implementation of more intensive farming and improved culture techniques. The production area increased quickly during this period, especially near Gaoyou city, Jiangsu Province. In 2009, production reached 144,467 t, 63 percent of global farmed giant freshwater prawn production (Fig. 1). Currently the majority of giant freshwater prawn production is concentrated in the Yangtze River Delta and Pearl River Delta.

The spectacular increase in giant freshwater prawn production is partly the result of the increase in culture area and rapid development of intensive culture. China's biggest giant freshwater prawn culturing and producing region is near Gaoyou City, Jiangsu Province. There, in 2009, the farming area reached 10,000 ha with a production of 53,300 t, and farming profit increased to US$ 6250/ha. The profitability stimulated more farmers to begin freshwater prawn culture.

FIGURE 2. *An early maturing female* Macrobrachium rosenbergii.

Current Status and Production Practices

The spectacular increase in giant freshwater prawn production is partly the result of the increase in culture area and rapid development of intensive culture. China's biggest giant freshwater prawn culturing and producing region is near Gaoyou City, Jiangsu Province. There, in 2009, the farming area reached 10,000 ha with a production of 53,300 t, and farming profit increased to US$ 6250/ha. The profitability stimulated more farmers to begin freshwater prawn culture.

As a tropical species, *M. rosenbergii* is sensitive to low temperature. The appropriate water temperature range is 22-32 C and the temperature range for optimal growth is 29-31 C (Chen *et al*. 1981, New 1990). When post-larvae are stocked, the water temperature should be above 20 C. Post-larvae of *M. rosenbergii* cultured in outdoor ponds in the Yangtze River Delta region can only be stocked at the end of May because of temperature restrictions. Marketable prawns are harvested in October when water temperature falls below 20 C. Therefore, only a single crop of freshwater prawn can be cultured in a year in China because production is restricted to the 4-5 months of warm weather.

Continuous innovations in aquaculture technology and many new efficient farming modes have been developed by the joint efforts of researchers and farmers. With the great progress in farming technology, the stocking density of *M. rosenbergii* also has increased. In general, increased stocking density results in an increase in production and higher revenues, enhancing economic performance substantially.

At present, local farmers in the Yangtze River Delta region use ponds covered with plastic greenhouses to increase water temperature, allowing stocking of seed in spring (generally in early March). This system is combined with selective harvest and multi-stage rotational stocking systems to allow increased production. When prawns reach market size, they are selectively seined and smaller animals are returned to ponds. This method allowed sufficient time for grow-out of smaller prawns remaining in ponds. Through stocking ponds in batches, prawns can be provided continuously to the market. Prawn famers can get higher profits by selling live animals in the market, inasmuch as the Chinese prefer to cook fresh aquatic products (Yang *et al*. 2012). These measures improve yield and extend the marketing time of fresh aquatic products from two months to more than four months. The influences of improved unit yield and earlier marketing of commodity prawns on enhanced economic performance are substantial.

Most prawn farmers stock seed into plastic-covered greenhouses during March and April every year. The stocking density is generally 100-150 PL/m^2 during the culture period. The first batch of PLs, grown to juveniles, is acclimatized in heated greenhouses before stocking in outdoor grow-out ponds. After about one month, the first batch of PLs grows to 3-cm juveniles and the second batch of PLs is moved into nursery greenhouses. When the outdoor water temperature exceeds 20 C, plastic-covered greenhouses are removed and all juveniles are stocked into outdoor ponds. If desired, a third batch of PLs is stocked directly into outdoor ponds as supplementary seed. Therefore, ponds are stocked with large, medium and small animals in outdoor grow-out ponds. Harvest of marketable prawns must be done periodically (every 10 days) to provide sufficient space for smaller animals remaining in ponds to grow rapidly.

In general, ponds are first seined in late June. Larger, commercial-size prawns are selectively harvested and smaller ones returned to ponds. Selective harvest of larger animals can be effective for increasing total yield. Ponds are drained and all animals sold before late October. Average production is 5,250 kg/ha by this system. Greater production is over 7,500 kg/ha and the highest can reach 9,000 kg/ha.

(CONTINUED ON PAGE 50)

The giant freshwater prawn has been grown in China for more than 30 years. So far, no country other than China has such an extensive farming area, even in the natural range of this species in other countries of Southeast Asia. Nonetheless, there are problems in the freshwater prawn industry of China.

Some other culture modes include rice-prawn culture, polyculture with fish, polyculture with Pacific white shrimp *Litopenaeus vannamei* and polyculture with crab *Eriocheir sinensis*. However, these culture systems are not large and often used only in experimental research, according to local conditions, and have not been developed on a large scale.

Main Issues of Commercial Freshwater Prawn Farming in China

The giant freshwater prawn has been grown in China for more than 30 years. So far, no country other than China has such an extensive farming area, even in the natural range of this species in other countries of Southeast Asia. Nonetheless, there are problems in the freshwater prawn industry of China. If these problems cannot be solved, they will have a serious negative influence on the sustainable development of prawn farming in China.

Genetic degradation. At present, all cultured stocks of *M. rosenbergii* in China are offspring of the original stock, a small group containing only one pair of broodstock and 48 postlarvae that was introduced from Japan in 1976. Since then, the giant freshwater prawn culture industry relies on non-improved stocks after more than 30 generations of reproduction. Little attention has been paid to genetic improvement in culture stocks. Broodstock are often collected directly from grow-out ponds. This phenomenon causes a high level of inbreeding, which can have a negative effect on stock productivity. Genetic diversity in cultured stocks is low as a result of inbreeding (Schneider *et al*. 2013). Genetic degeneration of the stock is indicated by slow growth rate, early sexual maturity, individual miniaturization and vulnerability to disease. Some female prawns become sexually mature at 6 g but fecundity is only 1,000-3,000 eggs in these small mature females (Fig. 2). Eggs obtained from these females often result in poor-quality offspring.

Lack of quality seed. Healthy and otherwise good-quality seed is the basis of sustainable development of the giant freshwater prawn farming industry. In China, the annual production of the giant freshwater prawn is over 100,000 t. The total demand for good-quality seed is 20-30 billion post-larvae. The particular demand for prawn seed is greatest near Gaoyou city, Jiangsu Province, the most important *M. rosenbergii* culture region and where demand for seed is around 15 billion post-larvae. Before 2010, when sufficient prawn seed could be produced by hatcheries, the average price of seed was only US$ 16 per 10,000 post-larvae. However, the price of high-quality seed increased to over US$ 64 per 10,000 post-larvae after the outbreak of *M. rosenbergii* larval syndrome, which caused many private hatchery enterprises to close, resulting in a shortage of seed.

Even more serious is that post-larvae produced by some private hatcheries grew slower than normal prawn seed, even stopping growth at 5-6 cm, leading to a smaller harvest size. These male prawns had the remarkable characteristics of a larger cephalothorax, longer second chelipeds, smaller abdomen (small edible portion), all similar to old blue-claw males (Ranjeet and Kurup 2002). The presence of large quantities of small male prawns led to a reduction of output and many farmers suffered severe economic losses. Local prawn farmers called this prawn type “stone prawn” or “iron prawn.” Finally poor-quality prawn seed contributes to the abuse of antibiotics in prawn hatcheries. An inadequate supply of quality seed is a major constraint to the healthy development of freshwater prawn faming in China.

New disease outbreaks. In the late 1990s, whitish muscle disease was first recorded in Guangdong Province, spreading gradually to Guangxi municipality, Zhejiang Province, Jiangsu Province and Shanghai. These disease outbreaks caused mass mortality in post-larvae ponds within a few days and serious economic losses in many prawn hatcheries and prawn farms (Qian *et al*. 2006 b). Later, through the work of scientific researchers, the causative agent of whitish muscle disease was determined to be a virus called MrNV (Qian *et al*. 2003 a). The development of SPF seed production technologies has been effective in preventing the whitish muscle epidemic.

However, since February 2010, the giant freshwater prawn seed production industry in China has suffered a severe recession from outbreaks of *M. rosenbergii* larval syndrome in many hatcheries, leading to mass mortality (80-90 percent) in larval stages. This disease spread across the country and many hatchery enterprises have closed down. The supply of prawn seed decreased greatly, causing heavy economic losses to hatcheries and farmers and brought tremendous constraints to the development of the freshwater prawn industry. The national production of *M. rosenbergii* in 2010 decreased by 13 percent compared to 2009. In 2011, the farmed production decreased further to 122,923 t, which was 21,544 t less than in 2009. *Macrobrachium rosenbergii* dicistrovirus (MrDV), a new pathogen, was the causative agent of the nationwide infectious disease outbreak (Pan *et al*. 2010). Additionally a new spiroplasma was found in diseased giant freshwater prawns in grow-out ponds (Liang *et al*. 2011).

Suggested Solutions

Effective measures must be taken to insure the healthy and sustainable development of the freshwater prawn farming industry in China.

Genetic improvement of giant freshwater prawn. It is widely accepted that genetic improvement is the effective method to improve economically important traits in *M. rosenbergii*. Now, traits such as body weight, survival rate, growth rate and disease-resistant performance are often used as important economic traits in genetic improvement programs. Since the 1990s, few scientists have carried out studies on *M. rosenbergii* breeding. The methods of new variety selection include crossbreeding, artificial selection, individual selection and family selection. Selection programs for new varieties of *M. rosenbergii* are an effective method to achieve sustainability of giant prawn farming.

Improvement of quality-seed production systems. It is necessary to guarantee the quality of broodstock prawns to produce better-quality larvae. Inasmuch as most hatcheries in China use farmed broodstock directly sourced from commercial grow-out ponds, selection standards should be taken into account for achieving healthy condition and body size of male or female brooders for overwintering indoors. Broodstock prawns should be selected to be guaranteed virus free. More hatchery technologies should be innovated to improve water quality and increase survival to metamorphosis. Above all, health management depends upon ecological technologies to produce quality seeds. The antibiotics used in hatchery production to control pathogens should be prohibited strictly to avoid drug residues and developing antibiotic-resistant pathogens.

Development of new disease prevention systems. It is important to improve the disease diagnosis technology of *M. rosenbergii* and perfect prevention and treatment systems, especially for viral diseases. At present, diagnostic techniques for WTD, using reverse transcriptase-PCR and TAS-ELISA methods have been developed. The development of SPF seed production technologies has been effective in preventing whitish muscle epidemics. The scientific research concerned with disease detection during seed production and grow-out farming of *M. rosenbergii* should be strengthened and the detection technology of new pathogens needs to be improved, thus providing scientific guidance for disease control.

Future Prospects

It is certain that the giant freshwater prawn industry still has bright prospects for expansion in China. Continued growth of commercial aquaculture of giant freshwater prawn will depend on joint efforts of the government, scientific researchers and farmers; the development of SPF prawn production systems; and stable hatchery output of quality prawn seed. Commercial prawn aquaculture has great growth potential, particularly where farmers cultivating *L. vannamei* suffered setbacks from early mortality syndrome (EMS). More attention must be directed to manage new virus outbreaks in the giant freshwater prawn to avoid a sharp decline in production, similar to the collapse of marine shrimp aquaculture in 1993 caused by WSSV.

Notes

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FIGURE 1. *Yellow catfish* Horabagrus brachysoma.

Hatchery Production of the Yellow Catfish *Horabagrus brachysoma* in India

S.K. Sahoo, S. Ferosekhan, M. Paramanik, S.K. Swain

India has witnessed the growth of aquaculture from backyard farming to commercial fish culture, where Indian major carps contribute the majority of aquaculture production. Recently, striped catfish *Pangasinodon hypophthalmus* culture has become more popular in a few states of India. There are a large number of hatcheries that supply seed to farmers, inasmuch as seed is a primary requisite for successful aquaculture of any species. The minor carps, medium carps, catfishes and murrels are in great demand for Indian aquaculture.

Indigenous catfish are widely accepted among consumers in India because of the taste. Consumers prefer medium-size catfishes for making fish curry. Yellow catfish is sold for US$ 1.50-2.50/kg in the domestic fish market and at US$ 0.25/piece as an ornamental fish. The yellow catfish *Horabagrus brachysoma* has a high value as an ornamental fish because of black blotches on both sides of the body behind the opercula and a golden-yellow body color (Fig. 1).

The importance of yellow catfish as a food and ornamental species has attracted research attention. Production of yellow catfish is small but a hatchery operation has been established after overcoming various technical problems involved in hatchery and commercial grow-out production. This article documents the various techniques and practices involved in the captive production of yellow catfish. It is intended to provide guidance for hatchery managers producing yellow catfish seed.

The Yellow Catfish

Yellow catfish is endemic to Western Ghats of Kerala, India and shows very limited geographical distribution (Fig. 2) in India (Bhat 2001). The population of yellow catfish in nature is in gradual decline from overfishing throughout the river belt, destruction of spawning grounds and barriers across rivers. For this reason, this species is listed by the IUCN as vulnerable (Kurup *et al*. 2004, Ali *et al*. 2007). Its adaptability in different environments, its acceptance of a wide range of food and good growth and survival in confinement makes it a prospective species for diversification in aquaculture.

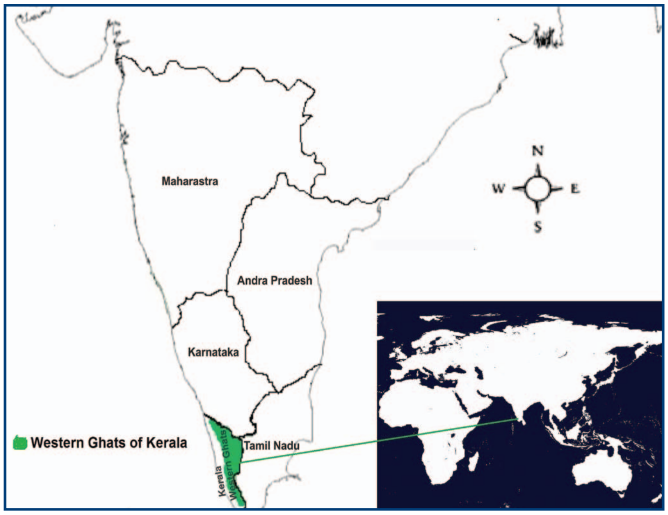

FIGURE 2. *Geographic distribution of yellow catfish in India.*

The fish is moderately elongated with a compressed body. It has a sub-terminal mouth with four pairs of barbels. The eyes are large and placed slightly below, which helps the fish see the bottom during feeding. Dorsal and pectoral fins possess strong, serrated spines that can cause painful injury if handled carelessly. It performs well at a pH of 6.5-7.5 and water temperatures of 27-30º C. Males and females grow isometrically.

Yellow catfish feed on aquatic vegetation, crustaceans, insects, fish larvae and detritus in natural water bodies (SreeRaj *et al*. 2006). Preferences for food items are size specific. Gut content analysis indicates that the proportion of crustaceans in the stomach decreases as the fish grows. Fullness of the stomach is easily observed during the post-monsoon period. Feeding intensity is affected during the pre-breeding season and the monsoon period. It has the capability of widening food choices as a function of food availability.

Yellow catfish will mature in confined water, with males maturing earlier than females. Males of 10-15 g start oozing milt in the first year of life under captive conditions and females mature in the second year. Absolute fecundity increases as length and weight increases (Kurian and Inasu 2003). The fish breeds in natural waters during monsoon periods.

Hatchery Propagation

Broodstock management. Yellow catfish adapts well to fresh water and cement tanks and earthen ponds can be used to raise broodfish. Broodfish of 80-100 g are the most suitable size for an induced breeding program. Feeding broodfish with a balanced diet and providing clean water are some of the management tools for obtaining good broodfish performance. Water quality parameters for raising brooders should be pH 6.5-7.5, dissolved oxygen of 5-6 mg/L and alkalinity of 120-125 mg/L as $CaCO_3$. Broodfish accept pelleted feeds in captive conditions and the feed protein content should be 30-32 percent, fed at 2 percent of body weight daily. Brooders are stocked at low density (1-2/m^2) in ponds to minimize competition during feeding.

Selection of broodfish. Morphological identification of males and females is only possible during the spawning season (July-August). The genital papillae in both sexes are identical so it is essential to press slightly above the genital papilla to see free oozing milt to identify males. The abdomen of the female bulges and yellowish uniform eggs can be expressed by slight pressure near the vent. Females at first maturity do not respond well to hormone injections on many occasions. Therefore, it is essential to select females of at least 80 to 100 g.

Induced breeding. Ovaprim is best for induced breeding in yellow catfish. Females need a single injection of Ovaprim at 1-1.5 mL/kg body weight (Sahoo *et al*. 2014) and after 12-13 h a free flow of eggs usually is observed in response to gentle pressure on the abdomen. Ovulated eggs are yellowish and the fecundity is about 15,000-18,000 per 100 g female. Milt expressed from one male is sufficient to fertilize eggs of a female of the same size. Eggs and milt should be mixed thoroughly to fertilize the eggs, which are then incubated in a flow-through hatchery system. Hatching is observed 21-22 h after egg fertilization. Newly hatched larvae are 4-5 mm in length and 1-2 mg in weight (Sahoo *et al*. 2011). Egg fertilization is typically 60-80 percent and hatching is about 40-60 percent. Reduced fertilization and hatching rates are generally a result of improper selection of broodfish for induced breeding, which produces immature eggs.

Seed Rearing

Larval rearing. Larvae need to be reared in an indoor system to obtain greater survival. The indoor system is comprised of fiberglass or smooth bottom ferrocement tanks with aeration. Hatchlings should be distributed into rearing tanks. Healthy larvae will migrate to the periphery of tanks by a slow tail-lashing movement. Deformed larvae and unhatched eggs that accumulate in the tank center must be removed daily. The yolk-sac provides nutrition to the larvae until three days after hatch. Because mixed zooplankton remains alive longer in freshwater, it is the best food for larvae from the fourth day after hatching. Maintaining 12-15 cm water depth, continuous aeration and the cleaning of tanks twice per day are some of the important husbandry practices (Sahoo *et al*. 2014). Larvae also accept compound feed from 10-11 days after hatching. Feeding live feed and compound feed (35 percent protein) to larvae enhances growth and survival rate. Improper cleaning leads to stress and secondary infection in the larvae from the accumulation of uneaten feed and dead plankton present on the tank bottom, resulting in larval mortality. High-density rearing (3000-4000 larvae/m^2) also results in low survival and growth. Hence, a low to medium larval density (500-1000/m^2) results in greater growth (50-60 mg) and survival (>60 percent)

(CONTINUED ON PAGE 54)

FIGURE 3. *Fry produced in high-density rearing during a 3-4 wk indoor rearing period.*

FIGURE 4. *Fingerlings produced in nursery tanks before grow-out.*

during the 3-4 weeks of rearing indoors (Fig. 3).

Fry rearing. Fry are further reared in cement tanks to fingerlings. Tanks may be prepared with a soil base and manured as in carp ponds to obtain a plankton bloom. Rearing tanks are filled with a minimum of 30 cm of water for easy visibility of fish activity. Fry show shoaling behavior and are active during feeding. Hence, a low density of 100-150/m^2 is maintained to minimize competition and obtain homogenous growth and better survival (Sahoo *et al*. 2014). Fry are fed with crumbled feed containing 30 percent crude protein *ad libitum*, as visually indicated by satiation of fish. Filamentous algae grows in tanks because of the low water level and must be removed to avoid oxygen depletion and retarding swimming activity of fry. Survival is >60 percent and weight gain is > 500 mg and ≥ 60 percent during the 6-7 weeks of rearing. Fingerlings can be sold directly as ornamental fish at this stage or can be further reared in nursery tanks before grow-out (Fig. 4).

Best Management Practices

- Broodfish of > 100 g is necessary to induce spawning.
- Broodfish can be reared by stocking at 1-2/m^2 and feeding a 30-32 percent protein pelleted diet. Intermittent water exchange in broodfish pond enhances maturity for a better output of healthy eggs.
- Injection of 1-1.5 mL Ovaprim/kg of female and stripping after 12-13 h of injection is sufficient to obtain good breeding performance and egg quality.
- Larvae can be reared at a density of 500-1000/m^2 for good growth within a short time, thereby enhancing survival.
- Live feed should be provided during an initial rearing phase and larvae should be gradually weaned to the compound larval feed after 10-11 days of fertilization. This acclimation to feed stimulates fry to accept feed immediately after release into nursery tanks, which ultimately increases survival.

Notes

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A Case for Commercial Shrimp Farming in the Niger Delta, Nigeria

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Stimulating Nigeria's economic growth (Millennium Development Goals and Vision 20:2020) is a key component of government efforts. One such effort centers on boosting production of specific agricultural products with the greatest potential for domestic consumption and increased foreign exchange and employment. Furthermore, as a country with great potential to lead the continent in fisheries and aquaculture development, it is expedient that the government actualize, without delay, the political commitment of African heads of state contained in the Abuja Declaration on food security, as it relates to fisheries and aquaculture.

Modern shrimp farming got started in the early 1970s and production grew steeply, particularly to service the US, Japan and Western Europe markets. Today, over fifty countries have shrimp farms and broodstock are shipped worldwide. Shrimp has grown into a major global seafood industry, producing nearly 4 million t, worth about US$18 billion annually. Approximately half of the global shrimp supply is traded internationally, with trade flowing mainly from the tropical developing world to the OECD (Organization for Economic Cooperation and Development) countries, especially North America, Europe and Japan. Imports of shrimp by these wealthy markets was worth US$ 7.8 billion in 2001.

The demand for shrimp products continues to rise. Overall demand in this complex, highly segmented market has been increasing at 3 percent per year, with the US market growing at 5 percent (Table 1). This motivates the expansion of the industry in some countries. In Asia, shrimp farming has been the most important foreign exchange earner within the agriculture, fisheries and forestry sectors (Jones 1988, FAO 1994). Shrimp are a relished and high-priced delicacy on the world food menu. Nigeria contributes to the market with largely wild-caught shrimp but the country has yet to fully key into the lucrative culture trade. There are no commercial shrimp farms in Nigeria nor any significant sustained development of the industry elsewhere in West Africa.

Benefits of Commercializing Shrimp Farming

Nigeria's domestic fish production hovers around 0.5 million t. This is far less than what is required to support the annual fish demand of a population that is growing at 3 percent per annum (Table 2). To fill the demand-production gap, Nigeria spent over US$ 200 million annually on imports of frozen fish to augment the shortfall in production.

Shrimp farming can significantly reduce Nigeria's dependence on imported food grade aquatic products, currently valued at US$ 270 million (FishNetwork 1998). According to Chemonics International, employment from shrimp farming alone could increase from 3,306 to 83,950 within a decade and that Nigeria's share of the world shrimp market could be increased from US$ 56 million to over US$ 300 million in that same decade (Table 3).

There are two major markets to target: the global shrimp market worth US$ 18 billion, and the local prawn market. The potential benefits of shrimp farming are accessible to all stakeholders, including artisanal fishermen, trawler owners, investors, oil companies, and international donors, who have the wherewithal to capitalize on opportunities afforded by a growing global market.

Research on shrimp farming has been conducted and documented by Nigerian scientists (Ezenwa 1991, Ezenwa *et al*. 1992, Marioghae and Deekae 1991, 1992, Tobor 1992, Hart *et al*. 2003). The aim of research into the propagation of shrimp stems from the need to complement production from capture fisheries to meet ever-increasing demand and to prevent over-exploitation or extinction of some wild species. However, because of the experience of some Asian countries that went into shrimp farming without taking environmental and health

TABLE 1. The main OECD markets for shrimp imports and their annual growth rate (percent), 1999-2000.

YEAR	US	EUROPE (EU)	JAPAN	TOTAL
1998	316,000	363,144	238,900	918,044
1999	331,700	348,034	247,300	927,034
2000	345,100	378,375	246,600	970,075
2001	400,300	363,184	245,000	1,008,484
GROWTH				
5-y avg	+6.4	+2.8	-1.7	+2.8
10-y avg	+5.0	+2.9	-1.5	+2.3

impacts into consideration, which eventually led to a collapse of industries in those countries, it is necessary for all stakeholders in Nigeria to take precautionary measures towards sustainable shrimp farming. The clarion call for sustainability is expedient in lieu of the already degraded Niger Delta environment caused by oil pollution.

Prospects for Shrimp Aquaculture

Nigeria has a long coastline of 853 km and there is a long fringe of unutilized beach in the Niger Delta that could be utilized for coastal shrimp culture without destroying the mangrove. The Niger Delta is richly endowed with freshwater, brackishwater and marine ecosystems. There are many under-utilized borrow pits, lakes, springs, creeks and rivers—all of which are rich in biodiversity—that could be used for shrimp farming.

The coastal shelf of the Niger Delta basin up to Qua Iboe and Cross River supports rich shrimp fisheries. Shrimp are also abundant at the mouths of Badagry, Lagos, Lekki Lagoon systems and mouths of other rivers on the Delta. *Penaeus vannamei* (Pacific white shrimp) and *Penaeus monodon* (giant tiger prawn) account for roughly 80 percent of all farmed shrimp. The freshwater prawn *Macrobrachium* spp are also farmed. The estuarine shrimp, *Nematopaleamon hastatus*, erroneously called "crayfish" locally, is a preferred condiment in many Nigerian dishes.

The maximum potential yield of the Nigerian continental shelf is estimated at 3,500-4,000 t.[1] The shrimp fishery is export-oriented. Annual inshore shrimp production in Nigeria is estimated at 12,000 t, of which 8,000 t are exported. Nigeria exports about US$65 million worth of shrimp to the European Union, the USA and other countries annually. This has necessitated processing to meet international standards. Nigerian shrimp is highly valued in the international market (Amire 2008). In addition, some shrimp are dried for export to other African countries.

Commercial shrimp farming is a new venture in Nigeria, recently pursued by mostly oil giants and their foreign collaborators. In an attempt to boost Nigeria's shrimp production and export, Shell Petroleum Development Company (SPDC) and the United States Agency for International Development (USAID) proposed in 2004 to embark on industrial shrimp aquaculture in the Niger Delta. This has not materialized.

The Nigerian economic pursuit can no longer be dependent exclusively on dwindling capture fisheries (FAO 2008). The prospect is tilting towards aquaculture; hence, commercial shrimp farming is a welcome development.

TABLE 2. Projected population and fish demand in Nigeria, 2006-2025.

YEAR	POPULATION (MILLION)	FISH DEMAND (MILLION TONNES)
2006	140.0	2.66
2007	144.5	2.75
2008	149.1	2.83
2009	153.9	2.92
2010	158.8	3.02
2011	163.9	3.11
2012	169.1	3.21
2013	174.5	3.32
2014	180.1	3.42
2015	185.9	3.53
2016	191.9	3.65
2017	198.0	3.76
2018	204.3	3.88
2019	210.9	4.01
2020	217.6	4.13
2021	224.6	4.27
2022	231.7	4.40
2023	239.2	4.54
2024	246.8	4.69
2025	254.7	4.84

Source: Federal Ministry of Agriculture and Water Resources, Fisheries Department (FDF).

Challenges of Shrimp Aquaculture in Nigeria

Development of the Nigerian shrimp and prawn industry faces the following problems and constraints:

- Fully or over-exploited wild capture shrimp production.
- Limited knowledge or exposure to shrimp and prawn farming.
- Absence of locally produced feeds for shrimp and prawn farming.
- Lack of infrastructure development. For sustainability, good seed for stocking should be obtained from standard hatcheries, of which there are none presently in the Niger Delta area.

(CONTINUED ON PAGE 58)

TABLE 3. Proposed Income Generation and Job creation for Nigeria (Source: Chemonics International Inc.)

CRITERIA	BASE YEAR (2003)	IN 2 YEARS (2005)	IN 5 YEARS (2008)	IN 10 YEARS (2012)
Total Export	$56 Million	$85 Million	$168 Million	$384 Million
Total Job Creation	3,306	4,475	26,575	83,950

- Land acquisition in the Delta by non-indigenous people is very difficult and suitable areas for shrimp farming tend to be also oil-rich areas.

There is presently great local and national opposition to shrimp farming. Critics have expressed their fears based on the experiences of other nations that have had challenges from the venture. Some of the reasonable challenges envisaged are:

Destruction of Mangroves. Nigeria contains the fourth largest area of mangrove forest in the world and the program being supported by the Food and Agricultural Organization (FAO) may spell disaster for these vital wetlands. Added to the already heavy handedness and ongoing destruction by the oil industry in Nigeria, commercial shrimp farming could deliver another serious blow to the health and future of the Niger Delta mangroves and the millions of local residents dependent upon these wetlands for their livelihood and protection.

Disease. The most damaging factor for shrimp farming during the past decade has been disease outbreaks. Viral diseases have damaged industries in China, Taiwan, Thailand, Vietnam, and Ecuador. Good water quality and lower stocking densities appear to be the best defense against all diseases.

As a novice, Nigeria has an advantage because these diseases have yet to manifest themselves as there is no shrimp culture. However, this potential problem serves to stress the benefits of avoiding importing exotic species and thus the advantage of having a known farmable species (*P. monodon*) already within the local ecosystem. Importation of post-larvae at the early stages of development of the industry should be avoided if possible, this being the way some devastating viral diseases are believed to have been transmitted between and within countries.

Pollution and the Environment. Whenever large numbers of semi-intensive and intensive shrimp farms concentrate on the same river, estuary or bay, effluents can lower the quality of the surrounding water, potentially overwhelm the environment and create conditions that favor shrimp pathogens. Moderate discharges of effluents from shrimp farms can have a beneficial effect on the environment, enriching it without overwhelming it. The mangroves and mangrove species that surround many shrimp farms thrive on moderate amounts of nutrients from shrimp farms. In turn, the mangroves prevent erosion and reduce turbidity by trapping sediments and binding nutrients. Nigeria can learn from Ecuador where extensive shrimp farms operate in a comfortable balance with the mangroves. In Thailand and Ecuador, shrimp farmers restore and protect mangrove areas. The Administrative Organization Act empowers local communities to manage and conserve natural resources and the environment in their localities. These powers enable local communities to regulate any activities in their area, including aquaculture.

Code of Conduct standards must be developed and implemented in the marine shrimp culture industry. Standards are a systematic approach to manage shrimp production to achieve international quality recognition and to manage impacts across the whole value chain, from farm to processing plant, to maintain a sustainable marine shrimp culture industry. Standards include guidelines for operation of shrimp hatcheries and farms and for harvesting and transportation from farms to processing plants, distributors and exporters. Standards provide a certification process that addresses a variety of issues, including the use of feed, veterinary drugs and other chemicals.

In addition, good aquaculture practice guidelines must be implemented for hygienic shrimp production and processing. To produce good quality and safe marine shrimp for consumers, shrimp farms must be standardized, clean, sanitized and generate minimal environmental impacts. Furthermore, shrimp health management must avoid use of therapeutic agents and chemicals that lead to residues in shrimp.

Expected Government Participation

Government participation should consist of the following activities:

- Provide necessary support, which could include land, selection of appropriate pilot areas.
- Take measures to reduce costs of materials and equipment for shrimp/prawn production and processing.
- Improve roads and increase transport options from producing areas to processing plants and from there to the port.
- As was done for fish farming, the government should champion this cause of establishing standard hatcheries and encourage private entrepreneurs to do the same. The hatcheries will accordingly be set up to sell post-larvae at a reasonable cost.
- Continue streamlining port operations to reduce cost and theft.
- Encourage more favorable monetary and fiscal policies.
- Assist with export promotion in cooperation with the Nigerian Export Promotion Council (NEPC).

To achieve the desired Vision 20:2020 and millennium goal of rapid agricultural development, commercial shrimp farming can play a vital role. Despite numerous challenges to operation, shrimp farming in the Niger Delta should be encouraged, putting in place all the necessary precautionary measures for sustainable production.

Notes

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Potential Effects of Cultural Eutrophication on Cage Culture in Lakes and Reservoirs in Nigeria

Moshood Mustapha

Freshwater cage culture is an aquaculture production system where fish are grown from fry to table size in cages or enclosures that are fixed, floating or submerged in lakes, reservoirs, rivers or streams. Cages are usually enclosed on all sides with mesh netting and the complete system often includes materials such as PVC pipes, bamboo, wood, used tyres, plastic or steel drums, weights and anchors (mooring) and ropes. Cage fish culture involves simple technology in operation and management and can use locally available and cheap materials for construction. Water exchange occurs between the water body and the cages.

Cage culture has existed for many centuries in several countries, especially in Asia (Beveridge 2004), but is now becoming widespread in other countries, especially in sub-Saharan African countries like Nigeria, where large bodies of fresh water abound. The expanion of cage culture can be attributed to the high demand for fish and increased competition for available resources faced by the existing aquaculture sector (Foley *et al*. 2005).

There are numerous advantages of cage culture. Cages use limited space in existing water bodies and thus eliminate the need to buy land. Compared to pond culture, the investment or capital needed to construct facilities is relatively low. Production capacity is high arising from high stocking densities; production in cages can be as much as 20 times greater than in pond culture (Das *et al*. 2009). Unwanted recruitment, especially in tilapia culture, can be controlled. Eliminating losses from predation, simple methods of harvesting, observation and sampling of fish, and quarantine and disease treatment is rapid and easy. The system is viable, economical and conserves the fishery of the water body in which it is sited. Above all, cage culture can contribute to the livelihoods of people through employment, income generation, poverty alleviation and provision of low-cost fish protein, ensuring food security.

With these advantages, the success of freshwater cage culture depends largely on the water quality of the water body in which the system is sited. Water quality includes all physical, chemical and biological factors of water that influence the beneficial use of that water for various purposes. Thus, water quality dynamics must be taken into account to conform with the requirements of the species cultured. Cage culture leaves the fish susceptible to prevailing physicochemical and biological conditions in the water body.

One of the challenges of freshwater cage culture in Nigeria is deteriorating water quality stemming from cultural eutrophication of lakes and reservoirs. Eutrophication from high nutrient loading is one of the most important causes of water quality deterioration and the consequent decline and collapse of fish populations and production in lakes and reservoirs (Allan *et al*. 2005, Jones-Lee and Lee 2005, Mustapha 2008, 2011). The focus of this article is to examine the potential effects of cultural eutrophication on the emergence of cage culture in lakes and reservoirs of Nigeria and to offer suggestions to mitigate possible effects.

The Threat of Cultural Eutrophication

Cultural eutrophication is the anthropogenic increase in loadings of nutrients, especially phosphate and nitrate, into water bodies. It also occurs through human alteration of the physical and biogeochemical conditions of the watershed of a lake or reservoir. Phosphate and nitrate limit the growth of phytoplankton and aquatic macrophytes and thus have significant impact on the trophic status and productivity of lakes and reservoirs. Freshwater lakes are more vulnerable to ecological changes caused by inputs of phosphorus than nitrogen (Rojas and Wadsworth 2007). When nutrient concentration increases from external loading, excessive phytoplankton and macrophyte production often results, leading to water quality problems.

Human activities that lead to cultural eutrophication of Nigerian lakes and reservoirs include bank erosion, urban runoff, agricultural runoff of fertilizers, washing and bathing with phosphate-based detergents and soaps, and runoff from concentrated livestock operations, all regarded as non-point sources. Point sources include discharges from wastewater treatment and industrial facilities. Non-points source nutrient inputs from the watershed are the leading causes of cultural eutrophication and water quality problems in lakes and reservoirs (Carpenter *et al*. 1998, Mustapha 2009). The rainy season often exacerbates cultural eutrophication from non-point sources during the rainy season in many Nigerian lakes and reservoirs.

Effects of Cultural Eutrophication on Lake and Reservoir Water Quality that Affect Fish in Cages

There are numerous potential effects of cultural eutrophication on water quality of lakes and reservoirs where fish cages are sited and that could negatively impact fish growth and production. Eutrophication increases the risk of dissolved oxygen depletion, potentially leading to severe mortality events in cages due to confinement at high densities. Eutrophication can increase biofouling of cage nets, restricting water exchange and oxygen supply. Biofouling can cause the weight of nets to double, reducing cage buoyancy (Piccolotti and Lovatelli 2003).

Erosion in the watershed can bring excessive suspended inorganic (mineral) matter, causing gill irritation to fish, causing stress that can lead to disease outbreaks in caged fish. High turbidity can lead to stunting of cultured fish populations (Lee and Jones-Lee 1991). High turbidity also reduces the ability of sight feeders, such as many carnivorous species, to locate feed.

Some algae, especially blue-green algae, produce metabolites that cause off-flavor in cultured fish. These off-flavors can cause economic losses because harvested fish are not acceptable by consumers. Although rare, some blue-green algae excrete toxins that can kill fish (Jones-Lee and Lee 2005).

Mitigating Eutrophication in Lakes and Reservoirs

The success of cage culture in Nigerian lakes and reservoirs depends on good water quality, which requires the reduction, control and management of cultural eutrophication. Mitigating measures for cultural eutrophication before the use of the lakes and reservoirs for cage culture should involve the following strategies.

An initial environmental examination provides a baseline assessment of the sources, quantities and concentrations of nutrients in the lakes and reservoirs to be used for cage fish culture. This will show the causes and potential severity of the eutrophication expected and possible mitigation measures that could be implemented before commencing cage culture. An environmental risk assessment from the perspectives of fish stocks in the cage should be carried out in association with the initial environmental examination. Lakes and reservoirs with large watersheds should not be used for cage culture because of the erosive tendency and high level of human activities on such watersheds.

An environmental impact assessment should be carried after the beginning of cage culture project. These assessments will provide information and data on eutrophication, ecological interactions and the impacts of watershed uses. This could then be used to guide management and operation of the cage culture project.

There should also be regular monitoring of anthropogenic activities in the watershed that can cause cultural eutrophication. Geographic Information Systems (GIS) allows effective environmental management planning. The usefulness of this methodology for site selection in cage fish culture has been explored and is now becoming widely established (Perez *et al*. 2003).

Best management practices (BMPs) in the watersheds of lakes and reservoirs should be adopted (Mustapha 2009, 2010a, 2010b). These include nutrient control, biomanipulation, regulations, public awareness, environmental education and changes in social and cultural perspectives of lakes and reservoirs. These will go a long way to mitigate cultural eutrophication.

Conclusion

The prospects of cage fish culture in providing cheap fish protein, sustaining livelihoods, alleviating poverty and ensuring food security largely depends on water quality in the lakes and reservoirs where cage culture is practiced. Good water quality depends on effective curbing, control and management of the threat of cultural eutrophication. An integrated and synergistic approach among various sciences, culture, society, legislation, governmental and non-governmental entities is necessary. Their involvement and participation in management and control of eutrophication will help to ensure that lakes and reservoirs have water quality that will sustain cage fish culture and thereby making the advantages of cage culture feasible and realizable.

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Single Cell Proteins: a Novel Approach in Aquaculture Systems

Vivekanand Bharti, P. K. Pandey[1] and Satish Kumar Koushlesh

The rapid growth in aquaculture and scarcity of fishmeal contribute to the high prices of aquafeeds. Currently fishmeal and soybean meal are the most common feed ingredients in aquafeeds, representing 40-60 percent of total variable costs. A serious challenge remains in reducing input costs through reducing the level of fishmeal in feeds and palliating pressure on natural fish populations.

Aquaculture producers are seeking alternatives to reducing input costs to enhance profitability. Furthermore, consumers have become more health conscious. The practice of organic farming in aquaculture is one current response to these drivers. Among various alternative strategies available today, the exploitation of microorganisms in aquaculture minimizes the use of antibiotics and represents a source of high-quality protein at low cost.

Microorganisms in aquaculture production are used as live organisms, killed organisms or extracted nutrients in aquafeed. Microorganisms such as algae, bacteria, yeast, molds and higher fungi — grown in large-scale culture systems or in biofilm/biofloc systems — can be used in aquaculture. The application of microorganisms or its products as single-cell protein (SCP) in aquafeeds is one of the best approaches to enhance aquaculture sustainability.

Single Cell Protein

Single cell protein broadly refers to microbial biomass or protein extract used as a food or feed additive. Yeast has been used as a source of protein in human food from ancient times. Microorganisms contain high levels of protein, fats, carbohydrates, nucleic acids, vitamins and minerals (Table 1). The importance of yeast and other microorganisms has been realized and further research has been directed toward its utilization in aquafeeds. Efficient exploitation of SCP of microbial origin can replace up to 50 percent of the fishmeal (Dhevendaran *et al*. 2013). Substrates such as whey starch, cellulose hydrocarbon, alcohols and molasses have been used to produce SCP.

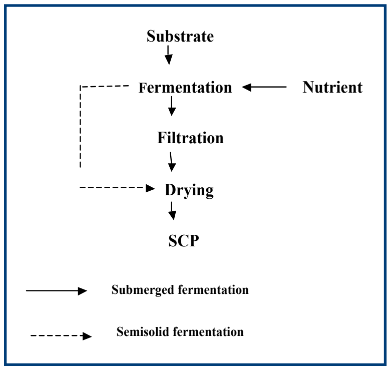

FIGURE 1. *Production of single-cell protein (SCP).*

There are several technologies for production of SCP at the industrial level and the basic steps are illustrated in Figure 1. Technically the production of microbial biomass is achieved either by a submerged or solid state fermentation process.

Production of Single-Cell Protein

Microorganisms can use inexpensive inorganic compounds, such as ammonium salts and carbon, to generate energy for metabolism and growth. Waste inorganic resources can be converted into protein biomass through rapid growth of microorganism on the substrate. Cheap and abundantly available agricultural and industrial wastes can be used for SCP production. Solid state fermentation utilizes solid substrates such as bran, bagasse and paper pulp while submerged fermentation uses free-flowing liquid substrates, including molasses and broths. Sterilization is not required because pathogenic microorganisms are not used for production of SCP for aquafeeds.

Sources of SCP in Aquaculture

Numerous microorganisms with a high nutritional value can be used in aquafeeds and these are discussed below.

Algae. Algae such as *Chlorella* sp., *Chondrus* sp., *Scenedesmus* sp., *Spirulina* sp. and *Porphyrium* sp. can be applied as feed supplements or substitutes for conventional protein sources (fishmeal and soybean meal) in aquaculture. The application of algal biomass in animal feeds, including aquafeeds, is about 30 percent of the current world algal production. *Euglena gracilis* is one of the most preferred algae for SCP production because it has a high protein content and high digestibility by fish (Baker and Gunther 2004). Diets containing 5 percent *Spirulina platensis* can replace *Artemia* nauplii in *Litopenaeus schmitti* larvae culture (Jaime-Ceballos *et al*. 2005). Algae contain 40-60 percent protein, 7 percent mineral salts, chlorophyll, bile pigments, fiber and nucleic acid content (4-6 percent). Production of algae is

TABLE 1. Nutrient composition (as percent dry weight) of the main group of microorganisms used for single-cell protein production (Miller and Litsky 1976).

Component	*Fungi*	*Algae*	*Yeast*	*Bacteria*
Protein	30-45	40-60	45-55	50-65
Fat	2-8	7-20	2-6	1-3
Ash	9-14	8-10	5-10	3-7
Nucleic acids	7-10	3-8	6-12	8-12

feasible only in regions where climatic conditions are suitable.

Fungi. *Aspergillus* sp., *Penecillium* sp., *Rhizopus* sp., *Scytalidium* sp., *Trichoderma* sp., and yeast (*Candida* sp., *Saccharomyces cerevicae*) may give promising result in aquaculture. Fungal oil extract is a superior alternative source of essential fatty acid such as DHA, EPA and ARA, which are required in larval feeds and broodstock diets (Harel *et al*. 2002). Fungal proteins contain high methionine and lysine content. Fungal protein can be used to enrich algal and bacterial proteins, which usually have low methionine content. It is also a rich source of B-complex vitamins.

Bacteria. Bacterial SCP is high in protein (around 80 percent of total dry weight) and certain essential amino acids. *Bacillus mergaterium*, *B. sustilis*, *Streptococcus faecium*, *Streptomyces* sp., *Thermomonospora* sp. and *Lactobacillus* sp. have positive effects in aquaculture (Selvakumar *et al*. 2013).

Nutritional Value of SCP

Single-cell protein from bacteria and fungi are sources of almost all essential amino acids, which may not be available in plant derivatives. Amino-nitrogen represents 70-80 percent of the total nitrogen of microbial cells. Algae contains a rich amount of fat and various vitamins like A, B, C, D and E. *Bacillus* species have carotenoid pigments with antioxidant properties. Algae contain β-carotene, tocopherols, and B vitamins. Yeasts also contain B vitamins, but filamentous fungi have poor vitamin content. The nutritional values of microorganisms are given in Table 1.

Importance of SCP in Aquaculture

In addition to serving as an alternative protein source for aquafeeds, SCP also acts as an immunostimulant and probiotic, substantially improving growth, health, disease resistance and immune system of cultured organisms. The use of probiotics is one of the best approaches to regulate disease occurrence in intensive aquaculture (Ige 2013). *Lactobacillus* (gram positive bacteria) as a probiotic has become an alternative to antibiotics among disease control strategies in aquaculture (Kolndadacha *et al*. 2011).

Single-cell protein from bacteria and yeast contain relatively high nucleic acid content in the form of RNA. The large amounts of RNA in microorganisms promote rapid protein synthesis (Adedayo *et al*. 2011). Rapid protein synthesis and short multiplication times are key factors related to high protein content in single-cell microbes. High nucleotide content in aquafeeds improves hepatic function and lipid metabolism in fish.

Single-cell protein production recycles wastes from agriculture and industries because these substances can be utilized by microbes as nutrient sources. Feed-derived wastes and ammonia released from cultured organisms can also be recycled through SCP.

Size and color of fish are regulating factors in the success of ornamental fish aquaculture. Both can be manipulated through the application of SCP derived from algae and bacteria that contain large amounts of carotenoid pigments. Microbial carotenoids can be used as a feed additive for the growth and coloration of ornamental fishes.

Conclusion

Single-cell protein is an important alternative protein source, reducing input costs via exploitation of naturally occurring microorganisms in aquaculture system or on other waste substrates acting as nutrient sources for the growing microorganisms. Single-cell protein has a high nutritional value, supporting the growth and survival of cultured organisms by enhancing the immune response and disease resistance capacity. Single-cell protein can be a source of β-carotene, enhancing the color of ornamental fish. The use of SCP supports one of the best and most-convenient techniques to produce low-risk and high-health benefit organic food. Thus, the application of SCP in aquaculture enhances production in an economically and ecologically sustainable manner.

Notes

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The steering committee for World Aquaculture 2017 is looking for students to enter a competition in designing the logo that will be used for the World Aquaculture Society's annual meeting in 2017. The conference logo for this event should take into account the location and theme: "**Sustainable Aquaculture-New Frontiers for Economic Growth**"

You do not need to be a WAS student member to submit a logo for this competition, just be a student! Logo submissions will be eligible for this competition from **any student** currently enrolled in courses or research hours.

Logo Submission Specifics:

- The **deadline** for this submission will be December 10th, 2014.
- Please submit your submission to Dr. Christopher Green electronically via email at cgreen@agcenter.lsu.edu
- Designs must be submitted in either JPEG or TIFF format and preferably in color. Submissions can be hand sketched and after evaluation will be submitted to third party graphic designers for construction and finishing.
- In addition to the logo submission, each student must provide **proof of their student status** (Student ID or verification by an advisor).

After the deadline, eligible entries will be evaluated by a panel of WA 2017 Steering Committee members. The winner will be required to sign a release form giving permission for WAS to use the logo in all conference materials and promotions.

For more information or questions, please contact Dr. Christopher Green at cgreen@agcenter.lsu.edu

Logos from past WAS meetings:

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USAS and Alltech have partnered to create an exciting opportunity for USAS students presenting at Aquaculture America 2015 in New Orleans, LA, February 19-22, 2015. The USAS student (graduate or undergraduate) receiving the **USAS Merck Best Presentation Award** will be eligible to advance to the Alltech Young Scientist (AYS) competition at the regional level for North America where they will compete with other AYS country/affiliation winners. Top three winners in of the each of the regional phases will be an 'AYS Finalist' and invited to compete (all expenses paid) in the Global Competition held at the Alltech Annual Symposium in Lexington, KY in May of 2015.

The USAS AYS winner and their mentor will receive AYS Affiliation Awards (trophies, medals and certificates). Regional and Global winners will receive certificates and cash awards. In order for USAS student winners to compete in the AYS North American Regional Competition, they will need to prepare and submit an aquaculture science-related paper following the AYS paper submission requirements (3,500 words for undergraduate and 5,000 words for graduate). For more information on the Alltech Young Scientist Program and requirements go to: http://www.alltech.com/education/alltech-young-scientist/about.

If the USAS Merck Best Presentation awardee is not available to compete USAS will select the Best Presentation runner-up winner.

World Aquaculture Society — Financial Report

This is my final financial report as Treasurer as I am rotating off the Board at the annual meeting in Jeju, Korea. It has been my pleasure to serve the Society as its fiscal officer, but I could not have done it without the help of the Home Office, particularly Mrs. Carol Mendoza, and our Executive Director, Mr. John Cooksey, who wisely manages our conferences and overall activities. I also appreciate the various Board and EXCOM members who make decisions that affect the finances of the Society. I encourage them to invest your money wisely and consider carefully the return on investment to continue to grow the Society and the benefits to its members.

For the fiscal year ending March 31, 2014, the World Aquaculture Society experienced an increase of $61,552 in net assets (total annual revenues minus total expenses) from the previous year. This increase was principally due to revenues from conferences and sound fiscal management from the Home Office management and Board to limit expenses. The financial situation over the past several fiscal years reflects well upon the overall health of the society despite the global economic situation: in a stable membership, successful annual and chapter conferences, and production and distribution of high quality publications, including the journal, magazine, and sales of WAS and non-WAS books on the on-line book store.

The outstanding accounting services by the WAS Home Office provides a solid fiscal foundation for our society and the financial statements were audited by the independent accounting firm of T. A. Harris, Inc. in Baton Rouge, Louisiana. These modified cash basis financial statements reflect account balances based on cash receipts and disbursements and are considered "modified" cash basis statements due to the recording of cash disbursed for equipment as assets and the provision for depreciation on the equipment over their estimated useful lives. The audit showed that these financial statements are a fair representation. A comparative summary from the audited financial statements of the past five fiscal years is shown below.

Summarized statement (Modified Cash Basis): Assets, liabilities and net assets for fiscal years ending March 31

Fiscal Year	*2014*	*2013*	*2012*	*2011*	*2010*
• Cash and investments	$1,334,907	$1,273,200	$1,233,671	$986,953	$965,673
• Net fixed assets after depreciation	$4,115	$4,056	$4,790	$5,847	$5,094
• Total assets	$1,339,022	$1,277,256	$1,238,461	$992,800	$970,767
• Liabilities	($212,977)	($212,763)	($264,869)	($98,678)	($167,106)
• Net assets	$1,126,045	$1,064,493	$973,592	$894,122	$803,661

Revenues collected, expenses paid and changes in net revenues for fiscal years ending March 31

Fiscal Year	*2014*	*2013*	*2012*	*2011*	*2010*
• Revenue collected	$729,205	$805,775	$621,767	$661,639	$724,047
• Expenses paid	$667,653	($714,874)	($542,297)	($571,178)	($575,095)
• Change in net revenues	$61,552	$90,901	$79,470	$90,461	$148,952

Components of revenues and expenses for fiscal years ending March 31

Fiscal Year	*2014*	*2013*	*2012*	*2011*	*2010*
Revenues					
• Dues and home office	18%	17%	20%	17%	18%
• Conferences	60%	55%	54%	57%	57%
• Publications	12%	13%	18%	14%	16%
• Other	10%	15%	8%	12%	9%
• Total	100%	100%	100%	100%	100%
Expenses (as a percent of total revenues)					
• Dues and home office	26%	22%	25%	23%	21%
• Conferences	44%	40%	36%	37%	29%
• Publications	16%	15%	22%	21%	24%
• Other	6%	12%	4%	5%	5%
• Total	92%	89%	87%	86%	79%
• Excess	8%	11%	13%	14%	21%

Due to the nature of the timing of our Society's conferences and meetings, cash basis revenues and expenses for any one period may vary significantly from other single periods. For the fiscal year 2013-2014 that ended in March 31, 2014, conference revenues and expenses included the AQUACULTURE 2013 triennial conference in Nashville, Tennessee, the Asia Pacific Chapter 2013 meeting in Ho Chi Minh, Vietnam and the Aquaculture America conference in Seattle, Washington with some income and expenses from previous and future meetings. WAS undertakes a number of ongoing and future joint efforts in the organization of our annual conferences with other associations. While the responsibility for conference-related assets and liabilities is shared among the partners, the revenues and expenses are mostly handled by WAS and the statements reflect the overall assets and liabilities related to our conferences, rather than just the proportional assets and liabilities for WAS. Conferences continue to account for a significant portion of the revenues (60%) and expenses (44% as a percent of total revenues) for the society; hence, the long-term financial strength of the society and the success of our meetings are based upon good attendance and participation by WAS members and others. In 2013-2014, our cash and investments increased $61,707 over the previous year despite the global economy. The next largest contributors to revenue are dues (18%) and publications (12%).

To facilitate fiscal stability and long-term planning, the WAS Board of Directors considers at least a three-year planning horizon. The current net assets of $1,126,045 provide an important buffer that allows for the continued emphasis on internationalization of the society in terms of meeting venues, chapter development and promotion of new initiatives for information and knowledge exchange. In addition, the WAS Board of Director as part of our long-term financial strategy continues to build up a balanced and diversified investment portfolio to a level that, at a minimum, will allow access to available funds that would equal our annual budget expenses ($583,431 for 2013-14). By striving to increase our investments to a level of our annual expenses, this will put the society in a stronger financial position; whereby, we would have a lower risk of financial hardship should a catastrophic financial event within the society ever occur. Making sound investments has been challenging under current global conditions, but the Board continues to move cautiously in this area.

In summary, WAS maintains a stable financial position with continued long-term positive monetary outcomes of our activities to date and for the future.

Respectfully submitted to the WAS membership,
Bill Daniels, WAS Treasurer

Conference Calendar

- *8-9 January 2015*
  XIII International Conference on Sustainable Global Aquaculture
  River View Hotel Singapore
  Singapore
  www.waset.org/conference/2015/01/singapore/ICSGA

- *14-16 January 2015*
  Northeast Aquaculture Conference and Expositionand the Milford Aquaculture Seminar
  Holiday Inn by the Bay
  Portland, Maine
  www.northeastaquaculture.org

- *20-22 February 2015*
  Aqua Aquaria India 2015
  Andhra Loyola College
  Vijayawada, Andhra Pradesh, India
  www.aquaaquaria.com

- *24-26 February 2015*
  2nd International Conference on Fisheries, Aquaculture and Environment in the Indian Ocean
  Sultan Qaboos University
  Muscat, Oman
  www.fishconference.om/home/

- *27 February 2015*
  9th Catfish Research Symposium
  Natchez Convention Center
  Natchez, MS

- *3-5 March 2015*
  10th North Atlantic Seafood Forum
  Radison Blu Royal Hotel
  Bergen, Norway
  www.nor-seafood.com

- *11-13 March 2015*
  VIV Asia 2015
  Bangkok International Trade & Exhibition Centre
  Bangkok, Thailand
  www.vivasia.nl/en/Bezoeker.aspx

- *15-20 March 2015*
  10th International Conference on Molluscan Shellfish Safety
  Hotel Patagónico
  Puerto Varas, Chile
  www.icmss2015.com

- *5-6 April 2015*
  Middle East Aquaculture Forum
  Dubai World Trade Centre
  Dubai, UAE
  www.meaf.ae

- *17-19 April 2015*
  International Conference on Marine Science & Aquaculture
  Kota Kinabalu, Sabah, Malaysia
  www.ums.edu.my/ipmb/icomsa

- *22-24 April 2015*
  2nd International Symposium on Aquaculture and Fisheries Education (ISAFE2)
  Shanghai Ocean University
  Shanghai, China
  www.asianfisheriessociety.org

- *3-5 May 2015*
  IAI Aquaculture Expo
  Pragati Maidan
  New Delhi, India
  10times.com/iai-aquaculture-expo

- *20-22 July 2015*
  International Conference on Aquaculture & Fisheries
  Brisbane, Australia
  aquaculture-fisheries.conferenceseries.com

- *7-11 September 2015*
  17th International Conference on Diseases of Fish and Shellfish
  Alfredo Krauss Auditorium
  Las Palmas de Gran Canaria, Spain
  eafp.org/eafp-2015-conference

- *20-23 September 2015*
  Aquaculture Europe 2015
  Rotterdam, Netherlands

- *5-10 October 2015*
  9th International Abalone Symposium
  Yeosu, Korea
  internationalabalonesociety.org

Future World Aquaculture Society Conferences and Expositions

AQUACULTURE AMERICA 2015 • Feb. 19-22

New Orleans Marriott • New Orleans, Louisiana USA

International Annual Conference & Exposition with U.S. Chapter, WAS, National Aquaculture Association and U.S. Suppliers Association

WORLD AQUACULTURE 2015 • May 26-30

Jeju Convention Centre • Jeju Island, Korea

International Annual Conference & Exposition of WAS with many other associations, industry and government sponsors.

LACQUA 2015 • November 16-19

Fortaleza, Brazil

Annual meeting of the Latin American & Caribbean Chapter, WAS with the annual FENECAM show

AQUACULTURE 2016 • Feb. 22-26

Paris Hotel • Las Vegas, Nevada USA

Triennial Int'l Annual Conference & Exposition with WAS, Fish Culture Section, AFS, National Shellfisheries Association, U.S. Aquaculture Society, National Aquaculture Association and Aquaculture Suppliers Association

ASIAN PACIFIC AQUACULTURE 2016 • April 26 - 29

Surabaya, Indonesia

Annual Meeting of the Asian Pacific Chapter, WAS and various Indonesian groups.

AQUACULTURE AMERICA 2017 • Feb. 19-22

Marriott Riverwalk Hotel • San Antonio, Texas, USA

International Annual Conference & Exposition with U.S. Chapter, WAS, National Aquaculture Association and U.S. Suppliers Association

WORLD AQUACULTURE 2017 • June 26-30

Cape Town Convention Centre • Cape Town, South Africa

International Annual Conference & Exposition of WAS with many other associations, industry and government sponsors.

AQUACULTURE AMERICA 2018 • Feb. 19-22

Paris Hotel • Las Vegas, Nevada USA

International Annual Conference & Exposition with U.S. Chapter, WAS, National Aquaculture Association and U.S. Suppliers Association

For information, contact: Director of Conferences:
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USAS, continued from page 4

WAS/USAS members who purchase this book through the website will receive a 10 percent discount.

Looking forward, I encourage and challenge the entire USAS membership to think and be vocal about what USAS means to you and what benefits you expect from membership in this WAS chapter. We are working on the Five-Year Strategic Plan and I want to be sure the leadership of this chapter is aware of and is addressing your needs.

Please vote for the 2015 open Board positions and the proposed bylaw changes. The ballot is available to download or you may vote online at the WAS website. The deadline for voting is January 19, 2015.

My time as USAS President will come to an end at AA15, where USAS will celebrate its 25th anniversary. I am so excited to be simultaneously at the end of an important part of USAS history and at the beginning of the next quarter century for USAS. I hope you all have a wonderful and safe holiday season. I am looking forward to seeing everyone in 2015!

— Kathleen Hartman, President

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