

**Feed the Future Innovation Lab for
Collaborative Research
on Aquaculture & Fisheries
(AquaFish Innovation Lab)**

The Collected Abstracts 2009-2018
CRSP Research Report Series
1 January 2009 – 14 September 2018
and
Unpublished Abstracts from 1986 to 2018

AquaFish IL Management Office
Oregon State University
Strand Agriculture Hall
Corvallis, OR USA



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Program activities are funded in part by the United States Agency for International Development (USAID) under CA/LWA No. EPP-A-00-06-00012-00 and by participating US and Host Country institutions.

The mission of the AquaFish Innovation Lab is to enrich livelihoods and promote health by cultivating international multidisciplinary partnerships that advance science, research, education, and outreach in aquatic resources. Bringing together resources from Host Country institutions and US universities, the AquaFish Innovation Lab emphasizes sustainable solutions in aquaculture and fisheries for improving health, building wealth, conserving natural environments for future generations, and strengthening poorer countries' ability to self-govern.

Acknowledgements

The AquaFish IL Management Entity acknowledges the contributions of researchers and the support provided by participating US and Host Country institutions. The editors acknowledge the contributions of Ford Evans, Kat Goetting, Stephanie Ichien, Lindsay Carroll and Margaret McCormick.

Disclaimers

The Feed the Future Innovation Lab for Collaborative Research on Aquaculture & Fisheries is funded under USAID Leader with Associates Cooperative Agreement No. EPP-A-00-06-00012-00 and by the participating US and Host Country partners. The contents of this document are the responsibility of the authors and do not necessarily reflect the views or endorsement of USAID or the United States Government.

This publication may be cited as:

AquaFish Innovation Lab. September 2018. AquaFish Innovation Lab Collected Abstracts 2009-2018. AquaFish Innovation Lab, Oregon State University. Corvallis, Oregon, USA.

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INTRODUCTION

The Research Report Series was launched in 1987 under the Pond Dynamics/Aquaculture Collaborative Research Support Program (PD/A CRSP) as a means of disseminating CRSP-sponsored research. The series has continued under the Aquaculture Collaborative Research Support Program (ACRSP), the Aquaculture & Fisheries Collaborative Research Support Program (AquaFish CRSP), the Feed the Future Innovation Lab for Collaborative Research on Aquaculture & Fisheries (AquaFish Innovation Lab). The complete Research Report series is available online at <http://aquafishcrsp.oregonstate.edu/nop>, offering a searchable interface.

In an effort to make the research more available to a wide audience, translations in French and Spanish are provided for a portion of the included abstracts. Included with each research report is information on the authorship and publication source. Copies of the complete reports may be obtained by contacting the authors directly.

Reports are ordered chronologically starting with research reports unpublished in our previous publications between the years 1987 and 2008. The previous publications, The Collected Abstracts from the PD/A CRSP Research Report Series and The Collected Abstracts 1996 to 2008, can be accessed [here](#) for the complete research report series published prior to 2008. Following these supplemental abstracts are the collected abstracts from the AquaFish CRSP and AquaFish Innovation Lab research reports received between 1 December 2008 and 14 September 2018 also entered in chronological order.

AQUAFISH RESEARCH REPORT 87-A02

THE COMMERCIAL FISHERY OF THE PERUVIAN AMAZON

Marcos Javier De Jesús and Christopher C. Kohler

Published in:

Fisheries (2004) 29(4).

A combination of increased human population growth, high fish harvest pressure, and adoption of more technologically advanced fishing equipment by the commercial fleet has generated concerns about the sustainability of fish stocks in the Peruvian Amazon. We assessed the status of the commercial fishery by conducting interviews with officials of the Peruvian Ministry of Fisheries as well as with commercial and artisanal fishers. We also reviewed pertinent publications and agency reports written in one of three languages (Spanish, Portuguese, and English). Based on the trend toward smaller-sized fish and greater effort needed to achieve full capacity catches, we suggest the commercial fishery is beginning to show the classical signs of overfishing. More comprehensive data collection, stringent enforcement of management regulations, research on the influence of flood level on fish production, and development of an ecologically and genetically sound native-species aquaculture program are measures we recommend be adopted to protect and sustain the fishery resources of the Peruvian Amazon.

AQUAFISH RESEARCH REPORT 88-A06

DEVELOPMENT OF APPROPRIATE POND MANAGEMENT TECHNIQUES FOR USE BY RURAL RWANDAN FARMERS

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Published in:

The Second International Symposium on Tilapia in Aquaculture (1988): 561-568.

With fishponds at elevations of 1,300-2,500 m, Rwanda has a unique environment for tropical fish culture. Average pond temperatures are 21°C in the afternoon. Introductory efforts at promoting aquaculture met with farmer support but their approach failed to compensate for cooler temperatures. Results were minimal with production of only 200-500 kg/ha/year, albeit, thousands of small hand-dug ponds were built. With an ever-increasing population, competition developed for land and agricultural inputs. Pressure to increase farm outputs, especially those with high nutritional and cash value, focused attention upon increasing yields from existing fishponds. With no commercial animal feeds, few agricultural byproducts, and little chemical fertilizer, fish production must depend upon limited quantities of organic fertilizer. Within this scheme, tilapia were viewed as the appropriate fish, although Clarias and carps had been cultured. Of tilapias cultured, *Oreochromis niloticus* proved most suited to management inputs. Initial work centered upon maximizing pond temperatures through water management. With appropriate pond depths and water regulation, morning pond temperatures can be 2-5°C warmer than surrounding natural waters. Subsequent efforts focused upon comparing nutrient inputs and stocking densities. A mixture of grasses and manure was applied at high and low rates with two stocking densities in ponds with and without stocking density, produced 854 kg/ha/year, with management techniques well within the scope of rural farmers. Average production of 1,382 kg/ha/year was obtained from fed ponds with similar management, but with inputs that were not appropriate for most farmers.

AQUAFISH RESEARCH REPORT 92-A04

PRODUCTION OF FRESHWATER PRAWNS IN THE MEKONG DELTA

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Published in:

Naga, The ICLARM Quarterly (1992): 24-26.

The Mekong River flows through southern Vietnam in two major branches, encompassing a 39,550- km² delta with 14.2 million inhabitants. With open access to vast estuaries, extensively interconnected rivers and canals constitute most of the aquatic environment in the Mekong Delta: an ideal habitat for the native freshwater prawn (*Macrobrachium rosenbergii*) (Fig. 1). The prawns are harvested primarily by a common small-scale method using shelter traps. The shelter traps installed along the edges of rivers and canals are square or rectangular enclosures surrounded with bamboo or wooden frames, within which piles of tree branches and aquatic vegetation (water hyacinth) are placed to attract prawns from the open water. Periodically, fishers surround the shelters with seine nets and remove prawns from within them. Prawns are harvested all year-round and the larger ones are sold at more than US\$4/kg, either to local markets or government processing plants. Smaller prawns and juveniles are kept alive and sold to prawn farmers at around US\$1.5/kg, which comprises 200 to 300 individuals.

The total annual freshwater prawn production in Vietnam during 1985-90 was reported to vary from 5,000 to 8,000 t, most of it from natural fisheries. Unless the harvest of wild juveniles is managed, it may undermine the sustainability of the natural fisheries.

There have been few efforts to estimate the standing stock of prawns in any given river or habitat. Nor is there information on catch/effort and rate of natural recruitment for the prawn population. Without such data, it will be difficult, if not impossible, to assess their present status and predict the future trend of the prawn fisheries.

AQUAFISH RESEARCH REPORT 92-A05

A STANDARD FORMAT FOR DESIGN AND EVALUATION OF POND EXPERIMENTS

James P. Szyper

Published in:

Naga, The ICLARM Quarterly (1992): 18-20.

The US Agency for International Development (US AID) funds a number of Collaborative Research Support Programs (CRSPs), which conduct research on a variety of food production issues, always with international collaboration among researchers from the host countries and the United States. One research group is called the Pond Dynamics/ Aquaculture (PD/A) CRSP. It aims to improve yields and reliability of animal protein production through increased understanding of pond ecosystems. Researchers from universities and government research stations in four tropical countries (Honduras, the Philippines, Rwanda and Thailand) work with colleagues from six US universities, usually at more than one site in each country. My home institution, the University of Hawaii, participates in projects in Thailand and the Philippines.

AQUAFISH RESEARCH REPORT 93-A04

NITRIFYING CHARACTERISTICS OF A HIGH RATE PACKED COLUMN

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Published in:

J.K. Wang (Editor), *Techniques for Modern Aquaculture*. Proceedings of an Aquacultural Engineering Conference. American Society of Agricultural Engineers (1993): 345–351.

A system of high rate biofilter packed columns was operated using “synthetic” fish waste in order to characterize the operating parameters and nitrification rate for aquacultural water. Two sets of experiments were conducted: the first was designed to determine the range of hydraulic loading rates that could be achieved with the nitrification columns. The second served to determine the effect of oxygen concentration on nitrification rate within the columns. Three columns (0.15m diameter and 3 m tall) were filled with 1.6 cm Pall™ rings. The columns were set on a 3 m³ reservoir (test tank). In the first experiment, the columns were operated at three different flow rates (2 L min⁻¹, 20 L min⁻¹, 40 L min⁻¹) and dissolved oxygen concentration was maintained at 100% saturation. In the second experiment, the three columns were operated at the same flow rate (24 L min⁻¹) with 150% dissolved oxygen concentration. The “synthetic” fish waste was prepared daily and maintained refrigerated at 4 °C to reduce bacterial contamination and activity prior to introduction to the test tank. The synthetic fish waste was introduced into the test tank by means of a metering pump. The first experiment verified that the lowest hydraulic flow rate did not allow effective nitrification in the column. Conversely, the highest flow rate resulted in high nitrification rate but the column had a tendency to flood or restrict air flow as the filter matured. The second experiment resulted in nitrification rates that average 0.08 g m⁻² d⁻¹ with maximum of 0.15 g m⁻² d⁻¹. The second experiment will be continued by operating the columns at alternate dissolved oxygen concentrations (100%, 200%). The higher concentrations of dissolved oxygen are expected to result in higher nitrification rates.

AQUAFISH RESEARCH REPORT 94-A08

EFFECTS OF FEEDING FREQUENCY AND HANDLING ON GROWTH AND MORTALITY OF CULTURED WALKING CATFISH *CLARIAS FUSCUS*

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Published in:

Journal of the World Aquaculture Society 25(2):175-182.

Two experiments were conducted to study the effects of feeding frequency on growth, and of handling stress on growth and mortality, in intensive tank culture of the walking catfish *Clarias fuscus*. In the first experiment, fish were grown from an initial weight of 37 g for 34 d. A fixed ration of 3.0% body weight per day was divided into either 1, 2, or 3 feedings per day, and fish were either handled weekly or left unhandled for the entire experiment. Fish given 3 feedings per day experienced 19% faster growth ($P < 0.05$) than fish given the same ration in a single feeding per day. These differences in growth reflect differences in assimilation efficiency, assuming all other metabolic costs were constant among treatments. Handling of individuals caused decreased growth; however, there was no effect on mortality.

In the second experiment, fish were grown from an initial weight of 78 g for 29 d. Fish were fed either 1 or 2 satiation feedings per day and were either handled weekly or left unhandled for the entire experiment. Fish fed 2 satiation feedings per day experienced 47% faster growth ($P < 0.05$) than fish fed 1 satiation feeding per day, which was assumed to reflect a higher level of food consumption. No effect of handling on either growth or mortality was observed for fish in experiment 2. Multiple meals per day also reduced compensatory growth among individuals in both experiments.

AQUAFISH RESEARCH REPORT 94-A09

SOCIOECONOMIC FACTORS AFFECTING THE TRANSFER AND SUSTAINABILITY OF AQUACULTURAL TECHNOLOGY IN RWANDA

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Published in:

Research and Development Series 38, International Center for Aquaculture and Aquatic Environments, Alabama Agricultural Experiment Station, Auburn University: 16.

Beginning in 1983, the Rwanda National Fish Culture Project helped farmers improve their ponds and pond management. It also identified and provided a species of tilapia better-suited to the high-elevation, cool-water environment. The report focuses on the experiences of three specific categories of farmers, about which little systematic information exists.

Interviews were conducted with 115 active farmers including 56 women who were pond group members or individual operators. Interviews were conducted with 21 dropouts about their reasons for quitting fish culture. Similarly, 16 emulators were interviewed about their lack of contact with extension personnel. The results suggest that aquaculture has become an integral part of the diversification strategy of Rwandan farmers. Despite a lessening in the intensity of extension assistance, farmers continue to grow repeated crops of fish. They express positive sentiments about the activity, its benefits, and the technical support they receive.

The segment of farmers that has stopped growing fish seems to have done so for reasons other than dissatisfaction with the enterprise per se. Dropouts were slightly more involved in other farm enterprises, but the problems they identified were more related to circumstances in their household or in the milieu of neighboring landowners than with fish culture itself. A narrow segment quit because the water was too cold or otherwise was not conducive to growing fish. Dropout farmers perceived more time and effort conflicts with other farm enterprises and household work. They were more interested in the cash proceeds of fish culture than the other sample segments and less likely to feel that the pond was the best use of the land it occupied.

Women in groups seemed the most satisfied and productive segment of the study respondents. They had larger harvests, they experienced fewer marketing problems, and they were more attentive to the general practice of fish culture. They also seemed to get better prices. Women in groups seemed better able to exploit pond bank sales as a marketing channel for tilapia. Friends, relatives, and neighbors are an immediate network of fish consumers that are readily alerted and mobilized to purchase fish at harvest. Women in pond groups were characterized by an overlay of multiple social networks, and seem better positioned to distribute fish among rural households.

Women in pond groups seem to have most effectively realized the promise of fish culture to yield benefits for families, particularly children. The access to land, sociability, and perhaps gender solidarity in a male-oriented society, are major advantages of fish culture for women.

AQUAFISH RESEARCH REPORT 95-A03

CALCULATION OF pH IN FRESH AND SEA WATER AQUACULTURE SYSTEMS

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Published in:

Aquacultural Engineering (1995) 14(4): 331-346.

A procedure for the calculation of pH in fresh and salt waters has been developed. The method is based on a fourth-order polynomial relationship between hydrogen ion concentration and other (conservative) water quality parameters.

The method avoids trial and error estimations and results in a direct calculation procedure that can be implemented in models developed in various modeling environments, such as spreadsheets, conventional programming languages (BASIC, C, FORTRAN, PASCAL, etc.) or specialized modeling languages (ExtendTM, StellaTM). The method developed is based on the solution of the full alkalinity-pH equation. Because of the need for simplification of the equations to yield explicitly solvable polynomial equations, the accuracy of the solutions depends on the simplification made and varies with water properties. Three simplifications are tested based on a second-, a third and a fourth-order polynomial equation for hydrogen ion concentrations. The equations have been tested for salinities ranging from 0 to 3.5% (fresh to sea water), for temperatures ranging from 0 to 35°C, for total carbonate carbon concentrations of 0.1 and 5.0 mmol/liter, and for total ammonia nitrogen concentrations of 0 and 10 mg/liter. Approximations are most accurate in waters of high total carbonate carbon and low ammonia concentrations, where the fourth-order approximation yields results that are within 0.05 pH units for the full range of pH values tested (5-10).

AQUAFISH RESEARCH REPORT 95-A04

EXPERIMENTAL OBSERVATIONS ON FEEDING BIOLOGY OF BLACK CARP (*MYLOPHARYNGODON PICEUS*)

Shelton WL, Soliman A, Rothbard S

Published in:

Israeli Journal of Aquaculture - Bamidgeh (1995) 47(2): 59-67.

Black carp, *Mylopharyngodon piceus*, has powerful pharyngeal teeth which are adapted for crushing mollusks. Several species of gastropods are nuisance organisms or intermediate hosts in parasite transmission. The black carp may serve as an agent for biological control of some of these pests. Laboratory experiments were conducted to test various aspects of their feeding biology. Mouth gape was determined to be a good estimator of the largest size snail that a particular fish could ingest, crush and swallow. The relationship, gape/total length, can be used to evaluate the scope of predator/prey potential in water bodies with snail pests. Fish between 100 and 500 mm had gapes from 7 to 25 mm, respectively. Based on the size of fish tested in predator/prey studies (120-320 mm; gape 7-17 mm) and gastropod species used, snails of 7 to 17 mm were eaten. Fish between 100 and 200 g (210-270 mm TL) were satiated at 1.5 to 13% of the body weight, while fish around 300 g (similar to 320 mm) were satiated at 1-6% of the body weight. Based on the limited and small size range of fish examined, about 10 g of snail biomass could be eaten per day by these relatively small black carp. These preliminary data might permit some estimate of fish numbers to stock for snail control.

AQUAFISH RESEARCH REPORT 96-A02

SOCIAL, ECONOMIC, AND INSTITUTIONAL IMPACTS OF THE AQUACULTURE RESEARCH ON TILAPIA:
THE PD/A CRSP IN RWANDA, HONDURAS, THE PHILIPPINES, AND THAILAND

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Published in:

Research and Development Series (1996) 40: 1-72.

The Pond Dynamics/Aquaculture Collaborative Research Support Program (PD/A CRSP) is a global research network organized to generate basic science that may be used to advance aquacultural development. One of a family of research programs funded by the United States Agency for International Development (USAID), this CRSP focuses on improving the efficiency of aquaculture systems.

The Pond Dynamics/Aquaculture CRSP began work in 1982 in Thailand, and subsequently in the Philippines, Honduras, Rwanda, Indonesia, and Panama. Research continues today in Thailand, the Philippines, Honduras, the US, and until recently, Rwanda. At all the sites, the goal is the same: to identify constraints to aquaculture production, and to design responses that are environmentally and culturally appropriate.

The PD/A CRSP has conducted a Global Experiment for over ten years. The Global Experiment has served as an organizing framework for guiding parallel studies in diverse locales in the tropics. Researchers have conducted a series of standardized research trials at each site, establishing baseline data on physical, chemical, and biological processes as they relate to fish growth. The research network has focused on tilapia (*Oreochromis niloticus*), although some sites have devoted attention to marine shrimp and other locally significant species. This report examines the impact of the network's investigations with tilapia.

AQUAFISH RESEARCH REPORT 96-A03

STRATEGIES FOR STOCKING NILE TILAPIA (*Oreochromis niloticus*) IN FERTILIZED PONDS

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In a 149-day grow-out experiment, we tested the effects of stocking density, partial harvesting and intermediate stocking on net fish yield (NFY) and harvest size of Nile tilapia (*Oreochromis niloticus*). Sex reversed male tilapia were raised in 280-m² earthen ponds, which received 8 kg dry weight chicken manure • ha⁻¹ • day⁻¹ with urea and triple superphosphate supplement to give a total fertilization rate of 4.0 kg N • ha⁻¹ • day⁻¹ and 1.0 kg P • ha⁻¹ • day⁻¹. The five treatments were three stocking densities of 0.8, 1.6, and 2.4 fish • m⁻², fish stocked at 0.8 fish • m⁻² with an additional 0.8 fish • m⁻² added after 2.5 months, and fish stocked at 1.6 fish • m⁻² with 50% of fish removed after 2.5 months. Stocking density significantly affected fish yield ($r^2=0.57$, $P<0.02$); extrapolated mean NFY in ponds stocked at 0.8, 1.6 and 2.4 fish • m⁻² were 14.2, 19.2 and 25.7 kg • ha⁻¹ • day⁻¹, respectively; mean weights were 335, 230 and 214 g • fish⁻¹, respectively. Mean NFY for the first 2.5 months exceeded 39.0 kg • ha⁻¹ • day⁻¹ in ponds stocked at 2.4 fish • m⁻². Partial stocking gave slightly higher total NFYs than partial harvesting, or 21.7 kg • ha⁻¹ • day⁻¹ compared to 18.0 kg • ha⁻¹ • day⁻¹. Additional stocking did not significantly affect fish growth of the originally stocked fish. Mean harvest weights of fish stocked at 0.8 fish • m⁻² were similar to the first stocked fish in the treatment receiving an additional 0.8 fish • m⁻² after 2.5 months. Results suggest a partial intermediate stocking and partial harvesting strategy may produce annual tilapia yields of 30 kg • ha⁻¹ • day⁻¹, with mean weights over 300 g • fish⁻¹.

AQUAFISH RESEARCH REPORT 96-A04

EFFECTS OF POND DEPTH & MECHANICAL MIXING ON PRODUCTION OF *OREOCHROMIS NILOTICUS* IN MANURED EARTHEN PONDS

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Published in:

R.S.V. Pullin, J. Lazard, M. Legendre, J.B. Amon Kothias, and D. Pauly (editors), *The Third International Symposium on Tilapia in Aquaculture*. ICLARM Conference Proceedings 41: 152-158.

An experiment to assess the effects of water mixing on production of Nile tilapia (*Oreochromis niloticus*) in fertilized earthen ponds was performed at the Asian Institute of Technology in Thailand. Male fingerlings stocked at 3 fish • m⁻³ grew to final weights of 106- 233 g in 173 days in nine ponds of approximately 370- m² individual surface area. Yields were statistically indistinguishable among treatments, averaging 5.4 t • ha⁻¹ • year⁻¹ in three ponds of 1.5 m depth whose water was mixed for two hours each day; 6.7 t • ha⁻¹ • year⁻¹ in three similar but unmixed ponds; and 6.9 t • ha⁻¹ • year⁻¹ in three unmixed ponds of 0.9 m depth. Survival was significantly lower in the deep mixed ponds (72% compared with 91-93%). Fish grew more rapidly and had larger final weights in the shallow unmixed ponds, which had larger standing stocks of phytoplankton, as measured by chlorophyll a, and greater rates of gross dissolved oxygen (DO) production per unit volume during most of the growth period. Treatments did not differ in gross DO production per unit area. Daily mixing produced higher nighttime bottom oxygen concentrations up until 2300 hours, but did not change overnight DO minima. No treatment-related differences in ammonia concentrations or other water quality parameters were found. The oxygen-conserving effect of mixing was not effective in enhancing production of this species, which grows and survives well in unmixed ponds, tolerating or avoiding waters of low oxygen content. Mixing and aeration strategies must be examined carefully for both detrimental and beneficial effects.

AQUAFISH RESEARCH REPORT 97-A10

WATER QUALITY IN PONDS

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Published in:

H.S. Egna and C.E. Boyd (Editors), *Dynamics of Pond Aquaculture*. CRC Press, Boca Raton, FL: 53-71.

The various chemicals dissolved in the water, as well as the temperature and other physical attributes of water, all combine to form what is called water quality. For aquaculture systems, changes in water characteristics that improve the production of an aquatic crop would be considered improvements in water quality, while those changes reducing production would be considered degradation of water quality. This definition is important in aquaculture, because the utilization of water to grow aquatic crops at high densities often results in chemical attributes which, by environmental standards, may be considered reductions in water quality. Unless these changes reduce the production, safety, or value of the target organism, they would not be considered degradations of water quality for aquaculture purposes. Good water quality characteristics will be considerably different for some species than for others. Characteristics that enhance production of tilapia might be detrimental to species such as rainbow trout. Species are often chosen for aquaculture because of their tolerance to poor water quality (Chapter 8). Thus, water quality must be viewed in the context of the species cultured. This chapter reviews the quality of water in relation to production of tilapia in semi-intensive to intensive ponds.

AQUAFISH RESEARCH REPORT 97-A11

FERTILIZATION REGIMES

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Research and Development Series 38, International Center for Aquaculture and Aquatic Environments, Alabama Agricultural Experiment Station, Auburn University: 16.

Pond Fertilization to increase fish yields has long been practiced throughout the world. It is a well-known tradition in China to utilize animal manures and human excreta as major sources of pond-inputs for polyculture of the major Chinese carps (Ling, 1967; Wohlfarth and Schroeder, 1979). The uses of inorganic fertilizer were introduced more recently in temperate regions (Mortimer, 1954; Gooch, 1967). There is voluminous literature on pond fertilization, documenting many conflicting and inconsistent results based on various types of fertilizer, rates of input, and methods and frequency of application (Coleman and Edwards, 1987). Those controversial viewpoints may actually reflect the differences in the physical and chemical environments of experimental ponds as well as variations in cultured fish species and stocking densities. Some of the problems have also stemmed from the lack of proper statistical designs with sufficient replication and common protocols for pond fertilization experiments. A major thrust of the PD/A CRSP during the past 14 years has been to develop a data base for pond dynamics and fertilization management strategies for pond culture. The common global experiments were conducted primarily on pond fertilization and its impact on water quality and fish yield. The practical goal was to provide fish growers with sound strategies and guidelines for pond fertilization. Standardized fertilizer experiments were carried out during 2 to 3 years at sites in Honduras, Indonesia, Rwanda, Panama, Philippines, and Thailand. Work plans for global experiments consisted of simple inputs of phosphorus to calibrate sites, comparison of inorganic and organic fertilizers, and comparison of various loading rates of organic fertilizers. Some site-specific experiments were also conducted, depending on the needs of the individual site and the perspective of the researchers. Standardized experimental design and work plan protocols were followed at all sites (Egna et al., 1987). Results from the various sites are comparable because Nile tilapia (*Oreochromis niloticus*) was used as the cultured species with specified 5-month grow-out cycles, during which measurements of water quality, fish sampling, and methods of fertilizer application were standardized.

AQUAFISH RESEARCH REPORT 97-A12

POND BOTTOM SOILS

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Published in:

H.S. Egna and C.E. Boyd (Editors), *Dynamics of Pond Aquaculture*. CRC Press, Boca Raton, FL: 135-162.

The importance of soil characteristics in pond construction was discussed in Chapter 5. Characteristics and condition of bottom soil are also important in pond management. The exchange of substances between soil and water affects water quality, which in turn influences fish production. Although it is generally recognized that there are strong effects and interactions among soil characteristics, water quality, and fish production in ponds, much more attention has been given to water quality than soil condition as a factor limiting fish production in ponds. The PD/A CRSP has placed emphasis on measuring the effects of pond water quality variables on fish production and developing management procedures for improving water quality. However, some research has been conducted on pond soils, and future work on pond dynamics will no doubt have a greater focus on pond soil condition. The purpose of this brief chapter is to provide the reader with an overview of the role of bottom soil in pond aquaculture and to provide a summary of PD/A CRSP research on pond soils.

AQUAFISH RESEARCH REPORT 97-A13

FACTORS AFFECTING FISH GROWTH AND PRODUCTION

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Published in:

H.S. Egna and C.E. Boyd (Editors), *Dynamics of Pond Aquaculture*. CRC Press, Boca Raton, FL: 199-213

Growth in Fishes in aquaculture is a complex process by which ingested energy is converted to biomass. The efficiency of this conversion is regulated by the growth potential of the organism, its trophic status, and various abiotic factors such as food supply, temperature, and adverse environmental factors brought about by the conditions in which the fish are cultured.

AQUAFISH RESEARCH REPORT 97-A14

FEEDING STRATEGIES

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Published in:

H.S. Egna and C.E. Boyd (Editors), *Dynamics of Pond Aquaculture*. CRC Press, Boca Raton, FL: 245-262.

Aquaculture of tilapia originally developed as an extensive to semi-intensive system for local consumption (Pillay, 1990). While this sort of aquaculture continues today, high demand in the U.S. and elsewhere has made intensive production and export of tilapia more feasible (Anonymous, 1995). Such culture systems usually include provision of formulated or compete feed. Utilization of such feed may be made more efficient by certain feeding practices or techniques. It may also be more cost effective because it utilizes locally available items rather than relying entirely on imported complete feeds. The purpose of this chapter is to review CRSP experiments related to supplemental feeding of Nile Tilapia and to put these into context as they relate to water quality and to pond fertilization.

AQUAFISH RESEARCH REPORT 97-A15

DISEASES OF TILAPIA

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Published in:

H.S. Egna and C.E. Boyd (Editors), *Dynamics of Pond Aquaculture*. CRC Press, Boca Raton, FL: 263-287.

Tilapias originated in Africa. They have a rapid growth rate and relatively few diseases, probably because of the nature of the environment within which they have evolved, with its regular droughts and other stresses. They have become one of the most economically important group of cultured species. Tilapia farms are widespread in the tropics and subtropics. The fish reared in ponds, cages, or pens, and they grow well in freshwater and brackish water environments. The high fecundity of the fish, its rapid growth rate, its few disease problems, and the ready availability of tilapia fry have resulted in intensification of production. Papers of diseases of tilapia were first published early this century.

Under the original extensive or semi-intensive culture systems, tilapias were more resistant to disease than many other fish species (Roberts and Sommerville, 1982). However, the intensification of culture systems and resultant deterioration in the environment have been associated with an increase in parasitic and infectious disease problems.

Formerly, parasitic diseases appeared to be more significant than other forms of infection, but the incidence of nonparasitic infections appears to be increasing. Consequently, although the literature on infectious diseases of tilapia is increasing rapidly, there has only been a slight increase in the reports of parasitic problems (Vega, 1988).

This chapter reviews the work on diseases of both wild and cultured tilapias.

AQUAFISH RESEARCH REPORT 97-A16

COMPUTER APPLICATION IN POND AQUACULTURE- MODELING AND DECISION SUPPORT SYSTEMS

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H.S. Egna and C.E. Boyd (Editors), *Dynamics of Pond Aquaculture*. CRC Press, Boca Raton, FL: 289- 323.

Modeling and the development of decision support systems for pond aquaculture have received considerable effort and support under the Pond Dynamics/ Aquaculture CRSP (PD/A CRSP). Models have been used as means for analyzing and organizing information and knowledge about aquaculture ponds. The models have served to test hypotheses of “how pond work,” and to design field experiments to test those assumptions. As the information base has improved, decision support systems have been designed for management purposes.

The current state of the art of pond modeling is very difficult from what it was at the initiation of the PD/A CRSP. At that time, Marjanovic and Orlob (1986) and Bernard (1986) conducted literature reviews of various aspects of pond modeling, especially as it referred to the types of ponds that were to be studied under the PD/A CRSP. In their reviews, they found that a great deal of related information existed but that there had been virtually no modeling of tropical aquaculture ponds. Related information found by Marjanovic and Orlob (1986) and by Bernard (1986) included models developed for lakes and reservoirs intemperate areas, as well as information about processes that are important in determining water quality in ponds.

General reviews of modeling of aquaculture systems have been conducted recently (Cuenco, 1989; Piedrahita, 1991), and their work will not be repeated here. The objective of this chapter is to review and highlight the contributions of the PD/A CRSP to the status of aquaculture pond modeling and to the development of decision support systems for pond aquaculture. The review will include examples of different types of models and of decision support systems developed under the PD/A CRSP. The examples will be preceded by a brief description of the data base established under the PD/A CRSP and of its significance to the development of aquaculture science.

AQUAFISH RESEARCH REPORT 97-A17

EXPERIMENTAL DESIGN AND ANALYSIS IN AQUACULTURE

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Published in:

H.S. Egna and C.E. Boyd (Editors), *Dynamics of Pond Aquaculture*. CRC Press, Boca Raton, FL: 325-375.

Although aquaculture as a farming practice dates back thousands of years, during the last three decades several simultaneous occurrences have stimulated scientific research of shellfish and finfish cultivation. First, per capita consumption of fish, long appreciated as an excellent source of dietary protein, is increasing across the globe. Second, in countries with rapidly expanding human populations, natural waters no longer meet the growing demand for fish due to overfishing and water quality degradation from poor watershed and waste disposal management (Edwards, 1991). And systems, and pelleted feeds, have moved the production of commercial species (e.g., the tiger prawn and channel catfish) into large-scale operations.

As aquaculture research rapidly expands in all directions, new species are constantly being considered for grow-out and market potential. Egg production and fry rearing strategies are improving with experimentation. Investigations into semi-intensive and integrated farming management often relate inputs (e.g., manures, cassava leaves, and urea) to water quality, primary production, and fish yield. Identification of nutritional requirements has helped develop more efficient formulated feeds for intensive fish culture systems. Progress has been made. But as the irony of science would have it, from each question answered springs forth more questions posed.

AQUAFISH RESEARCH REPORT 99-A02

SHRIMP FARMING IN SOUTHERN HONDURAS A CASE FOR SUSTAINABLE PRODUCTION

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Published in:

Tropical Mangement Ecosystmes: The Mesoamerican Experience, L.U. Hatchand M. Swisher (Eds.): 222-230.

Commercial shrimp farming in southern Honduras began in 1972 with the establishment of Sea Farms of Honduras near Punta Raton on the Gulf of Fonseca. Sea Farms was located on playon (salt flats) and private land shared with cattle ranchers. Water was pumped from Estero Los Butus, an embayment of the Gulf of Fonseca. Sea Farms expanded from 45 to about 300 hectares during the decade that followed, accounting for almost all shrimp production in Honduras.

AQUAFISH RESEARCH REPORT 00-A06

PARTIAL NUTRIENT BUDGETS FOR SEMI-INTENSIVE SHRIMP FARMS IN HONDURAS

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Aquaculture (2000), 190: 139-154.

Shrimp farms in Latin America typically have relatively low stocking rates and are managed without aeration. Nutrient budgets for these farms have not been well established. Intake and discharge from 21 ponds on six shrimp farms located on estuaries or embayments of the Gulf of Fonseca in Honduras were characterized during rainy and dry seasons. Mean shrimp stocking rate, yield, and feed conversion ratio FCR. for these ponds were 8.2/m², 633 kg/ha, and 2.74, respectively. Mean intake values of soluble reactive phosphate (SRP), dissolved inorganic nitrogen (DIN), total nitrogen (TN), total phosphorus (TP) and BOD₅ were significantly higher in estuaries than in embayments during both seasons. Water exchange produced a mean net discharge of TN, TP, BOD₅, chlorophyll a, COD, total alkalinity and salinity, and a mean net intake of DIN; mean SRP was practically equal in discharge and intake water. Each kilogram of feed nitrogen and phosphorus applied to ponds resulted in 0.21 kg of net nitrogen discharge and 0.16 kg of net phosphorus discharge by water exchange. Use of inorganic fertilizers promoted net discharge of phosphorus and nitrogen. Net nitrogen discharge by water exchange significantly increased as nitrogen input by feed increased ($P < 0.01$). Ponds gained nitrogen primarily from intake water (63%) and feed (36%), and nitrogen was lost primarily from water exchange (72%) and harvested shrimp (14%). Ponds gained phosphorus mostly from intake water (51%) and feed (47%) and phosphorus was lost primarily from water exchange (56%) and harvested shrimp (9%). About 7% of input nitrogen and almost a third (31%). of input phosphorus were not accounted for in measured losses, and presumably were fixed or metabolized in ponds. Mean conversion of feed nitrogen and phosphorus to shrimp flesh averaged 41% and 20%, respectively. Each kilogram of shrimp production resulted in 16.8 g of net nitrogen loss and 2.3 g of net phosphorus loss by water exchange.

AQUAFISH RESEARCH REPORT 03-A09

APPLICATION OF GIS FOR LAND EVALUATION OF WATERSHED AQUACULTURE DEVELOPMENT IN
THAI NGUYEN, VIETNAM

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Published in:

Proceedings, MAP Asia 2003, October 13-15, 2003 Kuala Lumpur, Malaysia:
www.gisdevelopment.net/application/nrm/water/overview/ma03166.htm.

This study was conducted in Dai Tu district of Thai Nguyen province during November 2001 – January 2003 to assess the aquaculture development potential for watershed ponds by integrating socioeconomic and environmental data into GIS database, detecting land use change, and identifying and estimating potential areas for aquaculture development in watershed ponds. The socio-economic and environmental data were collected using pre-test questionnaires and field measurements. Three SPOT multi-spectral band satellite images were used to detect land use change during three periods of 1994-1998, 1994-2002, and 1998- 2002. For land suitability evaluation, the suitability ratings were established according to FAO classification in terms of suitability of land for defined uses. Aquaculture production and economic returns from interviewed farmers were used to verify the results and comparisons among different land suitability levels.

The present study has predicted that about 4.7% (2,725 ha) of the total land area of 57,618 ha in Dai Tu district are suitable sites for watershed pond construction, compared to the existing 404-ha watershed ponds. The present study has demonstrated the usefulness of integration of remote sensing, GIS and attribute data to select suitable sites for the development of watershed ponds, and the importance to be a useful tool for planners to develop strategic plans for aquaculture development.

AQUAFISH RESEARCH REPORT 04-A21

EFFECT OF FISH POND EFFLUENTS IRRIGATION ON FRENCH BEANS IN CENTRAL KENYA

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Published in:

Communications in Soil Science and Plant Analysis, 35(7): 1021-1031.

When fish are recovered from ponds, the effluent is often drained presenting both an environmental challenge and an agricultural opportunity. The effects of irrigation with pond effluent and its interaction with applied fertilizer were assessed in a field experiment using French bean (*Phaseolus vulgaris*) over two growing seasons near Sagana, Kenya. Fresh yield of beans was recorded at harvest, and leaf samples were collected for determination of tissue nutrient concentration. In the first season plots receiving canal water and fertilizer at recommended rates had the highest yield (9.1 Mg fresh pod ha⁻¹), while those receiving no fertilizer or irrigation had the least yield (1.3 Mg fresh pod ha⁻¹). In the second season, the highest (4.4 Mg ha⁻¹) fresh pod yield was observed in pond effluent irrigated and fertilized plots, while the lowest (1.3 Mg ha⁻¹) was observed in nonirrigated/unfertilized plots. Low nutrient status in the pond water was responsible for low yield where it was substituted for canal water. Pond water from the Sagana Fish Farm supplied low amounts of nitrogen (N) and phosphorus (P) for crops, indicating that recommended rates of mineral fertilizers should be used when pond water is used for irrigation.

AQUAFISH RESEARCH REPORT 04-A22

EFFECTS OF ADDING SHRIMP (*PENAEUS MONODON*) INTO INTENSIVE CULTURE PONDS OF NILE TILAPIA (*OREOCHROMIS NILOTICUS*) AT DIFFERENT DENSITIES

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Published in:

Proceedings for the 6th International Symposium on Tilapia in Aquaculture, 12-16 September 2004, (2): 794-805.

This experiment was conducted in nine 200m² earthen ponds at the Asian Institute of Technology, Thailand for 133 days from 21 May to 2 October 2003, to investigate effects of adding shrimp (*Penaeus monodon*) into intensive Nile tilapia (*Oreochromis niloticus*) ponds on the growth performance, water quality and nutrient utilization efficiency in different stocking combinations of tilapia shrimp polyculture. There were three treatments in triplicate each: tilapia at 11m² and shrimp at 151m² (low tilapia density), tilapia at 21m² and shrimp at 151m² (medium tilapia density), tilapia at 41m² and shrimp at 151m² (high tilapia density).

Mean daily weight gains and final mean weight of tilapia in the low tilapia density treatment was significantly greater than those in the medium and high tilapia density treatments, between which there was no significant difference. However, total weight gain, and net and gross yields of tilapia were highest in the high tilapia density treatment, intermediate in the medium tilapia density treatment, and lowest in the low tilapia density treatment. Final mean weight of shrimp was not significantly different among all treatments, however, survival and net and gross "yields in the high tilapia" density treatment were significantly poorer than those in the medium and low tilapia density treatments, between which there were no significant differences.

Nutrients incorporated by Nile tilapia biomass accounted for 48.01%, 52.89%, and 48.99% of TN, and 60.55%, 68.47% and 62.25% of TP inputted from fertilizer and pelleted feeds in the low, medium and high tilapia density treatments, respectively, while shrimp recovered only 1.10% and 0.33% of TN, and 0.55% and 0.27% of TP in the low and medium tilapia density treatments. However, nutrients were lost through dead shrimps in the high tilapia density treatment. Overall mean DO concentrations at both surface and bottom were highest in the low tilapia density treatment, intermediate in the medium and lowest in the high tilapia density treatment. Overall mean concentrations of TAN tended to be higher at higher tilapia density. The present experiment indicated that adding shrimp into Nile tilapia ponds is technically feasible, however, more research is needed to optimize the tilapia-shrimp polyculture system.

AQUAFISH RESEARCH REPORT 04-A23

EFFECTS OF FERTILIZATION RATES ON GROWTH PERFORMANCE OF RED TILAPIA AT DIFFERENT SALINITIES

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Published in:

Proceedings for the 6th International Symposium on Tilapia in Aquaculture, 12-16 September 2004, (2): 439-450.

An experiment was conducted at the Asian Institute of Technology, Thailand, to investigate effects of fertilization rates and salinity levels on the growth of sex-reversed, Thai red tilapia (*Oreochromis* sp.). The experiment was designed to test two fertilization rates (28 kg N and 7 kg P ha⁻¹ week⁻¹, N: P=4:1; and 14 kg N and 7 kg P ha⁻¹ week⁻¹, N: P=2:1) and three salinity levels (10, 20, and 30 ppt) in brackishwater. An additional treatment using optimized fertilization rates (28 kg N and 7 kg P ha⁻¹ week⁻¹, N: P=4:1) in freshwater ponds served as control. Red tilapia fingerlings (20.2-23.7 g size) were stocked at 2.4 fish m⁻² in 5-m² cement tanks with soil bottoms. These were cultured for 160 days.

Growth performance of red tilapia was better in brackishwater than in freshwater. Growth of red tilapia in brackishwater was inversely related to the salinity levels ($r = -0.63$, $P < 0.05$), decreasing significantly with increasing salinity. For a given salinity level, there was no significant difference in size at harvest for the two fertilization regimes ($P > 0.05$). Best growth performance was achieved in the treatment with N:P ratio of 4:1 at 10 ppt salinity.

AQUAFISH RESEARCH REPORT 04-A24

SUPPLEMENTAL FEEDING FOR RED TILAPIA CULTURE IN BRACKISHWATER

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Published in:

Proceedings for the 6th International Symposium on Tilapia in Aquaculture, 12-16 September 2004, (2): 451-462.

An experiment was conducted at the Asian Institute of Technology, Thailand, to investigate effects of feeding regimes on growth of sex-reversed Thai red tilapia (*Oreochromis* sp.). There were five different supplemental feeding regimes: 0%, 25%, 50%, 75% and 100% of satiation. Red tilapia fingerlings (33.2-33.4 g size) were stocked at 62.5 fish m⁻³ in fifteen 0.8-m³ net cages suspended in a 200-m² earthen pond and cultured for 90 days. The pond was maintained at 10‰ salinity and fertilized weekly at rates of 4 kg N and 1 kg P ha⁻¹ d⁻¹. Growth performance of red tilapia was significantly better in feeding treatments than in the non-feeding treatment. Red tilapia growth and average feeding rate increased but FCR and net economic return decreased with increasing percentages of satiation feeding levels from 25% to 100%. Considering low FCR, good growth and yield performance, high economic return and potential for growing to greater size, 50% satiation feeding was the most efficient feeding rate.

AQUAFISH RESEARCH REPORT 04-A25

MANAGEMENT OF ORGANIC MATTER AND NUTRIENT REGENERATION IN POND BOTTOMS THROUGH POLY CULTURE

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Published in:

Proceedings for the 6th International Symposium on Tilapia in Aquaculture, 12-16 September 2004, (2): 763-772.

An experiment was conducted in twelve 200-m² earthen ponds at the Asian Institute of Technology, Thailand, during November 1997 through April 1998. The experiment was conducted for 149 days to assess effects of aerobic and anaerobic conditions at pond bottom on organic matter decomposition and nutrient release, as well as the effectiveness of common carp (*Cyprinus carpio*) in removing organic matter from pond sediments and recycling nutrients in Nile tilapia (*Oreochromis niloticus*) ponds. The experiment consisted of four treatments: (A) tilapia monoculture with water mixing; (B) tilapia monoculture without water mixing; (C) tilapia/carp polyculture with water mixing; and (D) tilapia/carp polyculture without water mixing. Sex-reversed all-male Nile tilapia were stocked at 2 fish m⁻² at a size of 8-12 g in all ponds, while common carp fingerlings at 0.3 fish m⁻² at a size of 13-17 g. All ponds were fertilized with chicken manure at the rate 1,000 kg ha⁻¹ week⁻¹ (dry matter basis) to create anaerobic bottoms. Aerobic pond bottoms in water mixing treatments (A and C) were created by fixing a submersible pump (0.5 kW) 30 cm above the bottom of each pond to mix surface and bottom water.

Results of the experiments indicate that inclusion of common carp into Nile tilapia ponds was effective in recycling nutrients, and might be effective in removal of organic matter if more common carp are added. Water mixing in the experiments largely reduced phytoplankton growth in both mono- and polyculture ponds. Water mixing did not affect the growth of Nile tilapia in monoculture ponds, but significantly ($P < 0.05$) reduced the growth of both Nile tilapia and common carp in polyculture ponds.

AQUAFISH RESEARCH REPORT 04-A26

INTEGRATED CAGE-CUM-POND CULTURE: STOCKING DENSITIES OF CAGED CLIMBING PERCH IN NILE TILAPIA PONDS

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Published in:

Proceedings of the 6th International Symposium on Tilapia in Aquaculture, 12-16 September 2004, Manila, Philippines: 597-598.

An experiment was conducted for 150 days at Cantho of Vietnam to determine the appropriate stocking density of caged climbing perch (*Anabas testudineus*) in Nile tilapia (*Oreochromis niloticus*) ponds, to assess the economic and environmental benefits of this integrated cage-cum-pond culture system. One of the 4 m³ cage was suspended in each of twelve 100-m² earthen ponds, and three ponds of same size served as control without cages. Climbing perch fingerlings 9 g in size were stocked at 50, 100, 150, and 200 fish/m³ in cages, while Nile tilapia fingerlings of 10g size were stocked at 2 fish/m² in all fifteen ponds, giving caged climbing perch to open-pond Nile tilapia ratios of 1:1, 2:1, 3:1 and 4:1, respectively. Caged climbing perch were fed commercial pelleted feed (26-28% crude protein) at rates of 5%, 3% and 2% body weight per day during the first, second and the remaining months, respectively. The control ponds were fertilized weekly with urea and TSP at 28 kg P/ha/week, while no fertilizers were applied in the treatment ponds.

Survival of climbing perch in the highest density treatment (97.1%) was significantly lower than that in other treatments (99.3-99.6%; $P < 0.05$), while there was no significant difference in survival of Nile tilapia, ranging from 72.5% to 87.2% ($P > 0.05$). Final mean weights of both climbing perch and Nile tilapia were not significantly different among all treatments, ranging from 19.5 to 20.5 g and from 111.5 to 133.9 g, respectively ($P > 0.05$). Total Harvest weight of climbing perch, ranging from 400 to 15.2 kg/cage, increased significantly with increasing stocking density ($P < 0.05$), while total harvest weight of Nile tilapia was highest in the 150 fish/m³ treatment (22.7 kg/pond), immediate in other cage treatments (19.0-20.7 kg/pond), and lowest in the control (15.8 kg/pond; $P < 0.05$). The combined total weights of both climbing perch and Nile tilapia in the high-density treatments (35.0 kg/pond in 150 fish/m³ treatment and 35.8 kg/pond in 200 fish/m³ treatments) were significantly greater than those in the low-density treatments (23.0 kg/pond in 50 fish/m³ treatment and 28.2 kg/pond in 100 fish/m³ treatments; $P < 0.05$). FCR of climbing perch in all treatments was very high, ranging from 5.05 to 6.00. FCR was lowest in the 150 fish/m³ treatment, intermediate in the 100 and 200 fish/m³ treatment, and highest in the 50 fish/m³ treatment ($P < 0.05$). The results indicate that caged climbing perch to open-pond Nile tilapia ratio of 3:1 was the best. Further research in feed protein level and feed strategy should be conducted.

AQUAFISH RESEARCH REPORT 05-A08

LIVE DIETS FOR PACU LARVAE TESTED IN PERU

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Published in:

Global Aquaculture Advocate (2005): 78-80.

The results of a study in Peru that evaluated three food sources for larval *C. macropomum* and *P. brachypomus* indicated that although *Artemia* are a more readily available and reliable larval food source, *Moina sp.* appear to be a cost-effective substitute for use in the Amazon Basin.

AQUAFISH RESEARCH REPORT 05-A09

AQUACULTURE OF *COLOSSOMA MACROPOMUM* AND RELATED SPECIES IN LATIN AMERICA

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Published in:

Aquaculture in the 21st Century: Proceedings of the American Fisheries Society Symposium 46, Bethesda, MD, USA. (2005).

Colossoma macropomum (Cuvier 1818), known as black pacu in the United States, is the second largest scaled fish after *Arapaima gigas* (Osteoglossidae) in the Amazon basin, reaching weights of 30 kg in the natural environment (Goulding and Carvalho 1982). The fish has excellent characteristics for use in aquaculture (Campos 1986; Saint-Paul 1986, 1991; Van der Meer 1997), which include, reproducing under aquaculture conditions; being low on the food chain; accepting prepared feed; being highly resistant to disease, handling, and poor water quality; having rapid growth; being amenable to high density; having high market acceptability; commanding a high price; and also, being marketable as an ornamental fish. Countries in Latin America culturing *Colossoma* and similar species include Argentina, Bolivia, Brasil, Colombia, Costa Rica, Ecuador, Mexico, Panama, Peru, and Venezuela (Figure 1). *Colossoma macropomum* has also been introduced into the United States, Africa, and Southeast Asia (Lovshin 1995). Until recently, problems associated with larval production and nutrition, exasperated because much of the information about its culture is dispersed or unpublished, have limited viable aquaculture ventures with this group of Amazonian fishes. Brazil is the first country that has commercially cultured these characids (Da Silva et al. 1976). Very few researchers have access to the advances in culture of characids because much of the research appears in agency reports and, to further complicate dissemination of information, appears in different languages. There are hundreds of papers scattered throughout the region that require scientific analysis to establish a successful cultural program. Approximately 54% of the publications/reports are in Portuguese, 40% are in Spanish, and very few are in English and other languages. This chapter is an attempt to compile some of the more relevant information on *C. macropomum* and related species.

AQUAFISH RESEARCH REPORT 06-A04

A PRELIMINARY STUDY ON THE MATURATION AND REPRODUCTION OF *SPINIBARBUS DENTICULATUS* (OSHIMA, 1926), AN INDIGENOUS SPECIES OF NORTHERN VIETNAM

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Published in:

Asian Fisheries Science (2006) 19: 349-362.

These preliminary studies were conducted to understand some of the basic reproduction parameters of the indigenous carp, *Spinibarbus denticulatus* (Oshima 1926) as a prelude to more specific research studies, and the subsequent development of hatchery technology. Gonad and oocyte development was assessed over a 12-month period. Observation of the annuli rings of the fish scale was found to be a reliable means of measuring fish age. Mature males were smaller and matured earlier (4 years) than females (5 years). The gonadosomic index revealed two peaks (April and October). Oocytes, developing at various stages were examined from January to March. In January the oocytes sizes were uniformly small. Two distinct oocyte-size groups were observed in the February sampling and three size groups were observed in March. The proportion of large-size oocytes (55%) was higher compared to mid-size (26%) and small-size (19%) oocytes during the near peak spawning months. The average number of oocytes in the ovaries in a female was 31,041. The mean sperm concentration was 8.42 ± 0.36 million cells per ml with only a small amount (3.3 ± 0.2 ml) of total expressible milt per male. However, when induced with LHRHa the milt production increased to 6.2 ± 0.5 ml without an increase in the total number of sperm cells. The species shows potential for mass production; however, low fecundity and late puberty could present obstacles to artificial seed production.

AQUAFISH RESEARCH REPORT 06-A05

BANGLADESH PRAWN-FARMING SURVEY REPORTS INDUSTRY EVOLUTION

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Published in:

Global Aquaculture Advocate, November/December (2006): 41-43.

Although many freshwater prawn farms in Bangladesh are small-scale operations, larger commercial facilities are driving production increases in the country. A survey of 100 prawn farmers from four prawn-farming areas indicated that nearly all farmers practice polyculture of prawns with carp. Primarily using hatchery fry, they apply modified extensive practices that include fertilization and supplemental feed.

AQUAFISH RESEARCH REPORT 06-A06

PHYSICAL AND CHEMICAL CHARACTERISTICS OF SEDIMENTS IN CATFISH, FRESHWATER PRAWN AND CARP PONDS IN THAILAND

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Published in:

Aquaculture Research, (2006) 37: 202-1214.

Sediment samples were collected from 42 catfish (*Clarias hybrid*) ponds, 40 freshwater prawn (*Macrobrachium rosenbergii*) ponds and 18 carp (*Puntius spp.*) ponds in Thailand. Regression analysis revealed that pond age (1–30 years) was not a major factor influencing the physical and chemical composition of pond sediments. Sediment depth, F+S horizon thickness and bulk density of S horizon were greater ($P<0.05$) in carp ponds than in catfish and prawn ponds. This occurred because sediment was removed from catfish and prawn ponds more frequently than from carp ponds. Total carbon, organic carbon and total nitrogen concentrations were greater ($P<0.05$) in carp ponds than prawn and catfish ponds. Few ponds had sediment organic carbon concentrations above 3%, and carbon:nitrogen ratio values did not differ ($P>0.05$) among ponds for the three species. Total phosphorus and other sediment phosphorus fractions increased in the order prawn ponds, carp ponds and catfish ponds. Sediment sulphur concentrations also increased in the same order. There were no differences in major or minor nutrient concentrations in sediment that would influence aquacultural production. Although there were significant correlations ($P<0.05$) between various sediment quality variables, no single variable or group of variables would be useful in estimating sediment quality. Pond bottom management practices used by producers in Thailand included drying of pond bottoms between crops, liming, tilling and periodic sediment removal. These practices have maintained relatively good bottom quality. They should be continued in Thailand and adopted in other places.

AQUAFISH RESEARCH REPORT 06-A07

TILAPIA PRODUCTION IN CHINA HUGE OUTPUT BALANCED BY HUGE CONSUMPTION

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Published in:

Global Aquaculture Advocate (2006): 58-59.

With almost half the global production and a quarter of global consumption, China is a critical player in the tilapia industry. In recent years, the quality and variety of Chinese tilapia products have improved, and state-of-the-art processing plants now handle the huge volume of product. New products and packaging are promoting additional international demand.

AQUAFISH RESEARCH REPORT 06-A08

A-LIPOIC ACID-ENRICHMENT PARTIALLY REVERSES TISSUE ASCORBIC ACID DEPLETION IN PACU (*PIARACTUS MESOPOTAMICUS*) FED VITAMIN C-DEVOID DIETS

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Published in:

The Journal of Fish Physiol Biochem (2006) 32: 329-338.

Effects of dietary α -lipoic acid (LA) and ascorbic acid (AA) on the growth, tissue vitamin C and tocopherol (vitamin E) levels, and malondialdehyde levels were examined in the tropical fish pacu, *Piaractus mesopotamicus*. Pacu juveniles were fed one of four casein-gelatin-based diets for 8 weeks: with 0.05% AA and 0.1% LA (+AA+LA), with AA and without LA (+AA-LA), without AA and with LA (-AA+LA), and without AA and LA (-AA-LA). When the fish received quantities of feed equal to 1.9–2.5% of its body weight, growth was not influenced, regardless of the presence of AA or LA throughout most of the experimental period. Growth was, however, slightly but significantly lower at week 8 in the AA deficient/LA-supplemented group. An AA-deficient diet caused a highly significant reduction in both total AA and dehydroascorbic acid content in the liver and gill tissues. This reduction of tissue AA concentrations was reversed in a significant manner by LA (antioxidant-sparing effect). The 8-week-long vitamin C deprivation was sufficient to initiate the reduction in tissue ascorbic acid; however, total ascorbate in the liver of fish in the (-)AA/(+)LA group was $127.7 \pm 54.3 \text{ nmol g}^{-1}$ tissue, whereas it was $28.6 \pm 26.3 \text{ nmol g}^{-1}$ in the (-)AA/(-)LA group, a 4.4-fold difference. This mitigating effect of the addition of the endogenous antioxidant LA to the diet indicates that LA exerts a vitamin C-sparing effect in teleost fish that by far exceeds the phenomena demonstrated in nonscurvy-prone mammals. There was no difference among the different diet groups for vitamin E and malondialdehyde levels in the liver. These results suggest that LA is a potent substance for the prevention of AA deficiency in cultured fishes. The optimal dietary level of LA needs to be determined in the light of the slight reduction in body weight gain after 8 weeks of feeding in the absence of AA.

AQUAFISH RESEARCH REPORT 06-A09

ON-STATION TRIALS OF DIFFERENT FERTILIZATION REGIMES USED IN BANGLADESH

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Published in:

Journal of Aquaculture in the Tropics (2006) 21(1-2): 37-49.

An on-station trial was conducted in fourteen 100-m² earthen ponds at the Bangladesh Agricultural University (BAU), Mymensingh, Bangladesh during July-December 2001. This trial was designed to evaluate different fertilization regimes currently used for aquaculture in Bangladesh, and to compare effects of different fertilization regimes on fish production, water quality, and economic returns. There were five fertilization regimes for culture period as treatments: (A) PROSHIKA fertilization regime - weekly application of 1,000 kg cow dung per hectare; (B) BRAC fertilization regime – weekly application of 156 kg cow dung, 28.125 kg urea and 13.1 kg TSP per hectare; (C) CARITAS fertilization regime – fortnight application of 1,500 kg cow dung per hectare; (D) BAU fertilization regime – fortnight application of 1.250 kg cow dung, 31.25 kg urea and 15.625 kg TSP per hectare; (E) A/CRSP fertilization regime developed from Nile tilapia (*Oreochromis niloticus*) ponds - weekly application of 250 kg cow dung (dry matter) per hectare supplemented with urea and TSP to give 28 kg N and 7 kg P/ha/wk. Six carps species used in this on-station trial were silver carp (*Hypophthalmichthys molitrix*), mrigal (*Cirrhinus mrigala*), rohu (*Labeo rohita*), catla (*Catla catla*), grass carp (*Ctenopharyngodon idella*) and common carp (*Cyprinus carpio*) stocked at a ratio of 9:8:6:6:3:2 at a stocking density of 1.02 fish/m², giving 27, 24, 18, 9, 6, fish per 100-m² pond, respectively. Mean stocking sizes of carps ranged from 6.3 to 10.1 g. Among all tested fertilization regimes, A/CRSP fertilization regime resulted in the highest fish production, followed by BAU, BRAC, CARITAS and PROSHIKA fertilization regimes ($P < 0.05$). The two fertilization regimes (PROSHIKA and CARITAS) using cow dung as the sole nutrient input during the culture period gave very poor fish growth performance and low production, mainly due to the low soluble nutrients derived from cow dung. The other three fertilization regimes (A/CRSP, BAU and BRAC) using the combination of organic and inorganic fertilizers resulted in much higher carp production. Analysis of water quality showed that the nutrients in A/CRSP fertilization regime were oversupplied, as this regime was developed in Nile tilapia monoculture system with higher intensification compared to the carp polyculture in the present trial. BAU fertilization regime gave the highest profitability among all fertilization regimes, followed by BRAC and A/CRSP. Therefore, it is concluded from the present study that BAU fertilization regime is the most appropriate for carp polyculture ponds in Bangladesh while A/CRSP fertilization regime is suitable to carp polyculture ponds with higher intensification.

AQUAFISH RESEARCH REPORT 06-A10

GROWTH, PRODUCTION AND FOOD PREFERENCE OF ROHU *LABEO ROHITA* (H.) IN MONOCULTURE AND IN POLYCULTURE WITH COMMON CARP *CYPRINUS CARPIO* (L.) UNDER FED AND NON-FED PONDS

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Published in:

Aquaculture (2006) 257(1-4): 359–372.

An experiment was carried out in 18 earthen ponds to investigate the effects of the addition of common carp *Cyprinus carpio* (L.) and artificial feed on natural food availability, food utilization and fish production in rohu *Labeo rohita* (Hamilton) ponds. Ponds were fertilized fortnightly with cow manure, urea and triple super phosphate. Rohu was stocked in all ponds at a density of 1.5 rohu m⁻². All treatments were carried out in triplicate. Treatments were: rohu with and without formulated feed, rohu plus 0.5 common carp m⁻² with and without feed, and rohu plus 1 common carp m⁻² with and without feed. The time period between stocking and harvesting was four and half months. Stocking 0.5 common carp m⁻² enhanced natural food availability in the pond, food utilization and rohu growth and production (P<0.05). The effect was less pronounced when stocking 1 common carp m⁻². Formulated feed administration did not influence phytoplankton availability (P>0.05) but increased zooplankton and benthic macroinvertebrate availability (P<0.001). Feed administration also enhanced growth of rohu and common carp (P<0.001). Rohu naturally ingests more phytoplankton than zooplankton but in the presence of formulated feed rohu shifted its natural food preference from phytoplankton to zooplankton. Common carp naturally ingests mainly zooplankton and benthic macroinvertebrate and small quantities of phytoplankton. However, when offered formulated feed, the latter becomes the preferred food item.

AQUAFISH RESEARCH REPORT 06-A11

EFFECTS OF SILVER CARP AND SMALL INDIGENOUS SPECIES ON POND ECOLOGY AND CARP
POLYCULTURES IN BANGLADESH

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Published in:

Aquaculture (2006) 261(3): 1065-1076.

A sustainable semi-intensive pond aquaculture technology including major carp species as cash-crop and small indigenous fish species (SIS) as food for the farmers' families is being optimized in Bangladesh. The inclusion of silver carp (*Hypophthalmichthys molitrix*), a cheap large species affordable by poor farmers, is now being considered. As part of a study on the effects of this filter feeder on polycultures including the large carps rohu (*Labeo rohita*), catla (*Catla catla*) and common carp (*Cyprinus carpio*) and the SIS punti (*Puntius sophore*) and mola (*Amblypharyngodon mola*), an experiment was carried out to test the effects of silver carp and of each SIS species on the growth, survival and yield of the large and small fish and on pond ecology.

The ecology of the ponds was dominated by changes in time, strongly related to the development of a surface plankton scum at the beginning of the culture season and weather conditions. The surface scum increased decomposition processes and decreased algal development in the water body, promoted photosynthesis and ammonium release and reduced nitrification. Over those effects, the presence of silver carp in the ponds decreased algal biomass through grazing and promoted nitrification providing and re-suspending particles in the water column. These effects were also produced by mola, but were evident only in the absence of silver carp. Punti stirring on the pond bottom increased nutrient flow from the sediments into the water column and promoted nitrification, but were also evident only in the absence of silver carp.

AQUAFISH RESEARCH REPORT 06-A12

EFFECTS OF THE FILTER FEEDER SILVER CARP AND THE BOTTOM FEEDERS MRIGAL AND COMMON CARP ON SMALL INDIGENOUS FISH SPECIES (SIS) AND POND ECOLOGY

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Published in:

Aquaculture (2006) 258 (1-4): 439-451.

A sustainable semi-intensive pond aquaculture technology including major carp species as cash-crop and small indigenous fish species (SIS) as food for the farmers' families is being optimized in Bangladesh. The inclusion of silver carp (*Hypophthalmichthys molitrix*), a cheap large species affordable by poor farmers, is now being considered. As part of a study on the effects of this filter feeder on polycultures including the SIS punti (*Puntius sophore*) and mola (*Amblypharyngodon mola*), an experiment was carried out in the ponds of the Bangladesh Agricultural University, Mymensingh, to test this fish effects in the presence of the bottom feeders either common carp (*Cyprinus carpio*) or mrigal (*Cirrhinus cirrhosus*) on production/reproduction of SIS, on the other fish species and on pond ecology. The data were analyzed using univariate and multivariate statistical techniques.

Reproduction of both SIS species occurred in all ponds, their fry numbers, weight and biomass at harvest not being affected either by silver carp or by the bottom feeder species. The addition of silver carp in mrigal ponds had a negative effect on both adult SIS, while its addition to carp ponds had a weaker negative effect on mola and a positive effect on punti. Common carp favoured mola growth and reduced punti survival. Silver carp performance was not affected by the species of bottom feeder present. Common carp performance was not affected by silver carp. Mrigal harvesting biomass and survival were not affected by silver carp, but its harvesting weight, growth rate and yield decreased respectively by 29%, 42% and 39% in its presence. Large carp and total harvested biomass and yields were over 50% higher when silver carp was also present. In the presence of silver carp, large carp and total yields were 20% higher in common carp ponds, while in its absence they were somewhat higher in mrigal ponds. The FCR calculated considering only the large fish were 10% higher in mrigal ponds. FCR calculated including all species were somewhat higher in common carp ponds without silver carp, and 35% higher in mrigal ponds with silver carp. The observed results are explained and discussed considering the feeding habits of each species, the natural food web, and the ecological processes developing in the ponds. The addition of silver carp did not reduce the income obtained from the cash-crop species and could contribute to the nutrition and/or extra income of the farmer's family. From the production and ecological point of views, addition of silver carp to common carp ponds is a better proposition than to add it to mrigal ponds.

AQUAFISH RESEARCH REPORT 06-A13

EFFECT OF SALINITY ON CARRYING CAPACITY OF ADULT NILE TILAPIA *OREOCHROMIS NILOTICUS* L.
IN RECIRCULATING SYSTEMS

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Published in:

Aquaculture Research (2006) 37(16): 1627-1635.

Effect of salinity on carrying capacity of a recirculation system for Nile tilapia, *Oreochromis niloticus* L.; production was assessed. Survival, growth and feed conversion ratio of adult Nile tilapia fed 30% crude protein diet for 88 days were measured at three different salinity levels (8, 15 and 25 g L⁻¹) and two stocking densities (20 and 40 m⁻³) in three independent recirculating systems. Highest survival (98%) and a linear growth in net biomass (P<0.01) was observed in both densities at 8 g L⁻¹ and in 20 m⁻³ treatment at 15 g L⁻¹. Highest net biomass growth was observed in the 40 m⁻³ stocking density treatment at 8 g L⁻¹ salinity level (P < 0.05). Overall biomass growth was significantly affected by salinity indicating a decrease in Nile tilapia carrying capacity with increased salinity. About 11000 kg ha⁻¹ crop⁻¹ of Nile tilapia can be obtained in recirculating systems at 8 g L⁻¹ salinity, significantly higher than the net production at 15 g L⁻¹ (5200 kg ha⁻¹ crop⁻¹) and 22 g L⁻¹ (4425 kg ha⁻¹ crop⁻¹).

AQUAFISH RESEARCH REPORT 06-A14

BANGLADESH PRAWN-FARMING SURVEY REPORTS INDUSTRY EVOLUTION.

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Published in:

Global Aquaculture Advocate 2006: 41-43.

Although many freshwater prawn farms in Bangladesh are small-scale operations, larger commercial facilities are driving production increases in the country. A survey of 100 prawn farmers from four prawn-farming areas indicated that nearly all farmers practice polyculture of prawns with carp. Primarily using hatchery fry, they apply modified extensive practices that include fertilization and supplemental feed.

AQUAFISH RESEARCH REPORT 07-A12

ECONOMIC EVALUATION OF FRESHWATER AQUACULTURE TECHNOLOGIES AND POLICIES IN
SELECTED PRODUCTION SYSTEMS.

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Published in:

Bureau of Agriculture Research Report published in 2007 by the Philippine Department of
Agriculture: 61.

The program generally aimed to perform an economic evaluation of Freshwater Aquaculture Technologies (FAT) and policies in selected production systems. It has two project components; one dealt with the analysis of matured FATs both at micro and macro levels (specifically its effects on fish supplies, income, consumption, and employment); the other dealt with policy studies on the role of fishery organizations, land use and fishery rights, dissemination strategies, and trade-related concerns. The nature of the studies required the collection of primary and secondary data. For the primary survey, 540 adopters and 108 nonadopters were interviewed in Luzon covering three top producing regions. The same sampling frame applied to the choice of provinces, towns and barangays. But at the barangay level, 8 adopter-respondents while 2 non-adopter-respondents were selected. The areas covered were Nueva Ecija, Bulacan and Pampanga for fishponds and hatcheries; Laguna, Batangas, and Isabela for fish cage/pens and hatcheries. The matured FATs are focused on grow-out and hatchery. For grow-out system, it included fishponds, cages, and pens. The technologies under grow-out were on broodstock improvement, level of management (extensive, semi-extensive, and intensive), and post harvest activities. For the hatchery component, the study looked at pond, hapa, and tank. The sex-reversed tilapia was included under this component. The preliminary results of Study 1 under Project 1 were focused on, the identification of financial benefits and costs of the matured technologies. The yield difference between adopters and non-adopters was 3,030 kg per cycle or about 59% in favor of adopters. Hence, there is an impression that the technology had benefited the adopters. Like-wise Study 2 of Project 1 identified and assessed the economic benefits and costs of FATs. It found out that tilapia's contribution to aquaculture was around 9.46% annually from 1992-2000. During the same period, tilapia production had behaved cyclically with an upswing in the first three years, downswing in the middle three years, and another upswing in the last three years. Historically, the significant government programs related to the fishery sector were the Kilusang Kabuhayan at Kaunlaran Biyayang Dagat Program, CBNFAC Supervised Credit Program, among others. Under Study 1 of Project 2, the organizations were identified and classified as Fisheries Organizations, Fisheries and Agricultural Resource Management Council, and Cooperatives. The organizations were generally aimed to provide technical, financial, and marketing assistance to members. However, the sustainability of these services was delimited by lack of sufficient funds hence, most organizations had failed to deliver and sustain those services to their members. Study 2 made a preliminary review of relevant local laws, rules, regulations, and ordinances within the spirit of the Fisheries Administrative Code. All of the ordinances were

meant to ban the use of illegal fishing methods or practices, which are detrimental to fish population, environmental protection and the like. However, the respondents qualified that its aggressive enforcement happened only during the onset of its implementation in the late 80's. Study 3 focused on determining the most effective dissemination strategy of FAT to intended clienteles. Training programs administered by BFAR, DA, LGUs and Sante Fe Company were the dominant dissemination mode for FAT. The use of print media such as brochure/leaflet/techno guides came next as important mode while the use of broadcast media was the least preferred. Study 4 had shown that the trade policies of the country in 1960s up to 1980s were characterized by lifting of import and foreign exchange restrictions; on and off imposition of quantitative restrictions, and tariff rates. But in the mid 90s, major tariff reform programs were implemented until the country's accession to the WTO-GATT accord. In 1996, quantitative restrictions were lifted, tariff rates for sensitive agricultural products were raised while minimum access volume to these products were defined. The fishery sector was still protected as indicated by positive Effective Protection Rates (EPRs). The trade balance volume of the sector remained negative in most years (from 1990-2000). However, the value of trade balance remained positive, which indicates better terms of trade for fishery products in the export markets. To know the impacts of trade reform on the sector, the initial regression results revealed that the real GDP and (production) was positively (negatively) and significantly affected by EPR

AQUAFISH RESEARCH REPORT 07-A13

AN ENZYME-LINKED IMMUNOSORBENT ASSAY IS NOT EFFECTIVE FOR SAMPLING BLOOD PLASMA INSULIN CONCENTRATIONS IN RED PACU, *PIARACTUS BRACHYPOMUS* AND BLACK PACU, *COLOSSOMA MACROPOMUM*

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Published in:

Journal of Fisheries International 2(3): 219-221.

Culture of Red Facu (RP), *Piaractus brachypomus* and Black Facu (BP), *Colossoma macropomum* is increasing due to increasing demand from human populations and declining supply caused by depletion of wild fish so practical diet formulations need to be developed for pacu. Insulin assays are a valuable tool in assessing carbohydrate utilization in fish for diet development. Therefore, we conducted procedures to validate an Enzyme-Linked Immunosorbent Assay (ELISA) for detection of plasma insulin concentrations in RP and BP. Red and black pacu were fed a commercial catfish diet containing approximately 40010 soluble carbohydrates (32% protein, 6% fat). Both species were then bled and plasma was used for validation of the assay. An ELISA was conducted using the Food and Drug Administration's Center for Veterinary Medicine validation of analytical procedures methodology. The results from this assay validation study indicate that an ELISA insulin kit was not suitable for experimental detection of blood plasma insulin concentrations in RP and BP. Almost no insulin (0.34 to 0.48 ng mL⁻¹, for red pacu; 0.40 to 0.67 ng mL⁻¹, for black pacu) was detected in unknown blood plasma samples from the fish. This indicated that the mammalian insulin antibodies are more derived or that the molecular structure of the insulin variants produced by pacu are not capable of being bound by the antibodies in the ELISA assay. The accuracy (mean recovery of spiked samples was 56.0010 for RP and 68.6% for BP), linearity (R² = 0.0011 for RP and R² = 0.1822 for BP), precision (mean recovery of serial dilutions was 212.8% for RP and 209.2% for BP) and reproducibility of the data were poor.

AQUAFISH RESEARCH REPORT 07-A14

EFFECTS OF SILVER CARP AND THE SMALL INDIGENOUS FISH MOLA *AMBLYPHARYNGODON MOLA* AND PUNTI *PUNTIUS SOPHORE* ON FISH POLY CULTURE PRODUCTION

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Published in:

Aquaculture (2007) 273(4):520-531.

A sustainable semi-intensive pond aquaculture technology including major carp species as cash-crop and small indigenous fish species (SIS) as food for the farmers' families is being optimized in Bangladesh. The inclusion of silver carp (*Hypophthalmichthys molitrix*), a cheap large species affordable by poor farmers, is now being considered. As part of a study on the effects of this filter feeder on polycultures including the large carps rohu (*Labeo rohita*), catla (*Catla catla*) and common carp (*Cyprinus carpio*) and the SIS punti (*Puntius sophore*) and mola (*Amblypharyngodon mola*), an experiment was carried out under farm conditions to test the effects of silver carp and of each SIS species on the growth, survival and yield of the large and small species and on pond ecology.

The experiment was performed in 38 farmers' fishponds of different sizes, from 220 m² to 1200 m². The results show that the larger the fish pond the better rohu performance, the larger punti fry weight and the lower punti fry harvested biomass. Pond size did not affect other fish species. The addition of 250 mola and/or punti per 100 m² fish ponds affected rohu and catla and did not affect common and silver carps. The addition of mola alone reduced rohu's parameters by 15%. The addition of SIS in the three combinations tested (250 mola, 250 punti, 125 of each species) reduced catla's parameters by 20–24%. Punti fry were larger when both SIS were stocked and punti fry biomass was larger when only punti were present. Total mola harvested biomass and yield were larger when the entire SIS stocked were only mola.

The addition of 10 silver carp over the 99 large carps stocked per 100 m² fishponds negatively affected rohu and catla growth and yield by about 15–21% and 45–50% respectively but not their survival, did not affect common carp performance, did not affect punti and mola reproduction in the ponds, reduced punti yields by 25%, reduced mola performance by about 35%, and silver carp own biomass increased total yield and total income in about 12% each. These effects are explained and discussed considering fish interactions through the food web. The decreased income from selling the more expensive large carps is more than compensated by that obtained from silver carp, which allows the option to the farmer to sell part of the silver carp to complete the cash income that would have been obtained from large carps only if silver carp would not be stocked, and consume the rest with the family.

AQUAFISH RESEARCH REPORT 08-235

THE EFFECTS OF FEEDING ON MUSCLE GROWTH DYNAMICS AND THE PROLIFERATION OF MYOGENIC PROGENITOR CELLS DURING PIKE PERCH DEVELOPMENT (*SANDER LUCIOPERCA*)

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Published in:

World Aquaculture (2008) 39:184-195.

The effects of feeding on the development and growth of pike perch muscle and on proliferation of their progenitor myogenic cells were evaluated. Larvae were fed starting on Day 5 after hatching with *Artemia nauplii*, two commercial diets (Aglo Norse [AN] and Biokyowa [BK]), and two formulated diets (C [nonhydrolyzed casein] and CH [25% casein hydrolysate]). The survival, body mass, and length of pike perch juveniles fed *Artemia nauplii* and AN and BK diets were significantly higher compared to the C and CH groups. The highest somatic growth rate was associated with an increased contribution of hyperplasia to white muscle growth. Significantly higher frequency of proliferating cell nuclear antigen- and Ki-67-positive nuclei in the white muscle of fish fed *Artemia nauplii* and commercial diets compared to those fed C and CH feeds indicates that feeding affected the number of fibers. The pike perch fed the CH diet exhibited significantly lower total cross-section area and average fiber area, additionally to the pathological changes in muscle morphology. The larvae fed natural food and diets promoting a fast growth rate exhibited a higher contribution of hyperplasia to muscle growth, which in turn, promoted an increase in the body size of adult fish.

AQUAFISH RESEARCH REPORT 08-236

DEVELOPMENT OF A SQUID-HYDROLYSATE-BASED LARVAL DIET AND ITS FEEDING PERFORMANCE ON SUMMER FLOUNDER, *PARALICHTHYS DENTATUS*, LARVAE

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Published in: *Journal of the World Aquaculture Society* (2008) 39:196-204.

Locally generated squid-processing byproduct was processed into concentrated hydrolysate (22% solids, 17.3% protein, and 3.0% lipid, primarily phospholipids-11.6% eicosapentaenoic acid/24.5% docosahexaenoic acid on a lipid weight basis). Two microparticulate diets (65% protein, 19% lipid, 7.5% carbohydrate, and 19.12 MJ/kg energy, on a dry weight basis) were prepared using squid hydrolysate (SH) and squid-herring hydrolysate as sole protein sources (73.3 and 78.65% of the whole diet, respectively). A 22-d feeding trial with summer flounder, *Paralichthys dentatus*, larvae of 17 d after hatch showed that the survival rate (92%) of larvae fed SH was significantly ($P < 0.05$) higher than those of larvae fed live *Artemia nauplii* (81%) and a commercial diet, Proton (65%), while specific growth rates (SGR) were comparable (2.23% /d for SH and 2.86% /d for *Artemia*) with the lowest for Proton (1.39%/d). After switching from commercial and *Artemia* diets to a SH diet for 17 d following the 22-d feeding, significant improvements were seen in survival rates of postweaning larvae fed previously commercial (65.28-76.57%) and *Artemia* diets (81.25-89.07%).

AQUAFISH RESEARCH REPORT 08-237

AQUICULTURA NA ÁFRICA: O PROJETO INTERREGIONAL DE INTERCÂMBIO DE TECNOLOGIA SOBRE PRODUÇÃO DE TILÁPIAS E OUTROS CICLÍDEOS

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Published in:

Panorama da Aquicultura (2008) 105:50-55.

A África é o berço de espécies produzidas intensivamente em vários países, como a tilápia e o bagre africano; mesmo assim, até recentemente as espécies eram pouco cultivadas no continente. A despeito da grandeza do continente africano, com mais de 30 milhões de km², 53 nações, 37.500 km de área costeira e mais de 200.000 km² de áreas alagadas e rios que abrigam uma abundante fauna aquícola, a produção de pescados em 2005 alcançou apenas 8 milhões de toneladas. Desse total, a aquicultura contribuiu com pouco mais de 656 mil toneladas, com destaque para o Egito, responsável por 82% dessa produção. Especialistas, no entanto, concordam que há na África grande potencial para a expansão da aquicultura e demanda crescente por alimentos; afinal, estima-se que sejam mais de 800 milhões de africanos, a maioria extremamente carentes. A seguir, apresentamos um panorama da aquícultura desenvolvida em três países africanos – África do Sul, Gana e Quênia – resultado das recentes visitas realizadas pelo projeto Aquafish CRSP, criado pela USAID - Agência Americana para o Desenvolvimento Internacional.

AQUAFISH RESEARCH REPORT 08-238

FOOD SAFETY, QUALITY CONTROL IN TILAPIA PRODUCTS

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Published in:

Global Aquaculture Advocate (2008) January/February: 42-44.

The most important quality issue for tilapia is the presence of off-flavors that derive from cyanobacteria and actinomycetes, which can be addressed by depuration. Methyltestosterone has been proven safe for sex reversal of fry. Farmers use lower stocking densities and improve water quality to reduce the need for antibiotics. Biosecurity and BMPs reduce contamination by environmental pollutants.

AQUAFISH RESEARCH REPORT 08-239

ENDOCRINE BIOMARKERS OF GROWTH AND APPLICATIONS TO AQUACULTURE: A MINIREVIEW OF GROWTH HORMONE, INSULIN-LIKE GROWTH FACTOR (IGF)-I, AND IGF-BINDING PROTEINS AS POTENTIAL GROWTH INDICATORS IN FISH

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Published in:

North American Journal of Aquaculture (2008) 70:196-211.

Growth in fish and other vertebrates is under endocrine control, particularly through the growth hormone (GH)-insulin-like growth factor (IGF) axis. For this reason, it has been of interest to aquaculture researchers and the industry to establish endocrine biomarkers that can both reflect and predict growth rates in fish subject to various biotic and abiotic manipulations. Ultimately, by understanding the hormones that control growth and utilizing them as biomarkers, we hope to achieve optimal growth conditions in the aquaculture environment with less need for lengthy and costly grow-out trials. While the most appropriate endocrine biomarkers for growth can be both species and situation specific, IGF-I may be the most promising candidate for measuring instantaneous growth in fish. This is based on the direct contributions of IGF-I in regulating cell proliferation and ultimately somatic growth, along with its previously established correlations with the specific growth rate in fish under various conditions that alter growth. However, other endocrine indices, such as GH and IGF-binding proteins (IGFBPs), are also important contributors and may in some instances prove a strong corollary to growth rate. This review discusses the potential utility of GH, IGF-I, and IGFBPs as growth biomarkers for those manipulations most relevant to the aquaculture industry, namely, feeding regimen, diet composition, temperature, photoperiod, and stress.

AQUAFISH RESEARCH REPORT 08-240

AQUACULTURE RESTORATION IN THE TSUNAMI ZONE, ACH PROVINCE, INDONESIA

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Published in:

World Aquaculture (2008) 39(1):41-43, 66.

Banda Aceh, at the north end of the island Sumatra, took the full brunt of the December 2004 tsunami. Over 33,000 households in the region had registered their primary income as being generated from aquaculture before the disaster. Along the coasts the majority of aquaculturists were small-scale shrimp farmers, operating family owned ponds (tambaks) of less than a hectare each. All of the shrimp produced were marketed locally. No freezing facilities were present, so shrimp could only be sold on ice or as dried products. Even before the tsunami, many of the farmers were plagued with low growth and survival rates resulting from poor water quality and several diseases. A virtual monoculture of shrimp, multiple-reuse of effluent waters, removal of mangroves and other vegetation and overfed ponds had contributed to a significant reduction in production in the years immediately prior to the tsunami. The tsunami itself essentially destroyed all the coastal ponds of Aceh province. The wave rushed over most of the villages built on the coastal berms and pushed much of the village contents into the ponds. Virtually all of the dikes, control structures, canals and other infrastructure elements were completely obliterated. Many of the shrimp ponds had been constructed in the coastal lagoons behind the beaches where most of the population lived. The lagoons had contained extensive mangrove forests before the shrimp ponds removed a considerable percentage of them. In addition to the farms destroyed, the local aquaculture research and extension station at Ujong Battee was almost completely destroyed and the regional fisheries and aquaculture trades school in Ladong lost an entire bus load of faculty and students en-route to a picnic when the waves struck.

AQUAFISH RESEARCH REPORT 08-241

STRATEGIES FOR NILE TILAPIA (*Oreochromis niloticus*) POND CULTURE

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Published in: *The Proceedings of the 8th International symposium on Tilapia in Aquaculture* Cairo, Egypt, 12-14 October 2008.

Different strategies for Nile tilapia (*Oreochromis niloticus*) culture in ponds with a series of progressive inputs were compared. The sequential experimental stages to increase fish production through intensification were: 1) triple superphosphate (TSP) only; 2) chicken manure only; 3) chicken manure supplemented with urea or urea and TSP; 4) urea and TSP; 5) continually supplemental feeding; 6) staged supplemental feeding; 7) feeding alone. The results showed that the choices of input regimes with increasing economic gains are: 1) fertilizing ponds with moderate loading of chicken manure; 2) fertilizing ponds with chicken manure supplemented with urea and TSP; 3) fertilizing ponds with urea and TSP; 4) fertilizing ponds initially with urea and TSP in combination of supplemental pelleted feed at 50% satiation level at later stage of grow-out cycle.

AQUAFISH RESEARCH REPORT 08-242

DETERMINATION OF QUERCETIN CONCENTRATIONS IN FISH TISSUES AFTER FEEDING QUERCETIN-CONTAINING DIETS

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Published in:

Aquaculture International (2008) 17: 537-544. [DOI 10.1007/s10499-008-9222-6](https://doi.org/10.1007/s10499-008-9222-6).

Concentrations of quercetin in fish tissues were measured for the first time using HPLC-electrochemical detection method. Its identity was also ascertained with UV-photodiode array detection. Quercetin, in aglycone form, was at measurable concentrations in tilapia plasma, liver, and whole body homogenate when fed with diets containing 1% quercetin (aglycone) for 1 or 15 weeks. Hydrolysis with glucuronidase/sulfatase treatment for the purpose of cleaving conjugates did not increase quercetin levels, suggesting that glucoronide or sulfate conjugates are not the major metabolic forms in Nile tilapia (*Oreochromis niloticus*). No quercetin was detected in plasma of rainbow trout (*Salmo gairdneri*) or white sturgeon (*Acipenser transmontanus*) fed commercial diets. The results suggest that quercetin is absorbed in tilapia and that this flavonoid is deposited mainly in aglycone form in the body after absorption.

AQUAFISH RESEARCH REPORT 08-243

OPTIMIZING TILAPIA, *OREOCHROMIS* SP., MARKETING STRATEGIES IN NICARAGUA: A MIXED-INTEGER TRANSSHIPMENT MODEL ANALYSIS

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Published in:

Journal of the World Aquaculture Society (2008) 39(3): 339-351.

Tilapia, *Oreochromis sp.*, production has increased in the Central American region in recent years. Yet, commercial tilapia aquaculture has not developed in Nicaragua on the scale that it has in other neighboring countries. Although demand for tilapia products exists, lack of thorough understanding of domestic markets and coordinated production and marketing efforts have hampered the development of a domestic market. The objectives of this study were to quantify domestic marketing costs for tilapia produced in Nicaragua and develop a mixed-integer transshipment mathematical programming model to identify the most profitable marketing alternatives for tilapia farmers. Results suggested targeting primarily outlets with higher sales prices such as restaurants with supplemental production delivered to local supermarkets. The model chooses cities with weekly restaurant demand capable of absorbing the farm's production with excess product sold to alternative outlets. Supply of farm-raised tilapia production in most regions of Nicaragua was insufficient and created problems associated with frequent and dependable deliveries required by higher paying outlets (restaurants and supermarkets). Larger farms will generate greater returns with regular consistent deliveries to higher priced restaurant outlets. Smaller farms with limited production volumes were not able to meet weekly delivery requirements. Biannual deliveries reduced transportation cost and sales price and were not profitable. However, sustaining markets with infrequent deliveries may not be feasible. This analysis provides guidelines for targeting those specific markets that optimize returns to specific farm sizes in specific regions.

AQUAFISH RESEARCH REPORT 08-244

EFFECTS OF DIFFERENT DIETARY LIPID SOURCES ON THE SURVIVAL, GROWTH, AND FATTY ACID COMPOSITION OF SOUTH AMERICAN CATFISH, *PSEUDOPLATYSTOMA FASCIATUM*, SURUBIM, JUVENILES

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Published in:

Journal of the World Aquaculture society (2008) 39(1): 51-61.

The present study examines the effect of four semi-purified diets (casein–gelatin based) where the source of fatty acids was free (esterified) oleic acid and linoleic acid (LA) (LOA diet), linseed and olive oil (predominantly LA and linolenic acid) (LO diet), cod liver oil (rich in highly unsaturated fatty acids) (CLO diet), and soybean lecithin (phospholipids; mostly LA) (LE diet) on the growth of juvenile South American catfish (surubim, *Pseudoplatystoma fasciatum*, *Pimelodidae*) (0.98 ± 0.04 g individual weight). Fish were fed at a restricted–readjusted feeding rate for 8 wk. At the end of the experiment, LE-diet-fed fish grew significantly larger than those of the other three groups ($P < 0.05$). Considerable cannibalism was observed in all the treatments. It is suggested that the quantitative growth performance may possibly change under other conditions, with less or no cannibalism. Survival did not differ significantly among the fish fed four different diets. Muscle and liver lipid contents did not vary among dietary treatments ($P > 0.05$), but whole-body lipid concentrations were affected by dietary treatments. Fish fed LE diet contained significantly lower lipid level than those fed three other diets ($P < 0.05$). Muscle and liver fatty acid profiles reflected dietary fatty acid composition. Arachidonic acid level was significantly higher in muscle and liver of fish fed LOA and LE diets than in those fed LO and CLO diets. The results suggest that the efficiency of elongation and desaturation of 18C fatty acids depends on the dietary lipid source, and South American catfish has considerable capacity to transform linoleate to arachidonate.

AQUAFISH RESEARCH REPORT 08-245

A COMPARATIVE STUDY OF COMMUNITY-BASED SEA TURTLE MANAGEMENT IN PALAU: KEY FACTORS FOR SUCCESSFUL IMPLEMENTATION

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Published in:

Conservation and Society (2008) 6(3): 225-237

This article investigates social, political and cultural aspects of sea turtle management led by the Tobian community at Helen Reef in the Republic of Palau. We use participant observation, unstructured interviews and examination of community-based natural resource management literature to compare and contrast the Tobian community with several other communities in Palau in order to identify some of the underlying factors that we believe contributed to the successful implementation of the Tobian community-based program. These factors include: robust structure of local and extra-local partnerships; remote location of the resource and small scale of the managing community; realized community benefits in terms of jobs and improved capacity to monitor and manage natural resources; adaptive capacity and autonomy in decision-making; and strong connections to traditional natural resource management systems. Sea turtle conservation and management is a large scale issue; preventing further decline of endangered sea turtles will require management at multiple scales. For the Tobian community, success may be attributable to several key factors that come together to produce a decentralized community-based program that operates with an adaptive, collaborative and bottom-up structure. This model may be applicable to comparable communities; it is, however, important to recognize that diverse societies will have a variety of formulas for success.

AQUAFISH RESEARCH REPORT 08-A07

NEAR-SHORE TRAWLING FISHERIES IN THE MEKONG DELTA OF VIETNAM

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Published in:

Achieving a Sustainable Future: Managing Aquaculture, Fishing, Trade and Development, Proceedings of the 14th Biennial Conference of the International Institute of Fisheries Economics & Trade, Nha Trang, Vietnam, 22-25 July, 2008.

Local community in the Mekong Delta is said to be “fish eating society” where 70% of their animal protein relies on fish products. The Mekong Delta contributes more than 60% of total aquaculture production and 40% of total wild fish catch of Vietnam. Among a large number of fishing boats, trawlers have developed and dominant in Vietnam fisheries. The small-scale trawlers cover about 70% total number of fishing boats and have been given too much concern in terms of both natural aquatic resources management and other socio-economic problems.

This paper describes the small-scale trawling fisheries in the Mekong Delta using surveyed data from 176 small and near-shore trawling fishers Bentre, Soc Trang, Bac Lieu, Camau and Kiengiang provinces, and compares the differences of major indicators between three main fisher groups: (i) Group 1 - Inside and around Camau National Park, 38 fishers; (ii) Group 2- Near, is that, ≤ 30 km from Camau National Park, 40 fishers, and (iii) Group 3 – Far, is that, > 30 km from Camau National Park, 98 fishers.

The analysis shows that small scale and near-shore fishing puts more pressure on the natural aquatic resources in the coastal areas of the Mekong Delta while there has been insufficient management on this type of fisheries. Mangroves and Camau National Park recognized by the local fishers via direct benefits obtained from the park. Shrimp and squid are two most important species of near-shore trawling fisheries but less efficient to the fishers who live near the park. Better investment for off-shore fishing and more alternatives of better income occupations are important to protect the natural aquatic resources along the coasts of the Mekong Delta, especially Camau National Park.

AQUAFISH RESEARCH REPORT 08-A08

AQUACULTURE AND HAPPINESS - A MICROECONOMETRIC ANALYSIS IN VIETNAM

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Published in:

Achieving a Sustainable Future: Managing Aquaculture, Fishing, Trade and Development, Proceedings of the 14th Biennial Conference of the International Institute of Fisheries Economics & Trade, Nha Trang, Vietnam, 22-25 July, 2008.

The contribution of aquaculture development to the Vietnamese national economy and to farmers' incomes has been documented in various government reports as well as working papers produced by development projects. However, the role of aquaculture in the life satisfaction of poor farmers has not been considered rigorously. In particular, it is very difficult to find any literature relating aquaculture adoption to job or life satisfaction of the adopters. Due to the controversial role of income in creating happiness and the increased contribution of fish production in the livelihoods of small scale farmers, there exists a question of whether income increases from adoption of aquaculture would raise happiness of farmers. This study identifies some determinants of job satisfaction and subjective well-being of small scale fish farmers in Vietnam and examines the role of earnings from fish production in generating their happiness. Cumulative logistic models with data from a 2001 survey in Southern Vietnam show that relative income, not absolute income, from aquaculture raises their job satisfaction. Higher satisfaction is also associated with involvement in extension services, a larger relative pond surface and a higher expectation level on earnings from aquaculture. The role of income per capita in job satisfaction or happiness is not confirmed. Happiness of the farmers increases with cash earnings from fish farming and income from wild fish relative to total household income.

AQUAFISH RESEARCH REPORT 08-A09

EFFECTS OF US ANTIDUMPING UNDER THE BYRD AMENDMENT: THE CASE OF CATFISH

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Published in:

Achieving a Sustainable Future: Managing Aquaculture, Fishing, Trade and Development, Proceedings of the 14th Biennial Conference of the International Institute of Fisheries Economics & Trade, Nha Trang, Vietnam, 22-25 July, 2008.

The Byrd Amendment permits US firms that petition successfully for antidumping duties to collect tariff revenues. Whether these payments strengthen the duty's ability to raise price depends crucially on market structure. In a competitive market where domestic and imported goods are imperfect substitutes, the payments are akin to a production subsidy and thus undermine the duty's ability to raise price. Applying the theory to antidumping duties imposed by the United States on catfish imports from Vietnam, a three-equation model estimated using monthly data from January 1999 to August 2006 showed the duties to have had a modest yet positive effect on the US price. Although the weak price effect is consistent with supply enlargement induced by the payments, our econometric results suggest substitution effects coupled with incidence shifting are stronger causal factors.

AQUAFISH RESEARCH REPORT 08-A10

TECHNICAL APPROACHES AND AQUACULTURE DEVELOPMENT ALTERNATIVES

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Achieving a Sustainable Future: Managing Aquaculture, Fishing, Trade and Development, Proceedings of the 14th Biennial Conference of the International Institute of Fisheries Economics & Trade, Nha Trang, Vietnam, 22-25 July, 2008.

Tam Giang - Cau Hai lagoon systems covered over 22,000 ha, along coastal region from North to South of Thua Thien Hue with 70 km and more than 400,000 inhabitants are living around in lagoon systems. There are many livelihood activities as fishing, aquaculture and farming. Aquaculture systems are diversified: pond, net-closure in high and low tide systems and farmers and communities had to choose and select proper species and models for adaptation of the regions but they still have not successful, even they lost investment money and capital by environmental problems and uncorrected carrying capacity leading to diseases and low productions. Research results were showed the different technical approaches and aquaculture system alternatives for property aquaculture models in the regions. More than 267 aquaculture households of 15 communes in 5 districts that related to Tam Giang - Cau Hai lagoon were investigated and shown the figures on over 4000 ha of aquaculture water area of 33 communes: high/low tides of pond systems; cage culture in low tide systems; sandy shrimp culture system; integrated poly-culture and monoculture, while *P. monodon* was main species in all of systems and models. Efficiency of different alternatives were conducted in intensive of high tide was highest income, net income 100 - 700 mil. VND; semi-intensive of high tide-mono, 10 - 25 mil.; semi-intensive high tide-integrated poly-culture, 20 -40 mil.; semi-intensive-low tide-mono, 3 - 10 mil.; extensive-low tide-poly, 30 -50 mil.; marine water cage culture-poly, 25 - 35 mil., respectively. Effect of different species alternatives were on 267 households in differences, 26.99; 90.22; 221.13; 48.21, $P < 0.01$. The stock density and composition was conducted in differences of income and benefit for farmers, $P < 0.05$. Water control and management, dietary composition and feed processing, animal health management were effected on the income and benefit of aquaculture models, $P < 0.01$ and 0.001 .

AQUAFISH RESEARCH REPORT 08-A11

ROLE OF AQUACULTURE IN POVERTY REDUCTION AND EMPOWERMENT OF WOMEN IN INDIA THROUGH THE MEDIUM OF SELF-HELP GROUPS

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Published in:

Achieving a Sustainable Future: Managing Aquaculture, Fishing, Trade and Development, Proceedings of the 14th Biennial Conference of the International Institute of Fisheries Economics & Trade, Nha Trang, Vietnam, 22-25 July, 2008.

Aquaculture remains as a suitable avenue in India for augmenting fish production, which is easy, cost effective and sustainable at the same time. It provides livelihoods to rural people through generating income and employment and reduces poverty by developing and strengthening community based approaches. The expansion of farmed fishery development in community water tanks and other water bodies makes remarkable additional contribution towards the nutritional well being and socio-economic advancement of rural farmers including women. This augurs well for the sustained development of these areas wherein fish can play an important role in providing required thrust in their economy and in the improvement of the economic status of the people living in the surroundings. In recent times, self-help groups (SHGs) have emerged as an alternative mechanism to promote savings habit among poor and to provide small and short term loans to its members at lower interest to meet their necessities, consumption and income generation activities like aquaculture. Women are considered as appropriate tool for implementing community and self-development programmes. Against this background, an attempt is made in this paper to review and examine the relevant literature regarding the efficacy of SHGs and other programmes and their impact on the fisherwomen and other stakeholders and also on aquaculture. Research results show that the SHGs are very successful as can be judged from the fact that a large number of people have accepted the system and taken up fish production as their main means of livelihood and source of main or additional income.

AQUAFISH RESEARCH REPORT 08-A12

INTERNATIONAL SEAFOOD AND ITS IMPACTS ON FISHERIES AND FISHING COMMUNITIES IN INDIA

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Achieving a Sustainable Future: Managing Aquaculture, Fishing, Trade and Development, Proceedings of the 14th Biennial Conference of the International Institute of Fisheries Economics & Trade, Nha Trang, Vietnam, 22-25 July, 2008.

This paper makes an attempt to examine the emergence of international trade in seafood and its impacts on the fisheries and fishing communities in India. It suggests some measures and strategies to maximize the benefits through sustainable fisheries development. Seafood is one of the leading non-traditional exports identified by the Government of India. Until 1960s, much importance was not attached towards export trade in general. With the changed policy of Government, seafood was considered as one of the thrust areas for augmenting exports; consequently, earning of foreign exchange was made as one of the basic objectives of marine fisheries development. Efforts were made to increase fish production, especially of shrimp, whose unit value was far higher in the international markets. Different kinds of fishing vessels including small mechanized boats, sona boats, larger deep sea trawlers were deployed and almost all of them confined their fishing operations to the inshore regions of the sea. Consequently, the production of fish as well as shrimp have gone up manifold thus enhancing the quantum and value of exports. However, the excessive fishing effort and over fishing in the inshore regions brought down the production levels leading to depletion and stagnation. No doubt the international trade has positively created massive infrastructure and employment besides huge foreign exchange earnings. But the over fishing has forced to withdraw some of the larger and mini-trawlers and the industry has suffered with shortage of raw material for the trade. Shrimp farming was taken up on a larger scale to offset the shortage but unplanned growth of the same met with disease attack and Supreme Court's restrictions on environmental considerations. The paper further discussed the negative as well as positive impacts encountered by the fishermen due to mechanization and shrimp farming on the one hand and that of Tsunami and WTO on the other and suggested remedial measures. Keywords: International trade, seafood, mechanization, shrimp farming, tsunami, WTO.

AQUAFISH RESEARCH REPORT 08-A13

AN EXAMINATION OF PRODUCTIVITY POTENTIAL OF AQUACULTURE FARMS IN ALLEVIATING HOUSEHOLD POVERTY: ESTIMATION AND POLICY IMPLICATIONS FROM NIGERIA

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Published in:

Achieving a Sustainable Future: Managing Aquaculture, Fishing, Trade and Development, Proceedings of the 14th Biennial Conference of the International Institute of Fisheries Economics & Trade, Nha Trang, Vietnam, 22-25 July, 2008.

This study examines income generation potential and resource- use efficiency of aquaculture farms in Nigeria. A total of 120 aquaculture farms were sampled. Using gross margin (GM) analysis, the result shows that, all the sampled farms were able to cover their total operating expenses with an average GM > 200,000 naira per annum. The assessed parameters of resource use-efficiency of the farms with stochastic frontier models (SFM) revealed that, elasticities of inputs, such as: pond size, feeds, fingerlings, and other costs were significantly different from zero. While returns to scale of 1.16 obtained from the analysis suggests that, an average farm from the study, exhibits increasing returns to scale. The estimated efficiency score revealed a significant level of inefficiency with an average technical efficiency of about 81%. This suggests that about 19% potential yield are forgone due to inefficiency from the study. The result of sources of technical efficiency shows that; extension, education, stock- ing density, and credit significantly influenced efficiency of the farms. Similarly, the result of the simulated marginal effects of the inefficiency variables shows that, extension has the highest marginal effects on the efficiency score follows by credit, education, and stocking density. The implications of these findings, therefore, suggest that, aquaculture will provide potential channel of income generation for households in the country considering the size of the profit obtained from the analysis. However, as matter of policy concern, extension with the highest simulated marginal effects on the efficiency score is expected to generate a large increase in the overall performance of the sector if strengthen for sustainable fish production in Nigeria.

AQUAFISH RESEARCH REPORT 08-A14

PARTIAL SUBSTITUTION OF BALANCED FEED BY CHAYA LEAVES IN NILE TILAPIA PRODUCTION: A BIO- ECONOMIC ANALYSIS

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Published in:

Achieving a Sustainable Future: Managing Aquaculture, Fishing, Trade and Development, Proceedings of the 14th Biennial Conference of the International Institute of Fisheries Economics & Trade, Nha Trang, Vietnam, 22-25 July, 2008

Tilapia culture in Yucatan State, Mexico, is largely semi-intensive. The producers are mostly poor farmers who receive government subsidies for purchase of fingerlings and balanced feed. Feeding practices are often inadequate (satiety rations), moreover, producers frequently suffer financial and resource shortfalls. During feed shortages producers are known to use empirical application of chaya (*Cnidoscolus chayamansa*) leaves, used traditionally in human and animal nutrition. A study was done of growth in juvenile tilapia using diets containing balanced feed with chaya (25 and 50% of substitution), complete, half-complete and satiety rations of balanced feed, during the warm season. The results were used to develop a bioeconomic model and implemented in MS Excel program, with a one-day time step. In order to minimize the cost of tilapia feeding, and maximize the benefits by using a limited amount of balanced feed per cycle. In addition, the analysis was completed using the Marginal Rate of Technical Substitution (*MRTS*). According to results from *MRTS*, it is necessary to add 2.51-3.91 units of chaya for each reduced unit of balanced feed, to maintain the same level of production. In a resource limited situation, substitution of 50% of balanced feed for raw chaya leaves generates a harvest size greater than complete and satiety rations of 24.8 and 28.8% respectively. When considering sale prices that are consistent with size at harvest and costs, treatments with chaya considerably maximized profits.

AQUAFISH RESEARCH REPORT 08-A15

ON CONSUMERS' WTP (WILLINGNESS TO PAY) FOR FISHERY PRODUCT TRACEABILITY SYSTEM IN CHINA

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Published in:

Achieving a Sustainable Future: Managing Aquaculture, Fishing, Trade and Development, Proceedings of the 14th Biennial Conference of the International Institute of Fisheries Economics & Trade, Nha Trang, Vietnam, 22-25 July, 2008.

Quality safety traceability system has adopted by most fishery enterprises as an important part of the strategic management. As the consequence, the end product is supposed to be higher. That consumers whether to accept has a direct impact on system successful implementation. This paper proposes a framework to research consumer awareness of fishery product and the traceability system and the degree of willingness to pay, cased study of consumers in Beijing on. The results contribute to the effectively apply the traceability system by aquatic products enterprises.

AQUAFISH RESEARCH REPORT 08-A16

ON THE POWER STRUCTURE OF AQUATIC PRODUCT SUPPLY CHAIN IN CHINA

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Published in:

Achieving a Sustainable Future: Managing Aquaculture, Fishing, Trade and Development, Proceedings of the 14th Biennial Conference of the International Institute of Fisheries Economics & Trade, Nha Trang, Vietnam, 22-25 July, 2008.

It is helpful to keep the stability of aquatic product supply chain and promote higher development of fishery economy to research power structure of aquatic product supply chain. This paper analyzes the power structure of aquatic product supply chain via the behavior theory in marketing discipline, cased study by Beijing and Guangdong province. The result shows the main reasons for lower operational performance in aquatic product supply chain are rather unbalance cost and benefit of power structure across the supply chain.

AQUAFISH RESEARCH REPORT 08-A17

CONSIDERATIONS ON THE POLICY ENVIRONMENT FOR AQUACULTURE IN VIETNAM

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Published in:

Achieving a Sustainable Future: Managing Aquaculture, Fishing, Trade and Development, Proceedings of the 14th Biennial Conference of the International Institute of Fisheries Economics & Trade, Nha Trang, Vietnam, 22-25 July, 2008.

The fishery sector, including capture, aquaculture, processing and supportive services, plays an important role to the whole economy of Vietnam. Total aquatic production of the country increased about 3 times after 15 years, from 1.02 million tones in 1990 to 3.43 million tones in 2005. The growth of aquaculture production was from 0.30 million tones in 1990 to 1.44 million tones in 2005 or increased 4.6 times, faster compared with that of capture (from 0.79 to 1.99 million tones, respectively). Aquaculture becomes more and more crucial when it contributes over 50% of the total aquatic production of Vietnam. How to obtain a sustainable development of the whole sector, particularly aquaculture, is a big and difficult question which requires the answers from different aspects, not only technical and socio-economic aspects but also environmental and political aspects. This paper is aimed at the policy environment for aquaculture development in Vietnam. Economic reform or Doi moi process started from the end of 1980s leading to further improvement in the policy environment and helped to result in an impressive development of Vietnam's fishery sector, especially aquaculture sub-sector. Major considerations are focused on: (1) Land reform policy/Laws with conversion of inefficient agricultural land into aquaculture; (2) Environmental Laws with the use and management of water, natural aquatic resources and wetland forests; (3) Finance and investment; (4) Seed supply, use and management; (5) Feed supply, use and management; and (6) Chemicals and medicine supply, use and management. The analysis is also linked with processing and export of aquatic products, the integration process (WTO), and three most important cultured species in Vietnam at the present time, i.e., tra/basa (*Pangasius hypophthalmus*/*Pangasius bocourti*), black tiger shrimp (*Penaeus monodon*) and hard clam (*Meretrix lyrata*). It is revealed that many of the issued policies and regulations were ineffective or even unacted while more and appropriate ones need to be provided for further development of aquaculture and fishery sector.

AQUAFISH RESEARCH REPORT 08-A18

GROWTH EVALUATION, SEX CONVERSION RATE AND PERCENT SURVIVAL OF NILE TILAPIA (*Oreochromis niloticus* L.) FINGERLINGS IN EARTHEN PONDS

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Published in:

8th International Symposium on Tilapia in Aquaculture, Cairo, Egypt, 12-14 October 2008: 403-413.

The objective of the study was to assess growth, sex conversion rate and percent survival of Nile tilapia (*Oreochromis niloticus* L.) fingerlings of the GIFT strain reared in twelve 500 m² earthen ponds. Each pond was stocked with size #24 sex-reversed tilapia fingerlings at a density of 4 pcs/m². The kinds of hatching system where the tilapia fry were hatched served as the treatments in this study and were as follows: I – artificial incubation-hatched fry, II – hapa-hatched fry, III – pond-hatched fry and IV – combination of hatched fry by stocking 33.3% from each hatching system. Each treatment was replicated three times. After the pond rearing, analysis of variance indicated no significant differences on the gain in length, gain in weight, specific growth rate, sex conversion rate and survival of tilapia fingerlings among treatments ($P>0.05$). It is concluded that the hatching systems used in the study had no significant effects on the specific growth rate, gain in length and weight, sex conversion rate and percent survival of tilapia fingerlings. Therefore, any hatching system can be used to produce tilapia fry for pond rearing.

AQUAFISH RESEARCH REPORT 08-A19

COMPARISON OF PLOIDY LEVEL SCREENING METHODS IN CHINESE DOJO LOACH (*MISGURNUS ANGUIL- LICAUDATUS*)

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Published in:

Journal of Applied Ichthyology (2008) 24: 664-669.

In search for an easy, rapid and cost-effective method to determine the ploidy levels of diploid and tetraploid dojo loaches *Misgurnus anguillicaudatus* distributed naturally in China, direct (karyotyping) and indirect (flow cytometry, erythrocyte nuclear measurements and morphometric analysis) methods were compared. The results revealed that all techniques employed may be successfully used to determine the ploidy levels. It was discovered that karyotyping is cumbersome; flow cytometry is expensive whereas erythrocyte nuclear measurement requires a long time and intensive labour. On the other hand, the morphometric analysis method, especially the measurement of head length (HL), snout length (SL) and depth of caudal peduncle (CPD), is the simplest, with no damage to the fish and can be considered a practical alternative to other techniques. The discriminant function developed from the specimens, $D = 7.539(HL/CPD) - 2.342(HL/SL) - 5.636$, categorized an observation as a diploid if the discriminant analysis gave a positive score, while negative scores were categorized as tetraploids.

AQUAFISH RESEARCH REPORT 08-A20

TRANSPOSITIONAL FEEDING RHYTHM OF LOACH *MISGURNUS ANGUILLICAUDATUS* FROM LARVAE TO JUVENILES AND ITS ONTOGENESIS UNDER ARTIFICIAL REARING CONDITIONS

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Published in:

Aquaculture International (2008) 16: 539-549.

The diel feeding rhythm and ontogenesis during early life stage of loach *Misgurnus anguillicaudatus* were investigated under experimental conditions (light: L 06:00–18:00, D 18:00–06:00 h). Morphological and behavioral developments of loach from newly hatched to 40 days after hatching were observed. Larvae were able to prey on daphnia 3–4 days after hatching at 23 ± 0.5 °C. As the larvae grew, they showed an increasing feeding capacity and a distinct feeding rhythm. Feeding intensity and incidence for day-4 larvae were highest at 10:00 and 16:00 h. The highest levels of feeding intensity for day-12 larvae occurred at 08:00, 12:00, and 18:00 h as did feeding incidence. By day 20, when the larvae metamorphosed, the highest levels of feeding intensity occurred at 06:00, 18:00, and 24:00 h and were concurrent with the highest feeding incidence. After metamorphosis, feeding capacity had again increased considerably and, in contrast to the earlier stages before day 20, feeding intensity for day-30 juveniles peaked at 05:00 and 20:00 h, about 1–2 h after the maximum feeding incidence. The feeding rhythm of loach juveniles at day 40 was almost the same as the day-30 juveniles. The estimated maximum daily feeding rates were 43.1%, 33.4%, 19.0%, 12.8%, and 5.8% of body weight on days 4, 12, 20, 30, and 40, respectively. Thus, loach was found to have different feeding rhythms in the pre- and post-metamorphosis stages, with the highest feeding activity in daytime during the larval planktonic stage before metamorphosis, and intensely nocturnal feeding behavior during the juvenile benthic stage after metamorphosis.

AQUAFISH RESEARCH REPORT 08-A21

MORPHOLOGICAL ANALYSIS OF THE FUNCTIONAL DESIGN OF THE CONNECTION BETWEEN THE ALIMENTARY TRACT AND THE GAS BLADDER IN AIR-BREATHING *LEPISOSTEID* FISH

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Published in:

Annals of Anatomy (2008) 190(4): 383-390.

There is considerable controversy in the literature regarding the existence of a “longitudinal slit” versus a “duct” connecting the respiratory gas bladder with the alimentary tract in various species of garfishes (*Lepisosteidae*). The aim of the present work has been to address these discrepancies on the basis of our own work on longnose gar *Lepisosteus osseus* in conjunction with a review of the literature. We provide anatomical evidence for a better understanding of the functional advantages of the “longitudinal slit” versus the “duct” in respect to feeding and respiration in juveniles longnose gar. The anterior part of the garfish body cavity, from the oral cavity to the stomach, was used for morphological and histological analysis. It has been observed that the air bladder in the longnose gar is open to the alimentary tract through a longitudinal slit which is present in the glottis on the dorsal side of the oesophagus. The external side of the glottal ridges in the anterior oesophagus, on the side of the opening, consist of stratified squamous epithelium which then turns into the pseudostratified columnar ciliated epithelium in the posterior oesophagus. The glottal ridges are comprised of epithelia and radially arranged striated muscle fibres surrounded by connective tissue. It can be surmised that the tunica muscularis in the anterior oesophagus of garfish aids the glottis in moving air in and out because it supports the dorsal retractor muscle in propelling air through the longitudinal slit from the buccal cavity. When the buccal cavity of the garfish is contracted during holding prey, the muscles of the gas bladder wall and tunica muscularis, located inside and outside the glottal ridge, participate in exhalation.

AQUAFISH RESEARCH REPORT 08-A22

DIETS, PHYSIOLOGY, BIOCHEMISTRY AND DIGESTIVE TRACT DEVELOPMENT OF FRESHWATER FISH LARVAE

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Published in:

J.E.P Cyrino; D.P. Bureau, B.G. Kapoor (Editors), 2008. *Feeding and Digestive Functions of Fishes*. Science Publishers, Enfield, N.H.: 227-279.

Live preys' availability to larval fish is determined on the basis of suitable size, frequently described as gape width/prey size proportion (Dabrowski and Bardeg, 1984). In some cases, larval freshwater fish, like the 4-5 mm total length yellow perch (Kolkovski and Dabrowski, 1998), eat prey smaller than 50-100 μm in width, whereas in the case of the first feeding larval walking catfish (*Clarias*), the largest size of *Artemia nauplii* offered, 205-295 μm (4% of fish body length), increased the growth, but compromised survival in comparison to ungraded size nauplii. Nauplii graded into two categories – below 59 μm and 59-183 μm , mesh size net – even when fed in excess, resulted in much lower fish size and survival was 14-28% in comparison to 67% in fish fed with unsieved *Artemia* (Petkam and Moodie, 2001). Therefore, it is important to readjust the feed particle size (live or inert) to the optimum acceptable size of larval fish. [Note: this is the first paragraph of the introduction]

AQUAFISH RESEARCH REPORT 08-A23

MORPHOLOGICAL ANALYSIS OF THE FUNCTIONAL DESIGN OF THE CONNECTION BETWEEN THE ALIMENTARY TRACT AND THE GAS BLADDER IN AIR-BREATHING LEPISOSTEID FISH

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Published in:

Annals of Anatomy (2008) 190: 383-390.

There is considerable controversy in the literature regarding the existence of a “longitudinal slit” versus a “duct” connecting the respiratory gas bladder with the alimentary tract in various species of garfishes (*Lepisosteidae*). The aim of the present work has been to address these discrepancies on the basis of our own work on longnose gar *Lepisosteus osseus* in conjunction with a review of the literature. We provide anatomical evidence for a better understanding of the functional advantages of the “longitudinal slit” versus the “duct” in respect to feeding and respiration in juveniles longnose gar. The anterior part of the garfish body cavity, from the oral cavity to the stomach, was used for morphological and histological analysis. It has been observed that the air bladder in the longnose gar is open to the alimentary tract through a longitudinal slit which is present in the glottis on the dorsal side of the oesophagus. The external side of the glottal ridges in the anterior oesophagus, on the side of the opening, consist of stratified squamous epithelium which then turns into the pseudostratified columnar ciliated epithelium in the posterior oesophagus. The glottal ridges are comprised of epithelia and radially arranged striated muscle fibres surrounded by connective tissue. It can be surmised that the tunica muscularis in the anterior oesophagus of garfish aids the glottis in moving air in and out because it supports the dorsal retractor muscle in propelling air through the longitudinal slit from the buccal cavity. When the buccal cavity of the garfish is contracted during holding prey, the muscles of the gas bladder wall and tunica muscularis, located inside and outside the glottal ridge, participate in exhalation.

AQUAFISH RESEARCH REPORT 08-A24

COMPARISON OF RICE STRAW AND BAMBOO STICK SUBSTRATES IN PERIPHYTON-BASED CARP POLY CULTURE SYSTEMS

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Published in:

Aquaculture Research (2008) 39(5): 464-473.

An experiment was conducted to compare rice straw mat and kanchi (bamboo sticks) as substrates in periphyton-based polyculture systems. The experiment had three treatments: (a) no substrate (control), (b) rice straw as a substrate (3 x 2.7 kg pond⁻¹) and (c) kanchi as a substrate (390 kanchi pond⁻¹). Fingerlings (n540) of rohu, *Labeo rohita* (24.5 ± 0.5 g); mrigal, *Cirrhinus mrigala* (25.1 ± 0.6 g); catla, *Catla catla* (25.8 ± 0.5 g); common carp, *Cyprinus carpio* (27.6 ± 0.6 g), and silver carp, *Hypophthalmichthys molitrix* (30.4 ± 0.9 g) were stocked at a 3:2:2:2:1 ratio and cultured for 90 days. There were no differences in the number of plankton, periphyton and macro-zoobenthos among the treatments. The total plate count of bacteria was higher in the rice straw treatment (41320million – cfu m⁻²) than that in the kanchi treatment (11780 million cfu m⁻²). Growth and the final mean weight of rohu, catla and common carp were higher in the substrate treatments than those in the control. Rice straw and kanchi treatment, respectively, resulted in 38% and 47% higher combined total weight gain over control. Gross margin analysis showed that rice straw treatment resulted in more profit than the control and kanchi treatment. Therefore, rice straw has the potential to be used to increase production in the low-input rural aquaculture.

AQUAFISH RESEARCH REPORT 08-A25

THE EFFECTS OF PARTIALLY SUBSTITUTING INDIAN CARPS OR ADDING SILVER CARP ON
POLY CULTURES INCLUDING SMALL INDIGENOUS FISH SPECIES (SIS)

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Published in:

Aquaculture (2008) 279(1-4): 92–98.

A sustainable semi-intensive pond aquaculture technology including major carp species (Indian, Chinese and common carp) as cash-crop and small indigenous fish species (SIS) as food for the farmers' families is being optimized in Bangladesh. Silver carp inclusion in the polyculture is now being considered, because this very efficient filter feeder has a strong impact on pond ecology and also on the farmers' family nutrition because it is a cheap fish that the family can afford to eat instead of selling. The present paper is centered on the reduction of silver carp negative effects on other species while keeping the advantages of increased total yield and income due to silver carp stocking. It presents the results of two experiments, one on-station and one on-farm, in which 3–5 silver carp/100 m² were added or partially substituted major carp filter feeders. The basic stocking density was 100 carps (rohu, catla and a bottom feeder, either mrigal or common carp, at a 1:1:1 ratio) and 250 SIS (punti and mola) per 100 m². In the on-station experiment silver carp density was 3 and 5 fish/100 m² and the large carp bottom feeder was common carp. In the on-farm experiment silver carp density was 5 fish/100 m² and the bottom feeder was either common carp or mrigal.

Most of the water quality and fish performance parameters tested were not affected by the polyculture composition. Adding 3–5% silver carp or substituting 3–5% of the herbivorous fish species by this highly efficient filter feeder increased grazing pressure on the phytoplankton, which led to a 25–40% reduction of the chlorophyll concentration in the water column. The increased grazing pressure was not enough to affect other water quality parameters and fewer effects on the availability of food for the other fish species occurred than when the silver carp addition was 10% of the polyculture, as reported in a previous work. The strong negative effects of silver carp on the other species of the polyculture and the higher total yields and income recorded in previous experiments with the addition of 10 silver carp/100 m² were much weaker and their expression depended on other pond conditions when 3 or 5 silver carp/100 m² were added or substituted the same number of rohu or catla, either when the bottom feeder was mrigal or common carp. It was concluded that stocking 3 silver carp/100 m² over the usual 100 large carp and 250 SIS /100 m² can be considered a 'no effect' stocking density in relation to the control without silver carp, while stocking 10 silver carp/100 m² should be preferred by farmers to keep the option of selling or consuming the silver carp.

AQUAFISH RESEARCH REPORT 09-246

SOCIAL, ECONOMIC, AND PRODUCTION CHARACTERISTICS OF GIANT RIVER PRAWN
MACROBRACHIUM ROSENBERGII CULTURE IN THAILAND

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Published in:

Aquaculture (2009) 287: 120-127.

The objective of this study was to review the state of grow-out production for giant river prawns (*Macrobrachium rosenbergii*) in Thailand, assess the perceived ecological impacts of the industry, and suggest avenues by which farmers might adopt more environmentally sound culture systems. A socioeconomic and technical survey of 100 prawn farmers was conducted during 1 May to 31 July 2005 in Thailand. The majority of respondents were male (70%) and average age was 46 ± 1 . Most farmers (77%) had completed an elementary level of schooling (4 years) and experience on the farm as owner, manager, or both averaged 10 ± 1 years. Most respondents (92.9%) obtained information about prawn culture from their neighbors and only 19% received formal training. Monoculture was the dominant system (96%) while remaining farmers utilized polyculture with prawns and white shrimp (*Litopenaeus vannamei*). The most common management strategy included a 30–60 day nursery phase for post larvae and harvesting with the combined method, culling only the largest market-sized individuals beginning at 5 months followed by every 30 to 45 days (66%).

Culture practices at the time of this survey are best described as intensive. Most farmers stocked at densities below 20 pieces m^{-2} and average production was 2338 kg $ha^{-1} yr^{-1}$, values typically described as semi-intensive. However, some farmers utilized higher stocking densities and obtained production values above those described as semi-intensive. Additional intensive practices were common, including the use of commercially produced feed, frequent water exchange, aeration, and lime and dolomite application. After the culture period water was generally discharged directly into canals without treatment. Average net profits were 3918 US\$ $ha^{-1} yr^{-1}$. The major problems identified were seed supply (67%), disease outbreak (64%), and external pollution (37%). External pollution was reported to have severe impacts on 16%, moderate impact on 46%, and no impact on 38% of farms. Pollution sources were identified as agriculture (75.4%), aquaculture (39.3%), and industrial and domestic waste (27.9% each).

At the time of this survey the giant river prawn industry in Thailand was valued at US\$79,096,000 and ranked third globally behind China and India. To maintain this level of production, research on alternative practices is necessary to balance adequate environmental

benefits and economic returns similar to or better than the current monoculture system. Two avenues to transition to these practices include augmenting existing certification programs and community training sessions to introduce best culture practices and provide a venue for farmers to plan local water supply management.

AQUAFISH RESEARCH REPORT 09-247

AQUACULTURE PRODUCTION AND BIODIVERSITY CONSERVATION

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Published in:

BioScience (2009) 59(1): 27-38.

This overview examines the status and trends of seafood production, and the positive and negative impacts of aquaculture on biodiversity conservation. Capture fisheries have been stabilized at about 90 million metric tons since the late 1980s, whereas aquaculture increased from 12 metric tons in 1985 to 45 metric tons by 2004. Aquaculture includes species at any trophic level that are grown for domestic consumption or export. Aquaculture has some positive impacts on biodiversity; for example, cultured seafood can reduce pressure on overexploited wild stocks, stocked organisms may enhance depleted stocks, aquaculture often boosts natural production and species diversity, and employment in aquaculture may replace more destructive resource uses. On the negative side, species that escape from aquaculture can become invasive in areas where they are nonnative, effluents from aquaculture can cause eutrophication, ecologically sensitive land may be converted for aquaculture use, aquaculture species may consume increasingly scarce fish meal, and aquaculture species may transmit diseases to wild fish. Most likely, aquaculture will continue to grow at significant rates through 2025, and will remain the most rapidly increasing food production system.

AQUAFISH RESEARCH REPORT 09-248

COMPARISONS OF GROWTH AND ECONOMIC PERFORMANCE AMONG MONOSEX AND MIXED-SEX CULTURE OF RED MUD CRAB (*SCYLLA OLIVACEA* HERBST, 1796) IN BAMBOO PENS IN THE TIDAL FLATS OF MANGROVE FORESTS, BANGLADESH

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Published in:

Aquaculture Research (2009) 40: 473-485.

An experiment was conducted in a randomized block design to compare growth and economic performance between monosex and mixed-sex culture of red mud crab (*Scylla olivacea* Herbst, 1796) fed with trash fish at 5-10% body weight per day in the mangrove tidal flat at Burigoaliny Union of Satkhira District, Bangladesh. The experiment had three treatments in triplicate each: (a) all-male culture, (b) all-female culture and (c) mixed-sex culture. Crabs of 80-120 g in size were stocked at a density of 0.5 crab m⁻² and cultured for 100 days. Specific growth rates (SGRs) by weight and internal carapace width (ICW) in the all-male culture were significantly higher than those in the all-female culture ($P < 0.05$), while SGRs in the mixed-sex culture showed no significant differences from those in the all-male and all-female culture ($P > 0.05$). No significant differences in final mean body weight, ICW, daily weight gain, survival rate, gross and net yields were found among all the treatments ($P > 0.05$). The area of high water level with mangroves gave significantly better results in terms of feed conversion ratio, survival rate, gross and net yields than the area of low water level ($P > 0.05$). The experiment suggests that the all-female culture in the area of high water level with mangroves could be suitable in developing commercial pen culture of red mud crabs in Bangladesh.

AQUAFISH RESEARCH REPORT 09-249

GROWTH, FAT CONTENT AND FATTY ACID PROFILE OF SOUTH AMERICAN CATFISH, SURUBIM (*PSEUDOPLATYSTOMA FASCIATUM*) JUVENILES FED LIVE, COMMERCIAL AND FORMULATED DIETS

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Published in:

Journal of Applied Ichthyology (2009) 25: 73-78.

South American catfish, barred surubim (*Pseudoplatystoma fasciatum*) juveniles (117.6 ± 11.8 mg individual weight; 28.3 ± 2.5 mm total length) were fed various diets: one live (*Tubifex* worms), two commercial (Aglo Norse and Bio Kyowa), and one semi-purified formulated diet (75% peptide based protein) over a 2-week period. Fish fed the Aglo Norse diet showed the highest growth performance, but cannibalism also was very high (42%). Fish fed peptide based formulated diet demonstrated the lowest growth rate, with no cannibalism. The highest survival was achieved with fish fed *Tubifex* worms (100%). Lipid level in the whole body of the fish fed four different experimental diets did not differ significantly, averaging $3.6 \pm 0.7\%$. Fatty acid composition of neutral and phospholipid fractions of whole body lipids of fish reflected the fatty acid composition of the diets. The high level of 20:4n-6 in *Tubifex* worms resulted in a high level of this fatty acid in the tissue of fish fed this diet. It remains uncertain how high survival and no cannibalism is related to dietary lipids/fatty acids. In all cases, the increasing ratio of n-3 HUFA (highly unsaturated fatty acids)/n-6 HUFA in phospholipid fractions suggested the elongation and desaturation of 18:3n-3 to 22:6n-3 via 20:5n-3. Moreover, in respect to the 20:4n-6 levels in the diets, an increase in the concentration of this fatty acid in phospholipid fraction suggests that South American catfish can transform linoleate into arachidonate

AQUAFISH RESEARCH REPORT 09-250

ECONOMIC AND RISK ANALYSIS OF TILAPIA PRODUCTION IN KENYA

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Published in

Journal of Applied Aquaculture (2009) 21: 1-23.

Commercial production of tilapia in Kenya has potential for expansion, but growth and development of the tilapia industry in Kenya will depend upon its profitability and the effect of associated risks. Data from pond experiments, on-farm trials, and farm surveys were used to develop enterprise budgets and a risk analysis for nine production scenarios. The nine scenarios include: 1) monoculture of sex-reversed male tilapia fed either rice bran, a pelleted experimental diet, or a pelleted pig finisher diet; 2) clarias monoculture fed with each of the three diets; and 3) tilapia-clarias (sex-reversed male fingerlings) polyculture fed with each of the three diets. Net returns/ha were highest for production with the pig finisher diet, with clarias in monoculture the highest followed by tilapia in monoculture and then the polyculture system. The lowest net returns/ha were obtained with clarias fed rice bran. Profitability was affected by feed cost and tilapia survival. Tilapia monoculture systems had lower probabilities of financial losses than either clarias monoculture or the polyculture system. Use of the pelleted diets also resulted in lower probabilities of financial losses. Lower yields from the rice bran feed scenario resulted in its greater sensitivity to fluctuating costs of rice bran and survival of tilapia.

AQUAFISH RESEARCH REPORT 09-251

INFLUENCE OF THE PHOTOPERIOD ON GROWTH RATE AND INSULIN-LIKE GROWTH FACTOR-I GENE EXPRESSION IN NILE TILAPIA *OREOCHROMIS NILOTICUS*

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Published in:

Journal of Fish Biology (2009) 75: 130-141.

The effects of the duration of the light phase photoperiod (8 h light or 16 h light) on the growth and hepatic insulin-like growth factor-I (IGF-I) gene expression in Nile tilapia *Oreochromis niloticus* were evaluated. There was a slight but not significant tendency for fish in the long light phase group (LP) to display elevated specific growth rate (G) both in mass (M) and standard length (LS) compared with that in the short light phase group (SP; $P = 0.057$ for GM; $P = 0.055$ for GL). Significantly, higher food conversion efficiency was observed in the LP than in the SP. There were significant positive correlations between IGF-I concentrations and G, both in M and LS. A significantly negative correlation was observed between IGF-I mRNA level and eye colour pattern. The lack of significant differences in G and hepatic IGF-I gene expression, despite the significant difference in feed conversion efficiency, may be related partly to the development of different levels of social interactions in the different groups within a photoperiod regime leading to increased variation of results within each group. These findings suggest that hepatic IGF-I gene expression has potential utility as a growth rate indicator for this species of fish and social status, as quantified by eye colour pattern, appears to be a much stronger determinant of growth rate and IGF-I transcript level than does light phase photoperiod length.

AQUAFISH RESEARCH REPORT 09-252

THE EFFECT OF THE INTRODUCTION OF NILE TILAPIA (*Oreochromis niloticus*, L.) ON SMALL INDIGENOUS FISH SPECIES (MOLA, *Amblypharyngodon mola*, HAMILTON; CHELA, *Chela cachius*, HAMILTON; PUNTI, *Puntius sophore*, HAMILTON)

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Published in:

Aquaculture Research (2009) 1-9: 904-912.

This is the first controlled experiment to quantify the effect of introduced tilapia on indigenous species. This experiment was conducted in small earthen ponds (100m²) to assess the impact of mixed-sex or all-male Nile tilapia (*Oreochromis niloticus*) on small indigenous species (SIS) commonly found in south Asia, mola (*Amblypharyngodon mola*), chela (*Chela cachius*) and punti (*Puntius sophore*). Ponds were fertilized, then stocked with 0.56 fish m⁻² of water surface area in the mixed-sex and all-male tilapia treatments and 0.42 fish m⁻² in the treatment without tilapia. No additional nutritional inputs were applied after stocking. Treatments were: mixed-sex tilapia with SIS, mono-sex male tilapia with SIS and SIS without tilapia (control). All treatments were stocked with 14 fish per species. All species reproduced during the 21-month culture duration. The number of recruits varied by species, Tilapia reproduced in greater numbers than SIS. Tilapia numbers at harvest were the highest (451 ± 25/100m²) in the mixed-sex treatment compared with mola (221 ± 22/100m²), chela (94 ± 8/100m²) and punti (100 ± 7/100m²). The number of mola was higher (399 ± 33/100m²) in the all-male tilapia treatment. There was reduction in the number of mola and chela in the treatment containing mixed-sex tilapia. Gut content analysis combined with water sampling revealed that all fish species fed selectively. Significant interspecies dietary overlap was found between Nile tilapia and SIS and among SIS. Thus, there is potential for tilapia to compete with indigenous fish species when space and other resources are limiting, but a longer duration study with varying level of management is needed to determine how successfully tilapia competes with locally adapted SIS.

AQUAFISH RESEARCH REPORT 09-253

ANALYSIS OF THE USE OF CREDIT FACILITIES BY SMALL-SCALE FISH FARMERS IN KENYA

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Published in:

Aquaculture International (2009) 18: 393-402.

The government of Kenya encourages aquaculture development by offering credit facilities through the government agricultural finance institution, Agriculture Finance Corporation. Nevertheless, the level of credit use in fish farming is very low. Access to credit is among several factors that affect farmers' decision of whether to use particular technology or services. The study examined factors that affected the decision of fish farmers in Kenya to utilize credit facilities in fish production using a probit model. The analysis suggests that farmers in the Western province will have a 19% more probability of using credit facilities for their fish farming operations than farmers from the other provinces such as the Rift Valley, Central, and the Eastern province. The effect of tilapia sales on the probability of credit use by fish farmers is more than three times that of catfish sales. Total pond acreage owned by fish farmers had a positive effect on credit use but the effect was very small and negligible. The level of fish farmers' use of credit facilities is very low, and there is probably the need to educate farmers on credit use and for the government agricultural lending agency and other commercial agricultural lenders to invest in this enterprise. Kenyan lending institutions have financed traditional agricultural enterprises, and with the growing production of farmed fish, more research is needed to document the aquaculture business model to assist in assessing the profitability potential in aquaculture.

AQUAFISH RESEARCH REPORT 09-254

AQUACULTURE INFORMATION SOURCES FOR SMALL-SCALE FISH FARMERS: THE CASE OF GHANA

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Published in:

Aquaculture Research (2009) 40: 1516-1522.

The Ghana ministry of fisheries and the ministry of Agriculture provide free extension services and other technical services to fish farmers in Ghana, e.g. producing fingerlings at government-operated fish hatcheries for sale to farmers. Non-governmental organizations and universities have also provided some technical assistance to fish farmers in efforts towards the development of aquaculture in Ghana. The study identified the various sources of aquaculture information to Ghanaian fish farmers and examined the factors that affected their decision to utilize these alternative sources of information. Using choice modeling techniques, the study found that the probability of farmers seeking information on aquaculture from the Ghana government increases with literacy by about 43% more than with illiteracy and by about 34% with an increase in total size of ponds. The probability that a literate farmer will choose to obtain aquaculture information from a non-governmental organization decreased by about 10% compared with an illiterate farmer. The probability of choosing 'other sources' for aquaculture information increased by about 27% for farmers residing in Ashanti region compared with farmers in the Brong-Ahafo region but the probability of farmers seeking information from 'other sources' decreased with literacy and number of years farming.

AQUAFISH RESEARCH REPORT 09-255

MARKETING EXTENSION AND OUTREACH IN SINALOA, MEXICO: A PRELIMINARY ANALYSIS OF PREFERENCES FOR OYSTERS

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Published in:

Marine Resource Economics (2009) 24: 89-95.

Shrimp mariculture, the leading form of aquaculture for the Pacific coast of Mexico is facing catastrophic losses due to disease and falling prices. Previous work conducted by a multi-institutional, international team since 1997 has built a solid foundation for diversification of aquaculture in Pacific Mexico emphasizing the use of native species, particularly those low on the food chain and with low culture technology requirements. Among the leading candidates are bivalves, which are currently cultured and fished extensively along the Gulf of California Coast, with much of the production attributed to wild capture fisheries. Great potential exists, however, to expand current aquaculture production through strengthening existing operations, either by developing new markets or increasing sales in current ones according to consumer preferences. From the Mexican government's perspective, specifically from CONAPESCA (National Aquaculture and Fishery Commission), economic diversification for aquaculture is stated as a prioritized policy goal. Today, the most available and feasible biotechnologies for species diversification in the country are tilapia and oyster farming (Martínez-Cordero 2007). In the last three years, the Program *Alianza para el Campo* (Alliance for the countryside), which is the main federal program operated at the national level that promotes and supports the development of aquaculture projects, has financed tilapia and oyster projects at different scales of operation in many states. Social groups, like cooperatives, are usually selected to receive support for oyster farming, and in Sinaloa, coastal communities have benefited from this program. This includes fishermen entering aquaculture activities for the first time, which the Mexican government calls system conversion. Women's groups are also being involved in oyster culture efforts by the Autonomous University of Sinaloa. While monetary assistance has been given to help in the establishment of new aquaculture enterprises, little work has been done to assess the social and economic impacts of increased production. Moreover, research on assessing market demand for said species and assisting farmers in market identification and market penetration strategies is lacking. The objective of this work is to assist oyster aquaculture cooperatives in the region of Bahia Santa Maria (BSM), Mexico, to identify opportunities for the marketing of oysters within the state of Sinaloa.

AQUAFISH RESEARCH REPORT 09-256

OUTREACH ASSESSMENT STUDIES EXAMINE AQUACULTURE LINKS TO THAI COMMUNITIES

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Published in:

Global Aquaculture Advocate (2009) 12(6):10-12.

Social surveys of three farming systems in Thailand showed significant differences. Prawn farming provided a good income and primary employment for farmers, who sold their prawns locally. Tilapia farming provided additional food and income to farmers who were otherwise employed, mostly in rice culture. Shrimp farming provided a good income and employment favored over other job opportunities. It added food locally as well as for export.

AQUAFISH RESEARCH REPORT 09-A01

PLASMA GHRELIN AND GROWTH HORMONE REGULATION IN RESPONSE TO METABOLIC STATE IN HYBRID STRIPED BASS: EFFECTS OF FEEDING, GHRELIN AND INSULIN-LIKE GROWTH FACTOR-I ON IN VIVO AND IN VITRO GH SECRETION

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Published in:

General and Comparative Endocrinology (2009) 161: 365-372.

The regulation of growth hormone (GH) secretion by ghrelin during variable metabolic states is poorly understood. We examined plasma GH and ghrelin in hybrid striped bass (HSB) undergoing seasonally-based feeding and temperature manipulations. Fasting for 21 days (d) at 24°C resulted in catabolism and up-regulation of plasma GH and ghrelin relative to fed controls. Continued fasting during cold-banking (14°C, 90d) resulted in a further 43- fold increase in ghrelin while GH remained elevated. A subsequent 19 day refeeding period at 24°C elicited hyperphagic and compensatory growth responses, accompanied by declines in ghrelin and GH. We then tested the role of ghrelin in stimulating GH release in vivo and in vitro. Intraperitoneal injections of ghrelin resulted in dose-dependent increases in plasma GH after 6 hours (h). Ghrelin also increased GH release from HSB pituitaries during 6 h incubations. Lastly, we assessed how metabolic state, ghrelin and insulin-like growth factor-I (IGF-I) affect in vitro pituitary GH release. Spontaneous GH release was 5.2-fold higher from pituitaries of fasted compared with fed animals. Ghrelin was equally effective in stimulating GH release from pituitaries of fed and starved animals, while it was ineffective in enhancing GH release from pituitaries of starved (21d) then refeed (4d) HSB. Incubation with IGF-I inhibited GH release regardless of metabolic state. These studies are the first to show that seasonally-based periods of feed deprivation and low temperature yield sustained increases in GH secretion that are likely mediated, at least partially, through elevated ghrelin, reduced IGF-I negative feedback and fasting-induced spontaneous GH release.

AQUAFISH RESEARCH REPORT 09-A02

AQUACULTURE IN GUYANA: TILAPIA, PACU, SHRIMP RAISED WITH PLANT CROPS

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Published in:

Global Aquaculture Advocate (2009) 12(2): 83-84.

With its large quantities of water and little industry to pollute it, Guyana has the potential to become a greater player in global aquaculture. Collaboration among government agencies, universities, commercial farms and international aid groups is advancing aquaculture in the country. Currently, small farmers produce tilapia, pacu and shrimp for primarily local consumption. Further integration of aquaculture and agriculture has additional potential. .

AQUAFISH RESEARCH REPORT 09-A03

TILAPIA PRODUCTION, MARKET REPORT: PRODUCTION, CONSUMPTION INCREASE DESPITE ECONOMIC DOWNTURN

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Published in:

Global Aquaculture Advocate (2009) 12(2): 67-70.

Global production and consumption of tilapia continues to rise. In 2008, China remained the major producer, with gains by its Asian neighbors and parts of Latin America. The global economic downturn and rising production costs hurt some smaller producers. China consumed half its huge production and showed a trend toward greater consumption of value-added tilapia. In U.S. retail stores, tilapia is now the second best-selling fish. The tilapia industry is working to bring “greener” tilapia products with improved quality control to market.

AQUAFISH RESEARCH REPORT 09-A04

EFFECTS OF CLAM SIZE ON HEAVY METAL ACCUMULATION IN WHOLE SOFT TISSUES OF *GALATEA PARADOXA* (BORN, 1778) FROM THE VOLTA ESTUARY, GHANA

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Published in:

International Journal of Fisheries and Aquaculture (2009) 1(2): 014-021.

The Volta basin clam, *Galatea paradoxa*, is collected for food and remains an important affordable protein source for the riparian communities in the catchment. Clams accumulate metals in their soft tissues, which can be toxic to humans when consumed. A study was, therefore, carried out to examine the concentrations of Mn, Zn, Fe and Hg in *G. paradoxa*, at 3 different size classes: small (20 - 40 mm), medium (41 – 60 mm) and large (>60 mm) at Ada and Aveglo in the Volta estuary area in Ghana. The concentrations of heavy metals in the clams varied considerably between the two locations. There were, however, no significant differences ($p > 0.05$) in Mn, Fe and Zn concentrations among the different size classes, indicating a similar bioavailability of the metals at both locations and, possibly, an efficient metabolism to keep the concentrations of Mn, Fe and Zn relatively similar. Mercury concentrations in the Ada clams varied significantly ($p < 0.05$) among the different size classes. A Risk Analysis indicated that the concentrations of heavy metals in the clams were within acceptable limits and safe for human consumption.

AQUAFISH RESEARCH REPORT 09-A05

BACTERIOLOGICAL CONTAMINATION OF THE FRESHWATER CLAM (*GALATEA PARADOXA*) FROM THE VOLTA ESTUARY, GHANA

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Published in:

African Journal of Microbiology Research (2009) 3(7): 396-399.

This study was designed to generate information on the microbiological quality of the clam, *Galatea paradoxa* harvested from the Volta estuary in Ghana. Total Viable Counts (TVC) for heterotrophic bacteria, Total coliforms (TC) and Faecal Coliforms (FC) as indicators of fecal contamination, were evaluated in the rainy season (June - August) and in the dry season (January - February). *G. paradoxa* from the estuary were found to be highly contaminated with the above mentioned micro-flora. There was a significant seasonal variation ($p < 0.03$) in the levels of total heterotrophic bacteria (TVC), total coliforms (TC) and fecal coliforms (FC). Total viable counts of heterotrophic bacteria in clams in the rainy season (June - August) was significantly lower ($p < 0.03$); (June, 1.0×10^7 cfu/g) than for the dry season (February, 7.0×10^{10} cfu/g). Total coliforms (TC) and FC portrayed a similar trend, being significantly higher ($p < 0.01$) in the dry season (1.0×10^{11}) than the rainy season (2.4×10^4 and 1.3×10^4 /g). Considering the importance of the clam fishery as an affordable protein source and a source of livelihood to the riparian communities along the Volta estuary, it is recommended that monitoring and regulatory controls of the fishery and growing waters be enforced whilst public education on the importance of depuration as a means of decontaminating the clams be pursued vigorously.

AQUAFISH RESEARCH REPORT 09-A06

LIVELIHOOD TRENDS IN RESPONSE TO CLIMATE CHANGE IN FOREST FRINGE COMMUNITIES OF THE OFFIN BASIN IN GHANA

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Published in:

Journal of Applied Sciences and Environmental Management (2009) 13(2): 5-15.

The livelihoods of forest fringe communities in Ghana depend, largely, on the renewable natural resources that they can find in the forests and any activities that impacts on the integrity of the forest disrupt the livelihood of the dependent communities. Forest fragmentation continues to take place in Ghana, mainly in response to a growing demand to feed an ever increasing population and for timber exploitation for export. One of the forest fringe communities in Ghana where the rural livelihoods of the people have been compromised due to deforestation and climate change is the Offin basin. The removal of forests impacts on local climate, water availability, and livelihoods due to influence of forests on precipitation and water balance. Fluxes in the quantity and frequency of rainfall contribute to decreasing food production and water availability. This study examines forest loss, precipitation and ambient temperature patterns in the forest fringe communities in the Offin river basin over the past four and a half decades and assesses current impacts and trends on rural livelihoods and coping strategies by the communities. The forests provide the communities with fuel-wood, fish and game, medicinal plants, food sources, and recreation. Between 2000 and 2005 deforestation rate in the basin was 2%. Mean annual precipitation decreased by 22.2% between 1960 and 2000 in response to a 1.3°C rise in ambient temperature over the same period. Considerable changes in the frequency of rainfall and its unpredictability impacted negatively on the livelihood of the fringe communities who are predominantly cocoa and subsistence crop farmers. The livelihood resources of the community are severely constrained leading to reduction in food security and economic losses. In response to deforestation and associated climatic changes, several coping strategies for sustenance of livelihoods have been adopted by the forest fringe communities.

AQUAFISH RESEARCH REPORT 09-A07

EVALUATION OF LARVAL GROWTH AND SURVIVAL IN MEXICAN MOJARRA, *CICHLASOMA UROPHTHALMUS*, AND BAY SNOOK, *PETENIA SPLENDIDA*, UNDER DIFFERENT INITIAL STOCKING DENSITIES

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Published in:

Journal of the World Aquaculture Society (2009) 40(6): 753-761.

Two experiments were conducted to evaluate the initial stocking density in larvae of Bay snook, *Petenia splendida*, and Mexican mojarra, *Cichlasoma urophthalmus*, using a recirculation system. Five initial stocking densities (0.5, 1, 5, 10, and 20 larvae/L) were evaluated by triplicate for 45 d. Weight and total length (TL) were measured every 15 d, and fish production was calculated for each density. The larvae stocked at the lowest densities (0.5 and 1 larvae/L) presented the highest growth for both species: *C. urophthalmus* (0.78 g and 45-mm TL, and 0.76 g and 45-mm TL, respectively) and *P. splendida* (0.80 g and 52-mm TL, and 0.79 g and 49-mm TL, respectively). However, lowest fish production was recorded (35 and 69 fish per tank, respectively, for *C. urophthalmus* and 34 and 70 fish per tank, respectively, for *P. splendida*) compared with those at densities of 5, 10, and 20 larvae/L (336, 584, and 604 fish per tank, respectively, for *C. urophthalmus* and 341, 679, and 912 fish per tank, respectively, for *P. splendida*). The polynomial model for biomass production related to the stocking density shows that the optimum stocking densities for *C. urophthalmus* and *P. splendida* are 12 and 14 larvae/L, respectively.

AQUAFISH RESEARCH REPORT 09-A08

MASCULINIZATION OF THE NATIVE CICHLID TENHUAYACA, *PETENIA SPLENDIDA* (GÜNTHER, 1862), USING ARTEMIA NAUPLII AS VEHICLE OF THE STEROID 17- α METHYLTESTOSTERONE

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Published in:

Hidrobiológica (2009) 19(3): 211-216.

At world-wide level the use of steroids to obtain all-male population in cichlids, has been widely used with the objective to avoid the reproduction process and to canalize the energy of the food in weight gain. In this sense, the application of steroids has been commonly through the artificial diets. Nevertheless, for some cichlid such as tenhuayaca or bay snook *Petenia splendida*, which is considered an appropriate species for aquaculture in the Southeastern of Mexico and Central America, the use of artificial diets during the larval period is not possible, for this reason the use of live preys is required which could be use as vehicle for the steroids. In the present study, the production of all-male population was evaluated in *P. splendida* using *Artemia nauplii* as vehicle for the steroid 17- α methyltestosterone (MT). For this study, the first feeding larvae were fed with *Artemia nauplii* with MT for 5, 10, 20, 28, 45 and 60 days of feeding, and a control treatment without MT. Significant differences were detected in the masculinization percentage and survival of the larvae fed for 60 days with MT using *Artemia nauplii* (96% and 85% respectively) compared with the control treatment where only 56% of males and a similar survival of 83% were obtained. For this reason, we conclude that the use *Artemia nauplii* as vehicle of MT is a suitable alternative to obtain all male production in *P. splendida* when larvae are feed for 60 days.

AQUAFISH RESEARCH REPORT 09-A09

OMEGA-6 (N-6) AND OMEGA-3 (N-3) FATTY ACIDS IN TILAPIA AND HUMAN HEALTH: A REVIEW

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Published in:

International Journal of Food Sciences and Nutrition (2009) 60(S5): 203-211.

A recent publication questions the nutritional value of tilapia in the human diet following the movement to eat fish for their omega fatty acid (FA) content. It suggests that tilapia have an elevated amount of omega-6 FAs (n-6) and a deficient amount of omega-3 FAs (n-3), a possibly unhealthy proportion for humans. A high n-6: n-3 ratio is problematic because too much arachidonic acid, an n-6 FA, promotes inflammation, which aggravates heart disease and other illnesses. This paper analyzes the numbers from different tilapia composition studies in an effort to understand the range of n-6 and n-3 totals and ratios present in both farmed and wild tilapia. Generally, wild tilapia have more n-3 FAs than farmed tilapia, but diet adjustments can alter the body composition of the domesticated variety. Consumers should consider fish as part of a balanced diet and evaluate their FA needs on an individual basis.

AQUAFISH RESEARCH REPORT 09-A10

THE POTENTIAL FOR CULTURE OF NILE TILAPIA AND AFRICAN CATFISH IN THE RIVER NJORO WATERSHED

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Published in:

Global Livestock CRSP Research Brief. (2009) April: 1-3.

Aquaculture systems have the benefit of being highly intensive with demonstrated economic returns. Aquaculture can be an efficient strategy for economical land use and serve as an alternative means of livelihood for rural communities. Consequently, fish farming can play a major role in environmental conservation and restoration programs by reducing extensive land use. However, regional variability in climate, soils, and water quality are limiting constraints on aquaculture success. This study was conducted to assess the potential for culture of two warm water fish species, Nile tilapia (*Oreochromis niloticus*, Linnaeus) and African catfish (*Clarias gariepinus*, Burchell) at high altitudes of the River Njoro watershed. Growth performance of Nile tilapia and African catfish were evaluated for 180 days in ponds and fertilized with organic manure and stocked at a rate of two fish per square meter for tilapia, and 0.5 fish per square meter for catfish. Results from this study demonstrated remarkable growth in Nile tilapia but poor growth and condition in African catfish. After several attempts, African catfish eggs fertilized for the study failed to hatch, most notably due to low temperatures and the poor water quality of the Njoro River. These results demonstrate the feasibility of Nile tilapia culture at high altitudes of the watershed, while African catfish culture was limited by poor growth performance and seed availability. The farming of Nile tilapia is therefore recommended in the Njoro River watershed as a potential livelihood strategy to intensive agriculture.

AQUAFISH RESEARCH REPORT 09-A11

TILAPIA FINGERLINGS FROM VARIED SYSTEMS DELIVER SIMILAR GROWOUT PERFORMANCE

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Published in:

Global Aquaculture Advocate (2009): 98-100.

Results of a 120-day study showed that Nile tilapia fingerlings produced in incubation units, hapas or ponds exhibited similar growout performance. Although not statistically significant, the tilapia from artificial incubation units performed optimally. Fish from hapas also did very well. These treatments produced the greatest yield of fish, and a greater proportion of harvested animals fell in larger size categories.

AQUAFISH RESEARCH REPORT 09-A12

FIRST RECORD OF THE NATURAL OCCURRENCE OF HEXAPLOID LOACH *MISGURNUS*
ANGUILLICAUDATUS IN HUBEI PROVINCE, CHINA

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Published in:

Journal of Fish Biology (2009) 75: 435-441.

Natural occurrence of hexaploid loach *Misgurnus anguillicaudatus* detected in central China is reported here for the first time. The evidence from karyotyping, DNA content analysis and nuclear volume measurements were described to confirm the hexaploid nature of the identified individual.

AQUAFISH RESEARCH REPORT 09-A13

EFFECTS OF GnRHA (D-ALA⁶, PRO⁹-NET) COMBINED WITH DOMPERIDONE ON OVULATION INDUCTION IN WILD LOACH *MISGURNUS ANGUILLICAUDATUS*

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Published in:

Aquaculture (2009) 291: 136-139.

The effects of a single intramuscular injection of gonadotropin releasing hormone analogue (GnRHa) alone or in combination with the dopamine antagonist domperidone (DOM) on ovulation induction of loach *Misgurnus anguillicaudatus* broodstocks collected from the wild were tested under routine hatchery conditions. The ovulation ratio, latency period, ovulation index, fertilization success and hatching rate were evaluated. The following hormone treatments were tested: 2 mg kg⁻¹ BW of CPE as a positive control (PC), GnRHa alone at doses of 10 µg (G10), 20 µg (G20), 40 µg (G40) and 60 µg (G60) kg⁻¹ BW and combinations of GnRHa and DOM at doses of 5 µg + 2.5 mg (GD5), 10 µg + 5 mg (GD10), 20 µg + 10 mg (GD20) and 40 µg + 20 mg (GD40) kg⁻¹, respectively. Physiological saline injected fish were used as a negative control (NC). The results showed that the combination of 20 µg + 10 mg (GD20) and 40 µg + 20 mg (GD40) kg⁻¹ of GnRHa and DOM, respectively, injection led to higher ovulation ratio and shorter latency periods in comparison with the control and the other hormone treatments ($P < 0.05$), and there was no significant difference between the two ovulating groups with respect to ovulation ratio and latency period ($P > 0.05$). There was a significant difference between the GnRHa alone groups and the GnRHa + DOM combined groups on the ovulation index (the former < the latter, $P < 0.05$), while no significant differences in the fertilization success and hatching rate were found in any of the hormone treatments ($P > 0.05$). Only 20% of the fish ovulated in group G10 and G20, and no fish ovulated in group NC, suggesting a dopaminergic inhibitory action on gonadotropin (GtH) secretion in this fish at the preovulatory stage. Therefore, it can be concluded that like many other cyprinids, dopamine inhibitory action was operating in loach and it was necessary to combine GnRHa with a dopamine antagonist for ovulation induction. As a result, ovulation can be induced successfully in loach broodstocks with 20 µg kg⁻¹ GnRHa + 10 mg kg⁻¹ DOM treatment in a single injection without any negative effect on egg quality. Application of this combination could be beneficial for hatchery and broodstock management in loach culture.

AQUAFISH RESEARCH REPORT 09-A14

EFFECTS ON GROWTH AND SURVIVAL OF LOACH (*MISGURNUS ANGUILLICAUDATUS*) LARVAE WHEN CO-FED ON LIVE AND MICROPARTICLE DIETS

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Published in:

Aquaculture Research (2009) 40: 385-394.

The effectiveness of co-feeding loach (*Misgurnus anguillicaudatus*) larvae with live microparticle diets on weaning performance was described here. Dry weight, total length, length and weight-specific growth rate (SGR) and survivals were monitored at 23-25 °C from the 4th day post hatching (dph) in different diet regimes, which included: microparticle diets (A), live cladocerans (B), enriched cladocerans (C), half microparticle diets plus half live cladocerans (D) and half microparticle diets plus half enriched cladocerans (E). The SGR (L and W) were significantly lower in treatment A than in other treatments after completing metamorphosis (day 4–20, $P < 0.05$). On 30 dph, dry weight (mg) a total length (mm) were significantly lower in treatment in A than in other treatments ($P < 0.05$). There were no significant differences in growth in treatments B, C, D and E before 30 dph. However, when live feed was withdrawn from 31-60dph, in metamorphosed fish, there were significant differences ($P < 0.05$) among the treatments in survival and growth. Metamorphosed fish in treatment E had higher survival than the fish in other treatments at the end of the experiment. The SGR (L and W) of weaned fish in treatments B and C were similar but lower than in treatments A, D and E respectively. However, dry weight and total length in treatment A were significantly lower than in treatments D and E. It is suggested that weaning of *M. anguillicaudatus* from early development would appear to be feasible and that larval co-feeding improves the growth and the survival.

AQUAFISH RESEARCH REPORT 09-A15

SNAKEHEAD AQUACULTURE IN THE MEKONG DELTA, VIETNAM

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Published in:
Cambodia Fisheries Magazine (2009): 13.

AquaFish will not be distributing this publication. Copies may be obtained by writing to the authors.

This Brief Communication is prepared based on data and information collected during the field trip to snakehead fish culture farms in the Mekong Delta in 2009, with the support of AquaFish CRSP.

In the recent years, aquaculture has played an economically important role in the Mekong Delta. Catfish, snakehead fish and freshwater prawn significantly contributed to an increased total freshwater aquaculture production. Of which, snakehead was an important species cultured in Mekong Delta. There are four key popular culture systems of snakehead fish, including pond culture, hapa culture, cage culture and nylon tank culture. Data collected from provinces in the Mekong Delta showed that the snakehead production in region was about 30,000 tons in 2009, of which *Channa micropelte* was 7,500 tons. However, the farmers in the Mekong Delta attended to small scale systems and spontaneous systems. There are four species of snakehead fish cultured in Mekong Delta, comprising of *Channa gachua*, *Channa lucius*, *Channa striata*, *Channa micropelte*. *Channa striata* and *Channa micropelte* are two main cultured species in Mekong Delta now.

AQUAFISH RESEARCH REPORT 09-A16

MACROINVERTEBRATE ASSEMBLAGES AS BIOLOGICAL INDICATORS OF WATER QUALITY IN THE MOIBEN RIVER, KENYA

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Published in:

African Journal of Aquatic Science (2009) 34(1): 15-25.

Benthic macroinvertebrate assemblages at eight stations in the Moiben River, corresponding to different catchment land uses, were assessed in 2006 as indicators of water quality. The relative abundance per taxon, diversity index, richness index, evenness, dominance, percentage of five dominant taxa and percentage *Ephemeroptera* + *Plecoptera* + *Trichoptera* (EPT) individuals were determined per sampling period per station. Significant spatiotemporal variation was observed in relative abundance, with *Diptera* dominating the study area. *Ephemeroptera*, *Plecoptera* and *Trichoptera* dominated the headwater stations, whereas *Coleoptera*, *Oligochaeta* and *Chironomidae* dominated further downstream. Significant relationships were recorded between physico-chemical parameters — conductivity, BOD, temperature, and discharge — and the occurrence of specific taxa, mainly *Heptagenia*, *Caenis*, *Baetis*, *Branchiobdella*, *Potamon*, *Ilyocoris*, *Elmis* and *Chironomus*. Significant changes in macroinvertebrate assemblages were primarily due to changes in water quality. As elsewhere, macroinvertebrate communities proved to be good indicators of water quality and should be used as bioindicators in long-term monitoring of this river.

AQUAFISH RESEARCH REPORT 09-A17

A PRELIMINARY BENTHIC MACROINVERTEBRATE INDEX OF BIOTIC INTEGRITY (B-IBI) FOR MONITORING THE MOIBEN RIVER, LAKE VICTORIA BASIN, KENYA

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Published in:

African Journal of Aquatic Science (2009) 34 (1): 1-14.

A Benthic Index of Biotic Integrity (B-IBI) was developed for the Moiben River. The index assesses effects of human disturbance on the biotic condition of stream macroinvertebrate communities. Eight stations were selected to represent different land-use types including forestry, settlement, grassland and mixed farming, practiced at different intensities. A total of 22 metrics were correlated against habitat quality and water quality parameters to determine their interrelationships. Ten metrics were shown to be responsive to changes in water and habitat quality, so could be used to separate sites according to levels of degradation. These were taxa richness (of *Ephemeroptera*, *Plecoptera*, *Trichoptera* and intolerant taxa richness), assemblage composition (percentage *Ephemeroptera* + *Plecoptera* + *Trichoptera* [EPT] individuals, and percentage of individuals in dominant taxa), pollution tolerance (percentage of tolerant individuals) and three functional feeding group metrics (ratio of scraper: filterer individuals, percentage gatherer genera, and percentage predator individuals). We calculated B-IBIs by summing metrics for each site, after transforming them to a discrete 1, 3, 5 scale. Values for the final index correlated well with measures of human influence based on qualitative assessment of habitat quality (Pearson's $r^2 = 0.88$). This preliminary benthic macroinvertebrate B-IBI shows promise for developing biological standards, which would facilitate long-term monitoring of streams in the upper reaches of Lake Victoria Basin.

AQUAFISH RESEARCH REPORT 09-A18

OYSTER PREFERENCES IN SINALOA, MEXICO, SURVEY: BUYERS WOULD PAY MORE FOR QUALITY, AVAILABILITY

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Published in:

Global Aquaculture Advocate (2009) November/December: 20-23.

The authors performed a small- scale survey of owners/managers of restaurants in Sinaloa, Mexico, to assist aquaculture cooperatives in identifying opportunities for marketing oysters within the state. Results showed that potential buyers preferred live, large- sized oysters with a three-day shelf life. Buyers also considered water quality at product origin and mode of transportation, important factors in food safety. All would pay more for quality product with year-round delivery.

AQUAFISH RESEARCH REPORT 09-A19

EFFECTS OF INTERVENTION IN THE WATER COLUMN AND/OR POND BOTTOM THROUGH SPECIES COMPOSITION ON POLYCULTURES OF LARGE CARPS AND SMALL INDIGENOUS SPECIES

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Published in:

Aquaculture (2009) 286(1-4): 246-253.

In Bangladesh, a sustainable semi-intensive pond aquaculture technology including large carp species as cash-crop and small indigenous fish species (SIS) as food for the farmers' families is being optimized. The present paper is on the effects on fish performance and pond ecology of interfering in the water column and/or on the bottom through changes in the polyculture composition. The Control polyculture was the 'no-effect' combination consisting of the traditional 33 rohu–33 catla–34 common carp stocking with the addition of 250 SIS and 3 silver carp per 100 m² of pond, as resulted from a previous experiment. Interferences on the water column were achieved by changing the density of the herbivorous fish (reducing the density of catla to 24/100 m² and increasing that of silver carp to 12/100 m²), and on the bottom by doing so on the benthophagous fish (replacing 10/100 m² common carp by the same amount of mrigal). Mola was the SIS included in the polyculture. Interfering in the water column and/or in the pond bottom through the polyculture composition produced complex responses in the pond ecosystem affecting the large carps' performances, while it did not significantly affect the reproduction and the harvested biomass of the small fish mola. Relationships among the different fish species and the environment are described for each polyculture. The four polycultures tested allowed a good production of large carp species as cash-crop, of silver carp as an option to consume or to sell, and of the small species mola as food for the farmers' families. The Control polyculture is appropriate to produce relatively large herbivorous species, mainly silver carp. The polyculture combination in the Water treatment is appropriate to obtain a larger amount of smaller silver carp that can be afforded by the poor people but also smaller rohu and catla, while maintaining the same level of total yield and income with reduced feed conversion ratio (FCR) than in the Control treatment. The polyculture combination in the Bottom treatment allowed a larger fish species diversity and also produced smaller herbivorous fish with still reduced FCR, while maintaining the same level of total yield and income than the Control treatment. The polyculture combination in the Water & Bottom treatment gave the best results: it allowed a larger fish species diversity, is appropriate to obtain a larger amount of small silver carp that can be afforded by the poor people, and gives the highest total yield and income with the lowest FCR.

AQUAFISH RESEARCH REPORT 09-A20

THE NATURE OF EXOCYTOSIS IN THE YOLK TROPHO BLASTIC LAYER OF SILVER AROWANA
(*OSTEOGLOSSUM BICIRRHOSUM*) JUVENILE, THE REPRESENTATIVE OF ANCIENT TELEOST FISHES

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Published in:

The Anatomical Record (2009) 292: 1745-1755.

We have chosen the silver arowana (*Osteoglossum bicirrhosum*), a representative of the most ancient teleost family Osteoglossidae, to address the question of yolk nutrients utilization. Silver arowana have particularly large eggs (1–1.5 cm of diameter) and a unique morphology of the yolk. We present evidence that the yolk cytoplasmic zone (*ycz*) in the “yolk sac juveniles” is a very complex structure involved in sequential processes of yolk hydrolysis, lipoprotein particles synthesis, their transport, and exocytosis. Vacuoles filled with yolk granules in different stages of digestion move from the vitellolysis zone through the *ycz* to be emptied into the microvillar-interspace in the process of exocytosis. The area of the *ycz* with the abundance of the mitochondria must play an important role in providing energy for both the transport of vacuoles and the release of their contents. There-fore, we postulate that the function of yolk syncytial layer (*ysl*) as the “early embryonic patterning center” transforms in fish larvae or yolksac juveniles into a predominantly specialized role as the yolk trophoblastic layer (*ytI*) involved in yolk nutrients utilization. In addition to discovering the mechanism of transformation of the *ysl* function into *ytI* function, we suggest that the machinery involved in nutrient mobilization and exocytosis in yolk of arowana yolksac juveniles can be very attractive system for studies of regulatory processes in almost all secretory pathways in animal cells.

AQUAFISH RESEARCH REPORT 09-A21

MARKETING EXTENSION AND OUTREACH IN SINALOA, MEXICO: A PRELIMINARY ANALYSIS OF PREFERENCES FOR OYSTERS

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Published in:

Marine Resource Economics (2009) 24(1): 89-95.

Shrimp mariculture, the leading form of aquaculture for the Pacific coast of Mexico is facing catastrophic losses due to disease and falling prices. Previous work conducted by a multi-institutional, international team since 1997 has built a solid foundation for diversification of aquaculture in Pacific Mexico emphasizing the use of native species, particularly those low on the food chain and with low culture technology requirements. Among the leading candidates are bivalves, which are currently cultured and fished extensively along the Gulf of California Coast, with much of the production attributed to wild capture fisheries. Great potential exists, however, to expand current aquaculture production through strengthening existing operations, either by developing new markets or increasing sales in current ones according to consumer preferences.

From the Mexican government's perspective, specifically from CONAPESCA (National Aquaculture and Fishery Commission), economic diversification for aquaculture is stated as a prioritized policy goal. Today, the most available and feasible biotechnologies for species diversification in the country are tilapia and oyster farming (Martínez-Cordero 2007). In the last three years the Program Alianza para el Campo (Alliance for the countryside), which is the main federal program operated at the national level that promotes and supports the development of aquaculture projects, has financed tilapia and oyster projects at different scales of operation in many states. Social groups, like cooperatives, are usually selected to receive support for oyster farming, and in Sinaloa, coastal communities have benefited from this program. This includes fishermen entering aquaculture activities for the first time, which the Mexican government calls system conversion. Women's groups are also being involved in oyster culture efforts by the Autonomous University of Sinaloa. While monetary assistance has been given to help in the establishment of new aquaculture enterprises, little work has been done to assess the social and economic impacts of increased production. Moreover, research on assessing market demand for said species and assisting farmers in market identification and market penetration strategies is lacking. The objective of this work is to assist oyster aquaculture cooperatives in the region of Bahía Santa María (BSM), Mexico, to identify opportunities for the marketing of oysters within the state of Sinaloa.

AQUAFISH RESEARCH REPORT 09-A22

AN EXAMINATION OF INCOME GENERATION POTENTIAL OF AQUACULTURE FARMS IN ALLEVIATING HOUSEHOLD POVERTY: ESTIMATION AND POLICY IMPLICATIONS FROM NIGERIA

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Published in:

Turkish Journal of Fisheries and Aquatic Sciences (2009) 9: 39-45.

This study examines income generation potential and resource-use efficiency of 120 aquaculture farms in Oyo state Nigeria. The data collected were analyzed using gross margin and stochastic frontier production (SFP) model. Result of gross margin (GM) shows that the farms were quite profitable with an average GM of N207, 000 per annum. The SFP model reveals that, elasticities of all considered inputs were positive and significantly different from zero. Returns to scale of 1.16 computed as sum of the inputs elasticities suggests that, an average farm from the study exhibits increasing returns to scale. Further analyses reveal that, an average technical efficiency estimate of about 81% was obtained from SFP model. This suggests that, about 19% potential yield are forgone due to inefficiency from the study. The result of sources of technical efficiency differential shows that extension; education, stocking density, and credit significantly influenced technical efficiency of the farms. Also, result of simulated marginal effects of these variables on technical efficiency shows that extension has the highest marginal effects on the efficiency estimates followed by credit, education, and stocking density. The study, therefore, suggests that, significant level of profit obtained from the study is synonymous to improve efficiency environment observed among the farms as promotion of aquaculture development has the potential in alleviating household income poverty in the country.

AQUAFISH RESEARCH REPORT 09-A23

EFFECTS OF CARBOHYDRATE-RICH ALTERNATIVE FEEDSTUFFS ON GROWTH, SURVIVAL, BODY COMPOSITION, HEMATOLOGY, AND NONSPECIFIC IMMUNE RESPONSE OF BLACK PACU, *COLOSSOMA MACROPOMUM*, AND RED PACU, *PIARACTUS BRACHYPOMUS*

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Published in:

Journal of the World Aquaculture Society (2009) 40(1): 33-44.

To facilitate economical culture of black pacu, *Colossoma macropomum*, and red pacu, *Piaractus brachypomus*, in the Amazon region of South America, we assessed locally available alternative energy sources for practical diets. We tested the effects of control diets (containing wheat products) versus diets with different Amazonian feedstuffs (yucca, *Manihot sculenta*, plantain, *Musa paradisiaca*, or pijuayo, *Bactris gasipaes*) on the performance of the pacus in three feeding trials. Black pacu (22.5 ± 0.03 g; Trial 1) or red pacu (2.56 ± 0.01 g; Trial 2) were fed diets containing 30% wheat bran (control) or cooked or uncooked yucca, plantain, or pijuayo for 12 wk. In Trial 3, larger black pacu (86.9 ± 6.4 g) were grown to market size in 24 wk on similar diets. Weight gain, feed conversion, survival, alternative complement activity, and lysozyme were similar among diets. Hepatosomatic index, liver glycogen, and dry matter were affected by diet in Trials 1 and 2, but effects were not consistent among trials. In Trial 3, protein efficiency ratio was lower in fish fed the diet containing wheat middlings. However, relative to wheat bran or wheat middlings, all feedstuffs tested were effective energy sources for juvenile black pacu and red pacu.

AQUAFISH RESEARCH REPORT 10-257

EFFECTS OF ADDITION OF RED TILAPIA (*OREOCHROMIS* spp.) AT DIFFERENT DENSITIES AND SIZES ON PRODUCTION, WATER QUALITY AND NUTRIENT RECOVERY OF INTENSIVE CULTURE OF WHITE SHRIMP (*LITOPENAEUS VANNAMEI*) IN CEMENT TANKS

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Published in:

Aquaculture (2010) 298: 226-238

An experiment was conducted in 21 outdoor cement tanks (2.5x2x1.2 m) from 8 December 2005 to 3 March 2006 to determine the effects of adding red tilapia (*Oreochromis* spp.) at different densities and sizes on production, water quality and nutrient recovery in intensive culture tanks of white shrimp (*Litopenaeus vannamei*). Shrimp postlarvae of 0.06 g were stocked into all tanks at a density of 60 postlarvae m⁻², while either small (13.8±0.2 g) or large (41.9±0.3 g) mono-sex tilapia fingerlings were stocked into the shrimp tanks two weeks later at low (0.4 fish m⁻²), medium (0.8 fish m⁻²) or high (1.2 fish m⁻²) density. Water depth in all tanks was maintained at 1 m and salinity at 20 ppt. Water loss due to evaporation was compensated weekly. The experiment was conducted in a 2x3 factorial design, while three additional tanks for shrimp monoculture were set as a control. All treatments and the control were randomly allocated to tanks in triplicate each. Shrimps were fed three times daily with commercial pellets using feeding trays made with metal frame and nylon mesh (0.6x0.6x0.05 m) at the same feeding rates as those for the control. No separate feed was given to tilapia.

The highest shrimp survival rate of 66.8% was obtained in the small–low density tilapia treatment, which was significantly higher than those in other treatments and the control. The small-low density tilapia treatment had the highest shrimp yield and lowest feed conversion ratio, which was similar to those in the control and the large-low and small-medium density tilapia treatments, but significantly better than those in other treatments. Factorial analyses revealed that the increase of tilapia density from 0.4 to 1.2 fish m⁻² and size from 13.8 to 41.9 g negatively affected shrimp production performance but remarkably increased the combined production of shrimp and tilapia. Polyculture incorporated 36.0-49.5% of the total nitrogen input and 14.2-26.5% of the total phosphorous input into shrimp and tilapia, which were significantly higher than those (27.1% and 8.9%) in the monoculture, respectively. The nutrient recovery efficiency increased with increased tilapia stocking size and density. Polyculture with small tilapia stocked

at low density had the best economic performance among all treatments and control, and significantly better than small-high, large-medium and large-high density tilapia treatments.

It was concluded that addition of red tilapia at suitable stocking densities and sizes into intensive white shrimp monoculture can improve productivity, profitability, nutrient utilization and environmental friendliness of shrimp monoculture. The suitable stocking density and size of red tilapia identified in this study were 0.4 fish m⁻² and 13.7 g respectively. Red tilapia could be stocked at higher density and larger size up to 1.2 fish m⁻² and 42 g respectively to maximize system productivity and minimize nutrient waste without affecting shrimp survival, but economic performance could be negatively affected. Shrimp–tilapia polyculture should be promoted to improve sustainability of shrimp culture.

AQUAFISH RESEARCH REPORT 10-258

GROWTH PERFORMANCE, SURVIVAL, FEED UTILIZATION AND NUTRIENT UTILIZATION OF AFRICAN CATFISH (*CLARIAS GARIEPINUS*) LARVAE CO-FED ARTEMIA AND A MICRO-DIET CONTAINING FRESHWATER ATYID SHRIMP (*CARIDINA NILOTICA*) DURING WEANING

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Published in:

African Journal of Microbiology Research, Aquaculture Nutrition (2010) 17(2): 1-8.

Problems of limited number of dry feeds as supplement or replacement of live feeds have led to poor larval nutrition in many species of fish. Therefore, the suitability of co-feeding 8-day-old African catfish (*Clarias gariepinus*) posthatch larvae using live feed (*Artemia salina*) and formulated dry diet containing freshwater atyid shrimp (*Caridina nilotica*) during weaning was investigated. The experiment ended after 21 days of culture and respective groups compared on the basis of growth performance, survival, feed utilization and nutrient utilization. Larvae co-fed using 50% *Artemia* and 50% formulated dry diet resulted in significantly ($P < 0.05$) better growth performance, food gain ratio (FGR), protein efficiency ratio (PER) and productive protein values (PPV) than other treatments. The lowest growth performance occurred in larvae weaned using 100% formulated and commercial dry diets. Better survival of over 90% was obtained in larvae weaned using 50% *Artemia* and 50% dry diet, while abrupt weaning using 100% dry diets resulted in lower survival (<75%). These results support a recommendation of co-feeding *C. gariepinus* larvae using a formulated dry diet containing *C. nilotica* and 50% live feed when weaning is performed after 8 days posthatching period.

AQUAFISH RESEARCH REPORT 10-259

COMPARATIVE STUDIES ON SURVIVAL AND GROWTH PERFORMANCE AMONG DIPLOID, TRIPLOID AND TETRAPLOID DOJO LOACH (*MISGURNUS ANGUILLICAUDATUS*)

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Published in:

Aquaculture International (2010) 18: 349–359.

To determine the cytotype with better traits for the aquaculture practices of the dojo loach (*Misgurnus anguillicaudatus*) from the viewpoint of fish farming improvement, factorial crosses ($2n_{\text{♀}} \times 2n_{\text{♂}}$, $2n_{\text{♀}} \times 4n_{\text{♂}}$, $4n_{\text{♀}} \times 2n_{\text{♂}}$, $4n_{\text{♀}} \times 4n_{\text{♂}}$) were conducted between natural diploids (D) and tetraploids (T), producing DD, DT, TD, and TT groups (female listed first). The potential benefits of the different cytotypes in culture were evaluated by comparing growth performance and survival rate for a 15-month rearing trial under the same production conditions. The average fertilization rate in DT and TT was significantly lower than in the DD and TD groups, possibly indicating the poor fertilizing capacity of the tetraploid sires. Survival rate in DT and TD was slightly lower than in DD but significantly higher than in the TT groups. Tetraploid females produced obviously larger eggs than diploids and, subsequently, significantly longer initial body length of TT and TD than DD and DT fry. However, from the second month of the growth trial, TT suffered higher mortality than other cytotypes, which significantly influenced morphometric growth parameters. The TD group exhibited superior growth performance throughout the experiment. The mean body length of DT was comparable with that of DD fish during the first 7 months but began to outgrow DD from the 9th month. This study suggests that the relatively better growth of tetraploid and higher survival rate of diploid can be integrated via inter-ploidy hybridization to get TD triploids with better culture traits.

AQUAFISH RESEARCH REPORT 10-260

MARKETS FOR HONDURAN TILAPIA

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Published in:

World Aquaculture (2010) 41(2): 39-40,72.

The first reports of tilapia in Honduras date from the mid-1930s when broodstock of Java tilapia (*Oreochromis mossambicus*) was introduced to Honduras from El Salvador. In 1955, the Honduran government, through the Secretariat of Natural Resources, created the Jesus de Otoro Aquaculture Station for the culture of freshwater shrimp (*Macrobrachium rosenbergii*). In 1958, because of various problems, this activity was discontinued. In 1968, the station resumed activities, this time oriented to the culture of tilapia. Two additional aquaculture stations were created by the government during the 1960s and 70s. The El Carao National Fish Culture Research Station was constructed in 1979. That station was utilized to initiate a national program of fish culture through extension programs and distribution of tilapia fingerlings to local farmers. The program focused on promoting subsistence-level fish culture throughout the country. Target groups included rural farmers and community organizations.

AQUAFISH RESEARCH REPORT 10-261

DEVELOPMENT OF TESTIS AND DIGESTIVE TRACT IN LONGNOSE GAR (*LEPISOSTEUS OSSEUS*) AT THE ONSET OF EXOGENOUS FEEDING OF LARVAE AND IN JUVENILES

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Published in:

Aquaculture Research (2010) 41(10): 1486-1497.

The aim of this study was to describe the ontogenetic development of the testis and the alimentary tract in longnose gar (*Lepisosteus osseus*) related to fish size and age at the onset of exogenous feeding and late ontogenesis. Using light microscopy, testes were first detected histologically by the appearance of primordial germ cells 9 days after the first exogenous feeding [31-31.5 mm total body length (TL)] and presumptive seminiferous tubules (maleness characteristic) in fish of 107 mm TL. The present histological studies indicated that the alimentary tract of lepisosteids is completely functional at the beginning of exogenous feeding, several days before the completion of yolk absorption. Based on these results, we have concluded that garfish larvae/juveniles can be effectively trained to consume formulated diets at early stages, after an initial feeding of live food for 2-3 days (23.5 mm TL). Our findings provide evidence of the first controlled rearing of longnose gar using live and formulated diets, providing the possibility of experimental work with this non-teleost fish.

AQUAFISH RESEARCH REPORT 10-262

AQUACULTURE RESEARCH AND DEVELOPMENT AS AN ENTRY-POINT AND CONTRIBUTOR TO
NATURAL RESOURCES AND COASTAL MANAGEMENT

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Published in:

Coastal Management (2010) 38: 238–261.

Recent, fervent international dialogue concerning the existence and magnitude of impacts associated with aquaculture has had both positive and negative outcomes. Aquaculture stakeholders have become sensitized to requirements for improved environmental management of aquaculture. On the other hand, in some cases aquaculture development has been negatively affected by some of the unwarranted and unproved allegations to the detriment of the stakeholders most in need of aquaculture development (i.e., resource users, particularly the poor, who are dependent on natural resources). These resource users are targeted by, and directly influence biodiversity and conservation agendas; hence the need to understand how to gain their active participation. This discussion focuses on examples of how aquaculture research and development can be a useful tool or strategy for resource management initiatives and provide tangible positive including increased stakeholder participation and cooperation, offering alternatives to resource extraction and use in otherwise difficult or intransigent resource management conflicts.

AQUAFISH RESEARCH REPORT 10-263

MARKET CHANNEL AND TRADE OF FERMENTED SMALL-SIZED FISH PASTE IN CAMBODIA

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Published in:

International Journal of Environmental & Rural Development (2010) 1(1): 145-151.

Fermented small-sized fish paste is considered to be one of the main food sources for Cambodians, especially for the poor. However, most small-sized fish are used as direct feed for aquaculture or dried for animal feed. This study was conducted in order to identify market channel and trade of fermented small-sized fish paste. Phnom Penh city, Kendal, Kampong Chhnang, Battambang, and Siem Reap Provinces were selected as the study areas. The study revealed that there were three main sources of product which should be considered when analyzing total volume of annual production. The total production of the fermented fish paste in 2007-2008 was around 6,659 tons, of which 50.18% was domestically consumed and 49.82% exported to Thailand and Vietnam. Marketing and trading differed according to trading sites, stakeholder characteristics, and fish species containing in the fermented fish paste.

AQUAFISH RESEARCH REPORT 10-264

TILAPIA UPDATE 2010

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Published in:

The Practical: Asian Aquaculture (2010) 1(2): 32-34.

International production continues to grow rapidly (10-15% yearly) as markets in developed countries import more and consumption in the producing countries also increases. China continues to be the largest producer, consumer, and exporter with about 1.2 million metric tons of production in 2009. Indonesia, Thailand, Vietnam, and Philippines have all increased production by 10 to 20% per year in 2008 and 2009. Indonesia's production in 2008 reached 328,831 metric tons, becoming the world's number two producer, followed closely by Thailand and Egypt.

AQUAFISH RESEARCH REPORT 10-265

CLAY FLOCCULATION COUNTERS MICROCYSTIN POLLUTION IN CHINA STUDY

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Published in:

Global Aquaculture Advocate (2010) 13(E3): 26-27.

Since typical water treatment processes are ineffective at removing toxic microcystins, techniques for eliminating microcystin-producing algae in water bodies have been developed. The most promising microcystin control in aquaculture is flocculation and sedimentation of harmful algal blooms with clay. In a study with tilapia in a eutrophic fish pond, the authors found that polymeric aluminum chloride-modified clay had a faster and slightly stronger effect in removing *M. aeruginosa* than a more environmentally friendly chitosan-modified clay.

AQUAFISH RESEARCH REPORT 10-266

CAGE DESIGN, PLACEMENT AFFECT WATER QUALITY

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Published in:

Global Aquaculture Advocate (2010), 13(E3): 21-22.

Farm cages should be sited where water quality is good and water velocity is adequate. The size, shape and position of cages should be selected to favor rapid flushing. Fish can typically be cultured at greater density in small cages than in larger ones. Cages should be oriented with the greatest surface area perpendicular to the prevailing current. Cages should occasionally be fallowed or moved to allow benthic communities to recover.

AQUAFISH RESEARCH REPORT 10-267

REPLACEMENT OF FISH MEAL PROTEIN BY SOYBEAN MEAL PROTEIN WITH OR WITHOUT PHYTASE SUPPLEMENTATION IN SNAKEHEAD (*CHANNA STRIATA*) DIETS

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Published in:

The Scientific Journal of Can tho University (2010) 15a: 207-2013.

The study was conducted with snakehead *Channa striata* fingerlings (4-5g per fish) to determine the appropriate replacing levels of fish meal (FM) protein by soybean meal (SBM) protein with or without phytase supplementation. Nine isonitrogenous (45%) and isocaloric (4.7 Kcal g⁻¹) diets were formulated to replace FM protein by SBM protein. The control diet was prepared with FM protein. The other groups, FM protein was replaced by SBM protein in the diets at replacing levels of 20%, 30%, 40%, and 50% with or without phytase. The experiment results showed there were no significant differences in survival rate among the treatments ($P>0.05$), ranging between 54.4% and 63.3%. Fish growth had a downward trend (from 0.28 to 0.14 g.day⁻¹), the opposite was true for feed conversion efficiency (from 1.07 to 1.78) when SBM protein was increased in formulated feed. In addition, phytase did not affect body composition and there were not significant differences in hepatic somatic index among the treatments ($P>0.05$). In terms of economic profits, compared to control diet, re- placement of FM protein by SBM protein with phytase supplement at 40% in *Channa striata* diets decreased slightly by 0.89%. To sum up, FM protein in *Channa striata* fingerlings diets can be replaced by SBM protein at 30% and 40%, without or with phytase supplements, respectively in which growth performances, feed utilizations are not affected.

AQUAFISH RESEARCH REPORT 10-268

REPLACING FISH MEAL BY SOYBEAN MEAL IN GIANT SNAKEHEAD (*CHANNA MICROPELTES*) DIETS

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The Scientific Journal of Can Tho University (2010). [Online Aquafish Information](#)

This study was designed to determine the maximum replacing levels of fish meal protein (FM) by soybean meal protein (SBM), defatted with phytase enzyme supplementation for *Channa micropeltes*. FM in the basal diet was replaced by SBM in the diets at replacing levels of 20, 30, 40, and 50% with 0.02% phytase supplementation. *Channa micropeltes* fingerlings (4.3 ± 0.03 g/fish) were randomly distributed into 15 tanks (100 liters/tank) with 25 individuals per tanks. Fish were fed twice a day to satiate. After 8 weeks of feeding, there were no significant differences in survival rate (SR) among the treatments, ranging between 77.3% and 80%. Compare to control treatment (FM), replacement of 20, 30 and 40% of FM by SBM did not significantly affected on growth performance, feed conversion ratio (FCR) and protein efficiency ratio (PER) while the replacing level of 50% significantly reduced these parameters, except FCR. Results also showed that there weren't significant differences in crude protein content in whole body as the dietary soybean meal replacement levels increased. From economic view, replacement of FM by SBM up to 40% in *Channa micropeltes* diets reduced feed costs/kg diet and feed costs/kg weight gain by 10.8% and 4.83%, respectively.

AQUAFISH RESEARCH REPORT 10-269

ROLE OF AQUACULTURE POND SEDIMENTS IN SEQUESTRATION OF ANNUAL GLOBAL CARBON EMISSIONS

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Published in:

Environmental Pollution (2010) 158: 2537-2540.

Efforts to quantify carbon sequestration in inland water bodies have focused on inland seas, natural lakes, and large river impoundments (Mulholland and Elwood, 1982; Dean and Gorham, 1998). A recent study in Iowa (Downing et al., 2008) suggested that small, agriculturally-eutrophic impoundments bury carbon at an average rate of $2122 \text{ gm}^{-2} \text{ yr}^{-1}$ five times higher than in large, river impoundments, 30 times more than in small, natural lakes, and over 400 times greater than in inland seas and large natural lakes (Mulholland and Elwood, 1982; Dean and Gorham, 1998). The combined water surface area of small impoundments in farming areas was estimated at 21,000 km² in the United States and 77,000 km² globally (Smith et al., 2002; Downing et al., 2006), and these impoundments may bury more carbon than the world's oceans (Downing et al., 2008).

The area of agriculturally-eutrophic impoundments used for estimating carbon sequestration (Downing et al., 2008) did not include aquaculture ponds. According to statistical data on aquaculture production maintained by the Food and Agriculture Organization (FAO) of the United Nations, there are 110,830 km² of aquaculture ponds worldwide (Verdegem and Bosma, 2009). Aquaculture ponds also may be important in global, carbon sequestration.

Aquaculture ponds do not have large external sediment loads typical of river reservoirs or small, watershed ponds in agricultural or other rural areas (Boyd, 1995). However, earthwork of aquaculture ponds is eroded by rain, waves, and water currents generated by mechanical aerators, activities of culture species, and harvesting operations. Manure, grass, and other agricultural wastes traditionally have been applied to ponds as organic fertilizer to increase aquatic animal production, but high-quality, pelleted feeds are rapidly replacing fertilizers as a means of achieving greater production (Boyd and Tucker, 1998). Fertilizers and feeds contain inorganic nutrients that stimulate organic carbon production by phytoplankton photosynthesis in ponds (Boyd and Tucker, 1998).

Coarse, soil particles suspended by internal erosion settle near edges of ponds while smaller particles tend to settle in deeper areas (Boyd, 1995). Organic matter from dead plankton, organic fertilizers, uneaten feed, and excrement of culture species settles on pond bottoms and gradually

mixes with soil particles. Aquaculture management favors microbial decomposition of organic matter. For example, organic matter inputs usually have a narrow carbon: nitrogen ratio, ponds with acidic, bottom soils are limed, and mechanical aeration avoids oxygen-depletion at the sediment-water interface (Boyd and Tucker, 1998). Much recently-settled organic detritus is discharged when ponds are drained for harvest (Ayub et al., 1993). After draining, pond bottoms usually are dried to enhance soil aeration and accelerate decomposition of labile organic matter (Boyd, 1995). Nevertheless, a layer of sediment with an organic carbon concentration higher than that of the original pond bottom soil and with a characteristic profile of well-defined strata or horizons develops (Munsiri et al., 1995).

AQUAFISH RESEARCH REPORT 10-A01

SMALL SCALE FISHERIES MANAGEMENT: LESSONS FROM COCKLE HARVESTERS IN NICARAGUA AND TANZANIA

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Published in:

Coastal Management (2010) 38: 195-215.

The role of women in gleaning fisheries tends to be underestimated and poorly documented although they play an important role in coastal food security and income generation. This article describes two initiatives for co-management of women dominated cockle (*Anadara spp.*) fisheries implemented in Zanzibar Island of Tanzania and in Nicaragua that were based on a Fiji model. In each case, significant progress was made at the pilot scale but required adaptation to the community and national context. The Nicaragua case resulted in increasing densities of cockles inside and outside small scale no-take zones in a small estuary after a two-year period of implementation. In Zanzibar, out of several no-take sites established on reef flats, only one showed similar results. Other sites' poor performance is likely due to poor site selection, small size, and non-compliance. Varying degrees of poaching affected both locations and continues to be an issue. In Zanzibar, local and national government played highly supporting roles whereas in Nicaragua, local government was supportive but national government continues to exhibit top-down decision-making, while still evaluating the alternative co-management approach. In both cases, university extension initiatives were influential in building community capacity for management and playing an advocacy role with national government. Both locations are poised for scaling up to more geographic sites as well as fostering policy change that can lead to more integrated and ecosystem-scale approaches to sustainable fisheries management.

AQUAFISH RESEARCH REPORT 10-A02

HAEMATOLOGICAL AND BIOCHEMICAL CHARACTERISTICS OF TWO AQUACULTURED CARNIVOROUS CYPRINIDS, TOPMOUTH CULTER (*CULTER ALBURNUS*) AND YELLOW CHEEK CARP (*ELOPICHTHYS BAMBUSA*).

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Published in:

Aquaculture Research (2010) 41: 1331-1338.

The haematological and biochemical characteristics of two healthy farmed cyprinids, the topmouthculter *Culter alburnus* and yellowcheek carp *Elopichthys bambusa*, were investigated in this study. Erythro- cytes, thrombocytes, lymphocytes, monocytes and granulocytes (i.e. neutrophils and eosinophils) were observed in these two fish. Every type of these cells (excluding the erythrocyte and lymphocyte) showed similar sizes in the topmouth culter and yellowcheek carp. Thrombocytes and neutrophils were the two most abundant leucocytes in the topmouth culter while thrombocytes and lymphocytes were the two most frequent leucocytes observed in the yellow- cheek carp. The erythrocyte counts, hemoglobin concentrations and values of serumglucose in these two fish were high. There were significant differences in the leucocyte counts, haemoglobin concentrations, mean cellular haemoglobin contents, mean cell haemoglobin concentrations and values of serum glucose, triglyceride, total bilirubin, alkaline phosphatase and chlorine between the topmouth culter and the yellowcheek carp. The information of hematology and blood biochemistry obtained here would be useful for the prevention and diagnosis of diseases of farmed topmouth culter and yellowcheek carp.

AQUAFISH RESEARCH REPORT 10-A03

REPRODUCTIVE VARIATION IN WILD FEMALES OF *CENTROPOMUS PARALLELUS* BY USING THE DIAMETER OF OOCYTES

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Published in:

Aquaculture Research (2010) 41: 1331-1338.

The present paper describes the variation in reproductive females *Centropomus parallelus* using oocyte diameter along the sampling time; the maturity thereof shall be determined and this value was used as an indicator to apply hormone treatments and induce spawning. It was determined that the breeding season for the people of Tabasco coast this species occurs from October to March, being the ideal month for spawning induction by observing females with average diameters of oocytes 426.07 ± 37.54 microns March. For the month of October diameters smaller oocytes with 324.86 ± 105.02 microns were observed.

AQUAFISH RESEARCH REPORT 10-A04

RELEVANCE ANALYSIS OF ORGANIC POLLUTANTS PARAMETERS IN PONDS OF *LITOPENAEUS VANNAMEI* CULTURING.

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Published in:

Freshwater Fisheries (2010) 40(2): 67-69.

Organic contents in fourteen ponds of a *Litopenaeus vannamei* culturing farm in Fengxian District of Shanghai were investigated during two aquaculture cycles from April to September in 2009. Total organic carbon (TOC), Chemical oxygen demand (CODMn), and Biological oxygen demand (BOD₅) were analyzed respectively. The results showed that BOD₅ were (8.62±3.08) mg/L and (10.47±3.87) mg/L in the two cycles of April to July and July to September respectively, CODMn were (13.09±3.98) mg/L and (16.16±6.07) mg/L, while TOC were (17.60±5.91) mg/L and (20.32±6.07) mg/L. TOC/CODMn were 1.35±0.22 and 1.32±0.30, and TOC/BOD₅ were 2.10±0.44 and 2.08±0.63, while BOD₅/CODMn were 0.66±0.13 and 0.65±0.11. Significant relationships lied among the three water quality parameters. Linear regression equations and related coefficients were as follows. In cycle 1: BOD₅=0.4174TOC+1.2777, r=0.8022. CODMn=0.5616TOC+3.2091, r=0.8342. BOD₅=0.6264CODMn+0.4209, r=0.8106. In cycle 2: BOD₅=0.4764TOC+0.7902, r=0.7480. CODMn=0.7941TOC+0.0237, r=0.7962. BOD₅=0.568CODMn+1.2912, r=0.8920. The results showed that the equations established among TOC, COD and BOD₅ could be used to calculate the other two parameters if anyone of them had been measured so that further comparison with some water quality standards or correlated researches could be carried out, which would benefit water quality management and healthy culturing of *L.vannamei*.

AQUAFISH RESEARCH REPORT 10-A05

MULTIVARIATE STATISTICAL ANALYSIS OF CHLOROPHYLL-A AND WATER QUALITY PARAMETERS IN PONDS OF *LITOPENAEUS VANNAMEI* CULTURING.

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Published in:

Journal of Fisheries of China (2010) 34(11): 1712-1718.

Water quality parameters in 22 ponds of a *Litopenaeus vannamei* culture farm in Fengxian District of Shanghai were investigated from April to September in 2009. Fifteen parameters including chlorophyll-a (*Chl. a*), temperature, pH, dissolved oxygen (DO), transparency, suspended substance (SS), total organic carbon (TOC), biological oxygen demand (BOD₅), chemical oxygen demand (COD_{Mn}), nitrite nitrogen (NO₂-N), nitrate nitrogen (NO₃-N), ammonia nitrogen (NH₃-N), total nitrogen (TN), active phosphorus (PO₄³⁻-P) and total phosphorus (TP) were determined. Descriptive statistics was conducted and the correlation between *Chl. a* and other parameters was analyzed. The statistical analysis results showed that *Chl. a* had extremely significantly linear positive correlation with SS, TOC, BOD₅, COD_{Mn}, TN and TP. Significantly linear positive correlation existed between *Chl. a* and DO. Extremely significantly linear negative correlation was confirmed between *Chl. a* and transparency while *Chl. a* had significantly linear negative correlation with PO₄³⁻-P. *Chl. a* had no significant correlation with water temperature, pH, NO₂-N, NO₃-N and NH₃-N. According to the principles of selecting independent variables in the multiple linear regression analysis, four water quality parameters including TOC, TN, PO₄³⁻-P and TP were used for establishing the stepwise regression model which was $Chl. a = -0.0545 + 0.00349 TOC + 0.0153 TN - 0.418 PO_4^{3-} - P + 0.276 TP$ ($r = 0.7155$). The effects of these four factors on *Chl. a* were tested using the partial regression coefficient. The most influential water quality parameter on *Chl. a* were TP and then TOC, PO₄³⁻-P, TN in turn. The results would help further study on ecological rules and water environmental protection in aquaculture ponds.

AQUAFISH RESEARCH REPORT 10-A06

STUDY ON NITROGEN AND PHOSPHORUS BUDGETS AND PRODUCTION PERFORMANCE IN HIGHER-PLACE POND OF *LITOPENAEUS VANNAMEI*.

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Published in:

South China Fisheries Science (2010) 5: 13-20

Nitrogen and phosphorus budgets in the higher-place ponds of *Litopenaeus vannamei* were studied systematically to investigate the effects of stocking seasons, shrimp larvae strains and grading culture on shrimp production. Results indicate that feed is the main source of nitrogen and phosphorus inputs, accounting for 91.76%~93.68% and 94.55%~96.97% of total inputs, respectively, while 29.46%~40.46% of total nitrogen and 12.64%~17.41% of total phosphorus were deposited into harvested shrimp; 24.63%~54.52% of total nitrogen and 23.03%~59.02% of total phosphorous were discharged into effluent; 14.10%~44.59% of total nitrogen and 27.59%~62.25% of total phosphorous were accumulated in pond sediment. Shrimp production is significantly affected by different stocking seasons and shrimp larvae strains. The average growth rate of trial ZS in summer reaches $0.175 \text{ g} \cdot \text{d}^{-1}$, which is 73.0% and 139.3% higher than that of trial ZF in fall and trial ZW in winter, respectively. The survival of ZW is 77.70%~87.75%, which is significantly higher than that of ZS and ZF. Compared with ZW stocked at the same season, the survival of trial BW is 62.10%~72.30% with yield per unit area of 8 821~9 878 $\text{kg} \cdot \text{hm}^{-2}$, which are both significantly low. Trial ZWb of grading cultured shortens the culture cycle by 56.13%.

AQUAFISH RESEARCH REPORT 10-A07

CURRENT SITUATION AND CHALLENGES FOR FARMING OF SNAKEHEAD FISH (*CHANNA MICROPELTES* AND *CHANNA STRIATUS*) IN THE MEKONG DELTA, VIETNAM

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Published in:

Sustainable Aquaculture (2010) 15(4): 11-17.

Fish culture in ponds and cages is very common in freshwater areas of the Mekong Delta of Vietnam, where aquaculture plays a very important role in national fisheries production. The farming of giant snakehead began in the 1960s while the culture of common snakehead occurred since the mid 1990s. There are two groups of snakehead, that is, *Parachanna* and *Channa*. The *Channa* group is recorded to have 27 species and distributed in most of the Asian countries while *Parachanna* are mainly distributed in Africa, with three species, only. There are four species of Channidae in the Mekong Delta: *Channa gachua* (Ca Chanh duc), *Channa lucius* (Ca Day), *Channa striata* (Ca loc den), *Channa micropeltes* (Ca loc bong) (Khoa & Huong, 1993). However, two species - Ca loc den or Common snakehead (*C. striata*), and Ca loc bong (*C. micropeltes*) - are the main species of snakehead farmed in the delta. In Asian countries snakehead is cultured in semi-intensive or intensive systems in earthen ponds, cages, garden ditches and rice fields (Ling, 1997; Xuan et al., 1994). Long et al. (2004) estimated the production of cultured snakehead in the MKD in 2002 to be about 5,300 tonnes, mainly from An Giang, Dong Thap, Can Tho and Kien Giang provinces. Our estimated production of snakehead from the provinces in 2009 was about 30,000 tones, of which 7,500 tones was giant snakehead. All of the snakehead fish farmers surveyed in this study practiced aquaculture spontaneously at a small scale without any planning or sector management. However, the information on snakeheads is not much available (Huan, 2007) while there are many issues which need to be solved, in particular, dependence on the supply of small fish which are used for snakehead feed is an important source of animal protein for a significant proportion of population in the delta. It should be noted that there are three typical geographical conditions in freshwater areas of the delta by annual flood level, that is, deep flooded areas (more than 2 m depth in the peak of floods), medium flooded area (1-2 m depth), and shallow flooded area (less than 2 m depth). The wild fish stocks and fishing activities may differ in these areas.

AQUAFISH RESEARCH REPORT 10-A08

DISORDERS OF DEVELOPMENT IN FISH (CHAPTER 5)

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Published in:

J.F. Leatherland, and P.T.K. Woo (Editors), 2010. *Fish Diseases and Disorders, 2: Non-Infectious Disorders, 2nd edition*. CAB International, Wallingford: 166-181.

Among physical deformities in fish, skeletal, gill and fin malformations are most common, and they can range from barely detectable to lethal. With few exceptions, the motivation among fish growers to eliminate physical malformations is strong; at the very least these deformities reduce the market value of aquaculture crops. At worst, they can cause the loss of an entire cohort. The search for definitive information about the causes of deformities in fish leads us in several directions – some genetic configurations can increase the susceptibility to physical and developmental malformations, but in other cases morphologically similar deformities are clearly not heritable. Slight aberrations in the rearing environment, e.g. temperature, water flow rate or diet, can trigger high rates of deformities in a clutch of fish. Occasionally, associations are made between handling stress and an elevated incidence of deformities, suggesting that stress can disrupt a genetically predetermined plan of development. The sum of the available evidence suggests that certain fishes are more susceptible to environmentally induced aberrations of development than are others. In other words, some species appear to adapt relatively well to captive rearing and may be more suitable for culture and domestication than others. This is not surprising, considering the widely varying degrees to which other animals adjust to captivity and the relatively small fraction that have adapted well. In the 12 years that have elapsed since the publication of an earlier edition of this volume, the basic assortment of deformities commonly ascribed to fish has not changed appreciably, and to a large extent our understanding of the causes ontogeny of these patterns is not much more detailed than it was then. Some of the patterns of developmental deformities in fish have become clearer, and some associative trends are more apparent than they were earlier. Nevertheless, the differentiation of basic deformities in developing fish is still only superficially understood, in large measure because this remains a relatively poorly studied topic [Note: First two paragraph of introduction.]

AQUAFISH RESEARCH REPORT 10-A09

DISORDERS OF DEVELOPMENT IN FISH

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Published in:

J.F. Leatherland, and P.T.K. Woo (Editors), 2010. *Fish Diseases and Disorders, 2: Non-Infectious Disorders, 2nd edition*. CAB International, Wallingford: 166-181.

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AQUAFISH RESEARCH REPORT 10-A10

THE EFFECT OF THE INTRODUCTION OF NILE TILAPIA (*OREOCHROMIS NILOTICUS*, L.) ON SMALL INDIGENOUS FISH SPECIES (MOLA, *AMBLYPHARYNGODON MOLA*, HAMILTON; CHELA, *CHELA CACHIUS*, HAMILTON; PUNTI, *PUNTIUS SOPHORE*, HAMILTON)

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Published in:

Aquaculture Research, (2010) 41: 904-912.

This is the first controlled experiment to quantify the effect of introduced tilapia on indigenous species. This experiment was conducted in small earthen ponds (100m²) to assess the impact of mixed-sex or all-male Nile tilapia (*Oreochromis niloticus*) on small indigenous species (SIS) commonly found in south Asia, mola (*Amblypharyngodon mola*), chela (*Chela cachius*) and punti (*Puntius sophore*). Ponds were fertilized, then stocked with 0.56 fish m⁻² of water surface area in the mixed-sex and all-male tilapia treatments and 0.42 fish m⁻² in the treatment without tilapia. No additional nutritional inputs were applied after stocking. Treatments were: mixed-sex tilapia with SIS, mono-sex male tilapia with SIS and SIS without tilapia (control). All treatments were stocked with 14 fish per species. All species reproduced during the 21-month culture duration. The number of recruits varied by species, Tilapia reproduced in greater numbers than SIS. Tilapia numbers at harvest were the highest (451 ± 25/100 m²) in the mixed-sex treatment compared with mola (221 ± 22/100 m²), chela (94 ± 8/100 m²) and punti (100 ± 7/100 m²). The number of mola was higher (399 ± 33/100 m²) in the all-male tilapia treatment. There was reduction in the number of mola and chela in the treatment containing mixed-sex tilapia. Gut content analysis combined with water sampling revealed that all fish species fed selectively. Significant interspecies dietary overlap was found between Nile tilapia and SIS and among SIS. Thus, there is potential for tilapia to compete with indigenous fish species when space and other resources are limiting, but a longer duration study with varying level of management is needed to determine how successfully tilapia competes with locally adapted SIS.

AQUAFISH RESEARCH REPORT 10-A11

EFFECTS OF SELECTIVE HARVESTING AND CLAW ABLATION OF ALL-MALE FRESHWATER PRAWN (*MACROBRACHIUM ROSENBERGII*) ON WATER QUALITY, PRODUCTION AND ECONOMICS IN POLY CULTURE PONDS

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Published in:

Aquaculture Research (2010) 41(10): e404-e417.

The effects of selective harvesting (SH) and claw ablation (CA) of blue-clawed (BC) prawns on an all-male freshwater prawn-finfish polyculture system were compared with control (Co) in quadruplicate. Ponds were stocked with all-male freshwater prawn *Macrobrachium rosenbergii*, silver carp *Hypophthalmichthys molitrix*, catla *Catla catla* and mola *Amblypharyngodon mola* at 12000, 2000, 500 and 20 000 ha⁻¹ respectively. Prawns were fed with pelleted feed. Ponds were fertilized regularly with urea, triple super phosphate and cow-dung. SH of BC prawns in treatment SH and CA in treatment CA started on the 60th day during a 137-day culture and continued at 15-day intervals until the final harvest. Water quality parameters and plankton abundance did not vary significantly ($P > 0.05$) among the treatments. Treatment SH resulted in a higher ($P < 0.05$) net production of freshwater prawn (437 kg ha⁻¹), with better survival and mean weight, followed by CA (354 kg ha⁻¹) and Co (322 kg ha⁻¹). The combined net production of prawn plus finfish was also higher in SH (1244 kg ha⁻¹) as compared with CA (1161 kg ha⁻¹) and Co (1137 kg ha⁻¹), although the finfish production did not differ significantly. The periodic SH of BC prawns showed a better economic return with a BCR of 1.71.

AQUAFISH RESEARCH REPORT 10-A12

AQUACULTURE RESEARCH AND DEVELOPMENT AS AN ENTRY-POINT AND CONTRIBUTOR TO
NATURAL RESOURCES AND COASTAL MANAGEMENT

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Published in:

Coastal Management (2010) 38(3): 238-261.

Recent, fervent international dialogue concerning the existence and magnitude of impacts associated with aquaculture has had both positive and negative outcomes. Aquaculture stakeholders have become sensitized to requirements for improved environmental management of aquaculture. On the other hand, in some cases aquaculture development has been negatively affected by some of the unwarranted and unproved allegations to the detriment of the stakeholders most in need of aquaculture development (i.e., resource users, particularly the poor, who are dependent on natural resources). These resource users are targeted by, and directly influence biodiversity and conservation agendas; hence the need to understand how to gain their active participation. This discussion focuses on examples of how aquaculture research and development can be a useful tool or strategy for resource management initiatives and provide tangible positive including increased stakeholder participation and cooperation, offering alternatives to resource extraction and use in otherwise difficult or intransigent resource management conflicts.

AQUAFISH RESEARCH REPORT 10-A13

VARIACIÓN REPRODUCTIVA EN HEMBRAS SILVESTRES DE CHUCUMITE *CENTROPOMUS PARALLELUS* MEDIANTE EL EMPLEO DEL DIÁMETRO DE OVOCITOS

Contreras García María de Jesús¹, Contreras-Sánchez Wilfrido M., Mcdonal-Vera Alejandro, Hernández-Vidal Ulises, Vidal López Juan Manual, Álvarez-González Carlos A., Páramo-Delgadillo Salomón

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Published in:

Revisa de Divulgación: División Académica de Ciencias Biológicas. (2010) 17(31): 49-54.

En el presente trabajo se describe la variación reproductiva en hembras de *Centropomus parallelus* empleando el diámetro de ovocitos a lo largo del tiempo de muestreo; se determinó el grado de madurez de los mismos y se usó este valor como indicador para aplicar tratamientos hormonales e inducer desoves. Se determinó que la temporada reproductiva para las poblaciones de la costa de Tabasco de esta especie se presenta de octubre a marzo, siendo el mes de marzo ideal para la inducción a desoves al observar hembras con diámetros promedio de ovocitos de $426.07 \pm 37.54 \mu\text{m}$. Para el mes de octubre se observaron los diámetros de ovocitos más pequeños con $324.86 \pm 105.02 \mu\text{m}$.

AQUAFISH RESEARCH REPORT 11-270

DEVELOPMENT OF DIGESTIVE ENZYMES IN LARVAE OF MAYAN CICHLID *CICHLASOMA UROPHTHALMUS*

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Published in:

Fish Physiology and Biochemistry (2011) 37: 197-208.

The development of digestive enzymes during the early ontogeny of the Mayan cichlid (*Cichlasoma urophthalmus*) was studied using biochemical and electrophoretic techniques. From yolk absorption (6 days after hatching: dah), larvae were fed *Artemia nauplii* until 15 dah, afterward they were fed with commercial microparticulated trout food (45% protein and 16% lipids) from 16 to 60 dah. Several samples were collected including yolk-sac larvae (considered as day 1 after hatching) and specimens up to 60 dah. Most digestive enzymes were present from yolk absorption (5–6 dah), except for the specific acid proteases activity (pepsinlike), which increase rapidly from 8 dah up to 20 dah. Three alkaline proteases isoforms (24.0, 24.8, 84.5 kDa) were detected at 8 dah using SDS–PAGE zymogram, corresponding to trypsin, chymotrypsin and probably leucine aminopeptidase enzymes, and only one isoform was detected (relative electromobility, $R_f = 0.54$) for acid proteases (pepsin-like) from 3 dah onwards using PAGE zymogram. We concluded that *C. urophthamus* is a precocious fish with a great capacity to digest all kinds of food items, including artificial diets provided from 13 dah.

AQUAFISH RESEARCH REPORT 11-271

EFFECTS OF *MICROCYSTIS AERUGINOSA* ON LIFE HISTORY OF WATER FLEA *DAPHNIA MAGNA*

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Published in:

Chinese Journal of Oceanology and Limnology (2011) 29(4): 892-897.

Cyanobacterial blooms in eutrophic freshwater systems are a worldwide problem, creating adverse effects for many aquatic organisms by producing toxic microcystins and deteriorating water quality. In this study, microcystins (MCs) in *Microcystis aeruginosa*, and *Daphnia magna* exposed to *M. aeruginosa*, were analyzed by HPLC-MS, and the effects of *M. aeruginosa* on *D. magna* were investigated. When *D. magna* was exposed to *M. aeruginosa* for more than 2 h, Microcystin-LR (MC-LR) was detected. When exposed to 1.5×10^6 , 3×10^6 , 0.75×10^7 , and 1.5×10^7 cell/mL of *M. aeruginosa* for 96 h, average survival of *D. magna* for treatments were 23.33%, 33.33%, 13.33%, 16.67%, respectively, which were significantly lower than the average 100% survival in the control group ($P < 0.05$). The adverse effects of *M. aeruginosa* on body length, time for the first brood, brood numbers, gross fecundity, lifespan, and population growth of *D. magna* were density-dependent. These results suggest that the occurrence of *M. aeruginosa* blooms could strongly inhibit the population growth of *D. magna* through depression of survival, individual growth and gross fecundity. In the most serious situations, *M. aeruginosa* blooms could undermine the food web by eliminating filter-feeding zooplankton, which would destroy the ecological balance of aquaculture water bodies.

AQUAFISH RESEARCH REPORT 11-272

PHYSIOLOGICAL AND BIOCHEMICAL RESPONSES OF NILE TILAPIA (*Oreochromis niloticus*)
EXPOSED TO AQUEOUS EXTRACTS OF NEEM (*Azadirachta indica*)

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Published in:

Journal of Applied Aquaculture (2011) 23(2): 177-186.

In this study, the physiological and biochemical response of Nile tilapia (*Oreochromis niloticus*) after 96 and 24 h exposure to aqueous extracts of neem (*Azadirachta indica*) in extract concentrations ranging from 0 to 32,000 mg/l was evaluated. After 96 h and 24 h exposure, the LC₅₀ of neem extract was estimated at 3,200 and 6,800 mg/l, respectively. Plasma cortisol increased beyond pre-treatment levels at neem extract concentrations above 2,000 mg/l over 96 h and above 4,000 mg/l over 24 h. Blood glucose increased at neem extract concentrations above 1,000 and 5,000 mg/l at 24 and 96 h, respectively. Neem extract concentration had little effect on serum sodium and plasma chloride. Hematocrit was higher than the control at neem concentrations above 1,000 mg/l in the 96 h exposure and above 2,000 mg/l in the 24 h exposure. Plasma ammonia increased significantly at neem extract concentrations above 2,000 mg/l for both the 96h and 24h tests. Immediately after beginning treatment, cortisol levels increased significantly at neem extract concentrations above 2,000 mg/l in the 96 h test and 4,000 mg/l in the 24 h toxicity test. Exposure to neem extract interfered with the antioxidant defense system of the fish by reducing liver catalase activity. Even though extracts of neem are less toxic at low concentrations, concentrations exceeding 3,200 mg/l influence physiological and biochemical disturbances in fish.

AQUAFISH RESEARCH REPORT 11-273

LIFE CYCLE ASSESSMENT OF CHINESE SHRIMP FARMING SYSTEMS TARGETED FOR EXPORT AND DOMESTIC SALES

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Published in:

Environmental Science & Technology (2011) 45(15): 6531-6538.

We conducted surveys of six hatcheries and 18 farms for data inputs to complete a cradle- to-farm-gate life cycle assessment (LCA) to evaluate the environmental performance for intensive (for export markets in Chicago) and semi-intensive (for domestic markets in Shanghai) shrimp farming systems in Hainan Province, China. The relative contribution to overall environmental performance of processing and distribution to final markets were also evaluated from a cradle-to-destination-port perspective. Environmental impact categories included global warming, acidification, eutrophication, cumulative energy use, and biotic resource use. Our results indicated that intensive farming had significantly higher environmental impacts per unit production than semi-intensive farming in all impact categories. The grow-out stage contributed between 96.4% and 99.6% of the cradle-to-farm- gate impacts. These impacts were mainly caused by feed production, electricity use, and farm-level effluents. By averaging over intensive (15%) and semi-intensive (85%) farming systems, 1 metric ton (t) live-weight of shrimp production in China required 38.3 ± 4.3 GJ of energy, as well as 40.4 ± 1.7 t of net primary productivity, and generated 23.1 ± 2.6 kg of SO₂ equiv, 36.9 ± 4.3 kg of PO₄ equiv, and 3.1 ± 0.4 t of CO₂ equiv. Processing made a higher contribution to cradle-to-destination- port impacts than distribution of processed shrimp from farm gate to final markets in both supply chains. In 2008, the estimated total electricity consumption, energy consumption, and greenhouse gas emissions from Chinese white-leg shrimp production would be 1.1 billion kW-h, 49 million GJ, and 4 million metric tons, respectively. Improvements suggested for Chinese shrimp aquaculture include changes in feed composition, farm management, electricity-generating sources, and effluent treatment before discharge. Our results can be used to optimize market-oriented shrimp supply chains and promote more sustainable shrimp production and consumption.

AQUAFISH RESEARCH REPORT 11-274

POLYCULTURE OF SAHAR (*TOR PUTITORA*) WITH MIXED-SEX NILE TILAPIA

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Published in:

Aquaculture (2011) 319: 284-289.

Sahar (*Tor putitora*) is an economically important indigenous fish in Nepal, with major efforts to conserve and propagate the species. It is a predator and may function to control recruitment by naturally produced Nile tilapia (*Oreochromis niloticus*) in ponds. Sahar (*Tor putitora*) were cultured with Nile tilapia (*Oreochromis niloticus*) to evaluate control of tilapia recruitment in aquaculture ponds. Two experiments were conducted to assess the effects of the sahar to tilapia stocking ratio on the recruitment and growth of mixed-sex Nile tilapia. The first experiment was conducted in 100 m² earthen ponds at the Institute of Agriculture and Animal Science, Chitwan, Nepal to determine these effects. The second experiment was conducted on farm at Kathar, Chitwan, Nepal to verify the results in working ponds. The on-station experiment had four treatments with three replicates each: tilapia monoculture (T₁), 1:16 sahar to tilapia ratio (T₂), 1:8 sahar to tilapia ratio (T₃), and 1:4 sahar to tilapia ratio (T₄). Tilapia were stocked at 2 fish m⁻² (average size 11.3 g), and sahar were stocked at treatment densities (15.2 g average size) in each pond. The ponds were fertilized weekly using diammonium phosphate (DAP) and urea at the rate of 0.1 g P m⁻² d⁻¹ and 0.4 g N m⁻² d⁻¹ respectively. Tilapia were fed with a locally made pelleted feed (27% crude protein), at the rate of 2% body weight every other day after attaining a size of 100 g. Results showed significantly increased average harvest size ($P < 0.05$) for treatment 2, when sahar were stocked with tilapia compared to the tilapia monoculture. The number of recruits significantly decreased ($P > 0.05$) when sahar were stocked, and recruit numbers were inversely proportional to stocking density of sahar. Stocking of sahar reduced tilapia recruitment in a mixed-sex Nile tilapia pond culture system and produced better tilapia growth and production. Stocking at a 1:16 sahar to tilapia ratio gave the best overall performance.

The on-farm experiment was composed of three treatments with three replicates each: tilapia monoculture (T₁), 1:33 sahar to tilapia ratio (T₂), and 1:16 sahar to tilapia ratio (T₃). Ponds were fertilized every two weeks with DAP and urea at the same rate as on-station experiment, but there was no feeding. On-farm results showed significantly higher tilapia growth with a 1:33 stocking ratio of sahar to tilapia compared to tilapia monoculture. As with the on-station experiment, the number of recruits decreased with increasing stocking density of sahar. Lower sahar stocking provided higher growth and production of stocked tilapia, though there were fewer recruits at these levels. There might have some growth depression of tilapia at higher sahar stocking densities. Stocking sahar to Nile tilapia at 1:33 showed better overall performance than monoculture but not the 1:16 treatment in terms of Nile tilapia growth, production, growth of sahar and gross income.

AQUAFISH RESEARCH REPORT 11-275

THE DANGERS OF MICROCYSTINS IN AQUATIC SYSTEMS AND PROGRESS OF RESEARCH INTO THEIR DETECTION AND ELIMINATION

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Published in:

World Aquaculture (2011) 42(2): 53-57, 69

Microcystins (MC) are secondary metabolites of toxic cyanobacteria. The algae and metabolites often combine to cause strong discoloration of the water, accumulation at the surface in discrete scums and sometimes emit a strong odor (Figure 1, Figure 2A, Cai *et al.* 1997, Liang *et al.* 2001, Zurawell *et al.* 2005). MC belong to a family of extremely toxic compounds and are a health hazard to aquatic animals and even humans (Ding *et al.* 1998, 1999, Falconer 1991, Hernandez *et al.*, 2000, Lawton *et al.* 1994). Researchers have identified blooms of cyanobacteria from eutrophic freshwater bodies in many parts of the world, and their occurrence can create a major water quality problem. For example, massive fish kills occasionally have been related to severe cyanobacterial blooms. Chronic damages, such as development of liver tumors may arise from long-term exposure to low concentrations of MC (Chen *et al.* 2006, Ding *et al.* 1998, 1999, Ibelings and Chorus 2007, Lankoff *et al.* 2004, Li *et al.* 2007, Shen *et al.* 2003, Smith and Haney 2006, Zimba *et al.* 2006).

AQUAFISH RESEARCH REPORT 11-276

DIFFERENTIAL EFFECTS OF CORTISOL AND 11-DEOXYCORTICOSTERONE ON ION TRANSPORT PROTEIN mRNA LEVELS IN GILLS OF TWO EURYHALINE TELEOSTS, MOZAMBIQUE TILAPIA (*Oreochromis mossambicus*) AND STRIPED BASS (*Morone saxatilis*)

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Published in:

Journal of Endocrinology (2011) 209: 115-126.

The role of cortisol as the only corticosteroid in fish osmoregulation has recently been challenged with the discovery of a mineralocorticoid-like hormone, 11-deoxycorticosterone (DOC), and necessitates new studies of the endocrinology of osmoregulation in fish. Using an in vitro gill explant incubation approach, DOC-mediated regulation of selected osmoregulatory target genes in the gill was investigated and compared with that of cortisol in two euryhaline teleosts, Mozambique tilapia (*Oreochromis mossambicus*) and striped bass (*Morone saxatilis*). The effects were tested in gills from both fresh water (FW)- and seawater (SW)-acclimated fish. Both cortisol and DOC caused an up-regulation of the Na⁺, K⁺-ATPase α 1 subunit in SW-acclimated tilapia but had no effect in FW-acclimated fish. Cortisol conferred an increase in Na⁺, K⁺, 2Cl⁻ cotransporter (NKCC) isoform 1a transcript levels in FW- and SW-acclimated tilapia, whereas DOC had a stimulatory effect only in SW-acclimated fish. Cortisol had no effect on NKCC isoform 1b mRNA levels at both salinities, while DOC stimulated this isoform in SW-acclimated fish. In striped bass, cortisol conferred an up-regulation of Na⁺, K⁺-ATPase α 1 and NKCC transcript levels in FW- and SW-acclimated fish, whereas DOC resulted in down-regulation of these transcripts in FW-acclimated fish. It was also found that both corticosteroids may rapidly (30 min) alter the mitogen-activated protein kinase signaling pathway in gill, inducing phosphorylation of extracellular signal regulated kinase 1 (ERK1) and ERK2 in a salinity-dependent manner. The study shows a disparate organization of corticosteroid signaling mechanisms involved in ion regulation in the two species and adds new evidence to a role of DOC as a mineralocorticoid hormone in teleosts.

AQUAFISH RESEARCH REPORT 11-277

ANATOMICAL AND HISTOLOGICAL CHARACTERISTICS OF THE INTESTINE OF THE TOPMOUTH
CULTER (*CULTER ALBURNUS*)

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Published in:

Anatomia Histologia Embryologia: Journal of Veterinary Medicine (2011) 40: 292-298.

Topmouth culter (*Cuiter alburnus*), a freshwater carnivorous fish of the *Cyprinidae*, is one of the most popular fish species in aquatic market in China. The anatomy and histology features of fish intestine are very useful for understanding digestive physiology, diagnosing some intestinal diseases and formulating suitable feeds. Thus, here we first characterize topmouth culter intestine via light microscope, transmission electron microscope and scan electron microscope. The 'Z' shaped intestine can be divided into three parts (e.g. the anterior intestine, middle intestine and posterior intestine), with an intestinal coefficient of 0.68. The anterior intestine possessed the longest mucosa folds and thickest muscularis among the three intestinal parts, and microvilli were very well-developed whilst many mitochondria, endoplasmic reticuli and lysosomes were found in which. This indicated the anterior intestine was a main region for digestion and absorption of food in the topmouth culter. While the vacuoles observed in the posterior intestine may be closely related to the intracellular digestion. Neutral and acid mucus were strongly present throughout the intestine. This detailed descriptive paper will be very helpful for studies of topmouth culter related to its digestive physiology, intestinal disease control and feed nutrient.

AQUAFISH RESEARCH REPORT 11-278

EFFECTS OF *MICROCYSTIS AERUGINOSA* ON LIFE HISTORY OF WATER FLEA *DAPHNIA MAGNA*

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Published in:

Chinese Journal of Oceanology and Limnology (2011) 29(4): 892-897. DOI: [10.1007/s00343-011-0518-4](https://doi.org/10.1007/s00343-011-0518-4)

Cyanobacterial blooms in eutrophic freshwater systems are a worldwide problem, creating adverse effects for many aquatic organisms by producing toxic microcystins and deteriorating water quality. In this study, microcystins (MCs) in *Microcystis aeruginosa*, and *Daphnia magna* exposed to *M. aeruginosa*, were analyzed by HPLC-MS, and the effects of *M. aeruginosa* on *D. magna* were investigated. When *D. magna* was exposed to *M. aeruginosa* for more than 2 h, Microcystin-LR (MC-LR) was detected. When exposed to 1.5×10^6 , 3×10^6 , 0.75×10^7 , and 1.5×10^7 cell/mL of *M. aeruginosa* for 96 h, average survival of *D. magna* for treatments were 23.33%, 33.33%, 13.33%, 16.67%, respectively, which were significantly lower than the average 100% survival in the control group ($P < 0.05$). The adverse effects of *M. aeruginosa* on body length, time for the first brood, brood numbers, gross fecundity, lifespan, and population growth of *D. magna* were density-dependent. These results suggest that the occurrence of *M. aeruginosa* blooms could strongly inhibit the population growth of *D. magna* through depression of survival, individual growth and gross fecundity. In the most serious situations, *M. aeruginosa* blooms could undermine the food web by eliminating filter-feeding zooplankton, which would destroy the ecological balance of aquaculture water bodies.

AQUAFISH RESEARCH REPORT 11-279

PROFITABILITY ANALYSIS OF SMALL-SCALE AQUACULTURE ENTERPRISES IN CENTRAL UGANDA

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Published in:

International Journal of Fisheries and Aquaculture (2011) 2(15): 271-278.

The study had three overriding objectives. Firstly, to assess the profitability of small-scale aquaculture production enterprises in central Uganda; secondly, to ascertain the factors affecting profitability; and thirdly, to identify the constraints to fish farming in the region. The data were collected through a survey questionnaire administered to a random sample of 200 small scale fish farmers in the three major fish farming districts of Mpigi, Mukono and Wakiso in central Uganda. The analysis was carried out using descriptive statistics, enterprise budgeting and ordinary linear regression. Although the results show small-scale aquaculture enterprises to be profitable in the study region, the estimated profit margins are relatively small. Farming experience, fish price, record keeping, feed cost and volume of fish harvested were the most influential factors in explaining profitability. The key factors identified as hindrances to aquaculture development in the region included predators, unavailability of credit facilities, expensive feeds, shortage and poor quality of fingerlings.

AQUAFISH RESEARCH REPORT 11-280

BIOACCUMULATION OF HEAVY METALS IN THE VOLTA CLAM, *GALATEA PARADOXA* (BORN, 1778) IN RELATION TO THEIR GEOACCUMULATION IN BENTHIC SEDIMENTS OF THE VOLTA ESTUARY, GHANA

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Published in:

Water Quality Exposure and Health (2011) 2: 147–156.

Heavy metal accumulation in aquatic ecosystems is a common phenomenon among bivalve filter feeders. This study was carried out over an 18-month period at Ada and Aveglo in Ghana, where intense clam fishing represents a major livelihood. The study sought to investigate the concentrations of some heavy metals, zinc, manganese, iron and mercury, in whole soft tissues of three different size classes of the Volta estuary clam, *Galatea paradoxa*, in relation to geoaccumulation of the metals in benthic sediments. The study also sought to examine whether the levels of the metals in clam tissues were within acceptable limits for human consumption. Clam sizes were categorized as small (25–40 mm) medium (41–55 mm) and large (above 55 mm) based on shell lengths and predominant sizes captured in the Volta estuary. Mercury levels in clams and sediments were determined using a Mercury Analyser while Zn, Mn and Fe were determined using an Atomic Absorption Spectrophotometer. Heavy metal concentrations in clams were within permissible limits with reference to WHO safety standards. There were no significant spatial differences ($p > 0.05$) in the concentrations of Mn, Zn, Fe and Hg in clams at Ada and Aveglo. No relationship was observed between heavy metal concentrations in clams and geo-sediments indicating that metal accumulation in clams may not be directly or solely derived from sediments but from other sources such as dissolved metals in the water and seston. Highly significant differences ($p < 0.0001$) were observed between the clam size-classes and sediment samples for iron. Total mercury concentrations showed highly significant variations ($p < 0.0001$) between all the clam size-classes and the sediment samples.

AQUAFISH RESEARCH REPORT 11-281

DNA EXTRACTION FROM CRAYFISH EXOSKELETON

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Published in:

Indian Journal of Experimental Biology (2011) 49: 953-957.

Crayfish exoskeleton (CE) samples are generally less invasive and easy to be collected. However, it is difficult to extract DNA from them. This study was intended to investigate CE as a DNA source and design an easy and efficient DNA extraction protocol for polymerase chain reactions. Specific primer pair (PPO-F, PPO-R) was used to amplify extracted DNA from CE, and compared to crayfish tail muscle DNA sample. Moreover, seven microsatellites markers were used to amplify the CE DNA samples set. Since the extracted DNA from CE is suitable for gene amplification, the results present usefulness of CE as an easy and convenient DNA source for PCR-based population genetic research.

AQUAFISH RESEARCH REPORT 11-282

HAEMATOLOGICAL AND SERUM BIOCHEMICAL CHARACTERIZATION AND COMPARISON OF WILD AND CULTURED NORTHERN SNAKEHEAD (*CHANNA ARGUS* CANTOR, 1842)

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Published in:

Journal of Applied Ichthyology (2011) 27: 122–128.

The objective of this study was to compare haematological and serum biochemical parameters of cultured and wild specimens of the northern snakehead, *Channa argus*, to establish baseline values. Thirty sexually immature and disease-free wild fish (37.70 ± 13.68 cm total length, 555.3 ± 449.0 g weight) and 30 cultured fish (36.82 ± 1.72 cm total length, 450.5 ± 58.8 g weight) were examined. In cultured northern snakehead, the average values of alanine aminotransferases (370.1 IU L⁻¹), aspartate amino transferases (1145.3 IU L⁻¹), albumin (15.84 g L⁻¹), direct bilirubin (6.15 μ mol L⁻¹), urea (1.40 mmol L⁻¹), glucose (21.54 mmol L⁻¹) and cholesterol levels (6.60 mmol L⁻¹) were significantly higher ($P < 0.05$) than in the wild fish. In wild specimens the corresponding values were 9.81 IU L⁻¹, 394.1 U L⁻¹, 12.90 g L⁻¹, 2.57 μ mol L⁻¹, 0.97, 2.36 and 4.38 mmol L⁻¹, respectively. No significant difference ($P > 0.05$) was found for total protein, globulin, total bilirubin, chromium, sodium, chloride or triglyceride levels between wild and cultured populations. The mean values of the red blood cell (RBC) counts, hematocrit, haemoglobin, and mean corpuscular volume (MCV) were significantly higher ($P < 0.05$) in the cultured population, while the values of the white blood cell (WBC) counts, erythrocyte sedimentation rate (ESR), mean corpuscular haemoglobin (MCH), and mean corpuscular haemoglobin concentration (MCHC) were significantly higher ($P < 0.05$) in the wild population. The study showed that the environmental conditions significantly impacted the status of the fish. It is suggested that these physiological parameters can be conveniently employed as health monitoring tools in fish culture practices.

AQUAFISH RESEARCH REPORT 11-283

WHY TILAPIA IS BECOMING THE MOST IMPORTANT FOOD FISH ON THE PLANET

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Published in:

Liu Liping and Kevin Fitzsimmons (Editors), *Better Science, Better Fish, Better Life: Proceedings of the Ninth International Symposium on Tilapia in Aquaculture*, Shanghai, China, 22-24 April 2011: 8-17.

Tilapia has become the shining star of aquaculture with farms starting and expanding across the globe while consumption races ahead of even the most ambitious farm building plans. 2010 saw farmed tilapia exceed 3.2 million metric tons per annum, surging further ahead of the salmon and catfish industries. We are also seeing an explosion of product forms in the grocery stores that is only matched by the variety of preparations we see in the restaurant trade. The global adoption of tilapia as a substitute for all kinds of wild-caught fish has driven demand higher every year, even through the global recession of recent years. The description of tilapia as an “aquatic chicken” becomes more accurate every day. It’s wide acceptance across all cultural, religious, and economic groups is similar to chicken. A variety of breeds and strains have been developed and by most measures, tilapia is now the most highly domesticated of farmed fishes. Unique amongst the major farmed fishes, tilapia maintains a key role in rural aquaculture improving the welfare of the poorest farmers while at the same time, it is reared in the highest tech production systems and is sold into international markets for up-scale markets. Tilapia is still the darling of the environmental community and the industry continues to polish its “green” credentials.

Three or four closely related species of tilapias readily hybridize in captivity and produce fecund F1 progeny. This has provided a huge genetic base for the geneticists to perform basic selective breeding. The domestication of tilapias has been a great driver of productivity during the 1990’s and 2000’s. There is also a concerted effort to describe the tilapia genome. When these genetic maps are distributed we can expect a second wave of genetic research that should further improve productivity. All of this will have been accomplished without the need of transgenics or genetically modified organisms. The basic biology of the fish along with the skill of traditional breeders has provided all of the progress to this point and much more in the near future.

Tilapia continues its march towards eventually overtaking carp as the most important farmed fish crop. With a much wider distribution of production and consumption and a huge base of value-added product forms, it is almost certain that tilapia production will someday eclipse that of carp. As tilapia production and consumption grows globally, it is likely to become the foundation product for all farmed fishes, just as chicken is the base for the poultry industry. So someday soon instead of referring to tilapia as the aquatic chicken we may be referring to chicken as the “terrestrial tilapia”.

AQUAFISH RESEARCH REPORT 11-284

INTENSITY OF FRESHWATER USE FOR AQUACULTURE IN DIFFERENT COUNTRIES

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Published in:

Liu Liping and Kevin Fitzsimmons (Editors), *Better Science, Better Fish, Better Life: Proceedings of the Ninth International Symposium on Tilapia in Aquaculture*, Shanghai, China, 22-24 April 2011: 68-74.

The intensity with which 172 countries use freshwater for aquaculture was estimated by dividing annual, freshwater aquaculture production (tonne/yr) by annual total natural renewable freshwater (km³/yr). The freshwater aquaculture production: renewable freshwater ratio (AFR) varied among countries from 0 to 15,000 tonne/km³. Country-level AFRs were assigned to AFR classes as follows: no freshwater aquaculture, 0 tonne/km³; low, < 100 tonne/km³; medium, 100-1,000 tonne/km³; high, > 1,000 tonne/km³. The number of countries in each AFR class follows: no freshwater aquaculture, 35; low, 80; medium, 45; high, 12. There seems to be adequate renewable freshwater to allow considerable expansion of freshwater aquaculture – especially outside of Asia.

AQUAFISH RESEARCH REPORT 11-285

IMPACTS OF THE INTRODUCTION OF ALIEN TILAPIAS (*Oreochromis spp.*) ON THE FISHERIES AND BIODIVERSITY OF INDIGENOUS SPECIES IN TRI AN RESERVOIR, VIETNAM

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Published in:

Better Science, Better Fish, Better Life: Proceedings of the Ninth International Symposium on Tilapia in Aquaculture, Shanghai, China, 22-24 April 2011: 75-85.

This study was conducted at Tri An Reservoir of Vietnam from November 2007 to June 2009 to determine the impact of tilapias (*Oreochromis spp.*) on the fisheries and biodiversity of indigenous species in the reservoir. Historical and currently data on fish caught and fish species composition was collected. There are currently 19 different types of fishing gears in use at the reservoir, of which 14 fishing gears caught tilapias. Of the five fishing gears with highest total catches, only two caught tilapias. There were only 4.62% and 5.09% of tilapias in fishermen harvest and landing point records, respectively. However, tilapias (*Oreochromis spp.*) were 6th of 40 fish species caught from fishermen data, indicating the rather low productivity of most other fish species in the reservoir. Among the six species with highest biomass, the only economically valuable species recorded were the silver barb (*Barbonymus gonionotus*) and tilapias. The species with little or no economic value that are abundant in the reservoir (glass fish *Parambassis siamensis*, river sprat *Corica soborna*, repassan *Cyclocheilichthys repasson* and wrestling halfbeak *Dermogenys pusillus*), accounted for 64% of estimated total fish harvest (3823 tons) in the reservoir in 2008. The high production of low value species is also evidenced by their abundance at landing points, with glass fish and river sprat accounting for 355.91 and 243.68 of the total of 1661 tons landed in 2008. These indicated that the abundance of low economic value fishes may affect fisheries and fish biodiversity much more than the impact of alien tilapias species.

By using gill nets instead of seining, fish species composition was composed of more species with high economic value. Estimated tilapia catches and landing records show that tilapia species are abundant (84.62 of the total 1661 tons at landing points), second most only to silver barb (147.59 of 1661 total tons). This pattern holds despite the fact that tilapia haven't been stocked regularly as silver barb and other cultured fish species, indicating a favorable development of tilapia species in the reservoir. During the peak catches of tilapias in August in 2008, the other top five most commonly caught fishes are not at their peak catches, indicating a likely impact of tilapias on other economically important fish species such as silver barb, common carp (*Cyprinus carpio*), repassan and *Labiobarbus spilopleura*.

AQUAFISH RESEARCH REPORT 11-286

DURATION OF APPETITE INHIBITION PREDICTS SOCIAL DOMINANCE IN NILE TILAPIA,
OREOCHROMIS NILOTICUS L.

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Published in:

Better Science, Better Fish, Better Life: Proceedings of the Ninth International Symposium on Tilapia in Aquaculture, Shanghai, China, 22-24 April 2011: 86-94.

This study investigated whether the result of contest for social dominance among individuals in *Oreochromis niloticus* can be predicted by assessing the duration of appetite inhibition (DAI) during the isolation period. Fifty all-male juvenile *O. niloticus* of similar size were isolated for 10 days and were used in a social pair study. The DAI of each fish was observed when fish was transferred to the isolation unit. Body weight of dominant and subordinate individuals was recorded before and after the encounter. Eye color pattern (ECP) was also observed during the social encounter. The study revealed that tilapia with shorter DAI during the isolation had a greater possibility to win the fight for social dominance. Formation of stable dominant-subordinate relationship was observed in 24 of the 25 tested pairs. A total of seventeen fishes (70.93%) out of the 24 fishes that became dominant have shorter DAI compared to that of their conspecifics (Binomial test, $P = 0.03$). This indicates that social dominance can be predicted using the DAI of the fish during isolation. Reduced growth rate of both dominant and subordinate fish and a well-described physiological end result of social stress were observed one day after the social interaction. The significantly greater weight loss ($P < 0.01$) in subordinate fish (2.88 ± 0.21 g) compared to dominant fish (2.11 ± 0.19 g) a day after the establishment of social hierarchy was mainly attributed to behavioral differences such as appetite rather than to differences in physical activities. Death, which is the most overwhelming effect of stress, was observed in the subordinate individuals. All subordinate fish died within a week after the social interaction.

AQUAFISH RESEARCH REPORT 11-287

FISHMEAL-FREE DIETS IMPROVE THE COST EFFECTIVENESS OF CULTURING NILE TILAPIA (*Oreochromis niloticus* L.) IN PONDS UNDER AN ALTERNATE DAY FEEDING STRATEGY

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Published in:

Better Science, Better Fish, Better Life: Proceedings of the Ninth International Symposium on Tilapia in Aquaculture, Shanghai, China, 22-24 April 2011: 95-101.

Feed constitutes 60-70% of total production costs of tilapia (*Oreochromis spp.*). Reductions in quantity of feed used for fish growout and in the cost of formulated feeds are two approaches to containing feed costs. Our previous studies show that alternate day feeding at full ration produces Nile tilapia (*O. niloticus*) of comparable body size and harvest yield as those fed daily at full ration. The reduced feed consumption and 100% improved feed conversion with fish on the alternative day feeding strategy provided a significant cost savings to the semi-intensive growout of Nile tilapia in ponds in the Philippines. The cost of commercial fish feeds are rising sharply as the demand for fishmeal increases and its supply declines. We evaluated the growth performance of tilapia fed on alternate days with diets that incorporated plant ingredients widely available in the Philippines or other semi-tropical or tropical regions (cassava meal, copra meal, coconut oil, rice bran) and that contained porkmeal to replace fishmeal. Fish were grown out in ponds for 120 days with isocaloric balanced, 0% and 6% fishmeal diets contained 31% crude protein and 6% crude fat. Fish showed similar performance on diets containing 0% and 6% fishmeal. Final body weight, total length, specific growth rate were virtually identical in fish on the two diets. Survival rates were 84% and 89% for fish on the 0% and 6% fishmeal diets, respectively. Feed consumption and feed conversion were also similar among the two groups. Total extrapolated yield at harvest was 3062 and 3080 kg fish/hectare for the 0% and 6% fishmeal groups, respectively. A marginal budget analysis showed an 8% improved return on fish fed the cheaper diet lacking fishmeal. This along with the alternative day feeding strategy previously shown to be as effective as daily feeding protocols has the potential of reducing overall feed costs for growing marketable size tilapia by > 60%. Collectively, the results show that substitution of diets containing fishmeal with cheaper and more sustainable sources of protein are effective options for reducing the costs without negatively impacting the production of tilapia.

AQUAFISH RESEARCH REPORT 11-288

MASCULINIZATION OF NILE TILAPIA (*OREOCHROMIS NILOTICUS* L.) USING LYPHOLIZED TESTES FROM CARABAO (*BUBALUS BUBALIS CARABANESIS* L.) BULL (*BOS INDICUS* L.) AND BOAR (*SUS DOMESTICUS* L.)

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Published in:

Better Science, Better Fish, Better Life: Proceedings of the Ninth International Symposium on Tilapia in Aquaculture, Shanghai, China, 22-24 April 2011: 105-120.

The study was conducted to evaluate the use of lyophilized testes from carabao (*B. b. carabanesis*), bull (*B. indicus*) and boar (*S. domesticus*) in the masculinization of Nile tilapia (*O. niloticus*) fry, specifically, their efficacy in producing phenotypic males and their influence on the growth and survival rate of Nile tilapia fry on a 28-day treatment period in outdoor tanks.

The experimental treatments evaluated were: Treatment I- lyophilized testes from carabao, Treatment II- lyophilized testes from bull, Treatment III- lyophilized testes from boar, Control I- methyltestosterone (MT)- treated diet and Control II- untreated diet. Percent phenotypic males, specific growth rate and survival rate were determined after 28 days of treatment in outdoor tanks.

Results revealed that Nile tilapia fry fed with MT-treated diet gave the highest percent phenotypic males with a mean of 96.67%. Those fry fed with lyophilized testes from bull, boar and carabao gave means 80.67, 79.33 and 72.67%, respectively. There was a significant difference ($P < 0.05$) among the treatments. Based on the Chi-square test ($\alpha \leq 0.05$), the higher percentages of males produced from androgen-treated fry which are significantly different from that of untreated fry showed that lyophilized testes diets and MT treated diet were effective in masculinizing Nile tilapia fry.

Lyophilized testes from bull, carabao and boar gave higher specific growth rate of tilapia fry with means 15.85, 15.29 and 14.82%, respectively. Tilapia fry fed with lyophilized testes from carabao and boar did not differ significantly ($P > 0.05$) from MT-treated fry but differed significantly ($P < 0.05$) from those untreated fry. Those fry fed with lyophilized testes from bull were found to be significantly different ($P < 0.05$) from the two controls. All the experimental treatments gave relatively high survival rate of the tilapia fry with no significant differences ($P > 0.05$).

AQUAFISH RESEARCH REPORT 11-289

HOW TO PRODUCE BILLIONS OF HIGH QUALITY TILAPIA FRY

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Better Science, Better Fish, Better Life: Proceedings of the Ninth International Symposium on Tilapia in Aquaculture, Shanghai, China, 22-24 April 2011: 123-131.

Tilapia has now become a popular protein source to the poor, and also increasingly to middle class people. It serves as a typical model of a success story of farming outside its native area. Annual tilapia production was only 1.5 tons in 1950 which surpassed 1.5 million tons in 2002; increased by 1 million fold. Now it has surpassed even 3 million tons in 2010. Its production will still continue to grow exponentially, if high quality fry are readily available especially in countries like China where fry demand is in billions. How to produce and supply such a huge quantity of high quality tilapia fry has been a question for the countries which have potential to expand tilapia farming for domestic consumption and export markets. In Thailand, shortage of premium quality tilapia fry was realized as early as 1980s as the main constraint to the growth of commercial farming. Therefore, Asian Institute of Technology (AIT) developed a practical technique of mass-scale fry production through a series of on-station experimentation over a decade. The technology is basically to produce all-male fry by maintaining a large number of broodfish in hapas, collecting eggs, incubating them artificially in clean and controlled system and feeding with methyl-testosterone (MT) mixed with high quality feed as early as possible to ensure over 99% males in the fry population.

In addition to developing the production technology, AIT also successfully disseminated it applying all sorts of strategies involving public as well as private sector. However, a key turning occurred only after the success of a private hatchery in Thailand that triggering mushrooming of many others. There are over 100 hatcheries of such type in Thailand alone. Now the same trend can be seen in Bangladesh. The technology has now been adopted by many farmers and entrepreneurs of many countries especially in Asia and Latin America. However, in China where about half of the global tilapia is produced, most farmers use hybridization technique to produce mono-sex fry. In Thailand, three hatcheries annually produce 200 million fry each. This means, establishing about five such hatcheries could easily produce 1 billion high quality fry per year. A hatchery in Hainan island of China has been already established by a foreign company which has claimed to achieve the same level of production. However, this technology has not been widely adopted. Adoption of this technology could boost tilapia farming further increasing many folds as the demand for fish for local consumption is huge, and so the export market. Exploring potential and promoting this technology could bring a big leap in tilapia industry in China from its current level. With a view to assisting the industry, establishing functional linkages between China and Thailand and other countries that facilitate cooperation among the researchers /

scholars in sharing information and organizing study visits or trainings to government officials and farm hatchery managers could serve as solutions. This paper describes the techniques and approaches applied by AIT hoping that it provokes policy makers, extension workers, researchers and educators working especially in China, and also other countries to find various ways of collaborations.

AQUAFISH RESEARCH REPORT 11-290

IMPROVING THE SUPPLY CHAIN OF TILAPIA INDUSTRY IN THE PHILIPPINES

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Published in:

Better Science, Better Fish, Better Life: Proceedings of the Ninth International Symposium on Tilapia in Aquaculture, Shanghai, China, 22-24 April 2011: 132-150.

This study was designed to evaluate and develop an efficient tilapia supply chain to foster the development of viable fast food and supermarket purchases of tilapia from small scale producers; with the following specific objectives: Phase 1 – Evaluation: (1.) Develop tilapia supply chain maps for each market level, i.e., producer, wholesale, restaurant, supermarket, fast food stores, etc., to identify specific activities and services, key players, logistical issues, external influences, and flow of product, information and payment among market levels. (2.) Analyze tilapia supply chain performance for efficiency, flexibility and overall responsiveness. (3.) Identify areas for improvement in supply chain (i.e. behavioral, institutional and process), (4.) Provide recommendations to improve the tilapia industry, in general and specific supply chain items. Phase 2 - Development Undertaking: (1.) Design specific improvement measures based on the identified areas of improvement from Phase 1. (2.) Test the improvement measures in the market place, then assess and refine the improvement measures. (3.) Design and implement measures to ensure the sustainability of the improved supply chain of tilapia.

The country's tilapia industry supply chain is composed of the following parts, namely the hatchery and nursery farms which are responsible for the introduction of improved brood stocks to commercial or backyard fish farms which in turn responsible in providing improved quality tilapia fishes for the end-users such as consumers and institutional buyers. The institutional buyers could be further decomposed as processors, consolidators or traders, supermarkets, specialty shops, food chains, restaurants, bars and canteens, among others.

The provinces of Pampanga, Batangas and Laguna are the major tilapia sources while the cities of Metro Manila, Angeles and Baguio are the major demand centers. Dagupan City, Pangasinan being known as “bangus” or milkfish capital is a major transshipment point of tilapia and other seafood for the Northern Luzon provinces including Cagayan Valley and the Cordillera Administrative Regions. In addition to the major supply centers, Camarines Sur in Bicol Region is becoming a key source of tilapia fries. The product flow of tilapia fries from the hatchery to the nursery farms generally follows a continuous 18-day cycle while tilapia fingerlings from nursery to commercial or backyard farms follows thirty to forty five-day cycle depending on fish sizes required by the customers. Direct buying and selling, wholesaling, and retailing at central markets through agents and “consignation” are the most common marketing operations of the

tilapia industry. Consumers generally prefer whole live fish with size ranging from 250 – 300 grams per fish (or 4-5 pieces per kilogram) but the requirements of institutional buyers are more varied depending on their customers' preferences. Filleted tilapia requires about 2-3 pieces per kg or equivalent to 450 – 750 grams per fish. Grilled and barbequed tilapia are now becoming more popular recipes in the major demand centers.

The major concerns of hatcheries and nurseries are the high cost of outbound logistics, which is exacerbated by high competitive pressures of inferior quality but inexpensive stocks (e.g., non-sex reversed) and high levels of mortality due to environmental and cultural factors.

The fish farms' major concerns include; expensive but low quality feeds (at times mislabeled) and other inputs, very low fish recovery and longer culture period to reach larger fishes. Their transaction costs include the cost of waiting for buyers, delays in delivery, intransit mortality, and toll fees or "goodwill" as well as shrinkage losses. In addition, the lack of cold storage and transport vehicles equipped with tanks and aerators or refrigeration facilities delimits them to take market opportunities. Interestingly, many farmers adapted a "circuitous" production technique to take advantage of markets preference on tilapia with darker skin.

The major concerns of processors are too few farms that could supply regularly the desired quality and volume of tilapia, the lack of capital for market expansion, and competition with cheaper imported counterparts.

The concerns of traders including "consignacion", suppliers or consolidators are the following; (a) meeting the product quality and quantity orders on schedule (b) high logistics and transaction costs of consolidating and distributing fishes from sources to destinations (c) absence of product grades and standards.

The following are some recommendations to address the various issues and concerns namely of the various chain players: (1) encourage the establishment of more nursery farms for better quality brood stocks while intensifying technology transfer to farmers for better health and management of tilapia (2) conduct market promotion activities highlighting the various niche opportunities of tilapia among growers and consumers (3) motivate the participation of small farmers in supply chains by setting up an incentive scheme through a mix of patronage refund and profit sharing (4) institutionalize an accreditation program for feed manufacturers, hatcheries, processors and the like to improve the quality assurance of products and services (5) provide capital windows to improve facilities and reduce logistics and transaction costs in the entire supply chains of tilapia.

AQUAFISH RESEARCH REPORT 11-291

DEVELOPMENT OF SUSTAINABLE AQUACULTURE PRACTICES IN TABASCO, MEXICO USING NOVEL IAA TECHNOLOGY

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Published in:

Better Science, Better Fish, Better Life: Proceedings of the Ninth International Symposium on Tilapia in Aquaculture, Shanghai, China, 22-24 April 2011: 151-157.

The treatment and discharge of aquaculture effluent and resulting negative impacts on the environment remains a critical issue that is threatening the sustainable growth of the aquaculture industry. Three optimal sites has been selected to carry out IAA systems in order to deplete eutrophication, two indigenous communities, one from the highlands and other one from the wetlands were selected to produce agro and aqua products with the same amount of energy, also a demonstration system is building at UJAT. Part of our progress so far is: two workshops; the first one on integrated systems and the second one on bioflocs systems with more than 60 attendants among farmers, students and technicians. In Caridad Guerrero the highland indigenous community we have a 90% progress for the setting up phase, habanero pepper will be growth with Tilapia water effluents. In the wetland community there is a progress of 40% the group is already organizing and training is given, the demonstration system at UJAT has a 30% progress, materials and instruments have been already purchased and the design was made. In overall the project suffered a delayed due to major flooding events in the region.

AQUAFISH RESEARCH REPORT 11-292

CONSTRAINTS AND OPPORTUNITIES IN CAGE AQUACULTURE IN GHANA

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Published in:

Better Science, Better Fish, Better Life: Proceedings of the Ninth International Symposium on Tilapia in Aquaculture, Shanghai, China, 22-24 April 2011: 158-165.

This study was conducted to identify why the overall contribution of the aquaculture industry to local fish production in Ghana is low (<1%) although cage aquaculture has a potential to increase production. We administered 106 questionnaires to six respondent groups (current cage fish farmers, potential adopters of cage aquaculture, farmers who have abandoned cage aquaculture, Fisheries Commission, regional and district fisheries officers, and financial institutions) to obtain insight into the constraints in cage aquaculture as well as opportunities that can be exploited to promote cage aquaculture adoption. For the purpose of this study, potential adopters are individuals who have fish-related livelihoods including fishermen, pond-based fish farmers and fish traders. We also interviewed key informants in relevant government institutions. Preliminary results indicate that lack of funds and lack of government extension services are the main constraints in cage aquaculture in Ghana. Lack of funds manifests in farmers' inability to afford quality floating feed and could explain low production levels of current cage farmers, although most (95%) suggested they could market their fish if they increased production. Lack of funds also accounted for the inability of potential adopters and farmers who have abandoned cage aquaculture to start or continue cage aquaculture respectively. Major opportunities identified include 1) a high interest among potential adopters (97%) to start cage aquaculture and farmers who have abandoned cage aquaculture (100%) to resume if constraints are removed, 2) development of a feed production plant in Ghana by a private enterprise, 3) willingness of some financial institutions to provide loans for cage farmers, and 4) a number of government initiatives to promote cage aquaculture. Our preliminary recommendations are that the Fisheries Commission should work with the financial institutions to help determine farmers' ability to repay loans and guarantee loans made by the financial institutions. Also, there is a need for a more specialized aquaculture extension service accessible to farmers to help with technical issues built on the model of agricultural extension services in Ghana.

AQUAFISH RESEARCH REPORT 11-293

WHAT INFLUENCES THE SUCCESS OF AQUACULTURAL RESEARCH PROJECTS?

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Published in:

Better Science, Better Fish, Better Life: Proceedings of the Ninth International Symposium on Tilapia in Aquaculture, Shanghai, China, 22-24 April 2011: 167-173.

No research program can enjoy long-run success without a periodic assessment of how it is performing and what factors influence success and failure. While most such assessments are informal and specific to a particular study, formal evaluations eventually become important at the program level. A formal analysis the same as an informal one in the sense of comparing research outputs with the inputs or efforts expended to achieve them (a “knowledge production function”). Approaches to research assessment thus differ only in how such outputs and inputs are to be understood, measured, and compared.

Assessment methods can be either quantitative – typically statistical – or the kinds of institutional evaluation one sees in a case study. In biological disciplines, at least, most statistical analyses of the factors affecting research success employ the scientists’ publication counts, citations, or intellectual property as measures of research output. Methods are parametric or non-parametric, dynamic or static. In the parametric approach, the bibliographic output measures are regressed against current and lagged research expenditures, against other inputs or conditions poorly represented by expenditures, and sometimes against a time trend.

Adams and Griliches (1996), for example, examine U.S. university research performance in eight scientific fields during the 1980s. They find at the level of a particular university or field that diminishing returns to scale prevail in academic research. That is, increases in study size bring less-than-proportionate increases in the study’s publication output. At the aggregate level, however, there appears to be approximate equality between research expenditure and publication (or citation) performance, possibly because aggregate data incorporate cross-study knowledge spillovers that are not captured in more disaggregated data. These methods have more recently been applied to life-science research by Smith (1998), Xia and Buccola (2005), Groot and Garcia-Valderrama (2006), Buccola, Ervin, and Yang (2009).

The bibliometric approach is, despite its widespread use, inadequate in a number of respects. The first and probably most important difficulty is that publication, patent, and journal citation rates mask much of the detail of a study’s findings and thus only grossly reflect the findings’ nature, magnitude, and importance. Much published output also becomes available only years after the

study has been completed. Finally, the bibliometric approach is poorly suited to an exact matching of a study's outputs and inputs.

To help solve these difficulties, we examine here a new approach to research assessment. The new method focuses directly on the information a research study has generated, enabling a more exact and more contemporaneous matching of that information to the skills, expenditures, and capital devoted to the study. We apply the approach to the 116688 55 past and on-going aquacultural research investigations which AquaFish CRSP is pursuing in eleven countries.

AQUAFISH RESEARCH REPORT 11-294

METHODS FOR ASSESSING ECONOMIC, ENVIRONMENTAL AND SOCIAL IMPACTS OF AQUACULTURE TECHNOLOGIES: ADOPTION OF INTEGRATED AGRICULTURE-AQUACULTURE IN MALAWI

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Published in:

Better Science, Better Fish, Better Life: Proceedings of the Ninth International Symposium on Tilapia in Aquaculture, Shanghai, China, 22-24 April 2011: 174-183.

There is a growing demand for assessment of economic, environmental and social impacts of new food-related technologies, including the impacts of new methods for aquaculture management. This paper presents a new “minimum-data Tradeoff Analysis” (TOA-MD) model that can be applied to assess economic, environmental and social impacts in a wide array of agricultural systems that incorporate aquaculture, crops, and livestock (Antle 2011; Antle and Valdivia 2010). This model is widely applicable to assess impacts because it utilizes a generic model structure that can be parameterized with data available from a variety of sources, including farm surveys, experimental data, simulated data from biophysical simulation models, and expert judgment. A key feature of this model is that it takes into account the fact that farmers systematically selected themselves into adopting and nonadopting groups. Analysis shows that this selection must be taken into account to obtain accurate estimates of impact.

To illustrate the use of the TOA-MD model, we use it to implement an impact assessment of integrated agriculture-aquaculture (IAA) systems in southern Malawi developed by the World Fish Center, using a WorldFish farm survey data collected in 2004, together with data from other public sources. We use the TOA-MD model to demonstrate how it is possible to use available data to move a conventional economic impact assessment “along the impact assessment pathway” to estimate adoption rates in the relevant populations, and to quantify impacts on distributional outcomes such as poverty, environmental impacts such as soil and water quality, and social and health-related outcomes such as nutrition or gender impacts. The analysis predicts an adoption rate of about 44%. In two districts, there is a substantial increase in protein consumption associated with the adoption of IAA and substantial reductions in poverty, whereas in others the effects are smaller.

AQUAFISH RESEARCH REPORT 11-295

VALUE CHAIN OF CULTURED SNAKEHEAD FISH IN THE MEKONG DELTA OF VIETNAM

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Published in:

Better Science, Better Fish, Better Life: Proceedings of the Ninth International Symposium on Tilapia in Aquaculture, Shanghai, China, 22-24 April 2011: 184-186.

Snakehead fish is the fish species which is mostly preferred by consumers in the Mekong Delta of Vietnam. However, it is difficult to develop this industry due to a number of reasons. This study was carried out with the aims to describe the value chain of cultured snakeheads and to analyze the distribution of cost-benefit among the chain actors in the delta. Among 10 common market channels, two most important ones in term of total production were Channel 3 (Fish farmers – Wholesalers – Retailers – End consumers in the Mekong Delta), and Channel 9 (Fish farmers – Wholesalers – Wholesalers in Ho Chi Minh City). Profit was unbalanced distributed among the chain actors, mainly for the wholesalers (87.9-93.4% of total profit of the whole chain). In order to have an appropriate development of snakehead industry, to improve profit of the whole chain and to have a better competition power, the followings should be given more consideration: (i) more proper planning of cultured area and technological supports, and marketing of fish products; (ii) to encourage the application of pelette feed in order to reduce the pressure on fresh water wild fish stocks; and (iii) to have incentive policies/regulations that help to encourage the processors to export, especially processed products for a long-term market expansion in terms of higher production, more export value, and stable price of snakehead products.

AQUAFISH RESEARCH REPORT 11-296

USE OF GONADOTROPIN RELEASING HORMONE ANALOGS ON THE INDUCED REPRODUCTION OF CHAME *DORMITATOR LATIFRONS*

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Published in:

Better Science, Better Fish, Better Life: Proceedings of the Ninth International Symposium on Tilapia in Aquaculture, Shanghai, China, 22-24 April 2011: 187-192.

Chame (Pacific Fat Sleeper) is considered a relevant upcoming fish species for aquaculture; particularly in Ecuador and some preliminary trials in Mexico. Nevertheless, the reported production for the last 15 to 20 years in culture has been dependent of wild-caught juveniles. Thus, we are conducting research focused on the achievement of controlled reproduction and larvae production as well as to get relevant information on the reproductive biology of the fish. At this moment we have successfully induced gamete release in both genders using the following procedures: An experiment was conducted with 16 females divided into the following groups: control group (0.5 ml/kg 0.9% saline solution), Desgly10-Ala⁶ LHRHa injected at 40 µg/kg (priming dosage) and 80 µg/kg (resolving dose), 2 injections of Ovaprim® at 0.5 ml/kg or a single implant 75 µg (Ovaplant®). Spawning results showed 100% success within 24h and 48h for the Ovaplant group, and 25% for the LHRHa treatment but 0% for Ovaprim group within 48-72h. Only one natural spawn was observed. Obtained data establishes oocyte size as 300 µm and a relative fecundity of 80,000 to 100,000 cells per gram. All delivery treatments were effective to induce spermiation in volumes from 0.5 to 10 ml per male (LHRHa injected at 40 µg/kg, Ovaprim® at 0.5 ml/kg or a single implant 75 µg (Ovaplant®); however several males released sperm naturally up to 1ml throughout the reproductive season. Obtained data indicates that sperm activation time is close to 4 minutes, and overall concentration is within the range of 1 to 2X10⁹ cells per milliliter. Increased sperm motility is achieved after pre-dilution on a 1:10-1:40 ratio in Ringer's solution. As optimal salinity values, both for fertilization and egg incubation, our results indicate that there is no sperm activation above 5‰ of salinity; similar data were recorded for optimal incubation salinity as no hatching was observed above 5‰ salinity. These findings are relevant due to the differences with other spawning protocols previously used, given that other trials reported the need of repeated injections of Human chorionic gonadotropin (HcG) up to 10,000 UI per fish. Another difference with previous studies was the observance of only partial spawns. We conclude that these protocols allow to successfully obtaining viable gametes for chame larvae production.

AQUAFISH RESEARCH REPORT 11-297

SUPPLEMENTAL FEEDING OF NILE TILAPIA (*OREOCHROMIS NILOTICUS* L.) IN FERTILIZED PONDS USING COMBINED FEED REDUCTION STRATEGIES

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Published in:

Better Science, Better Fish, Better Life: Proceedings of the Ninth International Symposium on Tilapia in Aquaculture, Shanghai, China, 22-24 April 2011: 268-274.

The study was conducted in nine 500-m² earthen ponds at the Freshwater Aquaculture Center, Central Luzon State University, Science City of Muñoz, Nueva Ecija, Philippines, to determine the effect of using combined feed reduction strategies on the grow-out culture of Nile tilapia in fertilized earthen ponds. There were three treatments with three replicates: (I) 67% daily feeding until harvest; (II) 67% daily feeding for 60 days, 50% daily feeding until harvest; (III) 67% daily feeding for 60 days, 100% alternate day feeding until harvest. Ponds were stocked with sex-reversed GIFT tilapia fingerlings at 4 fish m⁻².

The study showed that Nile tilapia cultured in fertilized earthen ponds using different combined feed reduction strategy had no significant difference in terms of growth performance. Final mean weight and length of Nile tilapia in Treatment I were 183.1 + 77.1 g and 20.1 + 2.9 cm, Treatment II had 168.5 + 39.9 g and 19.9 + 1.4 cm and Treatment III had 183.1 + 16.0 g and 20.5 + 0.6 cm. Yield after harvest in Treatments I, II and III were 2,968.7 + 439.6, 1,980.7 + 541.8 and 2,024.7 + 329.0 kg ha⁻¹, respectively. Net tilapia yield in Treatment I was significantly higher compared to the other treatments considering the higher survival of the treatment.

Treatment I gave the highest net return among treatments with a mean value of US\$705.90 followed by Treatment III with a mean value of US\$6.41 then Treatment II with a mean value of US\$-36.12. Net return was low among treatments because of the low survival after the study. Numerically, Treatment I showed the most profitable reduction strategy with the obtained survival, however, analysis of variance showed no significant differences in net return among treatments.

With this result, Treatment I seemed to have the best result for tilapia culture, however, previous studies also shows feasibility of the use of other feed reduction strategies if more viable survival is attained leading to better FCR and net return.

AQUAFISH RESEARCH REPORT 11-298

GROWTH PERFORMANCE, SURVIVAL, FEED UTILIZATION AND NUTRIENT UTILIZATION OF AFRICAN CATFISH (*CLARIAS GARIEPINUS*) LARVAE CO-FED ARTEMIA AND A MICRO-DIET CONTAINING FRESHWATER ATYID SHRIMP (*CARIDINA NILOTICA*) DURING WEANING

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Published in:

Aquaculture Nutrition (2011) 17: e82-e89.

Problems of limited number of dry feeds as supplement or replacement of live feeds have led to poor larval nutrition in many species of fish. Therefore, the suitability of co-feeding 8-day- old African catfish (*Clarias gariepinus*) posthatch larvae using live feed (*Artemia salina*) and formulated dry diet containing freshwater atyid shrimp (*Caridina nilotica*) during weaning was investigated. The experiment ended after 21 days of culture and respective groups compared on the basis of growth performance, survival, feed utilization and nutrient utilization. Larvae co-fed using 50% Artemia and 50% formulated dry diet resulted in significantly ($P < 0.05$) better growth performance, food gain ratio (FGR), protein efficiency ratio (PER) and productive protein values (PPV) than other treatments. The lowest growth performance occurred in larvae weaned using 100% formulated and commercial dry diets. Better survival of over 90% was obtained in larvae weaned using 50% Artemia and 50% dry diet, while abrupt weaning using 100% dry diets resulted in lower survival ($<75\%$). These results support a recommendation of co-feeding *C. gariepinus* larvae using a formulated dry diet containing *C. nilotica* and 50% live feed when weaning is performed after 8 days posthatching period.

AQUAFISH RESEARCH REPORT 11-A01

APPLICATION OF WATER TREATMENT TECHNIQUES IN SHRIMP FARMING.

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Published in:

Ocean and Fisheries (2011), No further information provided

AQUAFISH RESEARCH REPORT 11-A02

MANIPULATION OF SPECIES COMBINATION FOR ENHANCING FISH PRODUCTION IN POLYCULTURE SYSTEMS INVOLVING MAJOR CARPS AND SMALL INDIGENOUS FISH SPECIES

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Published in:

Aquaculture (2011) 321(3-4): 289-297.

A sustainable semi-intensive pond aquaculture technology including major carp species as ‘cash-crop’ and small indigenous fish species (SIS) as food for the farmers' families is being optimized in Bangladesh. This is done through manipulations of the fish species combinations stocked, considering the ecological effects produced by bottom feeders on the pond bottom and filter feeders in the water column. The present paper presents results of experiments performed simultaneously in 64 farmers' fish ponds, located in 4 distant agroecological regions of Bangladesh. In each region each experiment involved 4 treatments, 4 replicates per treatment. The control polyculture was the traditional stocking of 33 rohu (*Labeo rohita*), 33 catla (*Catla catla*), and 34 common carp (*Cyprinus carpio*) per 100 m², with the addition of 250 SIS and 3 silver carp (*Hypophthalmichthys molitrix*) per 100 m². In previous experiments this silver carp addition was found to have no effects on the other fish and on the environment, compared to the traditional stocking without silver carp. Interferences on the water column (Water treatment) were achieved changing the density of the herbivorous fish (reducing catla density to 24/100 m² and increasing silver carp to 12/100 m²), and on the bottom (Bottom treatment) doing so on the benthophagous fish (replacing 10/100 m² common carp by mrigal). Both interferences were simultaneously carried out in the Water and Bottom treatment. Harvesting weight and biomass, growth rate, survival and yield of each species and total yield, food conversion ratio and income obtained in the different treatments and regions are presented and their interactions through the food web are discussed. Performing the same experiment in four distant regions of the country allowed observing if the effects of the Water column and/or Bottom interventions differ among regions, and accelerating the dissemination of the “cash-SIS” technology throughout the country. The manipulations performed did not affect the small fish mola, which reproduced and yielded equally well in all the polycultures. This allowed a continuous mola supply for consumption by the farmers' families throughout the culture season, and opened the option to consume or sell the larger amounts of mola gathered at final harvest. Manipulation of species composition proved to be a useful tool to affect the pond ecosystem towards improving fish yield and corresponding income. Just by substituting almost a third of the catla by silver carp increased total yield by 16%. When also almost a third of the common carp was substituted by mrigal, total yield increased a further 3%. In both cases selling the whole production increased income by 27%, which gives the farmer the option to keep part of the fish for family consumption.

AQUAFISH RESEARCH REPORT 11-A03

SURVIVAL AND PHYSIOLOGICAL RESPONSE OF *LABEO VICTORIANUS* (PISCES: CYPRINIDAE, BOULENGER 1901) JUVENILES TO TRANSPORT STRESS UNDER A SALINITY GRADIENT

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Published in:

Aquaculture (2011) 319(1-2): 226-231.

Survival and physiological response of *Labeo victorianus* juveniles under varying salinity gradients were studied during a 6 h transport. Salinity ranges were: 0, 0.25, 0.5, 1, 2, 4, 8 and 10 psu. To each transport bag, 100 juvenile *L. victorianus* (mean weight= 8.0 ± 1.1 g, stocking biomass= 16 kg m^{-3}) were transferred. Water temperature, dissolved oxygen (DO), pH, total ammonia nitrogen (TAN) and carbon dioxide (CO₂) were measured before and after transport. Plasma cortisol, blood glucose, plasma sodium, plasma chloride and blood ammonia were also determined. No juvenile mortalities occurred in salinity ranges of 1 to 4 psu. After transport, survival and parameters of physiological response in the juvenile of *L. victorianus* were significantly different among different salinity treatments ($p < 0.05$). Low survival, of less than 70% occurred in control treatments (0 psu) and in salinities 0.25, 0.5 psu and at 10 psu. Increased salinity correlated negatively with TAN and CO₂ in water after transport. Plasma cortisol in salinities of 0.5 to 8 psu, blood glucose and blood ammonia in salinities ranging from 1 to 4 psu as well as plasma sodium and plasma chloride in salinity ranging from 1 to 8 psu were similar before and after transport. This study recommends salinity ranges of 1 to 4 psu for minimizing the physiological effects associated with both the primary and secondary physiological response induced by transport stress in juvenile *L. victorianus*.

AQUAFISH RESEARCH REPORT 12-299

DEVELOPMENT IMPACTS OF LONG-TERM AQUACULTURE TRAINING PROGRAMS CONDUCTED IN KENYA AND THAILAND

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Published in:

J. Higher Education and Lifelong Learning (2012) 19: 1-8.

This paper reports the results of a survey conducted to assess the development impacts of USAID-supported aquaculture training programs conducted at three institutions of higher education in Kenya and Thailand. All program participants interviewed reported that they acquired specific knowledge, skills, and attitudes during the training and that it has had an important impact on their professional development. The programs have also had a marked effect on the institutions where the participants now work. Short-term training in the U.S. and short-term training in one's home country were rated as more effective training models than long-term training in the U.S.

AQUAFISH RESEARCH REPORT 12-300

BIOLOGICAL ASSESSMENT OF AQUACULTURE EFFECTS ON EFFLUENT-RECEIVING STREAMS IN GHANA USING STRUCTURAL AND FUNCTIONAL COMPOSITION OF FISH AND MACROINVERTEBRATE ASSEMBLAGES

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Published in:

Environmental Management (2012) 50: 166-180.

Biological assessment of aquatic ecosystems is widely employed as an alternative or complement to chemical and toxicity testing due to numerous advantages of using biota to determine ecosystem condition. These advantages, especially to developing countries, include the relatively low cost and technical requirements. This study was conducted to determine the biological impacts of aquaculture operations on effluent-receiving streams in the Ashanti Region of Ghana. We collected water, fish and benthic macroinvertebrate samples from 12 aquaculture effluent-receiving streams upstream and downstream of fish farms and 12 reference streams between May and August of 2009, and then calculated structural and functional metrics for biotic assemblages. Fish species with non-guarding mode of reproduction were more abundant in reference streams than downstream ($P = 0.0214$) and upstream ($P = 0.0251$), and sand-detritus spawning fish were less predominant in reference stream than upstream ($P = 0.0222$) and marginally less in downstream locations ($P = 0.0539$). A possible subsidy-stress response of macroinvertebrate family richness and abundance was also observed, with nutrient (nitrogen) augmentation from aquaculture and other farming activities likely. Generally, there were no, or only marginal differences among locations downstream and upstream of fish farms and in reference streams in terms of several other biotic metrics considered. Therefore, the scale of impact in the future will depend not only on the management of nutrient augmentation from pond effluents, but also on the consideration of nutrient discharges from other industries like fruit and vegetable farming within the study area.

AQUAFISH RESEARCH REPORT 12-301

IMPROVING GENDER EQUITY IN AQUACULTURE EDUCATION AND TRAINING: 30 YEARS OF EXPERIENCES IN THE POND DYNAMICS/AQUACULTURE, AQUACULTURE, AND AQUAFISH COLLABORATIVE RESEARCH SUPPORT PROGRAMS

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Published in:

Asian Fisheries Science Special Issue (2012) 255: 119-128.

The AquaFish Collaborative Research Support Program (CRSP) is dedicated to improving gender equality in the aquaculture and fisheries sectors and in the CRSP by creating equal opportunities for women and men in research, training and educational activities. Recognizing the barriers and complex issues women face, the AquaFish CRSP has taken a mindful approach towards gender integration by focusing on women beneficiaries of its research and outreach, and on women in the Program. Gender must be included in projects in a cross cutting and an individual way. Despite these steps, gender-segregated statistics from AquaFish display characteristics of a “leaky pipeline” as seen in other fields of science. During the original Pond Dynamics/Aquaculture CRSP (PD/A) and the subsequent Aquaculture CRSP (ACRSP) (1982-2008), 36.8% collectively, of degree students were women. In the AquaFish CRSP (2006-current), 55 women (55%) of degrees have been awarded to women. Although reaching a 50% target for women is a major accomplishment, the same proportion is not entering higher positions in science or research careers. Surprisingly, women still make up less than 50% of the CRSP short-term trainees. More research is needed to understand leaks in the pipeline and barriers to women’s participation.

AQUAFISH RESEARCH REPORT 12-302

HEMOLYMPH PROFILES OF POND-REARED AND LAKE PEN-CULTURED ADULT CHINESE MITTEN CRAB, *ERIOCHEIR SINENSIS* H. MILNE EDWARDS, 1853

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Published in:

Indian J. Fish., (2012) 59(1): 95-101.

Levels of seven hemolymph parameters (considered as indicators of physiological and immune status of organisms) in pond-reared (PR) and lake pen-cultured (PC) adult Chinese mitten crabs sampled from three experimental sites viz., a pond at Huangjin Lake area, a net-pen in the Huangjin Lake and a pond at Lu Lake area were analyzed. Two sites in the Huangjin Lake area where the pond meets the lake, possessed good water quality whereas at Lu Lake area where the pond was not connected to the Lu Lake, the water quality was relatively poor. Hemocyanin content and total hemocytes count in PR crabs from Lu Lake area were significantly lower than those of PR and PC crabs from Huangjin Lake area, indicating PR crabs from Lu Lake area had relatively poor physiological and immune status. There were no significant differences in hemolymph profiles between PR and PC crabs from Huangjin Lake area. These results indicate that water quality had a significant effect on the physiological and immune status of cultured Chinese mitten crabs. The results indicate that pond-rearing is better for culture of Chinese mitten crabs, especially in ponds which are connected to natural water resources.

AQUAFISH RESEARCH REPORT 12-303

THE EXPRESSION OF PROPHENOLOXIDASE MRNA IN RED SWAMP CRAYFISH (*PROCAMBARUS CLARKII*) WHEN IT WAS CHALLENGED

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Published in:

Genomics (2012) 99: 355–360.

The expression of the prophenoloxidase (proPO) gene was investigated in nine tissues of red swamp crayfish, *Procambarus clarkii*, by real-time PCR after challenges by CpG oligodeoxynucleotide (ODN), *Aeromonas hydrophila* and white spot syndrome virus (WSSV). The results can be summarized as follows: (i) the expression level of the proPO gene in hemocytes was highest among nine studied tissues before the challenge; (ii) the expression of proPO increased in all studied tissues after stimulation by CpG ODN and WSSV, and also increased in all tissues, except the ovary, after the *A. hydrophila* challenge; (iii) the whole expression profiles were different, suggesting that different immune mechanisms may exist for crayfish that are resistant to WSSV and *A. hydrophila*, although the expression in hemocytes was similar before and after the WSSV and *A. hydrophila* challenges.

AQUAFISH RESEARCH REPORT 12-304

CLONING AND CHARACTERIZATION OF LEPTIN IN A PERCIFORM FISH, THE STRIPED BASS (*MORONE SAXATILIS*): CONTROL OF FEEDING AND REGULATION BY NUTRITIONAL STATE

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Published in:

General and Comparative Endocrinology (2012) 178: 98–107.

In mammals, leptin is an anorexigenic peptide hormone that regulates energy homeostasis. It is produced predominantly by white adipose tissue and circulates as an endocrine indicator of energy reserves. Teleost leptin has been characterized in a few fish species, but its regulation is not well understood, particularly in response to nutritional status. In this study, we cloned a putative leptin in striped bass (*Morone saxatilis*) and report the first characterization of leptin in a Perciforme, the largest and most diverse order of fish. The striped bass leptin coding sequence was 65% homologous with pufferfish, 52% with Atlantic salmon, and 46% with human. PCR showed that leptin mRNA was exclusively expressed in the liver, and not adipose or other tissues. The leptin coding sequence of striped bass and the more widely cultured hybrid striped bass variety (HSB; *Morone chrysops*, white bass *M. saxatilis*) were identical. We then evaluated whether the metabolic status of HSB might alter leptin gene expression. Juvenile HSB were subjected to 3 weeks feed deprivation followed by 3 weeks of refeeding. Quantitative PCR showed that fasting for 3 weeks reduced hepatic leptin mRNA levels relative to fed controls. Leptin mRNA levels then increased upon refeeding, albeit levels were not completely restored to those seen in control fish fed throughout the experiment. Intraperitoneal injection of human leptin suppressed appetite in HSB. In as much as hepatic HSB leptin mRNA is regulated by nutritional state and has a corresponding anorexigenic effect, our results suggest that leptin may play a role in energy homeostasis in these advanced Perciformes.

AQUAFISH RESEARCH REPORT 12-305

POPULATION GENETIC STRUCTURE AND POST-ESTABLISHMENT DISPERSAL PATTERNS OF THE RED SWAMP CRAYFISH *PROCAMBARUS CLARKII* IN CHINA

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Published in:

PLoS ONE (2012) 7(7): e40652.

The red swamp crayfish (*Procambarus clarkii*) was introduced to China in the early 20th century. It has been spread to almost all forms of fresh water bodies including lakes, rivers and even paddyfields in most provinces of China. To clarify issues such as the initial entry point(s), dispersal pattern, genetic diversity and genetic structure of *Procambarus clarkii* in China, the genetic structure and diversity of *P. clarkii* populations at 37 sampling sites (35 from China, one from the USA and one from Japan) were analyzed using both mitochondrial gene sequences (COI and 16S rRNA) and 12 nuclear microsatellites. Multiple tests including phylogenetic analyses, Bayesian assignment and analysis of isolation by distance showed that (i) the population from Japan and those collected from China, particularly from NanJing (BGt and XG) and its some neighboring sites (CJr, NT and NB), have similar genetic composition, (ii) relatively high genetic diversity was detected in Chinese populations, (iii) the *P. clarkii* populations in China did not experience significant population expansions. Taken together, Nanjing, Jiangsu province is the presumed initial entry point, and human-mediated dispersal and adaptive variation are likely responsible for the observed genetic pattern of *P. clarkii* in China.

AQUAFISH RESEARCH REPORT 12-306

PROSPECTS AND POTENTIAL FOR AQUACULTURE OF AFRICAN LUNGFISH IN UGANDA

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Published in:

World Aquaculture (2012) 43(3): 38-42.

Shifting rainfall and temperature regimes are bringing new challenges to the management of water bodies and fish farms in sub-Saharan Africa (Dixon *et al.* 2003). Culturing species that are resilient to drought and stressful water quality conditions may be a major part of future African aquaculture. Air-breathing fishes, such as the African Lungfish *Protopterus aethiopicus* can use atmospheric oxygen to meet all or part of metabolic demands (Mlewa *et al.* 2007). Air-breathing fish have a role in managed fisheries and low-management culture systems where dissolved oxygen concentration is not a limiting factor. Among air-breathing fishes, the African Catfish *Clarias gariepinus* can tolerate low levels of dissolved oxygen but its flesh is held in lower esteem by consumers as compared to lungfish. The quality of *Pangasius* catfish flesh is high but it is not a native species in Africa.

African lungfish is native to natural waters of Uganda (Greenwood 1958, 1986, Birt *et al.* 2006) but populations are rapidly declining and the species is now endangered, mainly caused by overexploitation, environmental degradation and large-scale conversion of wetlands to agricultural land (Goudswaard *et al.* 2002, Balirwa *et al.* 2003). Therefore, it is essential to develop aquaculture to relieve pressure on natural stocks. This article explores the potential of African lungfish aquaculture to improve food security and livelihoods in Uganda; identifies indigenous production practices and approaches; consumer perspectives and markets; and an outlook for lungfish fisheries and aquaculture in Uganda and sub-Saharan Africa.

AQUAFISH RESEARCH REPORT 12-307

IS LOWER INTENSITY AQUACULTURE A VALUABLE MEANS OF PRODUCING FOOD? AN EVALUATION OF ITS EFFECTS ON NEAR-SHORE AND INLAND WATERS

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Published in:

Reviews in Aquaculture (2012) 4: 234-245.

The effects of aquaculture on the environment have been the subject of much examination, but most of the focus has been on shrimp and salmon. These are not the most common species grown in aquaculture, nor the most common systems used. About 60% of production today uses lower intensity culture to produce organisms in natural systems such as ponds. This paper is an overview of the positive and negative environmental impacts of lower intensity aquaculture. The ranked positive impacts of lower intensity aquaculture include: conservation aquaculture that supplements reproduction in natural populations; improving the quality of natural waters through filtering or consuming wastes by cultured organisms; reducing pressure on wild stocks by providing alternative sources in the market; and replacing damaging employment with more sustainable aquaculture jobs. Negative impacts include: escapement of alien species that become invasive; eutrophication of receiving waters from pond effluents; release of parasites and diseases into natural communities; escapement of unique genotypes resulting in genetic alteration of native stocks; land degradation due to pond construction; release of antibiotics or other drugs into receiving waters; depletion of natural resources such as water; loss of benthic biodiversity from settling of sediments; and reductions in natural populations by collection of larval or juvenile fish. Some impacts, especially the use of fishmeal and the transmission of disease, are much less common in lower intensity aquaculture systems. Aquaculture has an important role in current and future food production, and in many cases lower intensity aquaculture provides a sustainable solution to increased aquaculture production.

AQUAFISH RESEARCH REPORT 12-308

PRODUCTION OF “CHAME” (*DORMITATOR LATIFRONS*, PISCES: *ELEOTRIDAE*) LARVAE USING GnRHa AND LHRHa

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Published in:

Revista Colombiana de Ciencias Pecuarias (2012) 25: 422-429.

The Pacific fat sleeper is a potential species for aquaculture in Latin American countries. Nevertheless, production depends on wildcaught juveniles, thus needing hatchery produced larvae. Objective: the purpose of this study was to determine the ideal conditions for viable gamete release and larvae laboratory production. Methods: a total of 16 mature male and 16 female fish were allocated to one of four groups (n=4) that were injected with either saline solution, Desgly10-Ala6 LHRHa, salmon GnRHa + domperidone, or implanted with salmon GnRHa. Results: spermiation was observed in all treatments. Spawning rates were 100% at 24 and 48 h for the GnRHa implanted group, 25% for the LHRHa group, and 0% for the salmon GnRHa + domperidone group (48-72 h post injection). Conclusion: GnRHa and LHRHa are a successful tool for chame induced reproduction. A gross morphological description of oocytes, sperm quality, and first stages of larval development is included.

AQUAFISH RESEARCH REPORT 12-309

COMPARISON OF PROXIMATE COMPOSITION, AMINO ACID AND FATTY ACID PROFILES IN WILD, POND- AND CAGE-CULTURED LONGSNOUT CATFISH (*LEIOCASSIS LONGIROSTRIS*)

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Published in:

International Journal of Food Science and Technology (2012) 47: 1772-1776.

The proximate composition, amino acid and fatty acid profiles in the fillets of wild, pond- and cage-cultured longsnout catfish (*Leiocassis longirostris*) were determined to identify nutritional differences. Wild fish showed higher ($P < 0.05$) moisture and viscerosomatic index (VSI), but lower ($P < 0.05$) protein, ash and gross energy than cage-cultured fish. Pond- cultured fish contained lower ($P < 0.05$) protein and ash contents, but higher VSI compared to cage-cultured fish. The amino acid of glycine content was higher ($P < 0.05$) in wild fish than in pond- and cage-cultured fish. Most of the fatty acids had a significant difference among all fish groups. The percentages of total polyunsaturated fatty acids (\sum PUFAs) were higher ($P < 0.05$) in wild and pond-cultured fish than in cage-cultured fish. Pond-cultured fish had higher ($P < 0.05$) \sum n-3 PUFAs, eicosapentaenoic acid (EPA), docosahexaenoic acid (DHA) and \sum n-3/ \sum n-6 PUFAs ratio than wild and cage-cultured fish. The differences among the wild, pond- and cage-cultured fish may be attributed to dietary components and environmental conditions of the fish.

AQUAFISH RESEARCH REPORT 12-310

OPEN-WATER INTEGRATED MULTI-TROPHIC AQUACULTURE: ENVIRONMENTAL BIOMITIGATION AND ECONOMIC DIVERSIFICATION OF FED AQUACULTURE BY EXTRACTIVE AQUACULTURE

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Published in:

Reviews in Aquaculture (2012) 4(4): 209–220.

Integrated multi-trophic aquaculture (IMTA) seeks to diversify fed aquaculture (e.g. finfish or shrimps) with extractive aquaculture, recapturing the inorganic (e.g. seaweeds) and organic (e.g. suspension- and deposit-feeders) nutrients from fed aquaculture for their growth. The combination fed/extractive aquaculture aims to engineer food production systems providing both bioremediative services to the ecosystem and improved economic farm output through the co-cultivation of complementary species. Major rethinking is needed regarding the definition of an ‘aquaculture farm’ and how it works within an ecosystem. The economic values of the environmental/societal services of extractive species should be recognized and accounted for in the evaluation of the full value of these IMTA components. Seaweeds and invertebrates produced in IMTA systems should be considered as candidates for nutrient/carbon trading credits. While organic loading from aquaculture has been associated with localized benthic impacts, there have also been occurrences of increased biodiversity and abundance of wild species in response to moderate nutrient enrichment and the use of infrastructures as substrates. To develop efficient food production systems, it will be important to understand and use the duality of nutrients (essential when limiting/polluting when in excess) to engineer systems producing them in moderation so that they can be partially recaptured while maintaining their concentrations optimal for healthy and productive ecosystems. Measures of species diversity, colonization rates, abundance, growth and ecosystem functions with respect to nutrient partitioning and recycling, species interactions and control of diseases could represent valid indicators for the development of robust performance metrics.

AQUAFISH RESEARCH REPORT 12-311

COMPARATIVE ANALYSIS OF WATER QUALITY IN *LITOPENAEUS VANNAMEI* PONDS AND NUTRITIONAL QUALITY OF SHRIMP MUSCLE

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Published in:

Journal of Shanghai Ocean University (2012) 21(6): 955-964.

From May to September in 2010, water quality parameters such as water temperature, total dissolved salt, dissolved oxygen, pH, transparency, nitrite nitrogen, ammonia nitrogen, nitrate nitrogen, total nitrogen, reactive phosphorus, chlorophyll-a and biochemical oxygen demand were analyzed in 22 *Litopenaeus vannamei* ponds with different culturing methods in Fengxian District, Shanghai. Water used for Farm No. 1 was natural fresh water which had been precipitated before being introduced to the ponds. Mixed salt were added to the freshwater for culturing shrimp in Farm No. 2. Results were as follows: water temperature, dissolved oxygen and pH didn't change dramatically and could match the demand of *Litopenaeus vannamei*. The Proportion of nitrate nitrogen in ponds to TIN was the highest, the ratio of ammonia nitrogen to TIN increased with time extension, and that of nitrite nitrogen to TIN increased obviously in the later period of the culture cycle. Contents of reactive phosphorus decreased gradually while the total phosphorus increased in the whole process of culture. Biochemical oxygen demand and chlorophyll-a also increased gradually with the shrimp growing up. Muscle nutritional quality of *Litopenaeus vannamei* from the two farms were analyzed and the result were as follows: contents of crude protein and crude fat of shrimp muscle in Farm No. 1 were 16.30% and 1.42% respectively, lower than those in shrimp muscle from Farm No. 2 which were 18.30% and 1.61%. Content of total amino acids in shrimp from Farm No. 1 was 23.27%, and the essential amino-acid was 9.09%. While those in shrimp from Farm No. 2 were 27.52% and 10.74% respectively. Contents of flavor amino acids in shrimp Farms No. 1 and 2 were 8.52% and 10.16% respectively.

AQUAFISH RESEARCH REPORT 12-312

RESEARCH ON ARTIFICIAL SEAWATER QUALITY IN THE *PENAEUS VANNAMEI* LARVAL BREEDING PONDS

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Published in:

Guangdong Agricultural Science (2012) 1: 120-123.

In order to overcome the losses caused by long-distance transportation, we try to use artificial seawater for *Penaeus vannamei* larval breeding locally. In 2011, we added seawater crystal and coarse salt to the natural freshwater from adjacent river for *Penaeus vannamei* larval breeding in Fengxian district of Shanghai. During the breeding period, we monitored water quality every day and the results were as following: DO was 7.3(\pm 0.10) mg/L, pH was 8.00(\pm 0.04), temperature was 28.2(\pm 0.20)°C, PO₄-P was 0.88(\pm 0.14) mg/L, TP was 1.46(\pm 0.14) mg/L, NO₂--N was 0.21(\pm 0.02) mg/L, NO₃--N was 1.52(\pm 0.10) mg/L, TNH₄-N was 2.88(\pm 0.34) mg/L, TN was 7.01(\pm 0.36) mg/L, and CODMn was 18.05 (\pm 1.40) mg/L. Biological and chemical methods were used for water quality control to create a good environment for larval growth.

AQUAFISH RESEARCH REPORT 12-313

STUDY ON VARIATION CHARACTERISTICS AND CORRELATION ANALYSIS OF MAJOR ECOLOGICAL FACTORS IN INTENSIVE SHRIMP PONDS

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Published in:

South China Fisheries Science (2012) 8(4): 49-56.

To study the variation characteristics and correlation of major ecological factors in intensive shrimp farming ponds, we measured 16 aquatic ecological factors including the concentration of chlorophyll a (Chl-a) as well as the density of zooplankton, heterotrophic bacteria and vibrio, active phosphorus (PO_4^{3-} -P), etc. in 3 farming ponds of *Litopenaeus vannamei* in Paipu, Danzhou, from April to July in 2011. The results show that the values of DO, pH and transparency decreased slowly, and the total suspended solids (TSS), chemical oxygen demand (COD), nitrite nitrogen (NO_2^- -N), ammonia nitrogen (NH_4^+ -N) as well as the density of zooplankton, heterotrophic bacteria and vibrio slowly increased during the culture period. The concentration of Chl-a was low in the earlier stage but increased gradually in the mid and latter stages; Chl-a had a very significant positive correlation with NO_3^- -N and a negative correlation with PO_4^{3-} -P. The density of Copepod had a very significantly positive correlation with TSS and a significantly positive correlation with the density of heterotrophic bacteria, vibrio and rotifer, but had no significant correlation with Chl-a and COD. The density of heterotrophic bacteria had a very significant positive correlation with COD and TSS, but had a significantly negative correlation with transparency. The density of vibrio was very significantly correlated with TSS and COD, but had a significantly negative correlation with pH and DO.

AQUAFISH RESEARCH REPORT 12-A01

GEOSPATIAL MODELING OF SITE SUITABILITY FOR POND-BASED TILAPIA AND CLARIAS FARMING IN UGANDA

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Published in:

Journal of Applied Aquaculture (2012) 24: 147-169.

Seven criteria (water requirement, water temperature, soil texture, terrain slope, potential farm gate sales, availability of farm inputs, and access to local and regional markets) were analyzed to determine site suitability for tilapia and clarias farming in Uganda. Crisp and fuzzy approaches of criterion classification were implemented using GIS, and the results were compared. There was a statistically significant difference between maps generated by crisp and fuzzy approaches. For both the crisp and the fuzzy approaches, over 98% of the land was classified as moderately suitable or suitable. Overall, the crisp method classified 16,322 hectares (0.09%) as very suitable compared to zero hectares (0%) by the fuzzy method. Simultaneously, the crisp method gave 297,344 hectares (1.96%) as unsuitable compared to 168,592 hectares (0.96%) by the fuzzy method. Of the 138 surveyed fishponds that were operational, the crisp method classified 71% as suitable and 29% as moderately suitable, while the fuzzy method classified 71.7% as suitable and 28.3% as moderately suitable.

AQUAFISH RESEARCH REPORT 12-A02

PROTEIN REQUIREMENT IN MASCULINIZED AND NON-MASCULINIZED JUVENILES OF BAY SNOOK
PETENIA SPLENDIDA

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Published in:

Hidrobiológica (2012) 22(3): 219-228.

The effect of the dietary protein level on growth and total body chemical composition of the native cichlid Bay snook (*Petenia splendida*), masculinized and non-masculinized, was studied. Five semi-purified diets with protein levels 35, 40, 45, 50 and 55% crude protein (CP) were formulated and evaluated by triplicate. Groups of 50 juveniles were each stocked in 70 L tanks and fed to apparent satiation for 42 days trial. At the end, weight gain (WG) (403.41%), body length (BL) (6.58 ± 0.10 cm) and specific growth rate (SRG) (1.67%/day) of the masculinized fish were obtained with the 45% CP diet, and they were significantly different ($p = 0.002$) from the other treatments. In the case of non-masculinized fish, the 45 and 55% CP treatments showed significant differences ($p = 0.00001$), with respect to other treatments, with a WG of 398 and 394%, SGR of 1.66 and 1.63%/day, protein productive value (PPV) of 28.91 and 29.21%, and feed conversion rate (FCR) of 1.23 and 1.08 respectively. Protein body composition for masculinized fish was different ($p = 0.0001$) only for fish fed 35% CP compared with fish at the beginning of the experiment. We conclude that the optimum protein requirement, estimated by the broken-line model for masculinized and non-masculinized *P. splendida* was 45 and 44.8% PC respectively.

AQUAFISH RESEARCH REPORT 12-A03

FEMINIZATION OF YOUNG COMMON SNOOK *CENTROPOMUS UNDECIMALIS* (BLOCH 1792) USING 17 β -ESTRADIOL

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Published in:

Revista Ciencias Marinas y Costeras (2012) 4: 83-93.

Common snook *Centropomus undecimalis* is a protandric fish with a high commercial importance and aquacultural potential in Mexico and the United States. Several studies indicate that females have higher growth capacity than males. For this reason, the objective of this research was to evaluate the effect of a 17 β -estradiol (E₂) diet supplementation on sex proportion for this species. In this sense, an experimental study was conducted where fish were fed for different time periods (7, 14, 21, 28, 35, and 42 days) with food impregnated with 50 mg of E₂/Kg, and one control diet without the presence of the steroid. After feeding times, fish were raised for additional 204 days with the control diet to evaluate sex proportion, growth and survival. Our results showed that fish fed with E₂ for 21 days or more had the highest female sex proportion (93-100%), while the control group showed the highest male proportion (100%). The highest growth (weight and total length) was detected in fish fed with E₂ for 21 days (193.11 ± 1.83 mm and 28.56 ± 0.63 g) compared with the rest of the treatments. Survival did not show statistical differences between treatments (92-98%). We conclude that high percentage of *C. undecimalis* females can be obtained when fish are fed for 21 days or more with artificial food supplemented with E₂.

AQUAFISH RESEARCH REPORT 12-A04

PRODUCTION, GROWTH, AND INSULIN-LIKE GROWTH FACTOR-I (IGF-I) GENE EXPRESSION AS AN INSTANTANEOUS GROWTH INDICATOR IN NILE TILAPIA *OREOCHROMIS NILOTICUS*

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Published in:

Marco Saroglia and Zhanjiang (John) Liu (Editors), 2012. *Functional Genomics in Aquaculture*. John Wiley & Sons, Inc., Oxford, United Kingdom: 79-89.

Worldwide, rapid expansion of the market for *Oreochromis* spp. (tilapia) has increased the incentive for culturists to optimize the profitability of production techniques for these fishes. The establishment of best management practices for tilapia production has been slow, in part because they are omnivorous and relatively easy to grow. Their wide distribution in subtropical and tropical areas and the ease of adaptation to different culture methods have contributed to the highly variable approaches that are used to cultivate tilapia commercially. Ongoing refinement of the efficiency of tilapia culture in response to environmental, nutritional, and genetic variables is reliant on accurate assessment of growth rates. We describe herein a molecular method for the rapid assessment of the growth status of these fish. Earlier trials of culture conditions have been dependent on expensive commercial-scale production trials and labor-intensive physical measurements of growth, but expression of the insulin-like growth factor-I (IGF-I) gene provides a nearly instantaneous indicator of the growth status of these fishes. The relative accuracy and efficiency of quantifying the hepatic mRNA (messenger RNA) for this growth regulatory compound and its applicability as a growth indicator or marker in tilapia are discussed. We conclude that IGF-I mRNA abundance is suitable as an alternative approach to the assessment of growth during trials of the relative effectiveness of experimental culture conditions.

AQUAFISH RESEARCH REPORT 12-A05

ECONOMETRIC ASSESSMENT OF RESEARCH PROGRAMS: A BAYESIAN APPROACH

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Published in:

Agricultural and Applied Economics Association's 2012 Annual Meeting, Seattle, Washington, August 12-14, 2012: 1-23.

Effective research-project assessment typically is impeded by project variety. In particular, bibliometric approaches to science assessment tend to offer little information about the content of the projects examined. We introduce here a new approach – based on Bayesian theory – of econometrically evaluating the factors affecting scientific discovery, and use the method to assess a biological research program comprised of numerous heterogeneous projects. Our knowledge metric not only flexibly accommodates project variety but accounts for information in “failed” as well as “successful” studies. Using a mean-absolute-deviation utility functional form to measure new scientific knowledge, we decompose knowledge gain into a mean-surprise and statistical-accuracy effect. The two effects are econometrically examined independently, and then combined into the net knowledge production function. Research FTE and distance to study site have statistically significant but moderate effects on the amount by which research shifts the prediction of scientific outcome. However, scientist education powerfully improves the research study’s predictive accuracy or precision, a one-percent boost in the average investigator’s formal schooling improving precision by 4.3 percent. Largely on the basis of that precision effect, increasing returns to research project scale are evident.

AQUAFISH RESEARCH REPORT 12-A06

CURRENT STATUS AND PROSPECTS OF FARMING THE GIANT RIVER PRAWN *MACROBRACHIUM ROSENBERGII* (DE MAN) IN BANGLADESH

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Published in:

Aquaculture Research (2012) 43: 970-983.

Giant river prawn (*Macrobrachium rosenbergii*) farming plays an important role in the economy of Bangladesh. Presently, it is cultured in around 50 000 ha area with total annual production of 23 240 t. Traditional extensive prawn farming has been expanding over the last three decades through the introduction and adoption of improved culture systems, such as culture of prawn-carps, prawn-shrimp-fish and prawn-fish-rice as concurrent and rotational systems. Efforts for the development of improved techniques on broodstock management, seed production and rearing and grow-out of prawn have been made over the last decade. The outcomes are low-cost feed for broodstock, production of post-larvae in net cages (hapa), all-male prawn culture, periphyton based prawn-tilapia culture, C/N based prawn culture, organic prawn farming, prawn-mola culture and prawn-carp-mola polyculture. Despite the development of culture technologies, a number of challenges for sustainable development of prawn farming need to be overcome to realize the potentials of this promising sector. Good aquaculture practices at all levels and application of measures for quality control and food safety would ensure sustainable development of prawn farming in Bangladesh.

AQUAFISH RESEARCH REPORT 12-A07

THE SOLUTE CARRIER (SLC) FAMILY SERIES IN TELEOST FISH

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Published in:

Marco Saroglia and Zhanjiang (John) Liu (Editors), 2012. *Functional Genomics in Aquaculture*. John Wiley & Sons, Inc., Oxford, United Kingdom: 219-320.

Human genes encoding passive transporters, ion-coupled transporters, and exchangers are all included in the so-called Solute Carrier (SLC) gene series (the Human Genome Organization Gene Nomenclature Committee; <http://www.genenames.org/>), consisting of 51 families and at least 378 genes (<http://www.bioparadigms.org>). Ortholog genes encoding for transport proteins of the SLC series have comparatively been described in teleost fish, although their functional properties, in terms of kinetic parameters, substrate specificities, and inhibition patterns of the expressed transport proteins, have only sporadically been assessed in vitro. This chapter gives the latest updates for the SLC families and their members in teleost fish as well as relevant links to GenBank database and literature. By using a functional genomics approach, a list (version 1.0) of all currently known SLC families in teleost fish is provided in the form of SLC tables.

AQUAFISH RESEARCH REPORT 12-A08

ECONOMICS OF FISH MARKETING IN CENTRAL UGANDA: A PRELIMINARY ANALYSIS

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Published in:

The Proceedings of the Southern Agricultural Economics Association Annual Meeting, 4-7 February 2012, Birmingham, AL, USA: 237-242.

The paper examines profitability and market performance of small-scale fish traders selected randomly from a cross-section of nine fish markets in four districts in Central Uganda. Data were collected through a structured questionnaire which was designed to solicit information on traders' socio-economic characteristics, marketing characteristics, operating costs and returns, and problems associated with fish marketing in the study area. Percentages were used to describe the socio-economic characteristics, market characteristic and problems associated with fish marketing while gross profit and marketing performance models were used to determine profitability, marketing margin and operational efficiency, respectively. The results suggest that fish trade is carried out by both men and women. More men are involved in the trade of fresh fish while more women are involved in the processed (sundried/smoked) fish trade. Some traders dealt in more than one species of fish although a majority sold exclusively in one species. Gross profit was estimated at US\$358.40/kg and US\$234.73/kg for wholesalers and retailers, respectively, with marketing margins of 19.32% and 16.67% for wholesalers and retailers, respectively. The market operational efficiency was 279.27 percent, implying high efficiency in fish marketing in the study area. The major pressing concerns which included high supply cost, low prices, low fish supply and increased arrests for selling immature fish were common to both retail and wholesale marketing channels.

AQUAFISH RESEARCH REPORT 12-A09

NIBBLING FREQUENCY OF CARPS IN PERIPHYTON-BASED AQUACULTURE SYSTEMS WITH AND WITHOUT SUPPLEMENTAL FEED

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Published in:

The Israeli Journal of Aquaculture (2012) 64: 1-5.

The nibbling frequency of five carp species (rohu *Labeo rohita*, mrigal *Cirrhinus mrigala*, catla *Catla catla*, common carp *Cyprinus carpio*, silver carp *Hypophthalmichthys molitrix*) on bamboo lateral sticks (kanchi) colonized by periphyton was examined in fed and unfed systems. There were three treatments: (a) no carp and no supplemental feed (control), (b) carp without supplemental feeding (unfed treatment), and (c) carp with supplemental feeding (fed treatment). For 12 h (07:30-19:30) during six days, nibbling behavior was observed in real time via a digital video camera and recorded on a camcorder for later viewing. Rohu, catla, and common carp nibbled on the kanchi, while mrigal and silver carp did not. In rohu and catla, the nibbling frequency was significantly higher in the unfed treatment than in the fed treatment ($p < 0.05$); supplemental feeding reduced nibbling frequency by 81% and 91%, respectively. Hence, in periphyton-based aquaculture systems, there is no need for a high density of substrates in ponds that receive supplemental feed. Alternatively, the amount of supplied feed can be reduced to force these species to consume more periphyton.

AQUAFISH RESEARCH REPORT 13-314

RESPONSIBLE AQUACULTURE IN 2050: VALUING LOCAL CONDITIONS AND HUMAN INNOVATIONS
WILL BE KEY TO SUCCESS

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Published in:

Bioscience (2013) 63(4): 255-262.

As aquaculture production expands, we must avoid mistakes made during increasing intensification of agriculture. Understanding environmental impacts and measures to mitigate them is important for designing responsible aquaculture production systems. There are four realistic goals that can make future aquaculture operations more sustainable and productive: (1) improvement of management practices to create more efficient and diverse systems at every production level; (2) emphasis on local decision making, human capacity development, and collective action to generate productive aquaculture systems that fit into societal constraints and demands; (3) development of risk management efforts for all systems that reduce disease problems, eliminate antibiotic and drug abuse, and prevent exotic organism introduction into local waters; and (4) creation of systems to better identify more sustainably grown aquaculture products in the market and promote them to individual consumers. By 2050, seafood will be predominantly sourced through aquaculture, including not only finfish and invertebrates but also seaweeds.

AQUAFISH RESEARCH REPORT 13-315

GOVERNANCE OF GLOBAL VALUE CHAINS IN RESPONSE TO FOOD SAFETY AND CERTIFICATION
STANDARDS: THE CASE OF SHRIMP FROM VIETNAM

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Published in:

World Development (2013) 45: 325-336.

We use global value chain (GVC) theory to understand governance of Vietnam's shrimp farming industry. We describe this GVC as buyer-driven with important food safety standards imposed by governments of importing countries and new certification systems promoted by nongovernmental organizations (NGOs). Governance relations are clear between governments in importing countries and Vietnam, and between importers and NGOs. Governance relations become more fragmented further down the chain where large numbers of small-scale producers and traders operate. This fragmentation may adversely affect access to the most lucrative markets and have the unanticipated effect of marginalizing small-scale farmers and traders.

AQUAFISH RESEARCH REPORT 13-316

ANTIMICROBIAL USE IN AQUACULTURE RE-EXAMINED: ITS RELEVANCE TO ANTIMICROBIAL RESISTANCE AND TO ANIMAL AND HUMAN HEALTH

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Published in:

Environmental Microbiology (2013) 15(7): 1917-1942.

The worldwide growth of aquaculture has been accompanied by a rapid increase in therapeutic and prophylactic usage of antimicrobials including those important in human therapeutics. Approximately 80% of antimicrobials used in aquaculture enter the environment with their activity intact where they select for bacteria whose resistance arises from mutations or more importantly, from mobile genetic elements containing multiple resistance determinants transmissible to other bacteria. Such selection alters biodiversity in aquatic environments and the normal flora of fish and shellfish. The commonality of the mobilome (the total of all mobile genetic elements in a genome) between aquatic and terrestrial bacteria together with the presence of residual antimicrobials, biofilms, and high concentrations of bacteriophages where the aquatic environment may also be contaminated with pathogens of human and animal origin can stimulate exchange of genetic information between aquatic and terrestrial bacteria. Several recently found genetic elements and resistance determinants for quinolones, tetracyclines, and beta-lactamases are shared between aquatic bacteria, fish pathogens, and human pathogens, and appear to have originated in aquatic bacteria. Excessive use of antimicrobials in aquaculture can thus potentially negatively impact animal and human health as well as the aquatic environment and should be better assessed and regulated.

AQUAFISH RESEARCH REPORT 13-317

ECONOMICALLY FEASIBLE OPTIONS FOR INCREASED WOMEN PARTICIPATION IN KENYAN AQUACULTURE VALUE CHAIN

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Published in:

Aquaculture (2013) 414- 415: 183-190.

This paper used value chain analysis to determine economically viable opportunities for increased female participation in the aquaculture value chains in Kenya. The main opportunities for women are as fish marketers and as fish farmers, especially in the Western Province of Kenya. Fish marketing is economically more viable than fish farming with an overall benefit–cost ratio of over 1.00 while the benefit–cost ratios for fish farmers were less than 0.5. The western region had the strongest fish production sector compared to the Central Province and the Rift Valley and provides relatively better opportunities for women participation in fish production. In the Rift Valley Province, women could work as paid laborers on fish farms as this region showed the largest employment impact on the community from a growth in fish farming activities.

AQUAFISH RESEARCH REPORT 13-318

NITROGEN AND PHOSPHOROUS BUDGET ANALYSIS OF CARP BASED POLYCULTURE PONDS IN CHITWAN, NEPAL

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Published in:

Our Nature (2013) 11(2): 116-125.

An experiment was conducted in 12 earthen ponds of 200 m² at Kathar VDC, Chitwan, Nepal for 270 days to analyze the productivity and nutrient budget in some carp based polyculture systems. The experiment was conducted in a completely randomized design with four treatments in triplicate each: a) Carps only or control (7000 fish/ha) (T₁); b) Carps (7000/ha) + tilapia (3000/ha) (T₂); c) Carps (7000/ha) + tilapia (3000/ha) + sahar (500/ ha) (T₃); and d) Carps (7000/ha) + tilapia (3000/ha) + sahar (1000/ha) (T₄). Silver carp (*Hypophthalmichthys molitrix*), bighead carp (*Aristichthys nobilis*), common carp (*Cyprinus carpio*), grass carp (*Ctenopharyngodon idella*), rohu (*Labeo rohita*) and mrigal (*Cirrhinus mrigala*) of mean stocking size 3.0, 4.2, 10.0, 18.8, 10.5, 2.2 g, respectively were stocked in all ponds at the ratio of 4:2:1:1:1:1. The mean stocking size of Nile tilapia (*Oreochromis niloticus*) and sahar (*Tor putitora*) were 9.7 and 3.4 g, respectively. The ponds were fertilized weekly with urea and diammonium phosphate @ 4 g N and 1 g P/m²/day. Fish were fed with locally made pellet feed (20% CP) once in an alternate day at @ 2% body weight. At harvest, the extrapolated fish yield ranged from 1.5 to 1.7 t/ha/year in different treatments, without significant differences among treatments (P>0.05). Inclusion of sahar in Nile tilapia ponds decreased recruits by 63 to 72%. There were no significant differences in water quality parameters among treatments, except dissolved oxygen concentration, which was significantly lower in T₁ and T₃ than T₂ and T₄ (p<0.05). Both nitrogen and phosphorous were gained from fish species and lost from soil and water. There were no significant differences in nitrogen and phosphorous contents of all inputs and outputs among treatments. The unaccounted nitrogen and phosphorous loss ranged from 9.8-17.1% and 51.2-64.4%, respectively. The nitrogen and phosphorous required for producing 1 kg fish ranged from 337.5-375.9 g and 130.3-150.9 g, without significant difference among treatments. The nitrogen and phosphorous discharged for producing 1 kg fish ranged from 1.59-4.35 g and 1.6-9.3 g, respectively.

AQUAFISH RESEARCH REPORT 13-319

GENETIC VARIABILITY OF THE COMMON SNOOK *CENTROPOMUS UNDECIMALIS* (PERCIFORMES: *CENTROPOMIDAE*) IN CONNECTED MARINE AND RIVERINE ENVIRONMENTS

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Published in:

Revista de Biología Tropical (International Journal of Tropical Biology) (2014) 62(2): 627-636.

The Common Snook, *Centropomus undecimalis*, inhabits riverine and marine areas of the Southern Gulf of Mexico, where it is subject to intense use and exploitation. It has been reported that the genetic identification of fish stocks constitutes a valuable tool for wild population management; nevertheless, there is no available information on the genetic identification on fish stocks of this species in the region. The aim of this study was to determine the genetic relationship between *C. undecimalis* captured in marine and freshwater environments of the Gulf of Mexico and the San Pedro River. For this, muscle tissue samples of 79 specimens were obtained from areas located more than 300km apart. The genotype of each individual was determined using seven microsatellite primer pairs. Five primers amplified efficiently presenting between six and 28 alleles per locus. High levels of heterozygosity were observed in samples from both environments. Deviation from HWE due to an excess of heterozygotes was observed. The values of genetic difference indicate an absence of population structure ($F_{ST}=0.0075$ and $R_{ST}=0.016$, $p=0.051$) and similarity in the allele frequencies, defined by Nei's index (0.805). Data showed the existence of a high gene flow due to the number of migrants ($N_m=18.7$). Our results suggest that individuals living in these environments belong to the same genetic population. We suggest the development of management and protection plans for this fish species population in the wild.

AQUAFISH RESEARCH REPORT 13-320

CIRCULATING LEVELS OF PLASMA IGF-I DURING RECOVERY FROM SIZE-SELECTIVE HARVESTING
IN *MENIDIA MENIDIA*

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Published in:

Comparative Biochemistry and Physiology Part A, Molecular & Integrative Physiology (2013)
166(2): 222- 227.

Selection for growth-related traits in domesticated fishes often results in predictable changes within the growth hormone-insulin-like growth factor (GH-IGF-1) axis. Little is known about the mechanisms controlling changes in growth capacity resulting from fishery-induced evolution. We took advantage of a long-term study where *Menidia menidia* were selected for size at age over multiple generations to mimic fisheries-induced selection. This selection regime produced three populations with significant differences in intrinsic growth rate. These growth differences partially rebounded, but persisted even after selection was relaxed, resulting in fast, intermediate, and slow-growing lines. Plasma IGF-1 was measured in these populations as a potential target of selection on growth. IGF-1 was significantly correlated with current length and mass, and was positively correlated with growth rate (g d^{-1}) in two lines, indicating it may be an appropriate indicator of growth capacity. The slow-growing line exhibited higher overall IGF-1 levels relative to the depressed IGF-1 seen in the fast-growing line, contrary to our prediction. We offer possible explanations for this unusual pattern and argue that somatic growth is likely to be under control of mechanism(s) downstream to IGF-1. IGF-1 provides an interesting basis for understanding endocrine control of growth in response to artificial selection and recovery.

AQUAFISH RESEARCH REPORT 13-321

CHARACTERIZATION OF MEMBRANE RECEPTOR BINDING ACTIVITY FOR CORTISOL IN THE LIVER AND KIDNEY OF THE *EURYHALINE TELEOST*, MOZAMBIQUE TILAPIA (*OREOCHROMIS MOSSAMBICUS*)

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Published in:

General and Comparative Endocrinology (2013) 192: 107-114.

Glucocorticoids (GCs) regulate an array of physiological responses in vertebrates. Genomic GC actions mediated by nuclear steroid receptors require a lag time on the order of hours to days to generate an appreciable physiological response. Experimental evidence has accumulated that GCs can also act rapidly through a nongenomic mechanism to modulate cellular physiology in vertebrates. Causal evidence in the Mozambique tilapia (*Oreochromis mossambicus*) suggests that the GC cortisol exerts rapid, nongenomic actions in the gills, liver, and pituitary of this euryhaline teleost, but the membrane receptor mediating these actions has not been characterized. Radio receptor binding assays were conducted to identify a putative GC membrane receptor site in *O. mossambicus*. The tissue distribution, binding kinetics, and pharmacological signature of the GC membrane-binding activity were characterized. High affinity ($K_d = 9.527 \pm 0.001$ nM), low-capacity ($B_{max} = 1.008 \pm 0.116$ fmol/mg protein) [³H] cortisol binding was identified on plasma membranes prepared from the livers and a lower affinity ($K_d = 30.08 \pm 2.373$ nM), low capacity ($B_{max} = 4.690 \pm 2.373$ fmol/mg protein) binding was found in kidney membrane preparations. Competitors with high binding affinity for nuclear GC receptors, mifepristone (RU486), dexamethasone, and 11-deoxycorticosterone, displayed no affinity for the membrane GC receptor. The association and dissociation kinetics of [³H] cortisol binding to membranes were orders of magnitude faster ($t_{1/2} = 1.7\text{--}2.6$ min) than those for the intracellular (nuclear) GC receptor ($t_{1/2} = 10.2$ h). Specific [³H] cortisol membrane binding was also detected in the gill and pituitary but not in brain tissue. This study represents the first characterization of a membrane GC receptor in fishes and one of only a few characterized in vertebrates.

AQUAFISH RESEARCH REPORT 13-322

ENDOCRINE REGULATION OF COMPENSATORY GROWTH IN FISH

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Published in:

Frontiers in Endocrinology (Lausanne) (2013) 4: 74.

Compensatory growth (CG) is a period of accelerated growth that occurs following the alleviation of growth-stunting conditions during which an organism can make up for lost growth opportunity and potentially catch up in size with non-stunted cohorts. Fish show a particularly robust capacity for the response and have been the focus of numerous studies that demonstrate their ability to compensate for periods of fasting once food is made available again. CG is characterized by an elevated growth rate resulting from enhanced feed intake, mitogen production, and feed conversion efficiency. Because little is known about the underlying mechanisms that drive the response, this review describes the sequential endocrine adaptations that lead to CG; namely during the precedent catabolic phase (fasting) that taps endogenous energy reserves, and the following hyperanabolic phase (refeeding) when accelerated growth occurs. In order to elicit a CG response, endogenous energy reserves must first be moderately depleted, which alters endocrine profiles that enhance appetite and growth potential. During this catabolic phase, elevated ghrelin and growth hormone (GH) production increase appetite and protein-sparing lipolysis, while insulin-like growth factors (IGFs) are suppressed, primarily due to hepatic GH resistance. During refeeding, temporal hyperphagia provides an influx of energy and metabolic substrates that are then allocated to somatic growth by resumed IGF signaling. Under the right conditions, refeeding results in hyperanabolism and a steepened growth trajectory relative to constantly fed controls. The response wanes as energy reserves are re-accumulated and homeostasis is restored. We ascribe possible roles for select appetite and growth-regulatory hormones in the context of the prerequisite of these catabolic and hyperanabolic phases of the CG response in teleosts, with emphasis on GH, IGFs, cortisol, somatostatin, neuropeptide Y, ghrelin, and leptin.

AQUAFISH RESEARCH REPORT 13-A01

ENDOCRINE REGULATION OF PROLACTIN CELL FUNCTION AND MODULATION OF OSMORECEPTION IN THE MOZAMBIQUE TILAPIA

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Published in:

General and Comparative Endocrinology (2013) 192: 191-203.

Prolactin (PRL) cells of the Mozambique tilapia, *Oreochromis mossambicus*, are osmoreceptors by virtue of their intrinsic osmosensitivity coupled with their ability to directly regulate hydromineral homeostasis through the actions of PRL. Layered upon this fundamental osmotic reflex is an array of endocrine control of PRL synthesis and secretion. Consistent with its role in fresh water (FW) osmoregulation, PRL release in tilapia increases as extracellular osmolality decreases. The hyposmotically-induced release of PRL can be enhanced or attenuated by a variety of hormones. Prolactin release has been shown to be stimulated by gonadotropin-releasing hormone (GnRH), 17- β -estradiol (E2), testosterone (T), thyrotropin-releasing hormone (TRH), atrial natriuretic peptide (ANP), brain-natriuretic peptide (BNP), C-type natriuretic peptide (CNP), ventricular natriuretic peptide (VNP), PRL-releasing peptide (PrRP), angiotensin II (ANG II), leptin, insulin-like growth factors (IGFs), ghrelin, and inhibited by somatostatin (SS), urotensin-II (U-II), dopamine, cortisol, ouabain and vasoactive intestinal peptide (VIP). This review is aimed at providing an overview of the hypothalamic and extra-hypothalamic hormones that regulate PRL release in euryhaline Mozambique tilapia, particularly in the context on how they may modulate osmoreception, and mediate the multifunctional actions of PRL. Also considered are the signal transduction pathways through which these secretagogues regulate PRL cell function.

AQUAFISH RESEARCH REPORT 13-A02

GROWTH, BODY CHEMICAL COMPOSITION AND TRYPSIN ACTIVITY OF SOUTH AMERICAN CATFISH, SURUBIM (*PSEUDOPLATYSTOMA* SP.) JUVENILES FED DIFFERENT DIETARY PROTEIN AND LIPID LEVELS

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Published in:

Aquaculture Research (2013) 44: 760-771

To evaluate protein and lipid requirement of South American catfish surubim (*Pseudoplatystoma* sp.) juveniles, nine semi-purified diets containing three levels of protein (40%, 45% and 50%) and three levels of lipid (12%, 16% and 20%) were tested. After 8-week feeding trial, body weight increase averaged $2124.3 \pm 295.7\%$. Growth performance was significantly affected by dietary level of protein ($P < 0.05$). At the 40% protein level, increasing level of dietary lipid had a positive effect on final individual mean weight (protein sparing effect). Whole body protein and moisture contents were affected by the dietary level of lipid ($P < 0.05$). Whole body lipid content positively correlated with the level of dietary lipid ($P < 0.05$). Cannibalism related mortality was observed despite rearing fish in 24 h dark. Fatty acid composition of fish was affected by the dietary lipid level ($P < 0.05$). Polyunsaturated fatty acids increased with the increasing level of dietary lipid while saturated fatty acids and monounsaturated fatty acids decreased. Trypsin activity in the digestive tract of surubim was influenced by dietary levels of protein and lipid ($P < 0.05$). Our preliminary results suggest that the optimum protein/lipid ratio might be close to 45/16% for surubim juveniles.

AQUAFISH RESEARCH REPORT 13-A03

ROLE OF LIFE CYCLE ASSESSMENT IN SUSTAINABLE AQUACULTURE

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Published in:

Reviews in Aquaculture (2013) 5: 61–71

As an alternative food source to wild fisheries, aquaculture shows a great potential to help meet the growing demand for seafood and animal protein. The expansion of aquaculture has been achieved partly by system intensification, which has drawn vast criticisms of aquaculture for its environmental, social and economic sustainability issues. Life cycle assessment (LCA) has become the leading tool for identifying key environmental impacts of seafood production systems. A LCA evaluates the sustainability of diverse aquaculture systems quantitatively from a cradle-to-grave perspective. It provides a scientific basis for analyzing system improvement and the development of certification and eco-labelling criteria. Current efforts focus on integrating local ecological and socio-economic impacts into the LCA framework. A LCA can play an important role in informing decision makers in order to achieve more sustainable seafood production and consumption. This article reviews recent applications of LCA in aquaculture, compares the environmental performance of different aquaculture production systems, explores the potential of including biodiversity issues into LCA analysis and examines the potential of LCA in setting criteria for certification and eco-labelling.

AQUAFISH RESEARCH REPORT 13-A04

CHARACTERIZATION OF POTENTIAL AQUACULTURE POND EFFLUENTS, AND PHYSICOCHEMICAL AND MICROBIAL ASSESSMENT OF EFFLUENT-RECEIVING WATERS IN CENTRAL GHANA

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Published in:

African Journal of Aquatic Science (2013) 38(2): 185-192.

An understanding of specific aquaculture systems and the impacts of their management practices leads to sound and cost-effective policies to protect the aquatic environment. Water samples were collected in 2009 from fish ponds, streams that receive effluents directly from ponds and reference streams in Ghana to assess potential environmental impacts of pond aquaculture. Although relatively dilute, fish ponds had higher levels of all physicochemical variables measured compared to those of locations upstream and downstream of farms, and to reference locations. Total nitrogen and BOD₅ were most clearly statistically significant. Of 292 earthen fish ponds surveyed in central Ghana, approximately 92% were used for either *Oreochromis* monoculture or *Oreochromis*–*Clarias* polyculture. These had similar pond water (i.e. potential effluent) quality but different management practices. The study ponds had the potential to pollute effluent-receiving streams, but their actual impacts will depend on how pond effluents are managed. Conventional treatment of effluents from these small-scale, low-volume operations, which discharge relatively dilute effluents infrequently, might not be cost-effective.

AQUAFISH RESEARCH REPORT 13-A05

IMPACTS OF INCLUSION OF COLUMN FEEDER ROHU (*LABEO ROHITA*) AT DIFFERENT STOCKING DENSITIES ON GROWTH, PRODUCTION AND ENVIRONMENT IN FRESHWATER PRAWN-CARP-MOLA POLY CULTURE SYSTEM

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Published in:

International Journal of Biological Research (2013) 1(2): 48-54.

The research investigated the impacts of inclusion of column feeder rohu (*Labeo rohita*) on growth and production in freshwater prawn-carp-mola polyculture system for a period of 172 days. Four stocking densities of Rohu were maintained as 500, 1,000, 1,500 and 2,000 ha⁻¹ in treatment R₅₀₀, R₁₀₀₀, R₁₅₀₀ and R₂₀₀₀, and A. Nahar, respectively in triplicates. All ponds each 120 m² were stocked with juvenile freshwater prawn (*Macrobrachium rosenbergii*), silver carp (*Hypophthalmichthys molitrix*), catla (*Catla catla*) and small fish mola (*Amblypharyngodon mola*) at the fixed stocking densities of 20,000, 1,500, 1,000 and 20,000 ha⁻¹, respectively. Prawns were fed with pelleted feed twice daily started with 10% and gradually reduced to 3% of body weight and continued throughout the study period. All fish were fed with mixture of soaked rice bran and mustard oilcake (2:1) at the rate of 3% of the body weight daily. All the water quality parameters and chlorophyll-a were measured. The density of rohu significantly ($P < 0.05$) influenced the survival rate, growth and production of freshwater prawn. Catla and Mola production were affected adversely with increasing rohu density. The production of rohu increased with increasing density although the individual weight decreased. The combined production of all finfish was significantly lower in R₀ whereas, the combined production of all species including prawn did not differ significantly ($P < 0.05$) among the treatments. The treatments R₀ and R₅₀₀ fetched higher net profit without significant difference between them. Therefore, inclusion of rohu at a density of 500 ha⁻¹ may be recommended for prawn-carp-mola polyculture.

AQUAFISH RESEARCH REPORT 13-A06

UTILIZATION OF *CARIDINA NILOTICA* (ROUX) MEAL AS A PROTEIN INGREDIENT IN FEEDS FOR NILE TILAPIA (*OREOCHROMIS NILOTICUS*)

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Published in:

Aquaculture Research (2013) 46(2): 1-12.

The effects of replacing fish meal with *Caridina nilotica* as a protein ingredient on growth performance, nutrient utilization, carcass, proximate composition and economic benefits in Nile tilapia (*Oreochromis niloticus*) culture was evaluated. Replacement of the FM with *C. nilotica* was done at 25%, 50%, 75% and 100% (D25, D50, D75 and D100) and the substitution effects was compared with the control diet (D0, 0% *C. nilotica*). After 140 days of culture, the best growth performance, nutrient utilization and economic benefits occurred in fish groups fed diets with 25% *C. nilotica* inclusion. However, growth performance in fish fed diets D50 and D75 were comparable with the control ($P > 0.05$). At 100% substitution level of FM with *C. nilotica*, the growth performance and fish survival was lower than control. Protein and lipid contents in the fish and their digestibilities were highest in diet D25 and decreased with increasing levels of substitution of FM with *C. nilotica*. This study demonstrates that utilization of local protein sources (*C. nilotica*) can be effectively used to replace up to 75% of FM in the diets without compromising growth performance, survival, nutrient utilization and economic benefits in *O. niloticus* culture.

AQUAFISH RESEARCH REPORT 13-A07

IMMUNOSTIMULANTS FOR AQUACULTURE HEALTH MANAGEMENT

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Published in:

Marine Science Research & Development (2013) 3(3): doi: 10.4172/2155-9910.1000134.

Aquaculture is gaining momentum in several parts of the world in recent years. Intensification has become a common practice in both finfish and shellfish culture to optimize the returns. High stocking densities, artificial feeding and fertilization have become common husbandry practices in both carp and shrimp culture systems. Due to intensification of culture practices, diseases of microbial etiology of economical significance has surfaced in rearing and grow out ponds and are major threat to the sustainability of the aquaculture industry. Synthetic chemicals and antibiotics have been used to prevent or treat fish and shrimp and have achieved at least partial success. Vaccination against specific pathogens has been developed recently with some success depending on the particular disease. An alternative approach has been the application of various compounds to boost or stimulate the innate immune system of farmed fish and shrimp. These compounds, termed immunostimulants is considered an attractive and promising agent for the prevention of diseases in fish and shellfish. In recent years, the established beneficial effects of immunostimulants in many living systems promote their application for disease management in aquaculture practices.

AQUAFISH RESEARCH REPORT 13-A08

STUDY ON ENVIRONMENTAL IMPLICATIONS AND ITS IMPACT ON AQUATIC PRODUCTIVITY IN THE SOUTHWEST COASTAL REGION

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Published in:

Journal of Environmental Science and Natural Resources (2013) 6(2): 71-78.

An experiment was conducted on environmental implications and its impact on aquatic productivity in the southwest coastal region for a period of 2 months (May-June/2013). Five Rivers such as Pira River, Andarmanik River, Sonatala River, Khaprabhanga River and Rupsha River were selected for sample collection and were treated as T₁, T₂, T₃, T₄ and T₅. Three sampling sites were selected from each River based on salinity. The overall mean values of water temperature were 28.17 ± 0.98, 27.41 ± 1.21, 28.12 ± 1.11 and 27.13 ± 1.26, 26.62 ± 1.01 °C in treatment T₁, T₂, T₃, T₄ and T₅, respectively. The mean values of water transparency of treatments T₁, T₂, T₃, T₄ and T₅ were 36.00 ± 1.26, 31.0 ± 0.0894, 34.00 ± 1.94, 28.00 ± 1.46 and 31.00 ± 1.86 cm, respectively. The overall mean values of water temperature were 6.56 ± 0.12, 6.47 ± 0.23, 6.34 ± 0.12, 6.19 ± 0.22, and 6.67 ± 0.29 ppm in treatment T₁, T₂, T₃, T₄ and T₅ respectively. pH values were found to fluctuate from 6.72 to 7.64, 6.48 to 7.13, 6.95 to 7.35 and 6.86 to 7.6 in treatment T₁, T₂, T₃, T₄ and T₅ respectively. Mean values of total salinity were 2.17 ± 0.12, 6.17 ± 0.82, 7.17 ± 0.92, 10.17 ± 0.112 and 1.78 ± 0.12 mg/l in treatment T₁, T₂, T₃, T₄ and T₅ respectively. Mean values of total alkalinity were 187.5 ± 2.25, 165.5 ± 3.1, 185.5 ± 2.15, 175 ± 2.5 and 180.5 ± 3 mg/l in treatment T₁, T₂, T₃, T₄ and T₅ respectively. Mean values of total alkalinity were 187.5 ± 2.25, 165.5 ± 3.1, 185.5 ± 2.15, 175 ± 2.5 and 180.5 ± 3 mg/l in treatment T₁, T₂, T₃, T₄ and T₅ respectively. Mean values of total alkalinity were 187.5 ± 2.25, 165.5 ± 3.1, 185.5 ± 2.15, 175 ± 2.5 and 180.5 ± 3 mg/l in treatment T₁, T₂, T₃, T₄ and T₅ respectively. Total hardness of water was found to range from 37 mg/l to 199 mg/l. The mean values of NH₃-N (mg l⁻¹) were found to vary from 0.23 ± 0.03, 0.27 ± 0.08, 0.23 ± 0.03, 0.25 ± 0.03 and 0.27 ± 0.05 mg l⁻¹ in treatment T₁, T₂, T₃, T₄ and T₅ respectively. The mean values of nitrite (NO₂) concentration were 0.63 ± 0.06, 0.68 ± 0.08, 0.67 ± 0.09, 0.73 ± 0.03 and 0.67 ± 0.06 mg l⁻¹ in treatment T₁, T₂, T₃, T₄ and T₅ respectively. There were no significant difference of temperature, dissolved oxygen pH and alkalinity among the treatments but significant difference found in transparency, salinity, hardness, ammonia, nitrite using ANOVA (P < 0.05). Ammonia and nitrite concentration of Rupsha River (T₅) higher than other four Rivers due to municipal waste product of Khulna city. A proportionally strong relationship was found among salinity, transparency and hardness. Highest concentration of phytoplankton was found in Rupsha River (lowest salinity) and lowest phytoplankton concentration was found in Khaprabhanga River (highest salinity).

AQUAFISH RESEARCH REPORT 13-A09

EFFICIENCY OF RESOURCE USE AMONG POND FISH FARMERS IN CENTRAL UGANDA: A STOCHASTIC FRONTIER PRODUCTION FUNCTION APPROACH

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Published in:

Aquaculture Economics & Management (2013) 17: 148–170.

This article presents the use of a stochastic frontier production function to examine the efficiency of resource utilization in pond fish farming in Uganda. The study draws on data from a field survey administered to 200 small-scale fish farmers in three major fish farming districts in Central Uganda: Mukono, Mpigi and Wakiso. The districts were part of a large aquaculture development project funded by the United States Agency for International Development-Aquaculture and Fisheries Collaborative Research Support Program. Productive efficiency was analyzed using stochastic frontier analysis with a translog production function while assuming a truncated-normal distribution for the inefficiency term. The output variable was total quantity of fish produced, while input variables were quantity or value of inputs used in the production process, namely labor, pond size, stocking density, capital and feeds. The estimated index of resource-use efficiency revealed that small-scale farmers were inefficient in resource allocation by over-utilizing labor with an estimated allocative efficiency index of 0.94 and grossly under-utilized pond size, feeds and fingerlings with allocative efficient indices of 1.15, 1.64, 3.71, respectively. The results suggest that there is considerable scope to expand output and also productivity by increasing production efficiency at the relatively inefficient farms and sustaining the efficiency of those operating at or closer to the frontier.

AQUAFISH RESEARCH REPORT 14-323

GENETICALLY-IMPROVED TILAPIA STRAINS IN AFRICA: POTENTIAL BENEFITS AND NEGATIVE IMPACTS

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Published in:

Sustainability (2014) 6: 3697-3721.

Two genetically improved tilapia strains (GIFT and Akosombo) have been created with *Oreochromis niloticus* (Nile tilapia), which is native to Africa. In particular, GIFT has been shown to be significantly superior to local African tilapia strains in terms of growth rate. While development economists see the potential for food security and poverty reduction in Africa from culture of these new strains of tilapia, conservationists are wary of potential ecological and genetic impacts on receiving ecosystems and native stocks of tilapia. This study reviews the history of the GIFT technology, and identifies potential environmental and genetic risks of improved and farmed strains and tilapia in general. We also estimate the potential economic gains from the introduction of genetically improved strains in Africa, using Ghana as a case country. Employing a combination of the Economic-Surplus model and Monte Carlo simulation, we found the mean net present value (NPV) of the introduction of the GIFT strain in Ghana to be approximately 1% of the country's gross domestic product. Sensitivity analysis indicated that the difference in growth or yield between the GIFT and locally-available strains has the largest effect on mean NPV. We conclude that improvements in management practices and infrastructure could increase the yield and profitability of the local strains even if genetically-improved strains are not introduced. These improvements also will ensure the realization of the full potential of introduced strains.

AQUAFISH RESEARCH REPORT 14-324

EFFECTS OF DIETARY PROTEIN LEVELS ON GROWTH PERFORMANCE OF CLAROTEID CATFISH, *CHRYSICHTHYS NIGRODIGITATUS*, FINGERLINGS

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Published in:

Annals of Biological Research (2014) 5(4): 17-22.

A 10-week experiment was conducted to determine the optimal protein requirement of *Chrysichthys nigrodigitatus*, claroteid catfish in twelve 60-L indoor flow through rectangular glass tanks provided with aerated underground water. Four isoenergetic diets were formulated to contain varying crude protein (CP) levels of 32.1%, 34.6%, 42.8%, and 47.1% using fish meal/soybean meal as protein sources. Each diet was fed to triplicate group of 12 fingerlings (initial weight 16.30 ± 0.07 g, mean \pm SE) in a completely randomized design. A digestibility trial was conducted with all the diets after the growth trial. Results after ten weeks of feeding showed an increase in body weight gain (BWG%) and specific growth rate with increasing levels of dietary protein up to 42.8% ($P < 0.05$) but a decline at 47.1% CP. Protein efficiency ratio followed similar trend but there were no significant differences between the treatments. Feed conversion ratio (FCR) reduced as dietary protein level increased, with the minimum FCR in the 42.8% protein diet, although this was not significantly different from the 34.6% and 47.1% protein diets. Analysis of dose (protein level)-response (BWG%) with polynomial broken stick regression suggested that the optimal dietary protein requirement for the juvenile of *C. nigrodigitatus* was 42.8%. Key words: Dietary protein requirement, growth performance, feed utilization, *Chrysichthys nigrodigitatus*, weight gain.

AQUAFISH RESEARCH REPORT 14-325

OVERCOMPENSATION OF CIRCULATING AND LOCAL INSULIN-LIKE GROWTH FACTOR-1 DURING CATCH-UP GROWTH IN HYBRID STRIPED BASS (*MORONE CHRYSOPS* × *MORONE SAXATILIS*) FOLLOWING TEMPERATURE AND FEEDING MANIPULATIONS.

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Published in:

Aquaculture (2014) 428-429: 174-183.

Teleosts and other aquatic ectotherms have the ability to withstand prolonged periods of low water temperatures (cold-acclimation) and fasting, and can often respond with phases of accelerated (compensatory) growth when favorable conditions are restored. We assessed whether complete feed restriction prior to (24 °C, days 0–23) and/or during (14 °C, days 24–114) a simulated period of cold-acclimation could elicit episodes of compensatory growth (CG) and catch-up growth upon warm-up to 24 °C and satiation feeding (days 115–148). Control hybrid striped bass (HSB: *Morone chrysops* × *Morone saxatilis*) were fed to satiation throughout the entire experiment under these temperature fluctuations. Compensatory growth and ultimately catch-up growth were achieved in groups of HSB that were deprived of feed during either the initial period at 24 °C (days 0–23), during the cold-acclimation period (14 °C, days 24–114), or during both of these periods (days 0–114). Further, it appears that HSB are better able to compensate for weight loss when skeletal length is not significantly compromised during the treatment period, which occurred in HSB feed restricted during cold-acclimation only. The most dramatic CG responses were defined by specific growth rates (SGRs) up to 4.2 times that of controls and were accompanied by hyperphagia and improvements in temporal and overall feed conversion. Levels of plasma insulin-like growth factor (IGF)-1 and muscle IGF-1 mRNA were significantly correlated to growth rate for all groups throughout the experiment ($R^2 = 0.40, 0.23$, respectively), with an overcompensation of both observed in HSB with the most elevated SGRs during the CG response. Interestingly, opposing trends were observed between muscle mRNA expression of growth hormone receptor (GHR)-1 and -2, with fasting at 24 °C and 14 °C resulting in depressed levels of GHR-1 and elevated levels of GHR-2 relative to controls. Levels of muscle myostatin (MSTN)-1 mRNA were significantly depressed in HSB fasted at 24 °C and/or 14 °C while MSTN-2 mRNA was lower following initial feed restriction at 24 °C. Likewise, levels of unprocessed pro-MSTN (precursor) and mature MSTN protein were both depressed in fasted fish at 24 °C. This study demonstrates that a previous period of feed restriction and cold-acclimation followed by realimentation at more favorable water temperatures produces a strong CG response and catch-up growth in fish. These studies also suggest that an overcompensation of circulating and local IGF-1 along with changes in MSTN mRNA and protein expression may contribute to accelerated growth rates characteristic of CG.

Furthermore, our studies indicate that overall feed conversion can improve by as much as 30% with CG induced through temperature and feeding manipulations with no adverse effects on growth of HSB. This raises the possibility that CG protocols can improve production efficiency of HSB and other temperate teleosts in pond or tank culture.

AQUAFISH RESEARCH REPORT 14-326

COMBINED EFFECTS OF STOCKING DENSITY AND BACKGROUND COLOUR ON GROWTH PERFORMANCE AND SURVIVAL OF NILE TILAPIA (*OREOCHROMIS NILOTICUS*, L.) FRY REARED IN AQUARIA

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Published in:

Journal of Fisheries Science (2014) 8(3): 228-237.

The effect of tank background colour and stocking density on growth rates and survival of Nile tilapia (*Oreochromis niloticus*) fry (0.32 g) were investigated. The fish were reared in aquarium with blue, black and clear backgrounds at two stocking densities of 2 fish L⁻¹ and 4 fish L⁻¹. The outside walls and bottoms of each aquarium were painted to achieve one of two colours (blue and black), while non-coloured (clear) aquarium served as a control. The fish were fed a commercial diet (40% crude protein) at a daily rate of 5% of their body weight twice a day for 70 days. The best growth rates, weight gain, specific growth rate, food conversion ratio and survival were achieved in larvae reared under 2 fish L⁻¹ stocking density in the blue background. Fish performance was significantly ($P < 0.05$) retarded in larvae reared in aquarium with black background. Increased aggression was observed under high density or when the fish were reared in clear backgrounds. Fish reared on black backgrounds were distinctively darker compared to those reared in the blue and clear backgrounds. These results suggest *O. niloticus* should be reared at 2 fish L⁻¹ in aquaria with blue backgrounds.

AQUAFISH RESEARCH REPORT 14-327

CONSUMER PERCEPTIONS AND PREFERENCES OF WILD AND FARMED NILE TILAPIA (*OREOCHROMIS NILOTICUS* L.) AND AFRICAN CATFISH (*CLARIAS GARIEPINUS BURCHELL 1822*) IN URBAN CENTRES IN KENYA

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Published in:

International Journal of Advanced Research (2014) 2(7): 694-705.

Past fish production research done in Kenya suggests a strong production focus, leaving many fish consumer and marketing questions unanswered. This study investigated consumer fish preferences and trends in demand for Nile tilapia and African catfish in five urban centres in Kenya. A total of 384 questionnaires were administered to fish consumers and retailers in open markets, supermarkets, hotels and landing beaches. Descriptive and inferential analyses were done using SPSS Version 20.0. Female consumers were significantly higher ($p > 0.05$) in all study areas except Nairobi. There were significant differences in levels of preference for either the wild and farmed Nile tilapia ($p > 0.05$). Main reasons for consuming fish by consumers were health benefits of fish, good taste and ease of cooking. Quantities of fish purchased by consumers was generally small ranging from 1.68 ± 0.20 kgs in Kisumu to as low as 0.30 ± 0.04 kgs in Nyeri. The main factors affecting consumer preference of Nile tilapia fish were price, overall fish quality, nutritional value, and healthiness. In order to promote preference and consumption of farmed fish in Kenya, the government should educate consumers about the safety, healthiness and nutritional value of aquaculture products.

AQUAFISH RESEARCH REPORT 14-328

VALUE CHAIN OF SNAKEHEAD FISH IN THE LOWER MEKONG BASIN OF CAMBODIA AND VIETNAM

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Published in:

Aquaculture Economics & Management (2014) 18(1): 76-96.

Snakehead fish are the most preferred fish species for food in Cambodia and Vietnam, and are consumed in both fresh and processed forms. The purpose of this paper is to describe the value chains of captured and cultured snakeheads in the Lower Mekong Basin (LMB). The important actors involved in the value chain of snakeheads in the LMB of Cambodia and Vietnam were fishers, fish farmers, wholesalers, retailers, and processors. The value chain of wild captured snakeheads in Cambodia was focused on 11 marketing channels, and for cultured snakeheads in Vietnam, 10 market channels. The distribution of benefits among the chain actors was unequal, with the highest proportion of profit going to wholesalers in Cambodia and collectors in Vietnam. In order to develop the value chain of snakehead for the long-term in the LMB, appropriate plans must be prepared for each country in association with better management and protection of natural aquatic resources.

AQUAFISH RESEARCH REPORT 14-329

INVESTIGATIONS OF TYPES OF PRODUCTS FROM SNAKEHEAD FISH (*CHANNA STRIATA*) AND THEIR PRODUCTION PROCESS IN AN GIANG PROVINCE.

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Published in:

Can Tho University Journal of Science (2014) 1: 36-41.

This study aimed at investigating the types of products from snakehead fish and technological processes for manufacturing these products in An Giang province. It has three main contents including (i) production situation and technological processes for manufacturing the products; (ii) investigating types of products; (iii) trade situation in the markets and customer tastes for the products. The results showed that (i) relatively good technological processes and good quality products were almost from processing facilities that operated longer than 20 years. However, these facilities primarily produced by traditional methods which could only meet the requirement of domestic customers without reaching food safety and hygiene standards for export; (ii) products from snakehead fish primarily were dry salted snakehead fish and salty fermented snakehead fish; (iii) consumption of these products were at the medium level because of high price. Customers aged 30-40 liked eating salty fermented snakehead fish while customers aged 20-30 liked eating dry salted snakehead fish. When buying these products, customers paid attention to quality, safety, hygiene, brand name and price of the products.

AQUAFISH RESEARCH REPORT 14-330

ASSESSMENT ON PRODUCTION EFFICIENCY AND WEATHER CHANGE IMPACTS ON SNAKEHEAD POND CULTURE IN AN GIANG AND TRA VINH PROVINCES

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Published in:

Can Tho University Journal of Science (2014) 2: 141-149.

This study was conducted by interviewing 64 snakehead farmers (pond culture) in An Giang and Tra Vinh provinces from February to April 2014. The results showed that farm scale in An Giang province was smaller than that in Tra Vinh province, the source of snakehead fingerling was mainly from hatcheries in An Giang. Pellet feed was used in snakehead farming with FCR: 1.32-1.33. Culture period, survival rate and yield were not significantly different between the two provinces; harvest size in Tra Vinh was larger than that in An Giang. Total cost of fish culture was rather high (4.9-5.8 VND billion/ha/crop), ratio of gained profit households in Tra Vinh and An Giang were 15.6% and 37.5%, respectively due to low farm gate price. Weather changes effected snakehead pond culture such as (prolong hot and drought, hotter in dry season, large temperature variation between day and night, colder in cold season, irregular rain and sunshine and saline water intrusion caused more diseases, poorer water quality, reduced survival rate and yield. Farmers' adaptive solution was increase the cost of water plumbing and using chemical- drug 24.2 - 29.2 VND million/ha/year.

AQUAFISH RESEARCH REPORT 14-331

REPLACING FISHMEAL BY SOME OF SOY PROTEIN SOURCES IN FEED FOR SNAKEHEAD (*CHANNA STRIATA*)

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Published in:

Can Tho University Journal of Science (2014) 1: 310-318.

The study was conducted to determine the appropriate replacing of fish meal (FM) protein by three type's soybean meal: defatted soybean meal (SB), fermented soybean meal (FSB) and soy protein concentrate (SPC) in snakehead (*Channa striata*) diet. Four isonitrogenous (45%) and isocaloric (4.6 Kcal/g) diets were formulated. The control diet was prepared with 100% FM protein. Three other diets was replaced 40% FM protein by three type's soybean meal protein. Results showed that there was no significant difference in survival rate between feeding treatments. Fish growth performance in control diet and diet replaced SPC were significantly higher than the diets replaced SB and FSB. Food intake observed in diet replaced SPC treatment was not significant difference compared to control treatment. There was no significant difference between treatments in Feed Conversion Ratio, Protein Efficiency Ratio and hematological parameters (red blood cells and white blood cells). Hepatosomatic Index calculated in control treatment was significantly higher than those of others. Thus, it can be replaced 40% fish meal (FM) protein by soy protein concentrate (SPC) in snakehead (*Channa striata*) diet.

AQUAFISH RESEARCH REPORT 14-332

EFFECTS OF TWO ENVIRONMENTAL BEST MANAGEMENT PRACTICES ON POND WATER AND EFFLUENT QUALITY AND GROWTH OF NILE TILAPIA, *OREOCHROMIS NILOTICUS*

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Published in:

Sustainability (2014) 6: 652-675.

The trajectory of aquaculture growth in sub-Saharan Africa has necessitated closer attention to the use of environmental best management practices (BMPs). Two BMPs in particular, water reuse and floating feeds, are being promoted for adoption by pond fish farmers in sub-Saharan Africa. In this study, we investigated: (1) the effect of water source and feed type on water quality; (2) the effect of water source and feed type on tilapia growth; and (3) the quality of potential effluents from ponds using different water source and feed types. The study was conducted in Ghana using on-farm experiments involving monitoring of water quality and growth of Nile tilapia *Oreochromis niloticus* for 160 days. Although considered low-intensity production systems, nutrients and solids in the study ponds exceeded levels expected in intensive culture ponds by wide margins, whereas BOD5 was within the range for semi-intensive ponds. Floating feed was associated with higher water quality, especially dissolved oxygen, and higher growth, but water source did not significantly affect growth. Water reuse appears to be a viable BMP for sustainable aquaculture in the region, but the use of floating feed as BMP will depend on the economic profitability of floating feed use.

AQUAFISH RESEARCH REPORT 14-333

ROLE FOR LEPTIN IN PROMOTING GLUCOSE MOBILIZATION DURING ACUTE HYPEROSMOTIC STRESS IN TELEOST FISHES

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Published in:

The Journal of Endocrinology (2014) 220(1): 61-72.

Osmoregulation is critical for survival in all vertebrates, yet the endocrine regulation of this metabolically expensive process is not fully understood. Specifically, the function of leptin in the regulation of energy expenditure in fishes, and among ectotherms, in general, remains unresolved. In this study, we examined the effects of acute salinity transfer (72 h) and the effects of leptin and cortisol on plasma metabolites and hepatic energy reserves in the euryhaline fish, the tilapia (*Oreochromis mossambicus*). Transfer to 2/3 seawater (23 ppt) significantly increased plasma glucose, amino acid, and lactate levels relative to those in the control fish. Plasma glucose levels were positively correlated with amino acid levels ($R^2=0.614$), but not with lactate levels. The mRNA expression of liver leptin A (*lepa*), leptin receptor (*lepr*), and hormone-sensitive and lipoprotein lipases (*hsl* and *lpl*) as well as triglyceride content increased during salinity transfer, but plasma free fatty acid and triglyceride levels remained unchanged. Both leptin and cortisol significantly increased plasma glucose levels *in vivo*, but only leptin decreased liver glycogen levels. Leptin decreased the expression of liver *hsl* and *lpl* mRNAs, whereas cortisol significantly increased the expression of these lipases. These findings suggest that hepatic glucose mobilization into the blood following an acute salinity challenge involves both glycogenolysis, induced by leptin, and subsequent gluconeogenesis of free amino acids. This is the first study to report that teleost leptin A has actions that are functionally distinct from those described in mammals acting as a potent hyperglycemic factor during osmotic stress, possibly in synergism with cortisol. These results suggest that the function of leptin may have diverged during the evolution of vertebrates, possibly reflecting differences in metabolic regulation between poikilotherms and homeotherms.

AQUAFISH RESEARCH REPORT 14-334

EFFECTS OF ADDITION OF MAIZE STARCH ON THE YIELD, WATER QUALITY AND FORMATION OF BIOFLOCS IN AN INTEGRATED SHRIMP CULTURE SYSTEM

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Published in:

Aquaculture (2014) 418-419: 79-86.

Integrated Multi-Trophic Aquaculture (IMTA) is an ecological and economic farming strategy that minimizes waste from culture systems, reduces the risk of diseases and provides additional income source. A trial was conducted to evaluate the effects of adding maize starch on the yield, water quality, formation of bioflocs and economic return in an IMTA system comprising white shrimp (*Litopenaeus vannamei*), spotted scat (*Scatophagus argus*) and water spinach (*Ipomoea aquatic*). Shrimp were randomly assigned to 12 cemented tanks (T1, T2, T3 and T4 with three replicates) and reared in monoculture (T1) without the addition of starch, or in polyculture (with spotted scat and water spinach) with (T3 and T4) or without (T2) the addition of starch. Shrimp in T4 were fed at 80% of the feeding amount of other treatments. The results showed that shrimp survival was higher in T3 and T4 (95.6% and 94.3%, respectively) than in T1 and T2 (51.1% and 56.5%, respectively) ($P < 0.01$). The shrimp yield was the highest in T3 (0.495 kg m^{-3}), which also had the lowest feed conversion ratio (1.02) and best economic performance. The levels of nitrite-N ($\text{NO}_2\text{-N}$) were significantly lower in T3 and T4 at the end of the experiment than in other treatments ($P < 0.01$). Similarly, total ammonia nitrogen (TAN) was lower and total suspended solids (TSS) was higher in T3 and T4 than in T1 and T2 ($P < 0.05$). The results suggested that the addition of starch into the IMTA system of shrimp, spotted scat and water spinach improved productivity, profitability and water quality. The combination of the IMTA model and biofloc technology had a synergistic effect on overall FCR and economic return, and was more effective at improving shrimp survival, production and reducing nitrite-N and TAN than use of the IMTA model alone.

AQUAFISH RESEARCH REPORT 14-335

PRICE INTEGRATION IN THE FARMED AND WILD FISH MARKETS IN UGANDA

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Published in:

Fisheries Science (2014) 80(5).

This paper looks at price integration in the aquaculture and wild-harvested African catfish market channels in Uganda. The issue of integration between the two market channels is important because African catfish has become an important traded species in Uganda with exports to regional markets rising even faster than production, yet limited research has been undertaken to understand price formation in the supply chain. The analysis draws on monthly price data from January 2006 to August 2013, and applies threshold autoregressive approaches to test for the existence of a long-run relationship and price asymmetry and to determine the time path needed for shocks to be transmitted from one market channel to the other. The results show that, over the studied period prices in both market channels are linked in the long-run, implying that farm-raised catfish forms part of the same market as wild-harvested catfish in the country. The findings have strong implications for aquaculture producers and artisanal fishers as they can serve as a basis for more efficient farm management and marketing decisions.

AQUAFISH RESEARCH REPORT 14-336

EFFECTS OF REDUCED SOYBEAN-MEAL DIETS CONTAINING *MORINGA OLEIFERA* OR *LEUCAENA LEUCOCEPHALA* LEAF MEALS ON GROWTH PERFORMANCE, PLASMA LYSOZYME, AND TOTAL INTESTINAL PROTEOLYTIC ENZYME ACTIVITY OF JUVENILE NILE TILAPIA, *OREOCHROMIS NILOTICUS*, IN OUTDOOR TANKS

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Published in:

Fisheries Science (2014) 45(5): 508-522.

Leaf meals are potential alternatives to soybean meal (SBM) in fish diets in developing countries because they are cheaper. *Moringa oleifera* (MOR) and *Leucaena leucocephala* (LEU) reduced nutrient digestibility of diets compared with SBM in an earlier study. However, fish raised outdoors consume natural foods, which might offset the negative effects of leaf-meal diets. We conducted a feeding trial using mixed-sex Nile tilapia (5.2 g) to assess performance of fish fed 36% protein diets with different concentrations of MOR and LEU leaf meals in place of SBM. Fish in static pools were fed daily to apparent satiation for 59 d. Individual weight gain (30.4–34.7 g), survival (91.8–97.3%), feed conversion ratio (FCR, 1.6–1.9), proximate composition, plasma lysozyme activity, and intestinal proteolytic enzyme activity were similar among diets. However, fish fed diets containing leaf meals had higher concentrations of n-3 fatty acids than those fed the SBM control. Despite lower nutrient availability of the leaf-meal diets compared with the soy diet, MOR or LEU could replace up to 30% of the SBM protein without reducing fish performance. Inclusion of poultry meal in the diets and probable nutrient supplementation from natural foods appeared to compensate for the lower nutritional value of the leaf meals compared with SBM.

AQUAFISH RESEARCH REPORT 14-337

PROLACTIN IS A MAJOR INHIBITOR OF HEPATIC LEPTIN A SYNTHESIS AND SECRETION: STUDIES UTILIZING A HOMOLOGOUS LEPTIN A ELISA IN THE TILAPIA

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Published in:

General and Comparative Endocrinology (2014) 207: 86-93.

The present study identifies regulatory interactions between leptin A (LepA) and the pituitary hormone prolactin (PRL). In order to measure tilapia (*Oreochromis mossambicus*) LepA, an enzyme-linked immunosorbent assay (ELISA) utilizing a rabbit polyclonal antibody specific to tilapia LepA was first developed. The antibody shows strong cross reactivity to recombinant tilapia LepA (rtLepA), and a corresponding 16 kDa protein in both tilapia and striped bass plasma, but not to recombinant human leptin (rhLep). The assay has a linear detection range of 0.25–1000 nM, with intraand interassay variability of 9% and 16%, respectively. Plasma LepA levels measured in tilapia ranged from 0.8 to 3.9 nM, similar to that found for other vertebrates. Hypophysectomy (Hx) increased circulating LepA and lepa mRNA levels in the liver, the dominant source of hormone production. Administration of ovine PRL (oPRL, 5 lg/g BW) to Hx fish restored circulating LepA and hepatic lepa mRNA levels to those of control fish. Additionally, oPRL reduced lepa mRNA levels in a dose- dependent fashion in cultured hepatocytes following an 18 h incubation. Previous work in our lab indicates that rhLep stimulates PRL release in vitro from tilapia pituitaries. Here, both rtLepA and rhLep (0.5 lg/g BW) increased mRNA expression of tilapia prolactin mRNAs (prl1, prl2) in the pituitary in vivo. These results demonstrate that LepA enhances pituitary prolactin synthesis and release, while PRL in turn inhibits hepatic leptin secretion and synthesis in teleosts. We postulate this regulatory interaction may be necessary for mobilizing energy reserves during acute hyperosmotic adaptation.

AQUAFISH RESEARCH REPORT 14-338

THE VALUE OF PIG MANURE AS A SOURCE OF NUTRIENTS FOR SEMI-INTENSIVE CULTURE OF NILE TILAPIA IN PONDS (A REVIEW)

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Published in:

Agricultural Sciences (2014) 5: 1182-1193.

Growing global needs for food call for substantial increases in protein production in coming years, and for diligent conservation efforts. Manures from farm animals have been viewed both as a resource and as a waste product, but they are critically important sources of nutrients for organic and integrated farming and for traditional Asian aquaculture. Given constraints on livestock production and capture fisheries, careful development of the aquaculture industry is a necessity. The production volume and market share of tilapia are advancing extremely rapidly, and so too is the proliferation of misinformation and controversy. Culture and feeding practices differ widely, but feeding is usually recognized as the single largest cost to producers. Traditional Asian integrated farming practices involve the use of manures and other farm wastes to promote algae and zooplankton production, serving as a sole or supplemental nutrient source to the food chain that supports tilapia growout. Tilapia also ingest manures. The efficient use of nutrients from manures can have multiple benefits to integrated terrestrial agriculture and aquaculture, as long as product safety and quality are not compromised. With efficient use, handling of manures is simplified, fish production costs are reduced, fish nutrition can be improved, and potentially polluting materials are cycled constructively on integrated farms. Consumer and press reactions to the use of farm manures in food production can be highly polarized. Published responses cover a range of extremes, from enthusiastic endorsement to volatile reactions and outright rejection; in some areas this practice is considered to be more of a “PR (Public Relations) problem” than a health hazard. The perception in online public media that tilapia coming from ponds fertilized with manure are heavily contaminated with pathogens has not been supported by evidence. The perspectives of farmers in two major tilapia production areas (China and the Philippines) are included.

AQUAFISH RESEARCH REPORT 14-A01

CULTURING THE AFRICAN LUNGFISH IN UGANDA: EFFECTS OF EXOGENOUS FISH FEED ON GROWTH PERFORMANCE IN TANKS

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Published in:

Uganda Journal of Agricultural Sciences (2014) 15(2): 137-155.

The availability of African lungfish (*Protopterus aethiopicus*) in many communities in Uganda is declining. Indigenous efforts to culture this fish usually produce poor yields and depend on feeding fish fry, minced meat, and leftover food. This study evaluates three formulated diets (diet- 1, diet-2, diet-3) fed to wild caught lungfish fingerlings reared in indoor tanks for 77 days. Experimental fish gradually accepted sinking pellets, and marginal increases in average body weight were observed. Mean (\pm SE) final weight (15.86 ± 0.80 g) for fish fed on diet-3 was significantly higher ($p < 0.05$) than fish fed diet-1 and diet-2. Specific growth rates (SGR) for diet- 3 were significantly higher ($p < 0.05$) than diet-1, and marginally more than diet-2 (0.37 ± 0.04 %/ d). Feed conversions were similar ($p > 0.05$), ranging from 1.61 ± 0.26 to 2.07 ± 0.11 . Survivals after an 11-week culture were relatively low ($< 60\%$), but generally increased ($R^2 = 0.667$, $P = 0.007$) with increasing dietary proteins. Diet-3 had a significant higher survival rate ($p < 0.05$) than diet- 1 and diet-2. Significant growth performance was attained with diet-3. This study demonstrated that sinking fish feed pellets can be used to culture wild-caught African fingerlings in captivity.

AQUAFISH RESEARCH REPORT 14-A02

DIETARY ADMINISTRATION OF DAIDZEIN, CHRYSIN, CAFFEIC ACID AND SPIRONOLACTONE ON GROWTH, SEX RATIO AND BIOACCUMULATION IN GENETICALLY ALL-MALE AND ALL-FEMALE NILE TILAPIA (*OREOCHROMIS NILOTICUS*)

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Published in:

Discourse Journal of Agriculture and Food Sciences (2014) 2(3): 91-99.

Aromatase inhibitors can produce monosex populations of fish by blocking estrogen induced ovarian differentiation. Phytochemicals such as flavonoids and other phenolic compounds can exhibit aromatase inhibitor-like characteristics as reported for many of these compounds. Two experiments were conducted with genetically all-female or genetically all-male first feeding Nile tilapia to evaluate the potential *in vivo* aromatase inhibitory activity of three selected phytochemicals in parallel with synthetic steroidal compound treatments. Experimental diets were the following: control, 17 α -methyltestosterone (MT); 1,4,6-androstatrien-3-17-dione (ATD); spironolactone (SPIRO); daidzein (DAID); chrysin (CHR) and caffeic acid (CAFF) at different inclusion levels. Fish were fed for 6 weeks (all-male) and 8 weeks (all-female). Survival, final individual body weight and specific growth rate and final sex ratios were recorded. All phytochemicals were effectively detected using HPLC analyses. No differences were observed in survival, final mean weight, SGR between treatments in all-male tilapia. For all-female tilapia, MT and ATD groups showed significantly smaller final mean weights ($p < 0.05$); still, survival or SGR were not significantly different. Final sex ratios were as follows: for all-male juveniles no effect was observed in the final sex ratio for any of the phytochemicals or spironolactone. The sex ratio of genetically all-female tilapia was not affected by the inclusion of tested phytochemicals and pironolactone, while MT and ATD male ratios of 100% and 50%, respectively. Thus, selected dietary inclusion levels of phytochemicals did not exert an *in vivo* effect on sex differentiation in Nile tilapia.

AQUAFISH RESEARCH REPORT 14-A03

NUTRIENT DIGESTIBILITY OF REDUCED-SOYBEAN-MEAL DIETS CONTAINING *MORINGA* OR *LEUCAENA* LEAF MEALS FOR NILE TILAPIA, *OREOCHROMIS NILOTICUS*

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Published in:

Discourse Journal of Agriculture and Food Sciences (2014) 2(3): 91-99.

Vegetable leaf meals are cheaper feed ingredients than soybean meal (SBM) in developing countries, and leaf meals are less important as human food. We evaluated the nutrient digestibility of practical diets containing reduced levels of SBM in combination with leaf meals made from *Moringa oleifera* and *Leucaena leucocephala* in Nile tilapia, *Oreochromis niloticus*. Five isonitrogenous diets (32% crude protein) were made: the control diet contained 50% SBM, and the test diets were made by substituting 15 or 30% of SBM protein with either *Moringa* or *Leucaena*. Dry matter, protein, and lipid digestibility decreased with increasing *Moringa* or *Leucaena* in the diet. Protein and lipid digestibility were high across diets (75–90%). Ash digestibility of the control diet was similar to that of both *Moringa* diets, while the ash digestibility of the *Leucaena* diets was lower than other diets. Overall, nutrient digestibilities of *Moringa* diets exceeded those of *Leucaena* diets. Dry matter, protein, and lipid digestibilities decreased with increasing dietary fiber, which increased with increasing leaf meals. Ash digestibility was generally low for all diets. Better digestibility of practical diets containing *Moringa* compared to *Leucaena* indicates greater potential for *Moringa* to replace SBM in Nile tilapia diets without compromising fish performance.

AQUAFISH RESEARCH REPORT 14-A04

REPRODUCTIVE VARIABILITY OF THE COMMON SNOOK, *CENTROPOMUS UNDECIMALIS*, IN ENVIRONMENTS OF CONTRASTING SALINITIES INTERCONNECTED BY THE GRIJALVA–USUMACINTA FLUVIAL SYSTEM

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Published in:

Ciencias Marinas (2014) 40(3): 173-185.

The common snook, *Centropomus undecimalis*, is a migratory euryhaline fish. In the southern Gulf of Mexico, fishing of large snooks occurs mainly in the marine environment (MA), while medium-size adults and juveniles are caught in freshwater environments (FW); however, large-size adults can also be found in FW far away from the sea, and the effect of different environments on their reproductive cycle is unknown. To describe the reproductive cycle of this species in different salinity habitats, we analyzed macroscopic reproductive characteristics during one annual cycle in FW and MA interconnected by the Grijalva-Usumacinta basin. Specimens with full-grown gonads and capable of spawning were found in FW, an unusual condition not reported for this habitat, but active spawning was observed only in MA.

Centropomus undecimalis has a biological strategy that allows the use of FW as a juvenile until it reaches sexual maturity as a male and joins the reproductive stock in MA. Adults of both sexes can remain in both FW and MA without affecting their reproductive cycle, suggesting that those that mature in FW migrate to the sea during the spawning season.

AQUAFISH RESEARCH REPORT 14-A05

ABUNDANCE AND CULTURE TRIALS OF *RUDITAPES PHILIPPINARUM* (ADAM AND REEVE, 1850), AND ABUNDANCE OF *TELLINA (QUIDNIPAGUS) PALATUM* (IREDALE, 1929) AT TWO SITES IN KA[¯]NE[¯]OHE BAY, O[¯]AHU, HAWAI[¯]I

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Published in:

Aquaculture Research (2014) 45(2): 312-319.

Abundance, length-frequencies and distribution of *Ruditapes philippinarum* (Manila Clams) and *Tellina (Quidnipagus) palatum* were measured at two beaches in Ka[¯]ne[¯]ohe Bay, O[¯]ahu, Hawai[¯]i in June, 2010. Abundances had decreased from 866.2 m for *Ruditapes* and from 75.5 m² to 1.5 m² to 3.4 m² for *T. palatum* since 1977. Distribution of both species was patchy, but both were most commonly found >40 m from shore. Size frequencies of live clams compared with empty shells suggest that few *Ruditapes* survive to sexual maturity. A similar trend was not detected for *T. palatum*. Aquaculture trials of *R. philippinarum* were conducted at the He[¯]eia and Moli[¯]i traditional Hawaiian fishponds in the same bay. The clams failed to thrive, although triploid and diploid *Crassostrea gigas* performed well in concurrent trials in the same fishponds. Current lower abundances for wild *R. philippinarum* could be due to factors related to predation or nutrient limitations. Previously, two large sewage outfalls existed at the surveyed clam bed areas which may have temporarily increased nutrient availability for both wild and cultured clams. Current nutrient levels may inhibit Manila clam growth and recruitment in Ka[¯]ne[¯]ohe Bay.

AQUAFISH RESEARCH REPORT 14-A06

CARP-SIS POLYCULTURE: A NEW INTERVENTION TO IMPROVE WOMEN'S LIVELIHOODS, INCOME AND NUTRITION IN TERAI, NEPAL

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Published in:

Asian Fisheries Science: Gender in Aquaculture and Fisheries: Navigating Change (2014),
Asian Fisheries Science Special Issue 27S: 165-174.

Based on lessons learned from field trials, carp-small indigenous fish species (SIS)-prawn polyculture technology was improved to a "carp-SIS polyculture" technology suitable for small scale farmers in Terai, Nepal. In December 2008, the project was initiated to improve income and nutrition of Tharu women in Chitwan (100 farmers) and Kailali (26 farmers) districts. SIS dedhuwa, *Esomus danricus* (Hamilton, 1822) and pothi, *Puntius sophore* (Hamilton, 1822) were intended to improve household nutrition through increased consumption due to their high micronutrient content whereas large carps rohu, *Labeo rohita* (Hamilton, 1822); mrigal, *Cirrhinus mrigala* (Hamilton, 1822); silver carp, *Hypophthalmichthys molitrix* (Valenciennes, 1844); bighead carp, *Aristichthys nobilis* (Richardson, 1845); common carp, *Cyprinus carpio* (Linnaeus, 1758) and grass carp, *Ctenopharyngodon idella* (Valenciennes, 1844) were grown mainly for sale. The farmers consumed 48.7% of the production and raised their fish consumption to twice the national average of 1.85 kg. caput⁻¹. year⁻¹. Farmers earned NPR 3,025 (USD 34.23) per household in 270 days which helped them economically. A women fish farmers' co-operative was established. Altogether 156 women directly benefited from the project. The training and project experiences improved their self-confidence. Micro-nutrient analysis of common SI showed that vitamin A was higher in mara, *Amblypharyngodon mola* (Hamilton, 1822) whereas iron and zinc were higher in dedhuwa. The approach was found to be a more economic and sustainable, and is being replicated in other districts.

AQUAFISH RESEARCH REPORT 14-A07

CAGE-POND INTEGRATION OF AFRICAN CATFISH (*CLARIAS GARIEPINUS*) AND NILE TILAPIA (*OREOCHROMIS NILOTICUS*) WITH CARPS

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Published in:

Aquaculture Research (2014) 45(8): 1311-1318.

Cage-pond integration system is a new model for enhancing productivity of pond aquaculture system. A field trial was conducted using African catfish (*Clarias gariepinus*) and Nile tilapia (*Oreochromis niloticus*) in cages and carps in earthen ponds. There were four treatments replicated five times: (1) carps in ponds without cage, (2) tilapia at 30 fish m⁻³ in cage and carps in open pond, (3) catfish at 100 fish m⁻³ in cage and carps in open pond, (4) tilapia and catfish at 30 and 100 fish m⁻³, respectively, in separate cages and carps in open pond. The carps were stocked at 1 fish m⁻². The cage occupied about 3% of the pond area. The caged tilapia and catfish were fed and the control ponds were fertilized. Results showed that the combined extrapolated net yield was significantly higher ($P < 0.05$) in the catfish, tilapia and carps integration system ($9.4 \pm 1.6 \text{ t ha}^{-1} \text{ year}^{-1}$) than in the carp polyculture ($3.3 \pm 0.7 \text{ t ha}^{-1} \text{ year}^{-1}$). The net return from the tilapia and carps ($6860 \text{ US\$ ha}^{-1} \text{ year}^{-1}$) and catfish, tilapia and carps integration systems ($6668 \text{ US\$ ha}^{-1} \text{ year}^{-1}$) was significantly higher than in the carp polyculture ($1709 \text{ US\$ ha}^{-1} \text{ year}^{-1}$) ($P < 0.05$). This experiment demonstrated that the cage-pond integration of African catfish and Nile tilapia with carps is the best technology to increase production; whereas integration of tilapia and carp for profitability.

AQUAFISH RESEARCH REPORT 14-A08

EFFECTS OF STOCKING DENSITY AND FEEDING DURATION IN CAGE-CUM-POND-INTEGRATED SYSTEM ON GROWTH PERFORMANCE, WATER QUALITY AND ECONOMIC BENEFITS OF *LABEO VICTORIANUS* (BOULENGER 1901) CULTURE

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Published in:

Aquaculture Research (2014) 45: 1672-1684.

We evaluated the effect of varying cage stocking density (60, 90 and 120 fish m⁻³) and feeding duration (10, 30 and 60 min) in a cage-cum-pond- integrated system on growth performance, water quality and economic benefits in *Labeo victorianus* culture. Interactions between stocking density and feeding duration significantly ($P < 0.05$) affected the fish growth performance and yields in the cages-cum-pond system. Stocking density of 60 fish m⁻³ resulted in the highest growth in cages and in ponds regardless of the feeding duration, but produced lower yields than at stocking density 90 fish m⁻³. The lowest Apparent Food Conversion Ratio (AFCR) in cages occurred at stocking density of 60 fish m⁻³ and feeding duration of 30 min. Growth performance in the open ponds declined with increased feeding duration of the caged fish. Survival in cages and in the open ponds decreased with increased cage density, but was not affected by feeding duration. Low dissolved oxygen were recorded, at stocking density of 120 fish m⁻³, the lowest DO occurred when feeding of caged fish lasted 60 min. Growth performance, water quality and economic benefits in *Labeo victorianus* culture positively respond to interaction between stocking density and feeding durations.

AQUAFISH RESEARCH REPORT 14-A09

TILAPIA AQUACULTURE IN GHANA: PONDS CAN CONTRIBUTE MORE TO OVERALL PRODUCTION, FOOD SECURITY

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Published in:

Global Aquaculture Advocate (2014) 17(4): 38-41.

Aquaculture in Ghana has overcome its historic fits and starts and is helping to narrow the gap between domestic seafood production and consumption. Production is based on Nile tilapia, with 90% of the reported volume raised in cages. Although low productivity and potential underreporting of pond numbers are limiting the contributions of pond aquaculture, the sector has huge potential to expand and reduce the cost of tilapia. Updated and expanded extension services could help address numerous problems in the sector.

AQUAFISH RESEARCH REPORT 14-A10

DYNAMIC OF STRESS RESPONSE IN VICTORIA LABEO (*LABEO VICTORIANUS*) DURING TRANSFER FROM THE HATCHERY TO CAGES AND PONDS UNDER DIFFERENTIAL CAGED STOCKING DENSITIES

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Published in:

International Journal of Science and Research (2014) 3(9): 311-315.

Variation in fish stocking densities translate to difference in growth performance, yields and economic benefits in fish culture. Transferring fish directly from hatcheries to the cages or ponds may induce stress. We evaluated the stress response of Labeo Victoria (*Labeo victorianus*) in an integrated cage-cum-pond culture during transfer of fish from the hatchery to the cages and ponds at different cage stocking densities. Cages were stocked at varying densities of 10, 30, 60, 90, 120, 150 and 180 fish/m³ and suspended in a static pond of 200 m². The *L. victorianus* fingerlings of a mean weight 23.6 ± 1.8 g were stocked in the cages and the pond respectively. 20 fish were sampled during the transfer period from the hatchery to ponds and cages for analysis of primary and secondary parameters of stress response. Primary stress response occurred when fish were directly transferred to cages and ponds at stocking density ≥ 60 fish/m³ and 90 fish/m³ respectively. Parameters of secondary stress response occurred in fish transferred to the cages at stocking density ≥ 120 fish/m³ and in ponds at density ≥ 150 fish/m³. Transfer of fish directly from the hatchery to the ponds induce primary and secondary stress.

AQUAFISH RESEARCH REPORT 14-A11

SILICON, DIATOMS IN AQUACULTURE

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Published in:

Global Aquaculture Advocate 17(3): 38-39.

The silicon plants take up in silicic acid from water strengthens cell walls. Among the phytoplankton, diatoms particularly need silicon. Diatoms have good nutritional value and do not degrade water quality, so shrimp farmers often attempt to increase their abundance relative to other planktonic algae. To support diatoms, farmers should use silica products that contain 20% silicon. However, silicates have lower neutralizing values than agricultural limestone or lime, which are cheaper and more readily available.

AQUAFISH RESEARCH REPORT 14-A12

HYDROGEN SULFIDE TOXIC, BUT MANAGEABLE

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Published in:

Global Aquaculture Advocate 17(2): 34-35.

Hydrogen sulfide, which can form in pond bottom sediment, is toxic to aquatic animals because it interferes with reoxidation of cytochrome a3 in respiration. The main practices for lessening the risk of hydrogen sulfide toxicity are conservative feeding to avoid wasted feed on pond bottoms, plenty of aeration to prevent low dissolved-oxygen levels and provide a flow of oxygenated water across the soil-water interface, and liming to prevent acidic sediment and water.

AQUAFISH RESEARCH REPORT 14-A13

NITRITE TOXICITY AFFECTED BY SPECIES SUSCEPTIBILITY, ENVIRONMENTAL CONDITIONS

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Published in:

Global Aquaculture Advocate 17(1): 34-37.

Nitrite, an intermediate compound in the oxidation of ammonia nitrogen to nitrate by nitrifying bacteria in soil and water, is considerably more toxic than nitrate. Exposure to nitrite causes gill lesions and edema in the skeletal muscles of fish, and also affects respiration. Nitrite concentration is affected by the dissolved-oxygen and chloride levels in water, as well as species' differences in nitrite susceptibility. Fish suffering brown-blood disease quickly recover when moved to water with low nitrite concentration.

AQUAFISH RESEARCH REPORT 14-A14

AMMONIA TOXICITY DEGRADES ANIMAL HEALTH, GROWTH

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Published in:

Global Aquaculture Advocate 16(12): 40-43.

Ammonia nitrogen occurs in aquaculture systems as a waste product of protein metabolism by aquatic animals and degradation of organic matter, or in nitrogen fertilizers. Exposure can reduce growth and increase susceptibility to diseases in aquatic species. Ammonia nitrogen concentrations vary with time of day, water depth and temperature, and increase as biomass and feed input increase. The best management is conservative stocking and feeding rates that minimize ammonia nitrogen and avoid excessive phytoplankton blooms that cause high pH.

AQUAFISH RESEARCH REPORT 14-A15

ATMOSPHERE POLLUTION AFFECTS WATER QUALITY

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Published in:

Global Aquaculture Advocate 17(5): 57-58.

Human activities have altered the concentrations of gases and other compounds in the atmosphere. Acid rain typically does not heavily affect aquaculture operations, and application of agricultural limestone can buffer water against the impacts of acid rain at facilities that use stream water. Due to higher carbon dioxide concentrations in the atmosphere, the amount of carbon dioxide that will dissolve in ocean water has increased. Decreased pH can thin the shells of some molluscan shellfish and reduce survival.

AQUAFISH RESEARCH REPORT 14-A16

VALUE CHAIN ANALYSIS HELPS OVERCOME GENDER BARRIERS IN AQUACULTURE

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Global Aquaculture Advocate 17(5): 70-72.

The AquaFish Innovation Lab has conducted research using value chain analysis as a tool to increase income and nutrition for small-scale fish farmers through improved market participation and efficiency. Integrating women into the aquaculture value chain is part of a systems approach to improve the economic and social benefits of aquaculture. Work in Africa and Asia has identified some of the underlying barriers to women's participation and begun to develop strategies for overcoming them.

AQUAFISH RESEARCH REPORT 14-A17

MODELING AQUACULTURE CARRYING CAPACITY IN SOUTHEAST ASIA

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Published in:

Global Aquaculture Advocate 17(4): 36-37.

The modeling of common water bodies to determine aquaculture carrying capacity has been identified as a critical need for countries in Southeast Asia. These countries would like to use models for aquaculture in various bodies of water, but modeling capabilities are currently limited. In addition, there is disagreement about how to balance the needs of farmers with protection of ecosystems. Effective management of carrying capacity will require a regional approach and participation by industry, governments, academia and non-governmental organizations.

AQUAFISH RESEARCH REPORT 14-A18

SPECIES, POND SIZE DEFINE AERATION APPROACHES

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Published in:

Global Aquaculture Advocate 17(4): 31-33.

Each type of aerator has advantages and disadvantages. The combination of paddlewheel aerators and propeller aspirator-pump aerators can be particularly effective in deep ponds. Diffused-air systems are most appropriate for small ponds. The amount of aeration can be increased as feeding rate increases to conserve energy. Aeration in shrimp ponds usually can be reduced from mid-morning until early evening. Research has demonstrated that considerable energy can be saved by using aerator automation systems.

AQUAFISH RESEARCH REPORT 14-A19

POND BOTTOM DRYOUT, LIMING

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Global Aquaculture Advocate 17(4): 34-35.

The main pond bottom soil management practices used in semi-intensive culture are pond dryout and liming between crops. These practices accelerate organic matter decomposition, neutralize soil acidity and destroy unwanted organisms. Since most soils become too dry for microbial decomposition of organic matter within three weeks, there is little need to dry pond bottoms more than that period. Where bottom sediment is deep, remove it to facilitate dryout. Ponds with soil pHs below 7.5 should be limed to enhance decomposition.

AQUAFISH RESEARCH REPORT 14-A20

STRATEGIES FOR REDUCING FEED COSTS IN SMALL-SCALE AQUACULTURE

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Published in:

Global Aquaculture Advocate 17(3): 24-26.

Facing rising aquafeed costs, researchers and farmers are investigating ways to lessen resources spent on feeds by feeding less and feeding differently. “Greenwater” technology applied through pond fertilization generates food items produced naturally in culture water. In conjunction, feeding on alternate days can maintain good harvest results. Further approaches include product substitutions through alternative sourcing of feed ingredients, increasing the nutritive content of feed to grow healthier fish and improving locally produced, low-cost feeds by the process of pelletization.

AQUAFISH RESEARCH REPORT 15-339

EFFECTS OF DIETARY ADMINISTRATION OF STINGING NETTLE (*URTICA DIOICA*) ON THE GROWTH PERFORMANCE, BIOCHEMICAL, HEMATOLOGICAL AND IMMUNOLOGICAL PARAMETERS IN JUVENILE AND ADULT VICTORIA LABEO (*LABEO VICTORIANUS*) CHALLENGED WITH *AEROMONAS HYDROPHILA*

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Published in:

Fish & Shellfish Immunology (2015) 44(2): 533-541.

We investigated effects of dietary administration of stinging nettle (*Urtica dioica*) on growth performance, biochemical, hematological and immunological parameters in juvenile and adult Victoria Labeo (*Labeo victorianus*) against *Aeromonas hydrophila*. Fish were divided into 4 groups and fed for 4 and 16 weeks with 0%, 1%, 2% and 5% of *U. dioica* incorporated into the diet. Use of *U. dioica* in the diet resulted in improved biochemical, hematological and immunological parameters. Among the biochemical parameters; plasma cortisol, glucose, triglyceride and cholesterol decreased while total protein and albumin in fish increased with increasing dietary inclusion of *U. dioica*. Among the haematology parameters: red blood cell (RBC), white blood cell (WBC) counts, haematocrit (Htc), mean cell haemoglobin (MCH), mean cell haemoglobin concentration (MCHC) and neutrophils increased with increasing dietary inclusion levels of *U. dioica*, some depending on the fish age. Serum immunoglobulins, lysozyme activity and respiratory burst were the main immunological parameters in the adult and juvenile *L. victorianus* measured and they all increased with increasing herbal inclusion of *U. dioica* in the diet. Dietary incorporation of *U. dioica* at 5% showed significantly higher relative percentage survival (up to 95%) against *A. hydrophila*. The current results demonstrate that using *U. dioica* can stimulate fish immunity and make *L. victorianus* more resistant to bacterial infection (*A. hydrophila*).

AQUAFISH RESEARCH REPORT 15-340

EVIDENCE OF RAPID TRANSFER AND BIOACCUMULATION OF MICROCYSTIN-LR POSES POTENTIAL RISK TO FRESHWATER PRAWN *MACROBRACHIUM ROSENBERGII* (DE MAN)

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Published in:

Aquaculture Research (2015): 1-10.

Microcystins accumulate in aquatic organisms and can be transferred to higher trophic levels, eventually affecting vector animals and consumers. We examined three levels of an aquatic food chain (*Microcystis aeruginosa*, *Daphnia magna* and *Macrobrachium rosenbergii*) to identify the transfer efficiency and risk of microcystin on prawns. Samples were analysed using ultra performance liquid chromatography-mass spectrometry (MS)/MS and microcystin-LR (MC-LR) distributions in prawn tissues were studied. The results showed that prawns accumulate MC-LR both directly from *M. aeruginosa* and indirectly through *D. magna* which was pre-exposed to *M. aeruginosa*. MC-LR was detected in the gills, digestive tracts and hepatopancreas of the prawns 2 h. after exposure. MC-LR accumulated in prawns to 0.49 +/- 0.04 µg g⁻¹ dry weight in hepatopancreas within 24 h, while it was not detected in muscle samples, and rarely appeared in blood samples in such a short period. Although MC-LR was not detected in muscle, the head including hepatopancreas of the prawns accumulated troublesome amounts of MC-LR. These results demonstrate that microcystis blooms in prawn farming potentially pose a risk to human consumers, although prawns may be exposed to the bloom for a very short time, hence regular monitoring of blue green algae population is recommended.

AQUAFISH RESEARCH REPORT 15-341

ECONOMIC ANALYSIS OF ALTERNATIVE SNAKEHEAD *CHANNA STRIATA* FEED

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Published in:

Aquaculture Economics & Management (2015) 19(2): 192-209.

The use of low-value small-sized fish (LVSSF) both as aquaculture feedstuff for snakehead and for human consumption in Vietnam and Cambodia could result in demand outstripping supply as human population and aquaculture production grow. Replacing LVSSF for snakehead aquaculture with pelleted feed would reduce the pressure on stocks of LVSSF. This study addresses the economics of this replacement strategy for snakehead culture in Vietnam. Economic engineering methods were used to assess the effects of pelleted feed for low, medium and high-productivity scenarios. The study compared net present values (NPV), internal rates of return (IRR) and differences in NPV between farms using pelleted feed and those using LVSSF. It also included sensitivity analyses that related NPV and IRR to increased snakehead prices. Results demonstrated strong economic incentives for high-productivity farms to use pelleted feed. However, pelleted feed was too expensive for medium- and low- productivity farms. NPVs were more sensitive to reductions in the cost of pelleted feed than to increases in the cost of LVSSF or the cost of capital.

AQUAFISH RESEARCH REPORT 15-342

IMPACT OF THE ADOPTION OF BMPs ON SOCIAL WELFARE: A CASE STUDY OF COMMERCIAL FLOATING FEEDS FOR POND CULTURE OF TILAPIA IN GHANA

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Published in:

Cogent Food & Agriculture (2015) 1(1): 1048579.

Best management practices (BMPs) are the most cost-effective means of mitigating negative impacts of pond aquaculture on the environment. The impacts of BMPs and other innovations on fish farm profits have been studied widely. This study estimates impacts of BMP adoption on social welfare. We employed the economic surplus model to determine net present value (NPV) of adopting the more expensive but less polluting commercial floating fish feed in the pond culture of Nile tilapia (*Oreochromis niloticus*) in Ghana. We also conducted a sensitivity analysis to determine which variables had the greatest influence on mean NPV. Our results indicate an NPV of US\$ 11 million from the adoption of commercial floating feed in pond farming alone in Ghana. The variables with the biggest impacts on NPV were level of change in tilapia yield, and level of change in production costs, with the adoption of the new feed type. We conclude that adoption of yield-enhancing BMPs and innovations in Ghana will result in significant social welfare benefits. We recommend that credit programs and other financial packages be set up by governments or nongovernmental organizations to help farmers meet the increased cost of fish feed and to accelerate diffusion of commercial fish feed in pond farming.

AQUAFISH RESEARCH REPORT 15-343

USING MODEL-BASED INFERENCE TO SELECT A PREDICTIVE GROWTH CURVE FOR FARMED TILAPIA

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Published in:

North American Journal of Aquaculture (2015) 77: 281-288.

Aquaculture presents a unique challenge to the modeling of fish growth, because the main objective is to accelerate growth for profit. Growth patterns of captive fish in well-fed conditions will diverge from that found in wild fish. For a fish-farming enterprise, overestimating growth will lead to expectations for revenue and profit that will not be realized. Underestimating growth will lead to planning for later harvest than is optimal and the unnecessary additional cost of feeding. We evaluated the performance of four candidate models—Gompertz, logistic, quadratic, and von Bertalanffy—in predicting the growth of Nile Tilapia *Oreochromis niloticus*. Each model was fitted to 20 weight-at-age data sets collected from five demonstration farms in Ghana over a 5-month period. We used the Akaike information criterion adjusted for small sample size and model weights to assess model fit. We also assessed predictive performance by comparing predicted to actual growth observed over the last month of the experiment. The logistic growth model performed best for both model fitting and prediction. For a 1-month period approximately between day 121 and day 152 all but the logistic model over predicted growth with corresponding SEs as follows: Gompertz (14.9 ± 3.8 g, mean \pm SE), von Bertalanffy (21.0 ± 3.9 g), and quadratic (34.0 ± 3.6 g). The logistic model (-0.5 ± 3.8) did not significantly over- or under predict growth, and is recommended for predicting future growth of Nile Tilapia under pond culture conditions in applications such as the construction of enterprise budgets to assess profitability of tilapia farms. The default fitting of the von Bertalanffy growth model to farmed tilapia data is not supported by this study.

AQUAFISH RESEARCH REPORT 15-344

DEVELOPMENT OF FORMULATED DIETS FOR SNAKEHEAD (*CHANNA STRIATA* AND *CHANNA MICROPELTES*): CAN PHYTASE AND TAURINE SUPPLEMENTATION INCREASE USE OF SOYBEAN MEAL TO REPLACE FISH MEAL?

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Published in:

Aquaculture (2015) 448: 334-340.

Culture of snakehead species is limited in Vietnam and banned in Cambodia because of the reliance of the industry on feeding them “small-size” fish (sometimes called trash fish or low-value fish), many of which are juveniles of commercially important species. In an effort to find substitutes for small-size fish, we conducted a series of experiments to test formulated diets with several levels of soybean meal (SBM) replacement of fish meal. Feeding trials lasted eight weeks, after which survival, growth, food conversion ratio and protein efficiency ratio were compared. In the first two experiments, with *Channa striata*, we substituted SBM, either with or without supplementation of phytase (20 mg/kg) (Experiment 1) or taurine (1 g/kg) (Experiment 2), for 0, 20, 30, 40, or 50% of the fish meal. Experiment 1 demonstrated that SBM can replace 30% of the fish meal without, and 40% of the fish meal with, phytase supplementation. Experiment 2 showed again that SBM can replace 30% of the fish meal without, and 40% of the fish meal with, taurine supplementation. The third experiment, with *Channa micropeltes*, which was done only with phytase supplementation, showed that 40% of fish meal can be replaced by SBM. In all the SBM diets, the essential amino acids (EAA) lysine, methionine and threonine were also added to make their dietary levels equal to those in the fish meal control diet. Use of the SBM replacement diets, in addition to conserving the small-size fish in the wild, would result in economic savings (cost/kg of fish produced) of about 11% compared to diets based on fish meal alone.

AQUAFISH RESEARCH REPORT 15-345

APPLICATION OF PORTER'S FRAMEWORK TO ASSESS AQUACULTURE VALUE CHAIN IN KENYA

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Published in:

African Journal of Food, Agriculture, Nutrition, and Development (2015) 15(3): 10118-10137.

Aquaculture (fish farming) is an agricultural as well as fisheries activity, competing with other agricultural enterprises and artisanal fisheries for the same basic inputs. Therefore, aquaculture is subject to the same basic resource constraints that traditional agricultural activities face. The literature suggests that competition within a value chain is between chains and not individual actors. This study examined the aquaculture value chain in Kenya, assessing the entire value chain, and determining the appropriate points to participate in economically sustainable ways. The competition analysis assessed attractiveness at each stage of the chain by reviewing the rivalry in terms of five competitive forces within the Kenyan aquaculture industry; competitive rivalry, the threat of new entrants, bargaining power of suppliers, threat of substitutes and bargaining power of buyers. The aquaculture industry in Kenya is assessed using Porter's model with marketing mix (Ps) and factor evaluation matrix (FEM). Input supply is found to be the most difficult value chain function in which to participate because it requires relatively large initial capital outlays and additional operating funds. Although fish farming is the driving function of the entire value chain, the significant capital investments required could be a barrier to entry. Fish farming has largely benefited from the support of government, NGOs and other regional development initiatives. The study established that the easiest sector to enter (in terms of low barriers to entry and exit and low labour requirements) is the fish marketing sector. This chain function provides the most flexibility and liquidity to participants, whether as full-time or part-time occupation. Overall, participation in the Kenya aquaculture value chain will depend on the prospective entrant's level of experience, time, capital commitment and financial goal (long term stability versus liquidity). Aquaculture requires a long-term commitment and high capital outlays, as well as persistence, and should therefore be considered by those looking for long term stability and not short term benefits. Established fish farmers may consider diversifying into input supply and value addition as well.

AQUAFISH RESEARCH REPORT 15-346

INFERRING INVASION HISTORY OF RED SWAMP CRAYFISH (*PROCAMBARUS CLARKII*) IN CHINA FROM MITOCHONDRIAL CONTROL REGION AND NUCLEAR INTRON SEQUENCES

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Published in:

International Journal of Molecular Science (2015) 16: 14623-14639.

Identifying the dispersal pathways of an invasive species is useful for adopting the appropriate strategies to prevent and control its spread. However, these processes are exceedingly complex. So, it is necessary to apply new technology and collect representative samples for analysis. This study used Approximate Bayesian Computation (ABC) in combination with traditional genetic tools to examine extensive sample data and historical records to infer the invasion history of the red swamp crayfish, *Procambarus clarkii*, in China. The sequences of the mitochondrial control region and the proPOx intron in the nuclear genome of samples from 37 sites (35 in China and one each in Japan and the USA) were analyzed. The results of combined scenarios testing and historical records revealed a much more complex invasion history in China than previously believed. *P. clarkii* was most likely originally introduced into China from Japan from an unsampled source, and the species then expanded its range primarily into the middle and lower reaches and, to a lesser extent, into the upper reaches of the Changjiang River in China. No transfer was observed from the upper reaches to the middle and lower reaches of the Changjiang River. Human-mediated jump dispersal was an important dispersal pathway for *P. clarkii*. The results provide a better understanding of the evolutionary scenarios involved in the rapid invasion of *P. clarkii* in China.

AQUAFISH RESEARCH REPORT 15-347

INDUCED SPAWNING OF THE COMMON SNOOK (*CENTROPOMUS UNDECIMALIS*) IN CAPTIVITY USING GnRH-A IMPLANTS

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Published in

Ecosistemas y Recursos Agropecuarios (2015) 2(6): 357-362.

Culture of *Centropomus undecimalis* shows great potential as this species tolerates handling and adapts easily to captivity. However, the difficulty in achieving spawning in captivity is a major obstacle for the development of commercial scale farming. Spawning of common snook was achieved using GnRH-a implants in single 100 and 200 µg doses per fish; control group specimens received no hormone and did not spawn. Both GnRH-a trial doses resulted in spawning with up to 100% fertilization rates per experimental unit, and a range of 60-75% per treatment, showing no statistical differences ($p < 0.05$). The percentage of hatching rate was between 50-100% and larvae measured between 1.56 ± 0.08 and 1.98 ± 0.05 mm total length after yolk sac absorption.

AQUAFISH RESEARCH REPORT 15-348

PRICE TRANSMISSION AND THRESHOLD BEHAVIOR IN THE AFRICAN CATFISH SUPPLY CHAIN IN UGANDA

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Published in:

Journal of African Business (2015) 16(1-2): 180-197.

The issue of price linkage in the catfish supply chain in Uganda is important because catfish has become an important traded species with exports to regional markets rising even faster than production, yet limited research has been undertaken to understand the linkages and the non-linearity in the price transmission mechanism. This paper explores the issue using monthly price data from January 2006 to August 2013, and applies threshold autoregressive approaches to test for the existence of a long-run relationship and price asymmetry. The results show that prices in the catfish value chain are tied together by a long-run relationship. It is also revealed that ex-vessel and wholesale price adjustments to retail price changes are symmetric while ex-vessel price adjustments to wholesale price changes are shown to be asymmetric. The direction of causal relationships was observed from the retail to the wholesale and ex-vessel markets, indicating that retailers are the price leaders in the Uganda catfish supply chain.

AQUAFISH RESEARCH REPORT 15-349

THREATENING “WHITE GOLD”: IMPACTS OF CLIMATE CHANGE ON SHRIMP FARMING IN COASTAL BANGLADESH

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Published in:

Ocean & Coastal Management (2015) 114: 42-52.

In Bangladesh, tiger shrimp (*Penaeus monodon*) is commercially known as “white gold”, because of its export value. However, the production of “white gold” under shrimp alternate rice and shrimp-only farming systems in coastal Bangladesh has been accompanied by recent concerns over climate change. Field survey reveals that different climatic variables including coastal flooding, cyclone, sea-level rise, salinity, drought, rainfall, and sea surface temperature have had adverse effects on shrimp culture as well as socioeconomic conditions of farming households. There is also overwhelming evidence that changes in climatic variables has detrimental effects on the ecosystem of shrimp farms, and thus, severe effects on survival, growth, and production of shrimp. Considering extreme vulnerability to the effects of climate change on shrimp farming, we propose that community based adaptation strategies and integrated coastal zone management are needed to cope with the challenges.

AQUAFISH RESEARCH REPORT 15-350

THE SOCIAL AND ECONOMIC IMPACTS OF SEMI-INTENSIVE AQUACULTURE ON BIODIVERSITY

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Published in:

Aquaculture Economics and Management (2015) 18: 303-324.

As a result of the concern and debate about the impacts of intensive aquaculture development on biodiversity, semi-intensive aquaculture is being considered as an alternative. Although the biophysical impacts of aquaculture on biodiversity have been examined, there is only limited understanding of the social and economic impacts of aquaculture on biodiversity, and especially the impacts of the shift from intensive to semi-intensive systems. The purposes of this article are twofold: (1) to identify and discuss the social and economic impacts of aquaculture on biodiversity, and (2) to examine the impacts while moving from intensive to semi-intensive systems. After discussing the findings of our study, we provide some recommendations as to how to minimize social and economic impacts of aquaculture on biodiversity by moving to a lower intensity aquaculture system. The integrated agriculture- aquaculture farming systems, stakeholder involvement in management, and well defined basic rights are aquaculture systems that contribute to conservation of biodiversity.

AQUAFISH RESEARCH REPORT 15-351

ASSESSMENT OF FARMED TILAPIA VALUE CHAIN IN GHANA

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Published in:

Aquaculture International (2015) 24(4): 903–919. [DOI 10.1007/s10499-015-9960-1](https://doi.org/10.1007/s10499-015-9960-1).

The study assessed the value chain of farmed tilapia in Ghana. A survey conducted in 2012 provided data on key actors, flow of products and information, costs and margins, and relationship among actors. The study showed that all key actors in the value chain: input suppliers; fish farmers; traders; and food services had positive margins except fish farmers. Input suppliers accrued most of the margins generated along the chain. The performance of chain actors was assessed using a factor evaluation matrix, which showed that product offering may be the strength at each stage of the value chain. The efficiency and profitability of tilapia value chain in Ghana can be improved by having well-defined payment transaction with customers, persistent relationships with customers, and good information management such as keeping good records on costs and revenues. Fish farming could be more profitable if farmers reduced their variable costs, priced their fish using a cost plus or percentage markup approach, and adopted target marketing.

AQUAFISH RESEARCH REPORT 15-352

DOES CLIMATE CHANGE MATTER FOR FRESHWATER AQUACULTURE IN BANGLADESH?

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Published in:

Regional Environmental Change (2015) 16(6): 1659-1669.

Freshwater aquaculture plays an important role in the economy of Bangladesh, providing food, income, livelihoods and export earnings. However, freshwater aquaculture in the Mymensingh area of north-central Bangladesh has been accompanied by recent concerns over climate change. Field survey revealed that different climatic variables including flood, drought, rainfall variation and temperature fluctuation have had adverse effects on pond-fish culture. These climatic variables have detrimental effects on the ecosystem of ponds and thus affect survival, growth and production of fish. Changes in climatic variables have adverse effects on fish reproduction, grow-out operation, parasite infestation and disease occurrence. Considering vulnerability to the effects of climate change on pond-fish culture, we propose adaptation strategies that need to be introduced to cope with the challenges.

AQUAFISH RESEARCH REPORT 15-353

A STUDY OF USING CRUDE BROMELAIN ENZYME IN PRODUCING SALTY FERMENTED FISH PRODUCT FROM COMMERCIAL SNAKEHEAD FISH

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Published in:

Science and Technology Journal of Agriculture and Rural Development (2015) 19: 78-85.

The study of using crude bromelain enzyme in producing of salty fermented fish product from commercial snakehead fish was conducted from March to November 2014 at college of Aquaculture and Fisheries of Can Tho University with two main experiments (i) the effect of mechanical handle on proximate composition and texture property of product (ii) effect of supplementing crude bromelain enzyme at different rates and different fermentation times on product quality. In the first experiment, snakehead was applied [by] mechanical handle for 10 minutes and soaked with salt for 5, 10, 15, 20, 25 and 30 days. In the control group, fish were not applied [by] mechanical handle and soaked with salt for 30 days. In the second experiment, salty snakehead fish was supplemented with 2, 3, 4 and 5% of crude bromelain and fermented for 2, 4, 6, and 8 weeks. The control group was done without crude bromelain addition and fermented for 8 weeks. The results in the first experiment indicated that the group with mechanical handle snakehead fish and soaked with salt for 20 days gained the highest proximate composition (salt content 20.62%, moisture content 55.53%, protein content 18.94%) and hardness (20091 g force). In the second experiment, salty snakehead fish of 20 days was fermented with 3% crude bromelain and fermented for 6 weeks provided high proximate composition (20.67% of salt, 56.45% of moisture, 19.79% of protein, 8.02 mg total amino acids, 10-2 g fermented fish) and hardness (16607 g force) and had higher sensory score (color: 6.13, aroma: 6.07, taste: 6.00, and overall: 6.20) (1: extremely undesirable and 7: extremely desirable) in comparison with control group. Therefore, applying of crude bromelain enzyme can shorten the processing period of the salty fermented snakehead fish product and still ensures quality on nutrition and sensory quality compared with traditional methods.

AQUAFISH RESEARCH REPORT 15-A01

ASSESSMENT OF THE TRASH-FISH DIET FOR SNAKEHEAD AQUACULTURE IN VIETNAM: SPECIES COMPOSITION AND CHEMICAL CHARACTERISATION

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Published in:

Asian Fisheries Science (2015) 28: 165-173.

Traditional culture of snakehead (*Channa striata* (Bloch 1793) and *Channa micropeltes*, (Cuvier 1831), *Channidae*) in Vietnam have been based on capture of snakehead fingerlings from the wild and feeding them with chopped trash-fish also taken from the wild. From August to October 2008, freshwater trash fish samples (3 kg composite samples) were collected from three fish distribution sites at Chau Doc, Thoai Son and Chau Thanh districts in An Giang province, in the Mekong Delta, Vietnam. The species composition was determined along with the size frequency, sources, and chemical composition of the freshwater trash-fish used for snakehead aquaculture. Thirty-three species of freshwater fish were identified in the freshwater trash-fish samples, 12 of which were juveniles of commercially important species. Marine trash-fish samples were also collected from the same distribution sites for analysis of chemical composition and product freshness. Chemical composition of freshwater trash-fish indicates their protein levels to be nutritionally adequate for snakehead aquaculture. Marine trash-fish showed high total volatile base nitrogen (TVB-N) values, compared to freshwater trash-fish, indicating that they are not fresh. The fish stocks of these freshwater trash-fish species should be assessed and the inland fishery should be managed properly, especially during the flood season.

AQUAFISH RESEARCH REPORT 15-A02

COASTAL TO INLAND: EXPANSION OF PRAWN FARMING FOR ADAPTATION TO CLIMATE CHANGE IN BANGLADESH

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Published in:

Aquaculture Reports (2015) 2: 67-76.

The practice of prawn (*Macrobrachium rosenbergii*) farming is widespread in coastal Bangladesh due to favorable biophysical resources. However, export-oriented prawn farming is particularly vulnerable to climate change in coastal Bangladesh. This study identified different climatic variables, including salinity, coastal flooding, cyclone, sea-level rise, water temperature, drought, and rainfall have profound effects on prawn farming in the Bagerhat area of southwest Bangladesh. Considering extreme vulnerability to the effects of climate change on prawn production, one of the adaptation strategies is to translocate prawn culture from coastal to inland (i.e., Bagerhat–Gopalganj) that appear less vulnerable to climate change. Although the prospects for prawn–carp polyculture and integrated prawn–fish–rice farming are positive in Gopalganj, a number of challenges were identified for the expansion of prawn culture. We suggest that institutional support would help to adopt prawn production.

AQUAFISH RESEARCH REPORT 15-A03

EVALUATION OF LOCALLY-AVAILABLE AGROINDUSTRIAL BYPRODUCTS AS PARTIAL REPLACEMENTS TO FISHMEAL IN DIETS FOR NILE TILAPIA (*OREOCHROMIS NILOTICUS*) PRODUCTION IN GHANA

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Published in:

Journal of Animal Research and Nutrition (2015) 1(1:2): 1-9.

Objective: This study assessed the potential of three widely-available local oilseed byproducts, soybean (SBM), copra (CM) and palm kernel meals (PKM) as partial replacements of fishmeal in Nile tilapia (*O. niloticus*) diets in terms of their digestibility and effects on growth and nutrient utilization.

Methods: Apparent digestibility coefficients (ADCs) were determined using chromic oxide as an inert marker in test diets formulated to contain 30% of each of the test ingredients by weight and 70% of a fishmeal-based reference diet. The 8-week growth trial evaluated the effects of partial replacements of fishmeal by the oilseed byproducts at different dietary inclusions. The soybean meal diets were formulated with the soybean meal contributing 25% (SBM25) and 50% (SBM50) of total dietary protein. Copra and palm kernel meals each contributed 10 (CM10 and PKM10) and 20% (CM20 and PKM20) of total dietary protein in their respective diets. The test diets were compared to a control diet with fishmeal as the sole protein source.

Results: Nutrient digestibilities of the test ingredients were generally significantly higher for the soybean meal than the copra and palm kernel meals. The ADCs of the soybean, copra and palm kernel meals were; protein, 90.57%, 69.36% and 61.12; lipid, 96.14%, 95.64% and 95.85%; fibre, 96.74%, 77.61% and 55.07% and energy, 91.99%, 73.61% and 75.14% respectively. All the dietary treatment groups recorded significant growth at the end of the trials with the fish in the control and SBM25 groups more than tripling their respective mean initial weights. All the other treatment groups more than doubled their mean initial body weights. Daily growth rates ranged from 1.40% day⁻¹ for the PKM20 group to 2.26% day⁻¹ for the control group.

Conclusion: The study has shown that the test ingredients can partially replace fishmeal in Nile tilapia diets without considerably compromising diet digestibility and carcass traits although higher dietary levels of the oilseed byproducts negatively affects growth.

AQUAFISH RESEARCH REPORT 15-A04

OPTIMIZATION OF PHOSPHORUS FERTILIZER IN SUPPLEMENTAL FEED-FED BASED NILE TILAPIA (*OREOCHROMIS NILOTICUS*) PONDS

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Published in:

Aquaculture Research (2015) 46: 2859-2870.

An experiment was conducted in earthen ponds at the Asian Institute of Technology, Thailand to determine different phosphorus fertilizer dose effects on Nile tilapia production, water quality variables, nutrient utilization and cost-benefit under supplemental feeding. Five phosphorus fertilization rates were used as treatments e.g. 100%, 75%, 50%, 25% and 0% of 7 kg P ha week⁻¹. Nitrogen fertilization rate was fixed at 28 kg N ha week⁻¹ for all the treatments. Sex-reversed Nile tilapia were stocked at 3 fish m⁻², and 30% CP floating feed fed at 50% satiation feeding rate. Nutrient budget showed higher phosphorus fertilizer input resulted in higher phosphorus sink in the sediment. Mean weight, mean weight gain, daily weight gain and net yield were not significantly different among treatments ($P > 0.05$). Total Kjeldahl nitrogen, total phosphorus and soluble reactive phosphorus were significantly different among treatments. Economic analysis showed phosphorus fertilization resulted in positive net returns. Though the gross income was not affected by different fertilization rates, significantly lowest cost was found in the treatment using 25% phosphorus fertilizer. It can be concluded from the research that 25% phosphorus fertilization might be used as an alternative strategy of Nile tilapia pond culture in terms of economic return and nutrient loss in sediment.

AQUAFISH RESEARCH REPORT 15-A05

GROWTH AND BODY COMPOSITION OF MIDAS (*AMPHILOPHUS CITRINELLUS*) AND NILE TILAPIA (*OREOCHROMIS NILOTICUS*) REARED IN DUOCULTURE

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Published in:

Revista Colombiana de Ciencias Pecuarias (2015) 28: 255-264.

Background: Cichlids are of economical importance either as food (Nile tilapia) or as ornamental fish (Midas) and both exhibit territorialism and aggressive feeding behavior depending on availability of food and space. Objective: to evaluate the growth rates and behavioral changes of Nile tilapia and Midas kept in mono or polyculture. Methods: Midas and tilapia were maintained in a semi-closed rearing system. Initial weight was 0.83 and 0.81 g for Nile tilapia and Midas, respectively. Four treatments with different fish proportions were used. Midas and tilapia were distributed in 12 glass aquaria with three replicates ($n = 30$ fish per tank). Treatment ratios between Midas and tilapia were 1:0, 1:1, 2:1 and 0:1, respectively. Fish were fed a commercial diet (40% protein, 12% lipids) for six weeks at 5% weight ratio. Feed offer was adjusted weekly. Observations of behavioral traits were recorded throughout the trial to determine social and feeding conduct. Body composition of fish was assessed at the end of the experiment. Results: Midas modified their feeding behavior and their weight gain increased (3.9 ± 0.3 g) in the 2:1 group. The 0:1 group exhibited the lowest growth rate throughout the experiment (2.9 ± 0.3 g). Midas did not affect Tilapia growth (5.8 ± 0.4 g) across treatments. Interspecies aggressiveness was less evident when reared in monoculture (groups 1:0 y 0:1). Intra and interspecies attacks were higher in the 1:1 and 2:1 groups. Proximate body composition indicated higher lipid levels in Midas across treatments in comparison to tilapia. Conclusions: duoculture benefits growth of juvenile Midas when present at 25-30% of total stocking density with Nile tilapia.

AQUAFISH RESEARCH REPORT 15-A06

LIVELIHOOD STATUS OF GHER FARMERS OF BEEL DAKATIA IN KHULNA DISTRICT, BANGLADESH

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Published in:

International Journal of Aquatic Science (2015) 6(1): 45-53.

The present research work was carried out to determine livelihood conditions of fish and Prawn/ Giant freshwater prawn (*Macrobrachium rosenbergii*) Gher farmers at Beel Dakatia in Dumuria, Phultala and Daulatpur thana under Khulna district from April to September 2013. From the survey the community indicated that 21-40 age groups made maximum strength and majority of them were Muslims (58%). It was found that 16% of them could sign only and the percentages of school going children were high (86%). In the study area, it was found that 88% were married, 62% of people lived with unit families and highest households were 5-7 people per family. The majority of families (72%) had one person for earning and highest income of the people (44%) were 128 to 256 US dollar (\$). About 62% people lived in local house and the construction materials were nipa palm and mud, 72% used electricity. The result also showed that 84% peoples main occupation was fish farming. Majority of the people (52%) used others tube well water for drinking, 56% used closed half build toilet. 52% fishermen got health service from Upazila health complex which was the most preferred place. For their recreation 76% used TV/ Radio. About 78% people used lease land for the fish and prawn farming. Thus to achieve better social structure, the government and its development partner needs to re-orient their programmer and to implement to an affirmative action for the fish and prawn Gher farmers.

AQUAFISH RESEARCH REPORT 15-A07

COMPARATIVE HISTOLOGICAL DESCRIPTION OF THE DIGESTIVE AND VISUAL SYSTEM DEVELOPMENT OF LARVAL CHAME *DORMITATOR LATIFRONS* (PISCES: *ELEOTRIDAE*)

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Published in:

Latin American Journal of Aquatic Research (2015) 43(3): 484-494.

This study was focused on the morphological description of chame larvae from one to six days post-hatching (dph), in order to generate information that helps understanding their feeding ability in early stages. The larvae were obtained by hormonal induction of a broodstock, using implants of GnRH synthetic analogues, during the spawning season from September to November 2010. The samples were included in historesin, and stained with hematoxylin-eosin. It was described that, once the larva hatched has a large amount of yolk it is gradually absorbed (from 1 to 3 dph). At day four, there is an open oral cavity with dental structures, the eye development is complete and there was pigmentation on it, the gills are observable and the foregut was differentiated in anterior and posterior intestine, showing the presence of digestive vacuoles in the anterior intestine. By five dph the larvae has developed muscle fibers and a structure identified as the stomach. At sixth dph, it is possible to identify the pancreas, the intestinal folds, and the brush border membrane, and there were food particles and bacteria rests in the gut. Based on the above, it is concluded that the larvae of *D. latifrons* from the fourth dph fully developed organs and systems that help the search of food, so they are capable of starting with exogenous feeding.

AQUAFISH RESEARCH REPORT 15-A08

LOW-COST TILAPIA PRODUCTION WITH FERTILIZATION AND SUPPLEMENTAL FEEDING

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Published in:

World Aquaculture (2015) 46(1): 43-46.

The production of tilapia, like other fed species, has been constrained by the cost of feeds, which can account for about 70 percent of the production costs of tilapia in several countries and regions (Bolivar et al. 2006, Elnady et al. 2010). There have been many attempts to replace expensive animal protein in tilapia feeds with plant protein sources, such as soybean meal, groundnut seed cake and others. Although animal protein replacement in tilapia feeds has been successful, feed continues to represent a major cost item in tilapia production. Rural pond aquaculture is typically practiced as small-scale fish polyculture systems, where natural productivity is enhanced with fertilizers and fish or shrimp are provided with supplemental feeds. The major constraints for small-scale, resource-poor farmers are fish feeds and chemical fertilizers, which are expensive and not readily available. Reducing feed costs in aquaculture is, therefore, important for long-term sustainability of rural aquaculture, where profit margins often tend to be rather small. There is potential to reduce feed costs in aquaculture by using less expensive feed and through adoption of prudent feed management strategies.

Field trials in Nepal, Thailand, Vietnam, Kenya and China has demonstrated that several best practices in pond culture of tilapia species can reduce feed costs by half (Diana et al. 1994, Yi et al. 2001). These practices include adequate fertilization using organic manures, fertilization and supplementary feeding, feeding on alternate days or reducing the daily feed ration to half the satiation level with adequate fertilization. These trials have demonstrated reasonably good growth and better performance of tilapia at relatively lower feeding costs. These approaches rely on the dynamics of pond productivity in response to different fertilizer and feed treatments.

The overall purpose of the research trials was to develop a low-cost pond culture system that could lead to increased profits, improve the supply of high quality fish protein to communities with limited food resources, and contribute to the overall growth of national aquaculture sectors. This article highlights the effects of combinations of fertilizers and feed on tilapia productivity in small earthen ponds. Experiments were conducted in Nepal, Cambodia and Kenya using a similar experimental design, stocking density and feeding regime. [This excerpt is the first four paragraphs of the publication]

AQUAFISH RESEARCH REPORT 15-A09

EMBODIED RESOURCE USE IN FEED-BASED AQUACULTURE

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Published in:

Global Aquaculture Advocate 18(3): 25-27.

In life cycle analysis of aquaculture, there is a danger of the entire array of embodied resources and impacts being assigned to the production facility. Producers have no control over the inefficiencies or impacts associated with feed production, but can help lessen resource use through good management practices. Improving feed conversion not only reduces resource use and impacts, but also lowers the amounts of nitro-gen and phosphorus discharged to the environment. Better feed conversion also lowers production costs.

AQUAFISH RESEARCH REPORT 15-A10

EFFICIENCY OF MECHANICAL AERATION

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Published in:

Global Aquaculture Advocate 18(6): 32-34.

Paddlewheel design greatly impacts standard aeration efficiency. Although widely implemented, the long-arm paddlewheel aerators typically used in Asia do not reflect the most efficient designs. Mechanical aerators are used increasingly in aquaculture because aeration can greatly increase the amount of production possible per unit area or volume of water. These devices usually are powered by electricity, but in some locations, small diesel engines are the power source. During a recent visit to a shrimp-farming area in Thailand, the author saw ponds aerated at 24-36 hp/ha (18-27 kW/ha). These aerators often are operated about 20 hours daily over a 60- to 100-day crop period. At a farm with 24 hp/ha of aeration and a 100-day crop, about 36,000 kWhr of electricity would be used for aeration. Shrimp production for successful crops of 14- to 18-g shrimp was reported to be around 7,000-9,000 kg/ha. Electricity costs about U.S. \$0.10/kWhr in Thailand. Thus, aeration costs \$0.41 to \$0.53/kg of shrimp for electricity alone. Aeration costs for fish production usually are lower than for shrimp, but still represent a major production expense.

AQUAFISH RESEARCH REPORT 15-A11

FISH CONSUMPTION AMONG WOMEN AND PRE-SCHOOL CHILDREN IN CAMBODIA

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Published in:

Catch and Culture 21(3): 34-35.

In 2014, the Inland Fisheries Research and Development Institute of the Cambodian Ministry of Agriculture, Forestry and Fisheries undertook a study of the consumption of fish and other aquatic animals by women and pre-school children. The study, supported by Oregon State University through the University of Connecticut under the AquaFish Innovation Lab programme, covered 300 women and 343 children in three provinces – Stung Treng and Prey Veng on the Mekong River and Kampong Thom on the Tonle Sap Lake. Interviews over two weeks in June estimated food intake over the previous 24 hours. Evaluations of energy, macronutrients and micronutrients were made using the ASEAN Food Composition Table. To determine nutritional adequacy, nutrient intake was compared with the Recommended Dietary Allowances for Southeast Asia.

AQUAFISH RESEARCH REPORT 15-A12

POLYCULTURE WITH CARP, NUTRIENT-RICH SMALL FISH AND PRAWN

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World Aquaculture 45(3): 46-50

Small fish have been considered trash fish and were often removed from ponds, based on a misconception that SIS exert competition for food and space with the main species cultured. Production was greater in ponds with SIS than those without SIS, suggesting a synergistic effect of SIS on carp production. Small fish contributed an average of 20 percent of total family consumption among SIS-growing farmers. SIS-stocked ponds provided 28 percent greater income over carp-only ponds because of comparatively greater production. Female farmers have learned to stock and grow SIS.

AQUAFISH RESEARCH REPORT 15-A13

AQUACULTURE CARRYING CAPACITY OF STUNG CHINIT RESERVOIR: A PILOT PROJECT

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Published in:

Catch and Culture 21(2): 58-60.

Cambodia has plans to expand freshwater aquaculture, including in reservoirs (Fisheries Administration, 2011). Lakes and reservoirs represent commonly owned or used water bodies and are therefore subject to the “tragedy of the commons”, in which too many users can destroy the quality of the resource (Hardin, 1968). It is not unusual in Southeast Asia to see reservoirs in which aquaculture has grown beyond reasonable limits, with subsequent declines in water quality (e.g. the Cirata and Jatiluhur reservoirs in Indonesia, with tens of thousands of fish cages).

AQUAFISH RESEARCH REPORT 15-A14

AQUACULTURE HELPS WOMEN IN NEPAL IMPROVE HOUSEHOLD NUTRITION

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Published in:

USAID Feed the Future Newsletter (28): 2-3.

In rural Nepal, widespread poverty is compounded by the lack of access to high-quality, nutritious foods. According to a recent report from the Nepal Demographic Health Survey, 41 percent of children under the age of five are chronically malnourished, and anemia is a significant problem, afflicting 47 percent of children and 36 percent of women.

One approach to mitigate the spread of anemia and to improve the overall health of rural Nepalese is to supplement their diets with vitamin-rich protein sources, such as fish. Researchers from Nepal's Agriculture and Forestry University (AFU) recognized the potential of aquaculture to help address this widespread nutritional deficit, and their recent effort in Nepal successfully established more than 70 family-run fishponds, all managed by women. In the first year of operation, the ponds produced over 500 kg of fish for household consumption.

AQUAFISH RESEARCH REPORT 15-A15

EFFICACY OF COMMON CARP (*CYPRINUS CARPIO*) TESTIS ON SEX REVERSAL OF NILE TILAPIA (*OREOCHROMIS NILOTICUS*) FRY

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Published in:

Nepalese Journal of Aquaculture and Fisheries (2015): 56-64.

Feeding common carp (*Cyprinus carpio*) testis (CCT) to Nile tilapia during the critical period of sex differentiation caused skewness towards male based on dose dependent manner. Six types of feed containing varied proportion CCT viz.: 0% (Control), 50%, 65%, 80%, 95% and 100% were fed to 9 DAH (days after hatching) tilapia fry for 25, 30 and 35 days. Treatment with CCT and control feed was carried out in 18 glass aquaria of 60cm x 30cm x 45cm while rearing was carried out in 50cm x 50cm x 100cm nylon happas suspended cemented tank up to 160 DAH. There was no significant effect of treatment duration on sex reversal. Highest proportion of male ($95.8 \pm 7.2\%$) was obtained with 100% CCT feed fed for 30-35 days compared to lowest ($62.5 \pm 12.5\%$) obtained with 50% CCT feed fed for 25-30 days excluding the normal sex ratio with 0% CCT feed. Thus, it was concluded that common carp testis can efficiently masculinize Nile tilapia fry when fed for at least 30 days after hatching. Further refinement of testis could be more effective in sex reversal of Nile tilapia which could replace the use of synthetic androgen (17α - methyltestosterone).

AQUAFISH RESEARCH REPORT 16-354

QUALITY ENHANCEMENT OF DRIED SNAKEHEAD FISH (*CHANNA STRIATA*) BY SUPPLEMENTING WINE AND GLYCEROL

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Published in:

Journal of Agriculture and Rural Development (2016) 1: 74-84.

The quality and safety of dried snakehead fish (*Channa striata*) on the local markets in Vietnam could not be controlled recently. Therefore improvement of this former processing is necessary concerned and conducted in order to obtain high quality of dried fish products as well as long-term storage to meet the diversified consumer taste. The study aims not only to assess the properties of dried snakehead fish (with sucrose addition) based on supplementing wine (30%) and glycerol into fish muscle but also to enhance the quality of dried fish products. Total plate count, chemical indices, and organoleptic evaluation were recorded to exam the changes of dried snakehead fish corresponding to 1, 2 and 3% (w/w) of wine (30%) addition. Then, the effects of adding glycerol (0, 1, 2, 3%, w/w) on dried snakehead fish with 2% of wine (w/w) were surveyed over a period of four weeks. As compared to the other treatments, addition of 2% (w/w) of glycerol and 2% (w/w) of wine (30%) to dried fish illustrated the highest sensory properties and the lowest parameters of total plate count, moisture content, water activity, peroxide value, total volatile base nitrogen in four weeks. In addition, these analyzed parameters were within acceptable limits. Therefore, the quality and safety of dried snakehead fish were obtained during storage time. The proximate composition of raw snakehead fish and dried products were also studied. The results showed that moisture, protein, lipid, ash and sodium chloride content of raw snakehead fish were 78.1, 18, 2.5, 1.14, 0.73% respectively, whereas those of dried products with wine and glycerol addition were 29.4, 58.9, 5.54, 5.49, 4.56%.

AQUAFISH RESEARCH REPORT 16-355

LEPTIN STIMULATES HEPATIC GROWTH HORMONE RECEPTOR AND INSULIN-LIKE GROWTH FACTOR GENE EXPRESSION IN A TELEOST FISH, THE HYBRID STRIPED BASS

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Published in:

General and Comparative Endocrinology (2016) 229: 84-91. [doi:](#)

<http://dx.doi.org/10.1016/j.ygcen.2016.02.003>.

Leptin is an anorexigenic peptide hormone that circulates as an indicator of adiposity in mammals, and functions to maintain energy homeostasis by balancing feeding and energy expenditure. In fish, leptin tends to be predominantly expressed in the liver, another important energy storing tissue, rather than in fat depots as it is in mammals. The liver also produces the majority of circulating insulin-like growth factors (IGFs), which comprise the mitogenic component of the growth hormone (GH)-IGF endocrine growth axis. Based on similar regulatory patterns of leptin and IGFs that we have documented in previous studies on hybrid striped bass (HSB: *Morone saxatilis* × *M. chrysops*), and considering the co-localization of these peptides in the liver, we hypothesized that leptin might regulate the endocrine growth axis in a manner that helps coordinate somatic growth with energy availability. Using a HSB hepatocyte culture system to simulate autocrine or paracrine exposure that might occur within the liver, this study examines the potential for leptin to modulate metabolism and growth through regulation of IGF gene expression directly, or indirectly through the regulation of GH receptors (GHR), which mediate GH-induced IGF expression. First, we verified that GH (50 nM) has a classical stimulatory effect on IGF-1 and additionally show it stimulates IGF-2 transcription in hepatocytes. Leptin (5 and/or 50 nM) directly stimulated *in vitro* GHR2 gene expression within 8 hrs of exposure, and both GHR1 and GHR2 as well as IGF-1 and IGF-2 gene expression after 24 hrs. Cells were then co-incubated with submaximal concentrations of leptin and GH (25 nM each) to test if they had a synergistic effect on IGF gene expression, possibly through increased GH sensitivity following GHR upregulation by leptin. In combination, however, the treatments only had an additive effect on stimulating IGF-1 mRNA despite their capacity to increase GHR mRNA abundance. This suggests that leptin's stimulatory effect on GHRs may be limited to enhancing transcription or mRNA stability rather than inducing full translation of functional receptors, at least within a 24-h time frame. Finally, leptin was injected IP (100 ng/g and 1 ug/g BW) to test the *in vivo* regulation of hepatic IGF-1 and GHR1 gene expression. The 100 ng/g BW leptin dose significantly upregulated *in vivo* IGF-1 mRNA levels relative to controls after 24 hrs of fasting, but neither dosage was effective at regulating GHR1 gene expression. These studies suggest that stimulation of growth axis component transcripts by leptin may be an important mechanism for coordinating somatic growth with nutritional state in these and perhaps other fish or vertebrates, and represent the first evidence of leptin regulating GHRs in vertebrates.

AQUAFISH RESEARCH REPORT 16-356

EFFECTS OF DIETARY LEVELS OF ESSENTIAL OIL (EO) EXTRACT FROM BITTER LEMON (*CITRUS LIMON*) FRUIT PEELS ON GROWTH, BIOCHEMICAL, HAEMATO-IMMUNOLOGICAL PARAMETERS AND DISEASE RESISTANCE IN JUVENILE *LABEO VICTORIANUS* FINGERLINGS CHALLENGED WITH *AEROMONAS HYDROPHILA*

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Published in:

Aquaculture Research (2016): 1-13.

Essential oils (EOs) are used in the food industry because of their biological activity. We evaluated the effects of administration of essential oil (EO) extracted from bitter lemon (*Citrus limon*) fruit peels on the growth performance, biochemical, haemato-immunological parameters and possible disease resistance in fingerlings (4 weeks old) *Labeo victorianus* challenged with *Aeromonas hydrophila*. Fish were divided into five groups and fed diets supplemented with *C. limon* fruit peels EO extract at 1%, 2%, 5% and 8% [as fed basis] and treatment compared with control group fed diet without *C. limon* fruit peels EO extract. The experiment was executed in triplicate. Concentration of plasma cortisol, glucose, triglyceride and cholesterol decreased while that of total protein and albumin increased as dietary inclusion of the EO extract of *C. limon* fruit peels was increased from 2% to 5%. Meanwhile haemato-immunological parameters including red blood cell (RBC), white blood cell (WBC) counts, haematocrit (Htc), mean cell haemoglobin (MCH), mean cell haemoglobin concentration (MCHC) and neutrophils increased with increasing dietary inclusion from 1% to 5% inclusion of *C. limon* fruit peels EO extract. Serum immunoglobulins, lysozyme activity and respiratory burst increased with increasing dietary levels up to 5% inclusion of EO extract of *C. limon* fruit peels. We demonstrate that formulation of feeds by incorporating up to 5% the EO extract from *C. limon* fruit peels significantly improved biochemical, haematological and immunological response in juvenile fish resulting to lower mortality than the untreated groups and appear to be effective antibacterial against *A. hydrophila*.

AQUAFISH RESEARCH REPORT 16-357

GROWTH PERFORMANCE AND IMMUNE RESPONSE OF SNAKEHEAD, *CHANNA STRIATA* (BLOCH 1793)
FED SOY DIETS WITH SUPPLEMENTATION OF MANNAN OLIGOSACCHARIDES

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Published in:

Asian Fisheries Science (2016) 29: 67-81.

This study evaluated the effectiveness of mannan oligosaccharides (MO) supplementation in fish meal (FM), soybean meal (SBM) and soy protein concentrate (SPC) formulated feeds for snakehead, *Channa striata* (Bloch 1793) in a two-way factorial experiment. Factors were diet (FM, 40% FM replacement by SBM, and 40% FM replacement by SPC) and MO supplementation (0%, 0.2%, or 0.4% MO). Growth was significantly affected ($p < 0.05$) by diet and MO supplementation, as well as their interaction. Feed conversion ratio, protein efficiency ratio and survival were significantly affected ($p < 0.05$) by diet, but only survival was significantly affected ($p < 0.05$) by MO supplementation, and interactions were insignificant ($p > 0.05$). Red blood cell counts were not significantly affected ($p > 0.05$) by diet, MO supplementation, or the interaction, but white blood cell counts were significantly affected ($p < 0.05$) by diet and MO supplementation, not the interaction. Immunoglobulin (Ig) levels were significantly increased ($p < 0.05$) by MO supplementation and the MO x diet interaction, but diet did not affect Ig levels ($p > 0.05$). Following a 15-d bacterial challenge with *Aeromonas hydrophila*, lysozyme levels were significantly increased ($p < 0.05$) by MO supplementation and the MO x diet interaction, but not by the diets themselves. Cumulative mortality did not differ among fish fed different diets ($p > 0.05$). Our results suggest that MO supplementation may improve diet performance in snakehead culture, although full-scale commercial trials should be conducted to confirm this.

AQUAFISH RESEARCH REPORT 16-358

CONSUMER PREFERENCES FOR FARMED TILAPIA IN TANZANIA: A CHOICE EXPERIMENT ANALYSIS

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Published in:

Journal of Applied Aquaculture (2016) 28: 131-143. [DOI: 10.1080/10454438.2016.1169965](https://doi.org/10.1080/10454438.2016.1169965).

This study used a choice experiment to analyze the preferences of consumers for the attributes of tilapia (price, mode of production, product form, and size), a major aquaculture product in Tanzania. The results showed that consumers were willing to pay a price 665.020 Tanzanian shillings (TZS) lower for farmed tilapia than for wild tilapia; a price TZS 833.210 and TZS 1799.110 higher for medium-size and large-size tilapia respectively than for small-size tilapia; and a price TZS 1214.090 higher for fresh tilapia than for smoked tilapia. Consumers' willingness to pay less for farmed tilapia than for wild tilapia is mainly attributed to issues related to taste and availability. It was also found that consumers were heterogeneous in their preferences for all the tilapia attributes (mode of production, size, and form) considered in this study.

AQUAFISH RESEARCH REPORT 16-359

REPLACEMENT OF FRESHWATER SMALL-SIZE FISH BY FORMULATED FEED IN SNAKEHEAD (*CHANNA STRIATA*) AQUACULTURE: EXPERIMENTAL AND COMMERCIAL-SCALE POND TRIALS, WITH ECONOMIC ANALYSIS

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Published in:

Aquaculture Reports (2016) 4: 42-27.

Traditional snakehead culture in Southeast Asia relies on use of small-size (trash) fish as food, an unsustainable practice. Following development of weaning methods and testing of formulated feed (FF) in laboratory experiments, we conducted feeding trials of FF vs. trash fish (TF) in experimental ponds at Can Tho University (CTU), followed by similar trials on commercial farms in two provinces in Vietnam. CTU pond trials consisted of five treatments (in triplicate), in which TF was replaced by FF in increasing percentages: 0 (control), 25, 50, 75, and 100% replacement of TF by FF (i.e., three treatments had mixed TF/FF diets). Although survival was significantly reduced in the 100% replacement treatment, and growth was significantly reduced in the 75% and 100% replacement treatments, the cost per kg of fish produced was 28–35% less in those high-replacement treatments compared to the 0% replacement treatment. On-farm trials were then conducted at two farms in An Giang and Dong Thap provinces for 6 months with snakehead fed TF only or FF only. At both farms, survival (73–80%) was not significantly different, but growth was significantly better on FF diet at both; however, FF-fed fish at the An Giang farm showed significantly higher levels of abnormal development. Overall production was about twice as high at the An Giang farm as at Dong Thap, but significantly greater production by FF-fed fish vs. TF-fed fish was only seen at Dong Thap. Sensory evaluation by a tasting panel found no difference in product quality between FF-fed fish, TF-fed fish, and a commercial sample bought in the market. Economic analysis indicated that profits were higher for FF-fed fish from both farms, although production costs and sales varied greatly, reflecting market differences in the two provinces.

AQUAFISH RESEARCH REPORT 16-360

EFFECTS OF REPLACING FISH MEAL WITH SOYA PROTEIN CONCENTRATE ON GROWTH, FEED EFFICIENCY AND DIGESTIBILITY IN DIETS FOR SNAKEHEAD, *CHANNA STRIATA*

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Published in:

Aquaculture Research (2016) 48(6): 3174-3181. DOI: [10.1111/are.13147](https://doi.org/10.1111/are.13147).

Soya bean meal-based formulated feeds have recently become available for snakehead culture in Vietnam. This study was conducted to determine the appropriate replacement of fish meal (FM) protein by another soya product, soya protein concentrate (SPC), in snakehead (*Channa striata*) diets. Five iso-nitrogenous (45% crude protein) and isocaloric (19 KJ g⁻¹) practical diets were formulated to replace 0% (control), 40%, 60%, 80% and 100% of protein FM by protein SPC (100% FM, 40% SPC, 60% SPC, 80% SPC and 100% SPC respectively). A digestibility experiment was also conducted with the same formulated diets with addition of 1% chromic oxide. Fish fed 100% FM and 40% SPC diets had significantly better growth and survival compared with other treatments. Feed intake, feed conversion ratio, protein efficiency ratio and net protein utilization, trypsin and chymotrypsin activities of experimental fish fed 100% FM and 40% SPC diets were significantly higher than those fed other diets. The apparent digestibility coefficient (ADC) of the diet and diet components, ADC_{diet}, ADC_{protein} and ADC_{lipid}, of fish fed diet 40% SPC and 100% FM treatment were significantly higher than those of other treatments. The cost/kg fish produced in diets 100% FM and 40% SPC was much lower compared with other treatments. Dietary inclusion levels of SPC in diet above 40% significantly affected fish survival, growth, digestibility and trypsin and chymotrypsin activities, although fish chemical composition was not greatly affected.

AQUAFISH RESEARCH REPORT 16-361

CONTROL OF LEPTIN BY METABOLIC STATE AND ITS REGULATORY INTERACTIONS WITH PITUITARY GROWTH HORMONE AND HEPATIC GROWTH HORMONE RECEPTORS AND INSULIN LIKE GROWTH FACTORS IN THE TILAPIA (*OREOCHROMIS MOSSAMBICUS*)

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Published in:

General Comparative Endocrinology (2016), DOI: [10.1016/j.ygcen.2016.07.017](https://doi.org/10.1016/j.ygcen.2016.07.017).

Leptin is an important cytokine for regulating energy homeostasis, however, relatively little is known about its function and control in teleost fishes or other ectotherms, particularly with regard to interactions with the growth hormone (GH)/insulin-like growth factors (IGFs) growth regulatory axis. Here we assessed the regulation of LepA, the dominant paralog in tilapia (*Oreochromis mossambicus*) and other teleosts under altered nutritional state, and evaluated how LepA might alter pituitary growth hormone (GH) and hepatic insulin-like growth factors (IGFs) that are known to be disparately regulated by metabolic state. Circulating LepA, and *lepa* and *lepr* gene expression increased after 3-weeks fasting and declined to control levels 10 days following refeeding. This pattern of leptin regulation by metabolic state is similar to that previously observed for pituitary GH and opposite that of hepatic GHR and/or IGF dynamics in tilapia and other fishes. We therefore evaluated if LepA might differentially regulate pituitary GH, and hepatic GH receptors (GHRs) and IGFs. Recombinant tilapia LepA (rtLepA) increased hepatic gene expression of *igf-1*, *igf-2*, *ghr-1*, and *ghr-2* from isolated hepatocytes following 24 h incubation. Intraperitoneal rtLepA injection, on the other hand, stimulated hepatic *igf-1*, but had little effect on hepatic *igf-2*, *ghr1*, or *ghr2* mRNA abundance. LepA suppressed GH accumulation and *gh* mRNA in pituitaries in vitro, but had no effect on GH release. We next sought to test if abolition of pituitary GH via hypophy- sectomy (Hx) affects the expression of hepatic *lepa* and *lepr*. Hypophysectomy significantly increases hepatic *lepa* mRNA abundance, while GH replacement in Hx fish restores *lepa* mRNA levels to that of sham controls. Leptin receptor (*lepr*) mRNA was unchanged by Hx. In in vitro hepatocyte incubations, GH inhibits *lepa* and *lepr* mRNA expression at low concentrations, while higher concentration stimulates *lepa* expression. Taken together, these findings indicate LepA gene expression and secretion increases with fasting, consistent with the hormones function in promoting energy expenditure during catabolic stress. It would also appear that LepA might play an important role in stimulating GHR and IGFs to potentially spare declines in these factors during catabolism. Evidence also suggests for the first time in teleosts that GH may exert important regulatory effects on hepatic LepA production, insofar as physiological levels (0.05–1 nM) suppress *lepa*

mRNA accumulation. Leptin A, may in turn exert negative feedback effects on basal GH mRNA abundance, but not secretion.

AQUAFISH RESEARCH REPORT 16-362

DEMAND FOR IMPROVED FISH FEED IN THE PRESENCE OF A SUBSIDY: A DOUBLE HURDLE APPLICATION IN KENYA

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Published in:

Agricultural Economics (2016) 47: 633-643.

Fish farming households' demand for improved fish feed from the private market in Kenya is potentially influenced by the government's feed subsidy program. This article applies the double-hurdle model to a cross-section of fish farms to analyze demand for improved fish feed from private markets, and whether the government feed subsidy program has an effect on private demand for improved feed. The results indicate that households' decisions to participate in the improved feed market are affected by the quantity of improved feed received from the government. Once the participation decision has been made, we find evidence of crowding-in of the private improved feed sector; that is, the government's allocations of subsidized feed appear to increase private sector demand. In addition, the price of improved feed negatively affects the quantity purchased as expected. Education, extension contacts, and ease of marketing matured fish increase household propensity to purchase improved feed commercially. Policies that help reduce the price of improved feed such as reduction in tariffs on imported feeds and feed ingredients will foster demand for the feed, as will policies that facilitate marketing of fish at reasonable prices by households.

AQUAFISH RESEARCH REPORT 16-363

THE MOBILIZATION OF SCIENCE AND TECHNOLOGY FISHERIES INNOVATIONS TOWARDS AN ECOSYSTEM APPROACH TO FISHERIES MANAGEMENT IN THE CORAL TRIANGLE AND SOUTHEAST ASIA

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Published in:

Elsevier (2016) 74: 143-152.

Several regional fisheries and marine conservation organizations in the Coral Triangle (CT) and Southeast Asia have indicated their support for an ecosystem approach to fisheries management (EAFM). It is also likely that science and technology (S&T) innovations will play a role in the region for the purposes of filling gaps in fisheries data, enhancing the coordination of fisheries management efforts, and implementing and operationalizing an EAFM. Here, we outline the methodology and results of an expert- opinion survey designed to elucidate and prioritize the implementation of these S&T innovations. As a first step and case study, the survey presented here was conducted on U.S. government experts. The U.S. market is one of the world’s largest importers of seafood, and therefore, in the framework of this study, is considered to be a stakeholder in the seafood supply chain that originates in the CT and Southeast Asia region. Results are discussed in terms of the data needs and principles of an EAFM, as well as current trends and contexts of the CT and Southeast Asia region. Next steps and recommendations are also provided on how S&T innovations can be implemented to enhance the cooperation and coordination of regional marine resource management efforts.

AQUAFISH RESEARCH REPORT 16-364

IMPACTS OF CLIMATE CHANGE ON SNAKEHEAD FISH VALUE CHAINS IN THE LOWER MEKONG BASIN OF CAMBODIA AND VIETNAM

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Published in:

Aquaculture Economics & Management (2016) 21(2): 1-22. [DIO: 0.1080/13657305.2016.1185196](https://doi.org/10.1080/13657305.2016.1185196).

The productive fisheries of the Lower Mekong Basin of Cambodia and Vietnam are essential to the food security and nutrition of 60 million people. Yet these fisheries, both culture and capture, are susceptible to the impacts of climate change. This article reports on a study undertaken to examine the vulnerability, as perceived by snakehead (*Channa striata*) fish farmers in Vietnam and fishers in Cambodia, to the impacts from climate change. Perceived impacts on various actors in the value chain are identified, as well as adaptation strategies currently being utilized and planned for the future. Recommendations are suggested to contribute to assisting snakehead farmers and fishers in adapting and preparing for the impacts of climate change.

AQUAFISH RESEARCH REPORT 16-365

ASSESSING THE RELIABILITY OF WATER-TEST KITS FOR USE IN POND AQUACULTURE

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Published in:

Journal of World Aquaculture (2016) 48(4): 555-562. [DOI: 10.1111/jwas.12377](https://doi.org/10.1111/jwas.12377).

Water-analysis kits are useful for practical aquaculture only if they provide equivalent decision-making as compared to standard water-analysis methods. This study used weighted Cohen's kappa (κ) statistics to compare management decisions made by farmers who used water-analysis kits (e.g., Seneye slide kit, Tetra EasyStrips, API test strips, Seachem Ammonia Alert, Salifert Profi test kit, and Hach dissolved oxygen (DO) and alkalinity kit) and decisions made by those who used standard methods. The decisions made by farmers were similar for water-analysis kits and standard methods, except for Tetra and API test strips, when measuring nitrate concentrations. The highest conformity between the two methods (κ -value = 1.0, $P < 0.0001$) was obtained with the Hach and Salifert Profi test kits (for measuring DO) and the API test strip (for measuring total hardness). The rapid, simple measurements by the kits appear suitable for use by farmers if they are properly maintained and manufacturer's instructions are followed.

AQUAFISH RESEARCH REPORT 16-366

MONITORING THE EFFECTS OF AQUACULTURE EFFLUENTS ON BENTHIC MACROINVERTEBRATE POPULATIONS AND FUNCTIONAL FEEDING RESPONSES IN A TROPICAL HIGHLAND HEADWATER STREAM (KENYA)

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Published in:

Aquatic Ecosystem Health & Management (2016) 19(4): 431-440.

Intensification of aquaculture may result in more fish culture waste being discharged into adjacent rivers and streams. Due to composition of such wastes, ecological conditions in waterbodies may be adversely affected. We determined the ecological consequences of freshwater land-based Tilapia farms on headwater streams using macroinvertebrate community attributes and functional feeding response in an upstream tributaries of a highland stream in Kenya. Nine aquaculture sites adjacent to tributaries of three headwater streams with different fish production volumes were sampled and monitored for macroinvertebrate abundance, richness, composition of *Ephemeroptera*, *Plecoptera* and *Trichoptera*, *Oligochaetes* and *Chironomids* (percentage *Oligochaetes* and *Chironomids*), species diversity as well as the functional feeding group responses. The total abundance of benthic macroinvertebrate consistently increased near discharge points and immediately downstream of the effluent outlets near the aquaculture farms. We observed positive correlations between macroinvertebrate attributes (except *Ephemeroptera*, *Plecoptera* and *Trichoptera*) with fish production at aquaculture facilities adjacent to the tributaries of the headwater streams. The proportion of *Oligochaetes* and *Chironomids* (percentage *Oligochaetes* and *Chironomids*) increased while that of *Ephemeroptera*, *Plecoptera* and *Trichoptera* at discharge points and downstream of the farms decreased. Also, relative abundance of scrapers and shredders decreased significantly, while significant increase of abundance was observed for deposit feeders, filter feeders and parasites with low predator population at discharge and downstream points. These consistent patterns indicated changes in ecosystem integrity and functioning, due to aquaculture effluents with particulate organic matter from fish food-derived wastes becoming a central source of energy in river benthic food webs.

AQUAFISH RESEARCH REPORT 16-367

GROWTH, YIELDS AND ECONOMIC BENEFIT OF NILE TILAPIA (*Oreochromis niloticus*) FED DIETS FORMULATED FROM LOCAL INGREDIENTS IN CAGES

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Published in:

International Journal of Fisheries and Aquatic Studies (2016) 4(6): 191-195.

Small-scale aquaculture in Africa is limited by cost of protein ingredient in fish feeds, which requires continuous research in ways of improving protein ingredients. We evaluated the suitability of replacing fishmeal with rice bran alone or rice bran in combination with atyid shrimp (*Caridina nilotica*) on growth performance and economic benefits of Nile tilapia (*Oreochromis niloticus*) cultured in cages suspended of statistic ponds. The best growth performance and feed conversion ratio (FCR) occurred in fish fed fishmeal followed by those fed a combination of rice bran and *C. nilotica*, while rice bran alone resulted in lowest fish growth performance. The best economic benefit was obtained from fish fed a combination of rice bran and *C. nilotica*. We therefore demonstrate that it is possible to replace expensive fishmeal in the diet of *O. niloticus* using combination of cheaper rice bran and *C. nilotica* without compromising economic benefits for the small-scale aquaculturists.

AQUAFISH RESEARCH REPORT 16-368

GENDER DIMENSIONS IN DISASTER MANAGEMENT: IMPLICATIONS FOR COASTAL AQUACULTURE AND FISHING COMMUNITIES IN THE PHILIPPINES

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Published in:

Michele Companion and Miriam S. Chaiken (Editors), 2016. *Response to Disasters and Climate Change: Understanding Vulnerability and Fostering Resilience*. Taylor and Francis Group, Florida: 159-172.

Women are critical to aquaculture and small-scale fisheries sectors, despite the lack of recognition and access to resources. In the Philippines, the status of women has improved over the last few decades. However, gender issues during disasters still emerge. In 2009, the Asia-Pacific Economic Cooperation (APEC) published a study that indicated a high level of awareness of the importance of gender integration for disaster risk reduction (DRR) in the Philippines, yet gaps remain during disaster plan implementation. This research builds on that study by assessing gender integration in disaster management in fishing and aquaculture communities since recent DRR legislation (2010) and two major typhoons (2013 and 2014). Results reveal that important steps are being taken to integrate gender at the disaster risk reduction and management (DRRM) programmatic level, yet gaps remain at the community level. Addressing these shortcomings and underlying perceptions of gender in disaster management will foster more resilient fishing and aquaculture communities in the Philippines and nations worldwide.

AQUAFISH RESEARCH REPORT 16-369

WATER QUALITY AND RED BLOOM ALGAE OF FISH PONDS IN THREE DIFFERENT REGIONS OF NEPAL

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Published in:

Our Nature (2016) 14(1): 71-77.

Present study determines the causes and seasonal variation of red bloom in fishponds of Eastern, Western and Central regions of Nepal. Monthly monitoring of water quality and phytoplankton was carried out for one year. Water parameters such as $\text{NH}_3\text{-N}$, total phosphorus, total Kjeldahl nitrogen (TKN), total dissolved solids (TDS) and conductivity were significantly higher ($p < 0.05$) in red bloom fishponds than non-red bloom fishponds. The total density of euglenophytes in red-bloom fishponds was significantly higher ($P < 0.05$) (1970 ± 260 cells L^{-1}) than non-red bloom fishponds (410 ± 30 cells L^{-1}). Euglenophyte density varied seasonally and significantly lower in spring season (1250 ± 220 cells L^{-1}) than autumn (1950 ± 390 cells L^{-1}), winter (2180 ± 370 cells L^{-1}), and summer (2490 ± 480 cells L^{-1}) in red bloom fishponds. High nutrients might favor the growth of euglenophytes (*Euglena sanguinea*) causing red bloom fish ponds of Nepal.

AQUAFISH RESEARCH REPORT 16-A01

INCORPORATION OF SOYBEAN PRODUCTS IN SUMMER FLOUNDER (*PARALICHTHYS DENTATUS*) FEEDS:
EFFECTS ON GROWTH AND SURVIVAL TO BACTERIAL CHALLENGE

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Published in:

Aquaculture (2016) 452: 395-401.

As demand for fish meal as a primary protein source in aquaculture feeds has continued to increase, aquaculturists have sought a replacement with similar nutritional profile and more consistent economic value. Two feeding trials were designed to evaluate the effect of replacing fish meal with soybean meal and soy protein concentrate in summer flounder (*Paralichthys dentatus*) diets on fish growth and survival to challenge with the pathogenic bacterium *Vibrio harveyi*. Fish fed for 12 weeks with a diet in which 60% of the fish meal was replaced with a 1:1 ratio (w/w) of soybean meal and soy protein concentrate (SBM/SPC) increased to a significantly greater mass than fish fed either a fish meal (FM) diet or a 60% replacement diet with soybean meal (SBM; $p < 0.05$). Survival following bacterial challenge was significantly lower in fish fed the FM diet than fish fed the SBM or SBM/ SPC diets ($p < 0.05$). In the second feeding trial, 60% of the fish meal was replaced in six diets by either soybean meal, soy protein concentrate, or varying ratios of the two. The highest body weights at the end of the trial were observed in the fish fed the FM and 60% SPC replacement diets compared to the other groups ($p < 0.05$). Fish fed a 12% SBM/48% SPC replacement diet had the highest survival to bacterial challenge, significantly higher ($p \leq 0.001$) than fish in other groups except the fish fed the 24% SBM/36% SPC diet. Fish fed 40% SBM/20% SPC and 60% SPC showed the lowest survival to bacterial challenge. These results show that: 1) growth of summer flounder fed a diet in which 60% of the fish meal was replaced with soy protein concentrate was similar to the growth seen in fish fed fishmeal diets; 2) addition of increasing amounts of soybean meal in the replacement diet led to a decrease in growth compared to diets with fish meal. However, replacement of 60% of the fish meal with a mix of soybean meal and soy protein concentrate containing 12 or 24% of soybean meal led to increased survival of fish to bacterial challenge. Further identification of the products in soybean meal leading to increased survival of summer flounder could lead to the development of replacement diets for summer flounder that provide increased survival to disease challenge without compromising growth.

AQUAFISH RESEARCH REPORT 16-A02

TECHNICAL-ECONOMIC EFFICIENCIES OF SNAKEHEAD SEED PRODUCTION UNDER IMPACTS OF CLIMATE CHANGE IN THE MEKONG DELTA, VIETNAM

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Published in:

Animal Review (2016) 3(4): 73-82.

This study was carried out from February to December 2014 by interviewing 75 farmers who operate snakehead seed production in An Giang, Dong Thap and Hau Giang provinces, Vietnam. The results showed that the total area for production was $629.01 \pm 756.77 \text{ m}^2$, whereas the volume for nursing was $582.10 \pm 119.81 \text{ m}^3$ for pond system and $1,019.56 \pm 736.66 \text{ m}^3$ for combining pond – hapa system). Each hatchery used 44.26 ± 22.63 pairs of broodstock/breeding cycle and produced whole year. The quantity of seed per cycle of pond system was a half of that figure of other system while seed productivity per m^3 was much lower. Snakehead seed was mainly sold to seed traders in the Delta (82.3%). With average production cost of 47.81 ± 16.23 thousand Vietnam dong (VND)/ m^3 , each farm in pond system could reach the total net profit of 49.83 ± 18.74 thousand VND/ m^3 , equivalent to 328 million VND/year. These corresponding numbers of pond – hapa system were 106.98 ± 86.25 ; 196.12 ± 87.45 thousand VND/ m^3 , equal to 1.75 billion VND/year. Factors of climate change affecting snakehead seed production involved rainfall change, droughts, water and air temperature increase, salinity intrusion which caused diseases easier (36%), affected seed production in general (31%), bad water quality (10%), To reduce the impacts of climate change to production, the farmer in snakehead seed production often changed selling market, suspended production of seeds, used better broodstocks by choosing them more carefully and a number of other measures.

AQUAFISH RESEARCH REPORT 16-A03

THE ROLE OF MOBILE PHONES IN FACILITATING AQUACULTURE DEVELOPMENT IN UGANDA

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Published in:

World Aquaculture (2016) 47(1): 39-46.

Aquaculture productivity in Uganda is less limited by technical or genetic barriers, compared to a lack of implementation of best practices for producing fish in earthen ponds and cages. Most small-scale fish farmers in Africa have limited access to reliable information about improved farming methods. Access to appropriate information, inputs, and technical support are significant determinants of agricultural productivity and business success. With corresponding innovation in existing social and institutional arrangements, mobile phones have potential to increase the income of small-scale fish farmers (Verheye 2000). As mobile phones converge with notebook and tablet devices, opportunities will proliferate. Affordability will remain an issue, but cell phone capability and market penetration will grow. Little is known about the use of mobile phones and the needs and interests of fish farmers in Uganda. [Excerpt is first two paragraphs from publication]

AQUAFISH RESEARCH REPORT 16-A04

ASSESSING THE IMPACTS OF CLIMATE CHANGE ON SNAKEHEAD FISH VALUE CHAINS IN THE LOWER MEKONG BASIN OF CAMBODIA AND VIETNAM

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Published in:

World Aquaculture (2016) 47(4): 53-55.

The productive Mekong fisheries are essential to the food security and nutrition of the 60 million people of the Lower Mekong Basin (LMB). Fish, from capture and culture, are a significant source of income and food security in Cambodia and Vietnam. Annual freshwater fish consumption in Cambodia and Vietnam ranges up to 40 kg/person, among the top three countries in the world. Fish contributes 81 percent of protein intake in Cambodia and 70 percent in Vietnam.

In Cambodia, inland capture fisheries remain of primary importance in the fisheries sector, while aquaculture is more important in Vietnam. Snakehead is a popular and highly valued food fish in both countries, and are consumed in fresh and processed forms in the Lower Mekong Basin (Sinh et al. 2014). There are two species of snakehead of economic importance, the snakehead murrel *Channa striata* and the giant snakehead *Channa micropeltes*.

The combination of high fish biodiversity, high productivity, high exploitation rate, long distance migrations, and fish trade make protecting these fisheries and aquaculture of great importance. However, they are highly vulnerable to climate and non-climate (specifically water development such as hydropower dam development) related drivers of change. These include increased temperatures; changes in rainfall patterns; changes in the hydrological regime (water levels, duration of flooding, timing of flooding); changes in runoff or sediment load/movement; and increased instances of extreme weather events (storms, floods and droughts) (Keskinen et al. 2010, Hoanh et al. 2010, Vastila et al. 2010, Lauri et al. 2012). [Excerpt is first three paragraphs of publication]

AQUAFISH RESEARCH REPORT 16-A05

SEAFOOD AND AQUACULTURE MARKETING HANDBOOK, 2ND EDITION

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Published in:

C.R. Engle, K.K. Quagraine, and M.M. Dey (Editors), 2016. *Seafood and Aquaculture Marketing Handbook*. Wiley-Blackwell, West Sussex: 594.

Aquaculture, the farming of aquatic animals and plants, and other seafood businesses continue to grow rapidly around the world. However, many of these businesses fail due to the lack of sufficient attention to marketing. The Seafood and Aquaculture Marketing Handbook provides the reader with a comprehensive, yet user-friendly presentation of key concepts and tools necessary for aquaculture and seafood businesses to evaluate and adapt to changing market conditions.

Markets for aquaculture and seafood products are diverse, dynamic, and complex. The Seafood and Aquaculture Marketing Handbook presents fundamental principles of marketing, specific discussion of aquaculture and seafood market channels and supply chains from around the world, and builds towards a step-by-step approach to strategic market planning for successful aquaculture and seafood businesses.

This book is an essential reference for all aquaculture and seafood businesses as well as students of aquaculture. The volume contains a series of synopses of specific markets, an extensive annotated bibliography, and webliography for additional sources of information. Written by authors with vast experience in international marketing of aquaculture and seafood products, this volume is a valuable source of guidance for those seeking to identify profitable markets for their aquaculture and seafood products.

AQUAFISH RESEARCH REPORT 16-A06

FISH FILL PONDS, PLATES AND POCKETBOOKS IN NEPAL

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Published in:

Feed the Future Newsletter (2016) November (56).

When it comes to nutritional value, fish are hard to beat. They are rich in high-quality protein and contain assorted vitamins and minerals, such as iodine and selenium, which are important to human health. Fish also happen to be the best source of omega-3 fatty acids, making it a popular food choice around the world; billions of people include fish in their diets.

According to the Food and Agriculture Organization, about half of the fish that's consumed in the world is produced by aquaculture—the farming of aquatic life—making this activity a valuable source of nutrition as well as income.

In Nepal, where 41 percent of children under 5 suffer from stunting, families can increase their consumption of nutrient-rich fish by raising them at home. It can also provide a source of income to women, who often manage their households but lack opportunities to improve their livelihoods.

AQUAFISH RESEARCH REPORT 17-370

CHARACTERIZATION OF THE NUTRITIONAL QUALITY OF AMARANTH LEAF PROTEIN
CONCENTRATES AND SUITABILITY OF FISH MEAL REPLACEMENT IN NILE TILAPIA FEEDS

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Published in:

Aquaculture Reports (2017) 5: 62-69.

A number of leafy vegetables, their protein concentrates and hydrolasates are under evaluation as alternative protein ingredients to fish meal (FM) in aquafeeds. This study evaluated the nutritional characteristics and suitability of replacing FM with the amaranth (*Amaranthus hybridus*) leaf protein concentrates (ALPC) as a protein ingredient in the diet of Nile tilapia (*Oreochromis niloticus*). Experimental diets were formulated, where 100%, 75%, 50%, 40%, 20% and 0% FM protein was substituted by protein from ALPC. The six dietary treatments were tested in triplicate in static flow-through tanks. The substitution effects were compared in terms of fish growth performance, nutrient utilization, whole body composition and apparent nutrient digestibility. After 160 days of feeding, the growth, nutrient utilization and Feed Conversion Ratio (FCR) in fish fed diets containing 100%, 75%, 50%, 40% and 20% FM were better ($P < 0.05$) than those fed diet with 0% FM. The apparent nutrient digestibility was high for protein, lipid and energy and differed significantly among the dietary treatments ($P < 0.05$). Protein digestibility in fish was highest in feed formulated with 100%, 75%, 50% and 40% FM, which were significantly ($P < 0.05$) higher than at 25% and 0% FM. Lipid digestibility was comparable for all the diets except fish fed 0% FM. Digestible carbohydrates and dry matter were similar for all dietary treatments ($P < 0.05$). We demonstrate that it is possible to replace up to 80% of fish meal with ALPC without compromising the performance *O. niloticus*. These results demonstrate that although it is possible to replace large part of fish meal with ALPC, it is not possible to eliminate it in Nile tilapia diet as alternative protein ingredient.

AQUAFISH RESEARCH REPORT 17-371

ASSESSING THE FUNCTIONAL ROLES OF LEPTIN IN ENERGY HOMEOSTASIS AND THE STRESS RESPONSE IN VERTEBRATES

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Published in:

Frontiers in Endocrinology (2017) 8: 63. DOI: doi.org/10.3389/fendo.2017.00063.

Leptin is a pleiotropic hormone that plays a critical role in regulating appetite, energy metabolism, growth, stress, and immune function across vertebrate groups. In mammals, it has been classically described as an adipostat, relaying information regarding energy status to the brain. While retaining poor sequence conservation with mammalian leptins, teleostean leptins elicit a number of similar regulatory properties, although current evidence suggests that it does not function as an adipostat in this group of vertebrates. Teleostean leptin also exhibits functionally divergent properties, however, possibly playing a role in glucoregulation similar to what is observed in lizards. Further, leptin has been recently implicated as a mediator of immune function and the endocrine stress response in teleosts. Here, we provide a review of leptin physiology in vertebrates, with a particular focus on its actions and regulatory properties in the context of stress and the regulation of energy homeostasis.

AQUAFISH RESEARCH REPORT 17-372

ASSESSMENT OF PRICE VOLATILITY IN THE FISHERIES SECTOR IN UGANDA

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Published in:

Journal of Food Distribution Research Society (2017) 48(1): 81-88.

This paper examines price volatility in the African catfish (*Clarias gariepinus*) supply chain in Uganda. The volatility process in the catfish markets was analyzed based on monthly price data from January 2006 to August 2013. A GARCH model is used to estimate the volatility parameters. Empirical results revealed that the value of the first-order autoregressive term and the value of the first-order moving average term were significant for both aquaculture and wild-harvest catfish supply chains. The observed long persistence of volatility in both supply channels suggests a fundamental level of uncertainty and risk in the catfish subsector over the studied period.

AQUAFISH RESEARCH REPORT 17-373

SOCIAL AND ECONOMIC PERFORMANCE OF TILAPIA FARMING IN GHANA

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Published in:

J. Cai, K.K. Quagrainie, and N. Hishamunda (Editors), 1997. *Social and economic performance of tilapia farming in Africa*, FAO Fisheries and Aquaculture Circular No. 1130, Rome, Italy: 49-90.

This report presents an overview of the social and economic performance of tilapia farming in Ghana from a value-chain perspective. The content is based primarily on the synthesis of the relevant literature on fisheries and aquaculture in Ghana, and the information gathered by the authors from interviews and interactions with key leaders of the sector in Ghana from 2009 to 2015. In addition, information is also included from postings on Ghana to the Sustainable Aquaculture Research Networks in sub-Saharan Africa (SARNISSA) listserv, unpublished material from the authors' recently completed and ongoing research involving more than 500 fish farmers, processors and traders, government administrators and field officers, and researchers in Ghana, and the reanalysis of information from a combination of all these sources. The social and economic analysis uses the framework of Trienekens (2011), and draws heavily on almost a dozen recently completed value chain and related studies and reviews of the aquaculture and fisheries sectors of Ghana (Asmah, 2008; Abban et al., 2009; Cobbina, 2010; Ofori et al., 2010; Antwi-Asare and Abbey, 2011; Hamenoo, 2011; Nunoo et al., 2012; Simpson, 2012; Anane-Taabeah, Quagrainie and Amisah, 2015). [Note that this is the first paragraph of the introduction.]

AQUAFISH RESEARCH REPORT 17-374

SOCIAL AND ECONOMIC PERFORMANCE OF TILAPIA FARMING IN KENYA

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Published in:

J. Cai, K.K. Quagrainie and N. Hishamunda (Editors), 2017. *Social and economic performance of tilapia farming in Africa*, FAO Fisheries and Aquaculture Circular No. 1130, Rome, Italy: 91-111.

Aquaculture makes an important contribution to livelihoods, economic development and food security in Africa (Quagrainie, Amisah and Ngugi, 2009). The effective start of aquaculture in most of sub-Saharan Africa was, in the 1950s, under the impetus of the various colonial administrations. The Abuja Declaration on sustainable fisheries and aquaculture called for increased fish production, focusing more on aquaculture promotion and development (Kaliba et al., 2007). It is increasingly recognized that promoting aquaculture as a business could yield adequate and solid benefits from the sector, and thereby leading to its sustainable development.

Similar to many countries in Africa, aquaculture production in Kenya has been low and stagnated over the past decade (Hetch, 2006). The slow progress of aquaculture growth in sub-Saharan Africa has been attributed to institutional, biotechnical and economic factors (Hecht, 2006).

Rural fish farming in Kenya dates back to the 1940s and was popularized in the 1960s by the Kenya Government through the “Eat More Fish Campaign”. The number of small-scale farmers increased and peaked at about 20,000 in 1985, with annual production of slightly over 1,000 tonnes (Aloo and Ngugi, 2005). [Note that this is the first three paragraphs of the introduction.]

AQUAFISH RESEARCH REPORT 17-375

SOCIAL AND ECONOMIC PERFORMANCE OF TILAPIA FARMING IN UGANDA

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Published in:

J. Cai, K.K. Quagrainie, and N. Hishamunda (Editors), 2017. *Social and economic performance of tilapia farming in Africa*, FAO Fisheries and Aquaculture Circular No. 1130, Rome, Italy: 127-144.

Uganda is a landlocked country in Eastern Africa bordering Kenya to the east, the United Republic of Tanzania to the south, Rwanda to the southwest, the Democratic Republic of the Congo to the west and South Sudan to the north. It has a surface area of 241,038 km² with about 18 percent covered by open waters and 3 percent by swamps. This offers enormous potential for aquaculture and fisheries development, as the sector contributed about 12 percent of agricultural GDP and 2.5 percent of GDP and provided a livelihood to 3.5 million people, who make up 4 percent of the population (Mulonde, 2013; MAAIF, 2012). Uganda has five major inland lakes out of about 165 lakes, which, together with the Nile River, are responsible for most of the capture fisheries production. The lakes, namely Lake Victoria, Lake Albert, Lake Kyoga, Lake Edward and Lake George, contribute 80 percent to Uganda's capture fisheries production. Lake Victoria accounts for about 58 percent of the total catch for the important export species, Nile perch and Nile tilapia. Main rivers in Uganda include the Victoria Nile, Albert Nile, Achwa River (called Aswa in South Sudan) and Kazinga Channel (Keizire, 2006). [Note that this is the first paragraph of the introduction.]

AQUAFISH RESEARCH REPORT 17-376

LINKAGES AND TRUST IN THE VALUE CHAIN FOR SMALL-SCALE AQUACULTURE IN ASIA

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Published in:

Journal of the World Aquaculture Society (2017) 48(4): 542-554.

The small-scale aquaculture (SSA) sector is recognized as making an important contribution to food security, poverty alleviation, and socioeconomic development. A value chain analysis can uncover insights into the linkages and trust within a value chain and constraints and challenges that face the sector. This paper examines the linkages and trust between SSA producers and traders in Asia in order to better understand the constraints and opportunities faced by small-scale producers. The perspective revealed by the value chain analysis provides response strategies that can enhance the sustainability and competitiveness of the entire value chain and the actors that comprise it.

AQUAFISH RESEARCH REPORT 17-377

WEANING METHODS USING FORMULATED FEEDS FOR SNAKEHEAD (*CHANNA STRIATA* AND *CHANNA MICROPELTES*) LARVAE

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Published in:

Aquaculture Research (2017) 48(9): 4774-4782.

The culture of snakehead fish (*Channa striata* and *Channa micropeltes*) in Vietnam is limited, and snakehead culture has been banned in Cambodia, because traditional practices include capture of fingerlings from the wild as seed, as well as capture of small-size (also known as trash fish or low-value) fish. As hatchery breeding technology has improved, we investigated the optimal weaning practices for these two species. Both laboratory experiments and farm trials were conducted. For *C. striata*, the optimal weaning procedure is to begin at 17 days after hatch (dah) and wean the fish at 10% replacement of live feed with formulated feed per day. However, for *C. micropeltes*, the optimal procedure is to wait until 40 dah to begin weaning and then to wean the fish with a 10% replacement of live feed with formulated feed every 3 days. These results should enable farmers to domesticate snakehead culture in Vietnam and Cambodia and eliminate reliance on fish captured from the wild as both seed and feed.

AQUAFISH RESEARCH REPORT 17-378

UNDERSTANDING THE ROLE OF FISH FARMER ASSOCIATIONS AS INTERMEDIARIES FOR THE
COMMERCIALIZATION OF AQUACULTURE IN UGANDA

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Published in:

Fisheries and Aquaculture Journal (2017) 8(3): 214. DOI:10.4172/2150-3508.1000214.

Aquaculture development commentary supports the formation of fish farmer associations or producer organizations as avenues for cultivating small- and medium-scale commercial farmers. However, little is known about the types of associations that facilitate commercialization. This research presents four qualitative case studies, based on semistructured interviews, profiling existing associations of commercial fish farmers in Uganda. We conclude that the umbrella organizations under which local fish farmer associations vertically align themselves have important implications for fish farmer production. Aquaculture-specific umbrella organizations contribute to the success of local member association's more than general umbrella organizations do. Successful fish farmer associations accept government assistance only when it directly improves their fish farm operations. Other farmer groups seemed to wait for direct subsidization. Training fish farmers, providing quality information, cost sharing, and advocating for the aquaculture sector, not donor seeking, are the top priorities in productive fish farmer associations.

AQUAFISH RESEARCH REPORT 17-379

SUCCESSFUL BREEDING OF SAHAR *TOR PUTITORA* IN SUB-TROPICAL NEPAL

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Published in:

World Aquaculture (2017) 48(2): 54-58.

Sahar (*Tor putitora*), also known as mahseer, is an important fish species of the torrential waters of the Himalayas. It is a popular, economically important, and high-value indigenous species. Sahar is a game and food fish that is widely distributed in rivers, streams, and lakes (Rai et al. 1997). The price of sahar in the Nepalese market is almost double that of commonly cultivated carps and tilapia. Sahar is captured from lakes and rivers but commercial cultivation has yet to begin in Nepal. This species is declining in its natural habitat mainly because of urbanization, poaching, overfishing, and ecological alterations of physical, chemical, and biological conditions in the natural environment (Bista et al. 2007). Hence, there is a need for conservation of this species. In recent years, successful artificial breeding at some research stations has led to additional enthusiasm towards developing sahar for commercial cultivation, as well as rehabilitation in natural waters (Rai et al. 2006).

Attempts to culture and conserve sahar were initiated in Nepal, with major efforts to develop culture technology and propagate the species (Gurung et al. 2002, Joshi et al. 2002). This has led to better knowledge of spawning biology, ecology, behavior, and preliminary growth performance in captive conditions. Enhanced growth in tropical and subtropical ponds and recent breeding success in hatcheries has raised new hope for the prospects of sahar aquaculture in Nepal (Shrestha et al. 2005, Bista et al. 2001, 2007, Rai 2008). In addition to the culture of fish to adult size for consumption, these new developments can contribute to rearing individuals that can be stocked into natural waters to replenish populations there. Its omnivorous and predatory feeding habits make sahar a good candidate to co-culture with mixed-sex tilapia to control tilapia recruits and provide better size at harvest and yield of tilapia (Shrestha et al. 2011). Inclusion of sahar in polyculture of mixed-sex tilapia with carps has enhanced overall fish production in these ponds.

Sahar is an intermittent spawner. It can spawn year-round in Nepal, except during January, under culture conditions. In natural waters, sahar typically migrate a long distance from large rivers to streams for spawning during the monsoon season when rivers and streams are at peak flows. The Fisheries Research Center (FRC) in Pokhara is the key center that produces sahar fry in limited quantity. Demand for sahar fry has increased for restocking rivers and lakes and for aquaculture production. Lack of fry availability is a major bottleneck for commercial production and

conservation. The objectives of the study described in this article were to test sahar breeding in the warmer climate of Chitwan, develop protocols for sahar reproduction and mass-scale seed production there, establish nursing and rearing management practices for sahar fry, and make sahar fry available for culture and restocking.

AQUAFISH RESEARCH REPORT 17-380

EVALUATION OF BLENDED VIRGIN COCONUT OIL AND FISH OIL ON GROWTH PERFORMANCE AND RESISTANCE TO *STREPTOCOCCUS INIAE* CHALLENGE OF NILE TILAPIA (*OREOCHROMIS NILOTICUS*)

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Egyptian Journal of Basic and Applied Sciences (2017) 4(3): 175-184.

Five isolipidic experimental diets (32% crude protein) were formulated to contain 3% fish oil (FO) and virgin coconut oil (3VCO) as sole lipids or blends of FO + VCO in ratios of 75:25% (0.75VCO), 50:50% (1.5VCO) and 25:75% (2.25VCO). Triplicate groups of *O. niloticus* were fed one of five diets to apparent satiation, twice daily for 8 weeks. It was observed that fish fed diet 3VCO exhibited the best performance with respect to feed intake (492.1 g), final weight (214.60 g) and weight gain (154.90 g). Significant effects of dietary fatty acid profile were reflected in fish fed the diets in whole body, muscle and liver C12:0 and C14:0. However, eicosapentaenoic (EPA, 20:5n-3) and docosahexaenoic (DHA, 22:6n-3) were significantly different (P 0.05) compared to their respective diets while liver n-3: n-6 ratio significantly increased and recorded low levels in whole body and muscle. Statistically, least values of mortality were recorded as VCO levels were elevated when fish were subjected to *Streptococcus iniae* infection while plasma metabolite indicators among treatments were not altered. The inclusion of VCO at 3% in the diet gave excellent performance, indicating that it could wholly replace FO and as such represents a better alternative lipid source for feeding *O. niloticus*.

AQUAFISH RESEARCH REPORT 17-381

ALTERNATIVE ARTIFICIAL INCUBATION SYSTEM FOR INTENSIVE FRY PRODUCTION OF NILE TILAPIA
(*OREOCHROMIS NILOTICUS*)

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Published in:

International Journal of Fisheries and Aquatic Studies (2017) 5(4): 425-429.

Jar incubation system is a well-established artificial incubation system for intensive fry production of Nile tilapia. However, this system needs special hatchery structure and huge amount of water for circulation of eggs. The present study aimed to explore a simple, economic and water efficient alternative incubation system appropriate for small-scale hatchery operators. Two incubation systems, i.e. atkin incubation system and aquarium incubation system were compared with jar incubation systems in terms of water use, hatching rate and subsequent survival of larvae. Results showed that the amount of water used was significantly higher in atkin ($127.0 \pm 3.1 \text{ m}^3$) and jar ($36.8 \pm 4.9 \text{ m}^3$) incubation systems compared to aquarium ($0.05 \pm 0.0 \text{ m}^3$) incubation system. The hatching percentage was significantly higher in jar incubation system ($95.5 \pm 0.6\%$) compared to aquarium ($65.2 \pm 7.7\%$) and atkin ($57.8 \pm 2.2\%$) incubation systems. Hatching tended to occur slightly earlier in the jar incubator than other systems. After 7 days of rearing, the mean larval survival rate was highest in jar incubation ($96.9 \pm 0.5\%$), intermediate in aquarium incubation ($90.9 \pm 3.4\%$) and lowest in atkin incubation (81.0 ± 3.1) system ($P < 0.05$). The dissolved oxygen was significantly higher in aquarium ($6.1 \pm 0.0 \text{ mg/L}$) than jar ($3.0 \pm 0.0 \text{ mg/L}$) and atkin ($3.0 \pm 0.1 \text{ mg/L}$) incubation systems. Further experiments indicated that about 5000 eggs can be successfully hatched with a hatching rate of 95% and reared to swim-up fry in in 50 L size glass aquarium with water exchange twice daily. This system is best suited for incubation of late stage eggs and rearing of newly hatched larvae up to free swimming stage. The results indicate that aquarium incubation can be used as an alternative of jar incubation system for Nile tilapia eggs, especially in water scarce areas.

AQUAFISH RESEARCH REPORT 17-382

MUD CRAB AQUACULTURE AND FISHERIES IN COASTAL BANGLADESH

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Published in:

World Aquaculture Magazine (2017) 48(2): 47-52

Coastal Bangladesh has the most commercially important species of mud crabs *Scylla* spp., from the family *Portunidae* (Macintosh *et al.* 2002). They dig and inhabit burrows in mangrove swamps and shallow, soft-bottom intertidal waterbodies (Quinitio *et al.* 2008). Mud crabs spend most of their life in estuaries and coastal environments that have mud or detritus, debris of leaves, branches, roots and enough shelter materials or places to hide to avoid cannibalism or to molt. Mud crabs are also known commonly as green crabs or mangrove crabs (Sha and Quddus 1982). Mud crabs are omnivorous or scavengers, feeding on dead animal and plant matter. The 734-km long coastline of Bangladesh, with the world's largest mangrove forest, is a hotspot for diverse aquatic organisms, including mud crabs, providing suitable breeding, feeding and nursery grounds.

AQUAFISH RESEARCH REPORT 17-383

TOWARDS ASSESSING GENDER AUTHORSHIP IN AQUACULTURE PUBLICATIONS

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Published in:

Gender in Aquaculture and Fisheries: Engendering Security in Fisheries and Aquaculture, Asian Fisheries Science Special Issue (2017) 30S: 129-141.

While gender disparities are decreasing in some areas of academia, studies have shown that gender inequities in scholarly literature still persist. A review of more than eight million papers across disciplines found that men predominate in the first and last author positions and women are underrepresented in single-authored papers.

The present study applies the vetted methodology of assigning authorship gender in peer reviewed literature, according to the U.S. Social Security Database of names, to the broad discipline of aquaculture in peer-reviewed journals in the complete JSTOR database archive, and compares these results to authorship by gender in the International Aquaculture Curated Database (IACD). The International Aquaculture Curated Database (IACD) is a compilation of over 500 peer-reviewed publications supported by four international aquaculture programs developed by Oregon State University researchers. Preliminary findings reveal that the percentage of women authors was similar to that for the JSTOR aquaculture journals subsample (13.8 %) and the journals in the IACD (15.7 %). Women, therefore, are not well represented in either database. The next steps for this work include comparing and contrasting the proportion of women authors in aquaculture journals to women working in the aquaculture discipline and to women graduates in the discipline. Learning how gender authorship has changed in the aquaculture discipline is a critical component for promoting gender equity in the academic discipline and broader field of aquaculture.

AQUAFISH RESEARCH REPORT 17-384

MICROSATELLITE MARKERS REVEAL GENETIC DIFFERENTIATION OF CHINESE DOJO LOACH
MISGURNUS ANGUILLICAUDATUS IN THE YANGTZE RIVER BASIN

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Published in:

Turkish Journal of Fisheries and Sciences (2017) 17(6): 1167-1177.

The fish fauna in the Yangtze-based riparian ecosystem has been imperiled largely due to genetic degradation of populations. Regular genetic monitoring of the fish populations is required for an effective management and conservation. The genetic structure of Dojo loach, *Misgurnus anguillicaudatus* was investigated in twelve populations originating from the Yangtze River basin by using thirteen microsatellite loci. The number of alleles per locus varied between 2 and 8 with an average of 4.6 alleles per locus. Overall, low-to-moderate level of genetic diversity was observed in the loach populations. Significant deviations from Hardy-Wienberg equilibrium were observed in about 50% of the total locus-population combination tests. The AMOVA indicated that most of the variance existed among the individuals (90.50%) rather than among populations within groups (9.03%). Significant differentiation was found among the samples from scattered habitats with different connections to the Yangtze River ($P < 0.05$). The clustering of sample populations in UPGMA dendrogram followed their geographic distribution except for Zigui and Xiaogan which clustered against their geographical origin. The factors involved in genetic differentiation and shaping the existing patterns of population structure of the loach were discussed so as to provide guidelines for conservation strategies and management programs.

AQUAFISH RESEARCH REPORT 17-A01

FORECASTING FARM-GATE CATFISH PRICES IN UGANDA USING SARIMA MODEL

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Published in:

Finance and Market (2017) 2(2): 1-12.

Stabilization of prices of essential agricultural commodities continues to remain an area of major concern for policy makers; given that price instability affects both producers and consumers, and has macroeconomic implications. This paper examines farm-gate price behavior in the African catfish markets in Uganda, and develops a forecasting model that adjusts for the seasonal fluctuations in the price series. The analysis utilizes monthly catfish real price series for the period January 2006 to December 2013. The model provides good in-sample and out-of-sample forecasts for the eight-year time period. The out-sample predictions based on SARIMA (1, 1, 1) (0, 1, 1)₁₂ model suggest that the stochastic seasonal fluctuations depicted in the price series are successfully modeled, and that catfish real prices follow an upward trend. The findings can assist policy makers and major stakeholders to gain insight into more appropriate economic and sectorial policies that can lead to the development of reliable market information systems and up-to-date data on catfish supply, demand and stocks.

AQUAFISH RESEARCH REPORT 17-A02

TOXIC EFFECTS OF AGRO-PESTICIDE CYPERMETHRIN ON HISTOLOGICAL CHANGES OF KIDNEY IN TENGRA, *MYSTUS TENGARA*

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Published in:

Asian Journal of Medical and Biological Research (2017) 3(4): 494-498.

Cypermethrin, the synthetic pyrethroid commonly used as a pesticide, contaminates the aquatic ecosystem as a toxic pollutant from agricultural and domestic washouts. An experiment was conducted to carry out an empirical study to investigate the sub-lethal effects of LC₅₀ value of a pyrethroid pesticide, cypermethrin 10EC on histological changes of kidney in Tengra, *Mystus tengara* at wet laboratory of the Faculty of Fisheries, Bangladesh Agricultural University (BAU), Mymensingh. The LC₅₀ value of cypermethrin 10EC was calculated by probit analysis and LC₅₀ value for 96 hours was found 0.133 ppm. The experiment was conducted with four treatments, each with three replications. Treatment one (T1) was used as control (0 ppm) and three concentrations, such as 0.026 ppm (20% of 96 h LC₅₀), 0.052 ppm (40% of 96 h LC₅₀) and 0.104 ppm (80% of 96 h LC₅₀) were used as Treatment two (T2), Treatment three (T3) and Treatment four (T4), respectively. For histological study kidney of studied fish were collected from control and experimental group at 7, 14 and 28 days interval up to the end of experiment of 28 days. The physical reactions observed in the treated fish were erratic swimming, discolorations of the skin, loss of reflex, hyperactivities, motionless state and these effects increased with increasing concentration of the toxicants and duration of exposure. The changes observed in the kidney tissues were vacuolation, necrosis, ruptured kidney tubules, Cellular degeneration and karyolysis were recorded. Cypermethrin 10 EC has adverse effects on the organs of fish, so it should not be used indiscriminately in agriculture and aquaculture.

AQUAFISH RESEARCH REPORT 17-A03

DIGESTIVE ENZYME ACTIVITIES OF SNAKEHEAD (*CHANNA STRIATA*) LARVAE FROM EARLY HATCHING TO 35 DAYS WITH DIFFERENT DIETS.

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Published in:

Can Tho University Journal of Science (2017) 49: 84-90.

The aim of this study is to describe activities of some digestive enzymes of snakehead larvae from day 1 to day 35 after hatching, feeding with two different diets. In the first treatment, larvae were fed with live feed including *Moina* sp. and marine trash fish; in the second treatment, larvae were still fed with live feed, but live feed was gradually replacement by formulated diet from day 17 onwards. Larvae were sampled at 1; 3; 5; 7; 9; 12; 15; 18; 21; 25; 30 and 35 days after hatching (DAH), before feeding in the morning. The result showed that, amylase enzymes activity fluctuated during the research period and reached 3.68 ± 0.17 mU/mg protein in live feed treatment and 5.77 ± 0.14 mU/mg protein in formulated diet treatment at 35 DAH. Proteolytic enzymes were detected at low level as early as hatching and remained constant until 12 DAH. Trypsin activity increased significantly at 21 DAH. The highest pepsin activity was 1.44 ± 0.26 mU/mg protein, recorded at 25 DAH, and the highest trypsin and chymotrypsin activities were 333 ± 19.9 mU/mg protein and $1,773 \pm 62.3$ mU/mg protein respectively, at 35 DAH. Pepsin and trypsin activities of larvae feeding with live feed were significantly higher than those fed formulated diet. However, the higher α -amylase activity was found in larvae fed formulated diet treatment.

AQUAFISH RESEARCH REPORT 18-386

IMPACT OF AQUACULTURE FEED TECHNOLOGY ON FISH INCOME AND POVERTY IN KENYA

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Published in:

Aquaculture Economics & Management (2018): 1-21.

The impacts of improved agricultural technologies on smallholder households in Africa are well documented in the literature. However, the literature on the welfare impacts of aquaculture technologies, especially in the context of smallholder households, is very scanty. This paper applies the propensity score matching technique to household survey data to examine the impact of improved feed technology on fish income and poverty in Kenya. After controlling for observable household characteristics, the results indicate that improved feed technology increases aquaculture income and reduces poverty among fish farming households. Specifically, the income effect of the technology is 23–37%, with resultant poverty reduction effect of 19–23% points. Evidence from the study indicates that the likelihood of adopting improved feed in Kenya will surge with improved extension service delivery, access to government subsidized feed, and easy market access for purchasing improved feed and sale of mature fish.

AQUAFISH RESEARCH REPORT 18-390

EFFECT OF IRON AMINO ACID CHELATE SUPPLEMENTED FISH FEEDS ON NUTRIENTS COMPOSITION OF SPINACH (*SPINACIA OLERACEA*) IN AN AQUAPONIC SYSTEM IN KENYA

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Published in:

International Journal of Sciences: Basic and Applied Research (2018) 37(2): 162-172.

Aquaponics is an environmentally friendly production system involving reuse of waste and nutrients in production of fish and vegetables. Currently aquaponic system is the only solution for fish and plants production but one unique challenge is the maintaining of micro and macro-nutrient and the pH balance in the system. The study was conducted at the University of Eldoret for 119 days. A complete randomized design was used. The supplementation rates in fish diets constituted 30g, 20g, 10g and 0g Fe kg⁻¹ respectively. Nile tilapia fry with a mean weight of 0.475 ± 0.025 g and nine spinach (height 3 ± 0.131 cm, 2 leaves) were stocked in 12 aquaria in an aquaponic system. 30g Fe kg⁻¹ treatment exhibited higher minerals content than other treatments with Phosphorus 67.51 ± 2.42 mgL⁻¹, Zinc 9.068 ± 0.45 mgL⁻¹, Iron 5.2 ± 0.218 mgL⁻¹, Manganese 7.655 ± 0.344 mgL⁻¹, Total Nitrogen 11.248 ± 0.141 mgL⁻¹ and Sodium 7.218 ± 0.028 mgL⁻¹. There was improved water quality at 30g Fe kg⁻¹ compared to other treatments. These results revealed that 30g Fe kg⁻¹ iron amino acid chelate supplementation had better nutritional attributes as feedstuff for spinach growth than the three other dietary treatments. The study recommends the incorporation of 30g Fe kg⁻¹ iron amino acid chelate in on-farm formulated diets for aquaponic system where complete diets are not easily accessible for small scale farmers.

AQUAFISH RESEARCH REPORT 18-391

EFFECTS OF LYSINE AND METHIONINE SUPPLEMENTATION AND COST EFFECTIVENESS IN PRODUCTION OF NILE TILAPIA DIETS (*OREOCHROMIS NILOTICUS*) IN WESTERN KENYA

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Published in:

International Journal of Research Science & Management (2018) 5(3): 12-23.

The proximate composition of local feed ingredient is limited by unbalanced dietary amino acid contents, thereby increasing de-amination and ammonia levels in water. This study formulated experimental diets and balanced the Essential Amino Acids (EAA) to enhance the feed nutritive value for culture of *Oreochromis niloticus*. Four diets comprising methionine+lysine and lysine supplemented at 5.1 g kg⁻¹, 2.7 g kg⁻¹ to non-EEAs supplemented and commercial diets at the University of Eldoret Fish Farm were tested. Growth performance was conducted in hapas suspended in earthen pond 150 m² in a randomized design for 105 days. There were significant variations in temperature (24 to 26° C), Dissolved oxygen (4.8 to 6.2 mg L⁻¹) and pH (7.2-7.6) but within optimal range for tilapia. The diets provided about 17.17 MJ kg⁻¹ with 22.9% digestible Crude Protein and 8.03% ash content. Lysine supplemented Diet 2 induced highest mean final weight of 156.05±1.74 g, 2.4 Specific Growth Rate, 1.42 Feed Conversion Ratio and 2.68 Protein Efficiency Ratio. A high profit index (2.286±0.07) at low incidence cost (0.437±0.05) was observed in Diet 2. The study reports reduced production cost by supplementing plant proteins with limiting amino acids hence increasing nutritive value of aquafeeds.

AQUAFISH RESEARCH REPORT 18-392

SURVEY OF FISH CONSUMPTION BY WOMEN AND CHILDREN IN AN GIANG PROVINCE

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Published in:

Journal of Vietnam Agricultural Science and Technology (2018) 86(1): 106-112.

The aim of this study is to assess amount of food and energy provided within 24 hours for women and children and to analyze the role of food fish for daily consumption. The study was conducted from January to November 2017 in An Giang province by interviewing 300 women and 300 children in the dry and wet seasons. The study found that women's daily dietary intake in dry and wet seasons was 750.3 g/day (1,411.8 kcal) and 780.6 g/day (1,403.5 kcal), respectively. For children, daily food intake in dry and wet seasons was 683.1 g/day (764.7 kcal) and 616.5 g/day (983.7 kcal), respectively. Food fish consumption by women accounted for 18.1-18.8% in quantity (10.9 - 12.8% in energy). For children, food fish products constituted 9.5 - 9.8% in quantity (6.8 - 9.3% in energy).

AQUAFISH RESEARCH REPORT 18-393

AQUACULTURE DEVELOPMENT AND UGANDA'S AGRICULTURAL EXTENSION SYSTEM: THE CASE OF FISH FARMERS IN CENTRAL AND NORTHERN REGIONS

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Published in:

Journal of Fisheries and Aquaculture Development (2018) 1.

Agricultural extension services are critical to the development of crops, livestock and fish farming in order to bring about social change. Fish farming, though introduced over 50 years ago through research and extension, remains at a slow pace of growth. There is a consensus in academic and policy literature about the potential benefits of fish farming, particularly nutrition and income generation. So why has extension not been more successful in improving the status of fish farming? Most explanations focus on supply side issues highlighting lack of inputs, particularly fingerlings and feeds with little consideration given to how the extension services themselves are organized in view of fish farming under general agriculture. Equally absent in the discourse are the perspectives on the motivations and experiences of individual fish farmers. Drawing from the Actor Oriented Perspective, this paper examines the organization and current status of extension service provision in aquaculture based on perspectives of policy makers, extension workers and fish farmers. Interviews were conducted with 246 fish farmers, eight extension workers and 11 key informants from government institutions. Secondary sources of information included various government documents on agriculture. Results revealed slow growth of aquaculture due to institutional and social factors regarding alignment of extension service provision to the needs of fish farmers. Reforms instituted over the past decades in search of better ways to avail farmers with improved farming knowledge have had minimal success. Less than 50% of fish farmers received extension visits from district extension staff with moderate difference ($p < 0.05$) between frequency of extension visits in central and northern regions. Bias of extension service provision towards production related technical and information aspects above building and strengthening social capital of fish farmers was noted. Extension interventions should be socially negotiated and adapted in view of aspirations and limitations of fish farmers.

AQUAFISH RESEARCH REPORT 18-394

LARVAL DEVELOPMENT OF THE MEXICAN SNOOK, *CENTROPOMUS POEYI* (TELEOSTEI: CENTROPOMIDAE)

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Published in:

Neotropical Ichthyology (2018) 16 (1).

We document for the first time the early ontogeny of *Centropomus poeyi* based on captive raised material representing 0-19 days posthatch (dph). The achievement of early developmental landmarks (i.e., yolk-sac depletion, flexion, development of fins) and changes in pigmentation are described (1.4 mm NL-10.6 mm SL; 0-19 dph) and documented for a subset of individuals using high quality photographs. The ontogeny of the viscerocranium is also described (2.4 mm NL-10.6 mm SL; 6-19 dph). Development in *C. poeyi* occurs over a short period with attainment of the juvenile stage (i.e., full complement of fin rays present in each fin) occurring by 6.9 mm SL. The ontogeny of external pigmentation in *C. poeyi* is marked by two trends throughout growth: (1) a decrease in pigmentation dorsally; and (2) an increase in pigmentation ventrally along the midline. Development of the viscerocranium begins with the appearance of the maxilla and dentary in individuals of 2.4 mm NL, coinciding with the depletion of the yolk-sac. By 10.6 mm SL all bones of the viscerocranium are present and teeth are present on all teeth-bearing bones of the adult. Aspects of early development in *C. poeyi* are compared with the congeners *C. undecimalis* and *C. parallelus*.

AQUAFISH RESEARCH REPORT 18-395

ANALYSIS OF EFFICIENCY OF SNAKEHEAD (*CHANNA STRIATA*) MODEL CULTURING IN EARTHEN POND IN THE MEKONG DELTA

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Published in:

Journal of Vietnam Agricultural Science and Technology (2018) 88(3): 107-112.

A survey of 131 households culturing snakehead with three scales production as following: 30 households with small scale (SS) 300 - 700 m²; 70 households with medium scale (MS) 700 - 1,500 m² and 31 households with large scale (LS) > 1,500 - 8,000 m² was carried out in the main snakehead culture areas in three provinces of An Giang, Dong Thap and Tra Vinh from January to December 2017. The study aimed to analyze production efficiency of snakehead culture to find out the optimal scale for recommend of sustainable culturing scale in the Mekong Delta. The technical analysis showed that the stocking density of small scale (SS) (55.1 ind/m²) was higher than that of medium scale (MS) (51.3 ind/m²) and large scale (LS) (51.9 ind/m²); survival rate of SS (63.1%) was lower than MS (64.5%) and higher than LS (57.5%); yield of SS (15.6 kg/m²) was lower than MS (16.2 kg/m²) and LS (16.9 kg/m²). In terms of economic efficiency: Direct cost of SS (485.2 thousand VND/m²) was lower than that of MS (502.5 thousand VND/ m²) and LS (525.6 thousand VND/m²); the production cost of SS (30.9 thousand VND/kg) was lower than that of MS (31 thousand VND/kg) and LS (31.2 thousand VND/kg); profit ratio of SS (4,3%) was higher that that of MS (1,4%) and lower than that of LS (5,8%). Feed cost accounts for the largest proportion (78.4-81.8%) of total cost at all farming scales. In summary, based on technical and economic aspects and actual conditions of production scale, SS is suitable for the sustainable development of snakehead fish in household culture in the Mekong Delta.

AQUAFISH RESEARCH REPORT 18-396

IMPACT OF AQUACULTURE FEED TECHNOLOGY ON FISH INCOME AND POVERTY IN KENYA

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¹ Department of Agricultural Economics, Purdue University, West Lafayette, Indiana, USA

Published in:

Aquaculture Economics & Management (2018): 1-21.

The impacts of improved agricultural technologies on smallholder households in Africa are well documented in the literature. However, the literature on the welfare impacts of aquaculture technologies, especially in the context of smallholder households, is very scant. This paper applies the propensity score matching technique to household survey data to examine the impact of improved feed technology on fish income and poverty in Kenya. After controlling for observable household characteristics, the results indicate that improved feed technology increases aquaculture income and reduces poverty among fish farming households. Specifically, the income effect of the technology is 23–37%, with resultant poverty reduction effect of 19–23% points. Evidence from the study indicates that the likelihood of adopting improved feed in Kenya will surge with improved extension service delivery, access to government subsidized feed, and easy market access for purchasing improved feed and sale of mature fish.

AQUAFISH RESEARCH REPORT 18-397

ALTERNATIVE FEEDING STRATEGIES AND FEED INGREDIENTS FOR SNAKEHEAD FARMING IN CAMBODIA AND VIETNAM

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Published in:

World Aquaculture. (2018) 49(2): 49-53.

Prior to 2006, the predominant method for culturing snakehead in Vietnam and Cambodia was to collect wild juveniles from natural sources like the Mekong River and Tonle Sap. Particularly in Cambodia, aquaculture farmers, who were also fishermen, would collect their own fingerling snakehead. They would then also collect “small fish” (also known as low-value fish or trash fish) from natural sources, chop them up and feed them to the snakehead in culture. A conflict existed between users of these fish: the aquaculture/fishing people and the remainder of the Cambodian population who rely on small fish (Fig. 1) for a variety of products, including fish sauce and prahok, that provide protein to the Cambodian people throughout the year. As a result, and to protect the nutrition of the Cambodian people, aquaculture of snakehead was banned in the country in 2004.

AQUAFISH RESEARCH REPORT 18-398

EFFECTS OF VITAMIN C ON GROWTH AND IMMUNE PARAMETERS OF SNAKEHEAD CULTURE IN HAPA

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Published in:

Journal of Vietnam Agricultural Science and Technology (2018) 89(4): 109-114.

The experiment was carried out to evaluate the appropriate supplementation method and dose of vitamin C supplemented in feed in order to stimulate on growth and healthy parameters of snakehead (*Channa striata*). The study was conducted in 5 months, including 2 experiments. The first experiment consisted of 4 treatments of feed A supplemented with different vitamin C of 0, 500, 750 and 1000 mg/kg of feed during processing. The second experiment also included 4 treatments of feed B mixed with the same level of vitamin C as with feed A by traditional method. The results showed that the -inclusion of vitamin C in pellet feed before extrusion was recorded better growth performance, survival rate and fish health compared to addition of vitamin C by traditional method in daily. Addition of vitamin C in diet for snakehead in commercial pellet feed at a level of 500 mg/kg of feed enhanced fish growth performance, survival rate, fish health and increasing profit.

AQUAFISH RESEARCH REPORT 18-399

GROWTH PERFORMANCE OF SPINACH (*SPINACIA OLERACEA*) ON DIETS SUPPLEMENTED WITH IRON-AMINO ACID COMPLEX IN AN AQUAPONIC SYSTEM IN KENYA

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Published in:

International Journal of Research Science and Management (2018) 5(7): 117-127.

Aquaponic is an environmental-friendly production system involving reuse of waste and nutrients in production of fish and vegetables. Currently the system experiences unbalance in pH and nutrients deficiency in plants. This study investigated the effect of iron amino acid chelate supplement in fish feeds on growth performance of spinach (*Spinacia oleracea*) in aquaponic system. The experimental research was conducted at the University of Eldoret from August-December 2016. A complete randomized design was used in triplicate treatments. The supplementation quantity in fish diets constituted 30 Fe kg⁻¹, 20 Fe kg⁻¹ 10 Fe kg⁻¹ and 0 Fe kg⁻¹ of iron amino acid chelate respectively. At 30 Fe kg⁻¹ treatments spinach indicated a significant growth at ($p < 0.05$) than other treatments with final mean height ($52.44 \pm 0.798\text{cm}$) and 19.33 leaves. The least growth of spinach was at 0 Fe kg⁻¹ treatments with final mean ($25.36 \pm 0.72\text{ cm}$, 9.704) height and leaves respectively. 30 Fe kg⁻¹ exhibited highest nutrients and improved water quality as compared to other treatments. The results revealed that 30 Fe kg⁻¹ iron amino acid chelate supplementation had significant nutritional attributes as feedstuff in aquaponic system for spinach growth than other dietary treatment tested.

AQUAFISH RESEARCH REPORT 18-400

PRICE SEASONALITY IN THE CATFISH VALUE CHAIN IN UGANDA

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Published in:

Professional Agricultural Workers Journal (2018) 6(1): 13-25.

Seasonal patterns in production and demand are common in many agricultural markets. Charting these patterns provides information that complements fundamental and technical analyses. It is in this spirit that this paper seeks to examine price seasonality in the catfish value chain in Uganda. The analysis draws on monthly prices taken from secondary source recorded data and uses moving average index to chart price patterns. The results reveal distinct seasonal patterns in the farm-gate, ex-vessel, retail, and wholesale market channels. Across market channels, the results for farm-gate versus ex-vessel prices reveal that farmgate prices are more affected by seasonal effects compared to ex-vessel prices. On the contrary, both price series in the retail versus wholesale market channels show a declining trend, with the wholesale price series showing stronger variability compared to the retail price series.

AQUAFISH RESEARCH REPORT 18-401

DIETARY METHIONINE AND LYSINE REQUIREMENT OF SNAKEHEAD (*CHANNA STRIATA*) FINGERLINGS

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Published in:

International Journal of Scientific and Research Publications (2018) 8(8): 795-805.

This study was aimed determine the dietary methionine (Met) and lysine (Lys) requirement for snakehead fingerlings (2-4 g fish⁻¹). Basal diets in two experiments contained approximately isonitrogenous 42% and isoenergetic 20.3 KJ g⁻¹. In the first experiment on Met requirement, L-Met was added to the basal diets including six treatments containing from 7.3 to 14.8 g Met kg⁻¹ diet (17.5 to 35.3 g Met kg⁻¹ protein) interval increasing of 1.5 g kg⁻¹ diet. In the second experiment determining Lys requirement, L-Lys HCL was added to basal diets including seven treatments containing from 12.6 to 36.6 g Lys kg⁻¹ diet (30.1 to 87.2 g Lys kg⁻¹ protein), interval increasing of about 4 g kg⁻¹ diet. The experiments were randomly designed with four replications for each treatment. The first experiment indicated that optimal weight gain, special growth rate, protein efficiency ratio was found in the diet containing 28.2 g Met kg⁻¹ protein and there were significant differences in those parameters between diet treatment containing 24.8 g Met kg⁻¹ protein and other diets containing lower Met levels. The hepatosomatic index and protein content in whole-body fish were significantly affected by dietary Met levels. Feed conversion ratio (FCR) was significantly improved with the increase of dietary Met level in diet to 28.2 g kg⁻¹ protein (P<0.05). Results of the second experiment showed that optimal growth rate and protein efficiency ratios were found in diet containing 73.1 g Lys kg⁻¹ protein and there were significant differences in those parameters between diet treatment containing 73.1 g Lys kg⁻¹ protein and other diets containing lower Lys levels. The hepatosomatic index, protein and fat content in whole-body fish were significantly affected by dietary Lys levels. The FCR was significantly improved by increasing dietary Lys concentration to approximately 77.9 g Lys kg⁻¹ protein. Fish survival rate were not significant differences among treatments in both experiments. Broken-line analysis on the basis of optimal growth rate showed that the dietary Met requirement was 11.9 g Met kg⁻¹ diet (28.4 g kg⁻¹ protein) and the dietary Lys requirement of snakehead was 30.7 g Lys kg⁻¹ diet (73.1 g kg⁻¹ protein).