ECONOMIC BENEFITS OF INTERGRATED RICE-FISH FARMING IN BANGLADESH

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By

MD MASUM BILLAH

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfillment of the Requirements for the Degree of Doctor of Philosophy

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DEDICATION

To my respected grand father late. AmbiaKhotib, my parents, Mrs. Jharna Mondal and late. Abdul Hai Khotib and my wife, Mrs. Naznin Islam Lubna, my daughter Mysha Zahan, my mother in law Mrs. Nurzahan Parvin, father in law Md. Nurul Islam and all of my brothers, sisters, friends & family members, for their endless love, support, care and encouragement

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December 2019

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Faculty: **Agriculture**

The integration of quality rice (*Oryza sativa* L), a globally important staple food crop with fish Nile tilapia (*Oreochromis niloticus)* and common carp (*Cyprinus carpio*) is deemed more profitable than a mono-crop culture of the rice. Thus, this study was undertaken to determine the best stocking density, fertilization application, feeding schedule, feeding rate, feed premix and their effects on nutrients uptake, weeds control as well as fish and rice production in rice-fish integrated farming system. A series of experiments were conducted at the Agronomy Field Laboratory, Bangladesh Agricultural University (BAU) in Mymensingh, Bangladesh from December 2017 to December 2018. In randomized complete block design (RCBD) with three replicates. Each plot was 15 m^2 and surrounded by elevated dikes of about 0.5 m height. Rice (BR dhan29) seedlings were transplanted from the nursery to the plots at alternative row spacing of 15 and 35 cm and a spacing of 20 cm within the rows. Common carp and Nile tilapia were released 20 days after transplanting (DAT) at an average weight of 25.32±0.81 g and 12.52±0.48g and 1:1 mixing ratio with stocking density of 6 fishes/m^2. The study determined a stocking density of 6/m^2 in 1:1 of carp and tilapia was the best stocking density. In experiment (II), each treatment of fish species cultured with different doses of fertilizer as follows (T0) control: without any fertilization; (T1) with 100% recommended fertilizer (RF); (T2) with 75% recommended fertilizer (RF); (T3) with 10t $h^{-1}$of compost fertilizer; (T4) with 5t $h^{-1}$of compost fertilizer + 75% RF, and (T5) rice culture with 5 t $h^{-1}$of compost fertilizer + 50% RF. The outcome shows that T4 9.72±5.35provided the maximum yield, followed by T5 9.72±5.35,T3 9.63±6.66, T2 9.45±6.32, T1 8.08±3.86 and T0 4.00±4.56 kg/m^2. However, in experiment (III) it was found that feed application for five days a week in morning and evening (0900-1800) has the best rice yield11.96 t h^{-1} and straw yield 6.63 t h^{-1}. Nevertheless, in experiment (IV) it was observed that feeding rate with 8% of body weight showed the highest production of rice and straw 5.35t h^{-1} and 6.59 t h^{-1}. While in experiment (V) the addition of 10g feed premix in the feed improved the productivity of the carp 225.75g, tilapia 375.24g at 75 days after transplanting. A stocking density of 6 fishes/m^2 at the ratio of 1:1 tilapia and carp; feeding five days morning (0900) and evening (1800) a week at 8% of body weight with 10g premix is recommended for carp and tilapia in the rice-fish farming system for better productivity and yield of rice.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Doktor Falsafah

MANFAAT EKONOMI LADANG PADI-IKAN BERSEPADU DI BANGLADESH

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Integrasi variety padi berkualiti (*Oryza sativa* L), yang merupakan makanan ruji dunia dengan tilapia Nil (*Oreochromis niloticus*) dan kap biasa (*Cyprinus carpio*) didapati lebih menguntung berbanding pertanian mono-tanaman padi. Oleh itu, kajian ini dijalankan untuk menentukan kepadatan, aplikasi pembajaan, jadual pemberian makanan, kada rpemakanan, dan pra-campuran yang terbaik dan kesannya ke atas pengambilan nutrien, kawalan rumpai dan pengeluan ikan dan padi di dalam system Pertanian integrase Padi ikan. Satu siri eksperimen telah dijalankan di Makmal Lapangan Agronomi, Bangladesh Agricultural University (BAU) di Mymensingh, Bangladesh dari Disember 2017 sehingga Disember 2018. Rekabentuk blok lengkap rawak (*randomized complete block design*) dengan tiga replikasi. Setiap plot adalah 15m^2 yang dikelilingi oleh batas dengan ketinggian 0.5m. Benih beras (*Oryza sativa* L., cv. BR dhan29) telah dipindahkan dari nursery ke plot dengan baris berselang di antara 15 dan 35cm, dagan jarak di antara baris adalah 20cm. Kap biasa dan tilapia Nil telah dilepaskan 20 hari selepas pemindahan benih beras (DAT) pada purata berat 25.32±0.81g dan 12.52±0.48g dan 1:1 nisbah di antara sepsis ikan tersebut deyan berkepadatan 6 ikan/m^2. Kajian ini mendapati kepadatan 6 ikan/m^2 dengan nisbah 1:1 kap dan tilapia adalah kadar penstokan yang terbaik. Dalam eksperimen kedua, rawatan dos baja adalah seperti berikut: (T0) kawalan: tanpa pembajaan; (T1) dengan 100% baja yang disyorkan (RF); (T2) dengan 75% baja yang disyorkan (RF); (T3) dengan 10 t h^{-1} baja kompos; (T4) dengan lima th^{-1} baja kompos + 75% RF, dan (T5) kultur beras dengan 5 th^{-1}baja kompos + 50% RF. Hasil eskperimen menunjukkan T4 memberikan hasil yang paling tinggi, diikuti dengan T5, T3, T2, T1 dan T0. Bagaimanapun, dalam eksperimen ketiga, kajian ini mendapati bahawa pemberian makanan selama lima hari seminggu pada pagi dan petang memberikan hasil yang ikan terbaik. Pada eksperimen keempat, kajian ini mendapati bahawa kadar pemberia nmakanan sebanyak 8% daripada berat badan menunjukkan produksi ikan yang paling tinggi. Pada eksperimen kelima, campuran 10g pra-campuran dalam makanan telah meningkatkan prestasi keseluruhan sistem. Kadar penstokan sebanyak enam ekor ikan per m^2 pada nisbah 1:1 kap dan tilapia, pemberian makanan pagi dan petang sebanyak lima hari seminggu pada kadar makanan 8% daripada berat badan ikan dengan 10g pracampuran adalah disyorkan untuk system Pertanian integrasi kap dan tilapia untuk kadar produktiviti dan hasil tuaian padi yang lebih baik.

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This thesis was submitted to the Senate of Universiti Putra Malaysia has been accepted as fulfillment of the requirements for the degree of Doctor of Philosophy. The members of Supervisory Committee are as follows:

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LIST OF ABBREVIATIONS

ANOVA	Analysis of variance
Cu	Cuprum
cm	Centimeter
CRD	Completely randomize design
DO	Dissolved oxygen
DHA	Docosahexaenoic acid
FCR	Food conversion ratio
g	Gram
h	Hour
ha^{-1}	Hectare
H_2SO_4	Sulfuric acid
IUCN	International Union for Conservation of Nature
ind	Individual
kg	Kilogram
L	Liter
Min	Minute
Mg/L	Milligram per liter
ml	Milliliter
MTL	Mean total length
NaOH	Sodium hydroxide
pcs	Pieces
PER	Protein efficiency ratio
ppm	Part per million
PVC	Polyvinyl chloride
RAS	Recirculating Aquaculture System
SE	Standard error
SGR	Specific growth rate
Sp.	Species
T	Treatment
TL	Total length
TW	Total weight
UPM	Universiti Putra Malaysia
USA	United States of America
^0C	Degree Celsius
%	Percentage
<	Less than
>	More than

CHAPTER 1

INTRODUCTION

1.1 Background of the Study

Rice-fish farming is quickly achieving appreciation worldwide as a promising way to offer better food and to confirm sustainable environment (Hazra *et al*., 2016). The blow exterior contribution methodology, risk lessening approaches, and recently recognized production practices can help to harvest additional reasonable diet for an improved number of population while lessening environmental influences (Rahman *et al*., 2017b; Dey *et al*., 2018). The perception of fish farming in rice field is not actual new it has been promoted and accepted by several countries, particularly in Southeast Asia (Chouichom and Yamao, 2010). Fish farming with rice is the foremost source of income in numerous portions of this world. Nearly irrigated rice cultivable land and 11 million hectares of flood-prone land under rice cultivation worldwide cover 81 million hectares.

Rice-fish farming currently being practiced in large scale covering millions of hectares of land in Asian countries such as Bangladesh, China, Malaysia, Egypt, Cambodia, Indonesia, Republic of Korea, Vietnam, Madagascar, Thailand and some West African countries (Saikia and Das, 2009a; Halwart, 1998; Heckman, 1979). Favorable agricultural climatic condition of Bangladesh as well as numerous and potential resources are appropriate for aquaculture in rice field farming (Ahmed *et al*., 2007).

Aquaculture production through the utilization of nature resources by utilizing rice fields is an important upgrade to Bangladesh rice farmers (Islam *et al*., 2015; Belton *et al*., 2011). The availability of water not fully utilized for the reason there is need to exploit these important resources by incorporated aquaculture to the present rice farming system (Ahmed and Garnett, 2011; DoF, 2017). A report from Asian Development Bank (ADB) in 2004 showed that, around 281,000.00 hectares of irrigated field of rice are available for this farming scheme. The potentiality of rice fields has the numerous opportunities for integrated rice-fish farming in Bangladesh, which is viable for income generations, and food security in the region. That study was also determined that the integrated rice-fish farming system increases productivity of the ecosystem, profitability, diversification, cropping intensity as well as sustainability of the land resources utilization (Ahmed *et al*., 2007; Jahan *et al*., 2010).

Likewise, Ahmed and Garnett (2011) evaluated fish culture in rice fields are inexpensive option to rice production in Mymensingh district in Bangladesh. Same study provided confirmation that, integrated rice-fish agriculture can perform a significant impact on food security as the integrated agriculture scheme is more productive and profitable than rice monoculture in terms of resource variety, efficiency of land and water utilization (Pimentel *et al*., 1997). Similarly, some of the study also suggested that, additional research on integrated rice–fish agriculture not only needed to have a clear picture of the influence of this system on the environment, socioeconomic and livelihood of the farmers but also the rural people of Bangladesh (Belton *et al.* 2011).

However, from some findings in Bangladesh net profit from rice-fish agriculture is over 50% better compare to rice monoculture because of higher net revenue and the lower cost of rice cultivation as well as higher harvested rice.

The fish and rice integrated farm which started and made good revenue of some non-governmental organization (NGOs) like CARE by supporting to the rice-fish farmers (Halwart and Gupta, 2004). As the main food of the agriculture, rice grown around 29 million tons whereas fish is produced around 2.70 million tons per year with a population of 16.4 core (Ahmed *et al*., 2011).

1.2 Statement of the Problem

Bangladesh is a country of agriculture which is situated in the south-east Asia and one of the most populated and least developed country with an area of 1,44,000.00 square kilometers in the world (Ahmed *et al*., 2011). The demand of both key agricultural foods such as rice and fish are increasing continuously in the country every year (Ahmed and Garnett, 2011). On the other hand, the average size of cultivable land is reducing due to high pressure from increasing population and forcing the farmers to bear high risk and cost to maximize crop production within a shortest possible time (Roy *et al*., 2013).

In this backdrop conditions, the practice of integrated rice-fish farming can be the only way to tackle the growing demand for food and minimizing the cost of production and meet the demand of carbohydrate and animal protein (Mamun *et al*., 2012; Roy *et al*., 2013). Therefore, producing of rice-fish concurrently in the same field meets the way for optimum resource utilization for maximum food production in terms of cost and benefit. It also supports to reducing production cost, where snails, insects, pest and other harmful flies caught and eaten by the fish. Though, there is some limitations to implement of this integrated farming system in Bangladesh like lack of technical knowledge on plot design, fertilizers or pesticides uses, preparation of the watering systems, fish fingerlings and feeding management (Dey *et al*., 2005a; Nabi, 2008).

Moreover, additional research on the strategy and implementation of appropriate guidelines, investments and better investigation are required to assess the effects of fish stocking density, proper doses of fertilization, fish feeding schedule, feeding rate and the modification of fish feed through the addition of essential vitamin premix to enhance the production and profit.

Thus, there is inadequate number of literatures that has covered those topics into household income and food safety influence of combined rice–fish agriculture schemes in Bangladesh. Correspondingly, little of these investigations in Bangladesh uses combined rice-fish farming methodology to regulate for self-selection that usually ascends when technology implementation is not indiscriminately allocated. Thus, this study was endeavored to fill up these gaps.

1.3 Specific Objectives

The specific objectives in this study were as follows:

1. To assess the effect of stocking density, mixture ratio of fish on weed control and the productivity of integrated rice-fish farming system.
2. To determine the fertilization effect on the growth performances of fish and rice yield of integrated rice-fish farming system.
3. To evaluate the impact of feeding schedule on the growth performances of fish and rice yield in combined rice-fish farming system.

4. To determine the impact of feeding rate on the growth performances of fish and rice yield in polyculture rice-fish farming system.
5. To evaluate the impact of feed premix on the growth performances of fish and rice yield in integrated rice-fish farming system.

REFERENCES

Adhikary, R.K., Kar, S., Faruk, A., Hossain, A., Bhuiyan, M.N.M., & Asif, A.A. (2018). Contribution of aquaculture on livelihood development of fish farmer at Noakhali, Bangladesh. *Asian-Australasian Journal of Bioscience and Biotechnology* 3, 106-121.

Ahmed, I. & Khan, M.A. (2006). Dietary branched-chain amino acid valine, isoleucine and leucine requirements of fingerling Indian major carp, *Cirrhinus mrigala* (Hamilton). *British Journal of Nutrition*, 96(3), 450–460.

Ahmed, N. & Garnett, S.T. (2011). Integrated rice-fish farming in Bangladesh: meeting the challenges of food security. *Food Security*, 3(1), 81–92.

Ahmed, N., Zander, K. K., & Garnett, S. T. (2011). Socioeconomic aspects of rice-fish farming in Bangladesh: opportunities, challenges and production efficiency. *Australian Journal of Agricultural and Resource Economics*, 55(2), 199-219

Ahmed, N., Wahab, M.A., & Thilsted, S.H. (2007). Integrated aquaculture-agriculture systems in Bangladesh: potential for sustainable livelihoods and nutritional security of the rural poor. *Aquaculture Asia*, 12(1), 14–22.

Anderson, J.S. & Sunderland, R. (2002). Effect of extruder temperature and dryer processing temperature on vitamin C and E and astaxanthin stability. *Aquaculture*, 207, 137–149.

Andrews, J.W. & Page, J.W. (1975). The effects of frequency of feeding on culture of catfish. *Transactions of the American Fisheries Society*, 104, 317–321.

APHA, AWWA. & WPCF. (1985). Standard Methods for the Examination of Water and Waste water, 16th edn. American Public Health Association, American Water Works Association, Water Pollution Control Federation, Washington, DC, USA, 1268pp.

Athar, N., Hardacre, A., Taylor, G., Clark, S., Harding, R., & McLaughlin, J. (2006). Vitamin retention in extruded food products. *Journal of Food Composition and Analysis*, 19, 379-383.

Aride P.H.R., Roubach R. & Val A. L., (2004). Water pH in central Amazon and its importance for tambaqui (*Colossoma macropomum*) culture. *Journal of World Aquaculture.*

Balzer, T., Balzer, P. & Pon, S. (2002). Traditional use and availability of aquatic biodiversity in rice-based ecosystems – I. Kampong Thom Province, Kingdom of Cambodia. In M. Halwart and D. Bartley (eds.) FAO Inland Water Resources and Aquaculture Service. FAO, Rome.

Bardi Jr., R.W., Chapman, F.A. & Barrows, F.T. (1998). Feeding trials with hatchery produced Gulf of Mexico sturgeon larvae. *Progressive Fish Culture*, 60, 25-31.

Barrows, F.T., Gaylord, T.G., Sealey, W.M., Porter, L. & Smith, C.E. (2008). The effect of vitamin premix in extruded plant-based and fish meal based diets on growth efficiency and health of rainbow trout, *Oncorhynchus mykiss*. *Aquaculture*, 283(1-4), 148-155.

Behera, U.K., Panigrahi, P. & Sarangi, A. (2012). Multiple water use protocols in integrated farming system for enhancing productivity. *Water Resources Management*, 26, 2605–2623.

Belton, B., Karim, M., Thilsted, S., Jahan, K.M., Collis, W. & Phillips, M. (2011). Review of aquaculture and fish consumption in Bangladesh. Studies and reviews 2011-53 (p. 76). Penang: The WorldFish Center.

Berg, H. (2001). Pesticide use in rice and rice-fish farms in the Mekong Delta. *Vietnam Crop Protection*, 20:897–905.

Berg, H. (2002). Rice monoculture and integrated rice-fish farming in the Mekong Delta, Vietnam economic and ecological considerations. *Ecological Economics*, 41, 95–107.

Billah, M.M., Uddin, M.K., Samad, M.Y.A., Hassan, M.Z.B., Anwar, M.P., Abu Hena, M.K., Shahjahan, M. & Asif, A.A. (2019). Fertilization effects on the growth of common carp (*Cyprinus carpio*) and Nile tilapia (*Oreochromis niloticus*) and rice yield in an integrated rice-fish farming system. *AACL Bioflux*, 12(1), 121-132.

Bisht, D. (2011). Integrated fish farming for food, nutritional security and economic efficiency in mid hills of Indian Central Himalaya. Research Journal of *Fisheries and Hydrobiology*, 6, 1-6.

Biswas, G., Jena, J.K., Singh, S.K., Patmajhi, P. & Muduli, H.K. (2006). Effect of feeding frequency on growth, survival and feed utilization in mrigal, *Cirrhinus mrigala*, and rohu, *Labeo rohita*, during nursery rearing. *Aquaculture*, 254, 211–218.

Bjoernsson, B. (1994). Effect of stocking density on growth rate of halibut (*Hippoglossus hippoglossus* L.) reared in large circular tanks for three years. *Aquaculture*, 123(3-4), 259–271.

Boland, M.J., Rae, A.N., Vereijken, J.M., Meuwissen, M.P., Fischer, A.R., van Boekel, M.A., Rutherfurd, S.M., Gruppen, H., Moughectaren, P.J. & Hendriks, W.H. (2013). The future supply of animal-derived protein for human consumption. *Trends in Food Science and Technology*, 29, 62–73.

Bray, F. (1986). The Rice Economics. Technology and Development in Asian Societies. Blackwell, Oxford, 250 pp.

Brett, J.R. (1979). Environmental factors and growth. In: Hoar, W.S., Randall, D.J., Brett, J.R. (Eds.), Fish Physiology. Bioenergetics and Growth, vol. VIII. *Academic Press*, New York, pp. 599–675.

Cai, R., Ni, D. & Wang, J. (1995). Rice-fish culture in China: the pest, present, and future. In: MacKay KT (ed) Rice-fish culture in China. International Development Research Centre (IDRC), Ottawa, pp 3–14.

Cai, X. & Rosegrant, M.W. (2003). World water productivity: Current status and future options. In: Kijne, J.W., Berker, R., Molden, D. (Eds.), Water Productivity in Agriculture: Limits and Opportunities for Improvement. CABI Publishing, Wallingford and Cambridge.

Cassidy, E.S., West, P.C., Gerber, J.S. & Foley, J.A. (2013). Redefining agricultural yield: from tonnes to people nourished per hectare. *Environment Research Letters*, 8: 034015.

Chapman, G. & Fernando, C.H. (1994). The diets and related aspects of feeding of Nile tilapia (*Oreochromis niloticus*) and common carp (*Cyprinus carpio*) in lowland rice fields in northeast Thailand. *Aquaculture* 123, 281–307.

Chen, D., Ying, H. & Shui, M. (1995). Rice-azolla-fish in rice fields, p. 169-176. In K.T. MacKay (ed.) Rice-fish culture in China. International Development Research Centre (IDRC) Ottawa, Canada, 276 p.

Cho, S.H, Lim, Y.S., Lee, J.H. & Park, S. (2003). Effect of feeding rate and feeding frequency on survival, growth, and body composition of ayu post-larvae *Plecoglossus altivelis*. *Journal of the World Aquaculture Society* 34, 85–91.

Choudhury, A.T.M.A. & Kennedy, I.R. (2005). Nitrogen fertilizer losses from rice soils and control of environmental pollution problems. *Communications in Soil Science and Plant Analysis*, 36(11-12), 1625–1639.

Chouichom, S. & Yamao, M. (2010). Comparing opinions and attitudes of organic and non-organic farmers towards organic rice farming system in north-eastern Thailand. *Journal of Organic Systems*, 5(1): 25-35.

Coche, A.G. (1967). Fish culture in rice fields. A worldwide synthesis. *Hydrobiology*, 30, 11-44.

Costa-Bomfim, C.N., Pessoa, W.V.N., Oliveira, R.L.M., Farias, J.L., Domingues, E.C., Hamilton, S. & Cavalli, R.O. (2014). The effect of feeding frequency on growth performance of juvenile cobia, (Linnaeus, 1766). *Journal of Applied Ichthyology*, 30, 135-139.

Costa-Pierce, B.A. (1992). Rice-fish systems as intensive nurseries. In: Rice-Fish Research and Development in Asia (ed. by C.R. de la Cruz, C. Lightfoot, B.A. Costa-Pierce, V.R. Carangall and M.P. Bimbao), World Fish Center-ICLARM, Manila, Philippines pp 117–130.

Darias, M.J., Lan Chow Wing, O., Mazurais, D., Cahu, C. & Zambonino-Infante, J.L. (2010). Alcian Blue–Alizarin red double staining technique for developing sea bass (*Dicentra chuslabrax*) larvae. *Journal of Applied Ichthyology*, 26, 280–285.

Das, D. R., Haque, M. R., Choudury, B. B. P., Haque, M. A. & Alam, M. N. (2011). Study on monthly variations of plankton in relation to the physico-chemical condition of rice-fish fields in boro season. *International Journal of Sustainable Crop Production*, 6(1), 43-49.

Daudpota, A.M., Abbas, G., Kalhoro, I.B., Shah, S.S.A., Kalhoro, H., Hafeez-ur- Rehman, H. & Ghaffar, A. (2016). Effect of feeding frequency on growth performance, feed utilization and body composition of juvenile Nile tilapia, *Oreochromis niloticus* (L.) reared in low salinity water. *Pakistan Journal of Zoology*, 48, 171-177.

De la Bretonne, L.W.J. & Romaire, R.P. (1990). Crawfish culture: selection, pond construction and water quality. SRAC Publication No. 240, January. Southern Regional Aquaculture Center, Stoneville, MS, USA.

De Silva, S.S. & Anderson, T.A. (1995). In: Fish Nutrition in Aquaculture. Chapman & Hall, New York, NY, pp.32–40.

Deng, D.F., Koshio, S., Yokoyama, S., Bai, S.C., Shao, Q., Cui, Y.B. & Hung, S.S.O. (2003). Effects of feeding rate on growth performance of white sturgeon (*Acipenser transmontanus*) larvae. *Aquaculture*, 217, 589–598.

Deng, X. (2000). Artificial Reproduction and Early Life Stages of the Green Sturgeon (*Acipenser medirostris*). MS Thesis, University of California, Davis. 63 pp.

Deomampo, N.R. (1998). Farming systems, marketing and trade for sustainable aquaculture, p. 201-217. Annex IV-5 of ADB/NACA, Aquaculture sustainability and the environment. Report on a regional study and workshop on aquaculture sustainability and the environment. Bangkok, Thailand. Asian Development Bank and Network of Aquaculture Center in Asia- Pacific, 492 p.

Dey, M.M., Spielman, D. J., Haque, A. M., Rahman, M.S. & Valmonte-Santos, R. (2013). Change and diversity in smallholder rice–fish systems: Recent evidence and policy lessons from Bangladesh. *Food Policy*, 43, 108-117.

Dey, M.M., Paraguas, F.J., Kambewa, P. & Pemsl, D.E. (2010). The impact of integrated aquaculture agriculture on small-scale farms in Southern Malawi. *Agricultural Economics*, 41, 67–79.

Dey, A., Sarma, K., Kumar, U., Mohanty, S., Kumar, T. & Bhatt, B. P. (2018). Prospects of rice-fish farming system for low-lying areas in Bihar, India. *Organic Agriculture*, 9(1), 99-106.

Dey, M.M., Prein, M., Haque, A.B.M.M., Sultana, P., Dan, N.C. & Hao. N.V. (2005). Economic feasibility of community-based fish culture in seasonally flooded rice fields in Bangladesh and Vietnam. *Aquaculture Economics and Management* 9(1-2): 65–88

Dey, M.M., Bose, M.L. & Alam, M.F. (2008). Recommendation Domains for Pond Aquaculture. Country Case Study: Development and Status of Freshwater Aquaculture in Bangladesh. WorldFish Center Studies and Reviews No. 1872. The WorldFish Center, Penang, Malaysia. 73 p.

Dey, M.M., Rab, M.A., Paraguas, J.P., Piumsombun, S., Bhatta, R., Alam, M.F. & Ahmed, M. (2005). Fish consumption and food security: a disaggregated analysis by types of fish and classes of consumers in selected Asia countries. *Aquaculture Economics and Management*, 9, 89–111.

Dey, M.M., Spielman, D.J., Haque, A.B.M.M., Rahman, M.S. & Valmonte-Santos, R. (2013). Change and diversity in smallholder rice–fish systems: Recent evidence and policy lessons from Bangladesh. *Food Policy*, 43, 108-117.

Diallo, A. (1998). Integrated farming: a new approach in Basse Casamanche, Senegal, p. 257-264. In J. A. Mathias, A.T. Charles and B. T. Hu (eds). Integrated Fish Farming. Proc. Workshop on Integrated Fish Farming, 11-15 Oct. 1994, Wuxi, Jiangsu Prov., P.R. China. CRC Press, 420 p.

DoF, (2010) Fisheries statistical yearbook of Bangladesh. Department of Fisheries, Ministry of Fisheries and Livestock, Dhaka

DoF, (2017). Yearbook of Fisheries Statistics of Bangladesh 2016-17. Fisheries Resources Survey System (FRSS), Department of Fisheries. Bangladesh. pp. 129.

Dugan, P., Dey, M.M. & Sugunan, V.V. (2006). Fisheries and water productivity in tropical river basins: Enhancing food security and livelihoods by managing water for fish. *Agricultural Water Management*. 80: 262-275.

Edwards, P. (2015). Aquaculture environment interactions: pest, present and likely future trends. *Aquaculture*, 447, 2–14.

FAO, (2006). Food and Agriculture Organization of the united nations, Rome.

Eroldogan, O.T., Kumlu,M. & Aktas, M. (2004). Optimum feeding rates for European sea bass *Dicentrarchus labrax* L. reared in seawater and freshwater. *Aquaculture*, 231, 501–515.

Fernández, I., Hontoria, F., Ortiz-Delgado, J.B., Kotzamanis, Y., Estévez, A., Zambonino- Infante, J.L. & Gisbert, E. (2008). Larval performance and skeletal deformities in farmed gilthead sea bream (*Sparusaurata*) fed with graded levels of vitamin A enriched rotifers (Brachionusplicatilis). *Aquaculture*, 283, 102–115.

Fernando, C.H. & Halwart, M. (2000). Possibilities for the integration of fish farming into irrigation systems. *Fisheries Management and Ecology*, 7, 45–54.

Fernando, C.H. (1993). Rice field ecology and fish culture- an overview. *Hydrobiologia*, 259, 91–113.

Folkvord, A. & Ottera, H. (1993). Effects of initial size distribution, day length, and feeding frequency on growth, survival and cannibalism in juvenile Atlantic cod (*Gadusmorhua* L.). *Aquaculture*, 114, 243–260.

Fontaine P., Gardeur J.N., Kestemont P. & Georges A. (1997). Influence of feeding level on growth, intraspecific weight variability and sexual growth dimorphism of Eurasian *perch Perca fluviatilis* L. reared in a recirculation system. *Aquaculture*, 157: 1–9.

Frei, M. & Becker, K. (2005a). A greenhouse experiment on growth and yield effects in integrated rice-fish culture. *Aquaculture*, 244, 119–128.

Frei, M. & Becker, K. (2005b). Integrated rice-fish culture: coupled production saves resources. *Natural Resources Forum*, 29, 135-143.

Frei, M. & Becker, K. (2005c). Integrated rice–fish production and methane emission under greenhouse conditions. *Agriculture Ecosystem and Environment*, 107, 51–56.

Frei, M., Khan, M.A.M., Razzak, M.A., Hossain, M.M., Dewan, S. & Becker, K. (2007a). Effects of a mixed culture of common carp, *Cyprinus carpio* L., and Nile Tilapia, *Oreochromis niloticus* (L.), on terrestrial Arthropod population, benthic fauna, and weed biomass in rice fields in Bangladesh. *Biological Control*, 41, 207–213.

Frei, M., Razzak, M.A., Hossain, M.M., Oehme, M., Dewan, S. & Becker, K. (2007b). Performance of common carp, *Cyprinus carpio* L. and Nile tilapia, *Oreochromis niloticus* (L.) in integrated rice-fish culture in Bangladesh. *Aquaculture*, 262, 250–259.

Gabaudan, J. & Hardy, R.W. (2000). Vitamin requirements. In: Stickney, R.R. (Ed.), Encyclopedia of Aquaculture. John Wiley & Sons, Inc., New York, NY., pp. 957–961.

Gawlicka, A., Gagnon, D., Dubeau, K., de la Nou¨e, J., Hung, S.S.O. & Barrows, R. (1997). Development and evaluation of water-stable microdiets for white sturgeon larvae. *Bulletin of Aquaculture Association of Canada*, 97, 26–32.

Gaylord, G. (1998). Re-evaluation of vitamin E supplementation of practical diets for channel catfish, *Ictalurus punctatus*, production. *Aquatic Nutrition*, 4 (2), 109–114.

Ghosh, A. (1992). Rice- fish farming development in India: pest, present and future. In: Rice-fish research and development in Asia. (eds. C. R. dela Cruz, C. Lightfoot, B.A., Costa-pierce, V.R. Carangal and M.P. Bimbao). *ICLARM Conference Proceeding*, 24, 27-41.

Giap, D.H., Yi, Y. & Lin, C.K. (2005). Effects of different fertilization and feeding regimes on the production of integrated farming of rice and prawn *Macrobrachium rosenbergii* (De Man). *Aquaculture Research*. 36: 292-299.

Gisbert, E. & Williot, P. (1997). Larval behavior and effect of the timing of initial feeding on growth and survival of Siberian Sturgeon (*Acipenser baerii*) Larvae under small scale hatchery production. *Aquaculture* 156(1-2):63-76

Gisbert, E., Williot, P. & Castello Orvay, F. (2000). Influence of egg size on growth and survival of early stages of Siberian sturgeon (*A. baeri*) larvae under small scale hatchery conditions. *Aquaculture*, 183, 83–94.

Gleick, P.H. (2003). Global freshwater resources: Soft path solutions for the 21st century. *Science*, 302, 1524–1527.

Goddard, S. (1996). Feed management in Intensive Aquaculture. Chapman and Hall, New York.

Gomez, K.A. (1972). Techniques for Field Experiments with Rice. International Rice Research Institute, Los Banos, Philippines, 49pp.

Gomez, K.A. & Gomez, A. (1984). Statistical Procedure for Agricultural Research—Hand Book. John Wiley & Sons, New York.

Graber, A. & Junge, R. (2009). Aquaponic systems: Nutrient recycling from fish wastewater by vegetable production. *Desalination*, 246: 147–156.

Grag, S.K. & Bhatnagar, A. (2000). Effect of fertilization frequency on pond productivity and fish biomass in still water ponds stocked with *Cirrhinus mrigala* (Ham.). *Aquaculture Research*, 31(5), 409-414.

Guerrero, L.A., Circa, A.V. & Guerrero, R.D. (1982). A preliminary study on the culture of *Macrobrachium lanchesteri* (de Man) in paddy fields with and without rice. In: Giant Prawn Farming (ed. by M.B. New), *Elsevier*, Amsterdam, the Netherlands, pp. 203–206.

Gupta, M.V. & Rab, M.A. (1994). Adoption and economics of silver barb (*Puntius gonionotus*) culture in seasonal waters in Bangladesh. *ICLARM Technical Report*, 41, 39-45.

Gupta, M.V., Rahman, M.A., Mazid, M.A. & Sollows, J.D. (1996). Integrated agriculture-aquaculture: a way for food security for small fanners and better resource management and environment. In: An International Symposium on Food Security and Innovations: Successes and Lessons Learned, 11-13 March 1996. University of Hohenheim. Stuttgart, Baden Wurttemberg, Germany. Working Group 1. pp. 165-176.

Gupta, M.V., Sollows, J.D., Abdul Mazid, M., Rahman, A., Hussain, M.G. & Dey, M.M. (1998a). Integrating aquaculture with rice farming in Bangladesh: Feasibility and economic viability, its adoption and impact (Report No. 55). *ICLARM Technical Report*, 90 pp.

Gupta, M.V., Sollows, J.D., Mazid, M.A., Rahman, A., Hussain, M.G. & Dey, M.M. (2002). Economics and adoption patterns of integrated rice-fish farming in Bangladesh. In: Rural Aquaculture (eds. P. Edwards, D.C. Little and H. Demaine), *CABI Publishing*, Oxford, UK, pp. 41-53.

Gupta, M.V., Sollows, J.D., Mazid, M.A., Rahman, M.A., Hussain, M.G. & Dey, M.M. (1998b). Integrating aquaculture with rice farming in Bangladesh: Feasibility and economic viability, its adoption and impact. ICLARM Technical Report, 55. The International Center for Living Aquatic Resources Management (ICLARM), Makati City, Metro Manila, Philippines.

Gupta, M.V. & Halwart, M. (2004). Culture of Fish in Rice Fields. Food and Agriculture Organization and the World Fish Centre, Rome.

Guttman, H. (1999). Rice field fisheries – a resource for Cambodia. NAGA, the *ICLRAM Q*, 22, 11-15.

Halwart, M. (1994). The golden apple snail *Pomacea canaliculata* in Asian rice farming systems: Present impact and future threat. *International Journal of Pest Management*, 40, 199-206.
Halwart, M. (1998). Trends in rice-fish farming. *FAO Aquaculture Newsletter*, 18, 3-11.
Halwart, M. (2003). Rice field fisheries and rice-based aquaculture underestimated and undervalued resources, p. 36-47. In FAO Inland Water Resources and Aquaculture Service. Review of the State of World Fishery Resources: Inland Fisheries. FAO Fisheries Circular No. 942, Rev. 1. Rome, 60 p.
Halwart, M. & Gupta, M.V. (2004). Culture of Fish in Rice Fields. Food and Agriculture Organization of the United Nations and World Fish Center, Penang, Malaysia.
Hamre, K. (2011). Metabolism, interactions, requirements and functions of vitamin E in fish. *Aquaculture Nutrition*, 17 (1), 98–115.
Hamre, K. & Lie, Ø. (1995). Minimum requirement of vitamin E for Atlantic salmon, *Salmo salar* L., at first feeding. *Aquaculture Research*, 26(3), 175–184.
Hancz, C. (1982). Preliminary investigations on the feeding frequency and growth of juvenile carp in aquaria. *Aquaculture Hungarica*, 3, 33–35.
Haroon, A.K.Y. & Pittman, K.A. (1997). Rice-fish culture: feeding, growth and yield of two size classes of *Puntius gonionotus* Bleeker and *Oreochromis* spp. in Bangladesh. *Aquaculture*, 154, 261–281.
Hayward, R.S., Noltie, D.B. & Wang, N. (1997). Use of compensatory growth to double hybrid sunfish growth rates. *Transactions of the American Fisheries Society*, 126 (2), 316–322.
Hazra, K.K., Swain, D.K., Bohra, A., Singh, S.S., Kumar, N. & Nath, C.P. (2016). Organic rice: potential production strategies, challenges and prospects. *Organic Agriculture*, 8(1), 39–56.
Heckman, C.W. (1979). Rice field ecology in north eastern Thailand: the effect of wet and dry seasons on a cultivated aquatic ecosystem. *Monographiae Biologicae*, Junk Publishers, The Hague, 34, 228.
Henken, A.M., Kleingeld, D.W. & Tijssen, P.A.T. (1985). The effect of feeding level on apparent digestibility of dietary dry matter, crude protein and gross energy in the African catfish *Clarias gariepinus* (Burchell, 1822). *Aquaculture*, 51, 1–11.
Herold, M.A. (1996). Lipid Nutrition in White Sturgeon (*Acipenser transmontanus*) Larvae During Ontogeny. PhD Thesis, University of California, Davis. pp. 204.
Hilton, J.W., Hodson, P.V. & Slinger, S.J. (1980). The requirement and toxicity of selenium in rainbow trout (*Salmo gairdneri*). *Journal Nutrition*, 110, 2527–2535. Indonesia, p.13.
Hibrands, A. & Yzerman, C. (2004). Agrodok 21: On-Farm Fish Culture 2nd Edn, Agromisa Foundation, Wageningen, The Netherlands, p.67.
Horstkotte-Wesseler, G. (1999). Socio-economics of rice aquaculture and IPM in the Philippines. ICLARM Technical Report, 57. The International Centre for Living Aquatic Resources Management (ICLARM), Makati City, Metro Manila, Philippines.
Hossain, M.A. & Joadder, M.A.R. (2011). Optimization of stocking density of Tilapia (*Oriochromis niloticus*) in rice-fish system of Northern Bangladesh. *Bangladesh Journal of Progressive Science and Technology* 9(2): 201–204.
Hung, S.S.O., Cho, C.Y. & Slinger, S.J. (1981). Effect of oxidized fish oil, DL-α-tocopherol acetate and ethoxyquin supplementation on the vitamin E nutrition of rainbow trout (*Salmo gairdneri*) fed practical diets. *Journal Nutrition*, 111, 648–657.
Hung, S.S.O., Conte, F.S. & Lutes, P.B. (1995). Optimum feeding rate of white sturgeon (*Acipenser transmontanus*) yearlings under commercial production conditions. *Journal of Applied Aquaculture*, 5, 45– 51.
Hung, S.S.O. & Lutes, P.B. (1987). Optimum feeding rate of juvenile white sturgeon (*Acipenser transmontanus*): *Aquaculture*, 65, 307– 317.
Hung, S.S.O., Lutes, P.B., Conte, F.S. & Storebakken, T. (1989). Growth and feed efficiency of white sturgeon (*Acipenser transmontanus*) subyearlings at different feeding rates. *Aquaculture*, 80, 147– 153.
Hung, S.S.O., Lutes, P.B., Shqueir, A.A. & Conte, F.S. (1993). Effect of feeding rate and water temperature on growth of juvenile white sturgeon (*Acipenser transmontanus*). *Aquaculture*, 115, 297– 303.

Hussain, M.S. & Yadav, C.N.R. (2016). Optimization of grass carp for supplementing feed and fertilizer in carp poly-culture. *International Journal of Fisheries and Aquatic Studies*, 4(4), 467-472.

Ichinose, K., Tochihara, M., Wada, T., Suguiura, N. & Yusa, Y. (2002). Effect of common carp on apple snail in a rice field evaluated by a predator-prey logistic model. *International Journal of Pest Management*, 48, 133–138.

Islam, A.H.M.S., Barman, B.K. & Murshed-e-Jahan, K. (2015). Adoption and impact of integrated rice– fish farming system in Bangladesh. *Aquaculture*, 447, 76-85.

Jahan, K.M., Ahmed, M. & Belton, B. (2010). The impacts of aquaculture development on food security: lessons from Bangladesh. *Aquaculture Research*, 41(4), 481–495.

Janiya, J.D. & Moody, K. (2008). Weed populations in transplanted and wet-seeded rice as affected by weed control method, *Tropical Pest Management*, Vol. 35;1989 pp.8-11

Jenkins, M. (2003). Prospects for biodiversity. *Science*, 302, 1175–1177.

Jintong, Y. (1995). Rice-fish culture and its macro-development in ecological agriculture. In: MacKay KT (ed) Rice-fish culture in China. International Development Research Centre (IDRC), Ottawa.

Jobling, M. (1986). Gastrointestinal overload – a problem with formulated feed? *Aquaculture*, 51 (3-4), 257–263.

Jobling, M., Arnesen, A.M., Baardvik, B.M., Christiansen, J.S. & Jorgensen, E.H. (1995). Monitoring feeding behavior and food intake: methods and applications. *Aquaculture Nutrition*, 1(3), 131– 143.

Jun, Q., Hui, W., Rui-Wei, L. & Jun, P. (2009). Effects of feeding frequency on growth, body biochemical composition and digestive enzymes of larvae and juvenile of hybrid tilapia (*Oreochromis niloticus O. aureus*). *Journal Zhanjiang Ocean University*, 29, 79-83.

Kamarudin, M.S., Sulaiman, M.A. & Ismail, M.F. (2018). Effects of dietary crude fiber level on growth performance, body composition, liver glycogen and intestinal short chain fatty acids of a tropical carp (*Barbonymus gonionotus*♀ X *Hypsibarbus wetmorei* male♂). *Journal of Environmental Biology*, 39(5), 813-820.

Kamp, K. & Gregory, R. (1993). Fish cultivation as a means to increase profitability from rice field: Implication for integrated pest management. Proceedings on the 3rd Asian Regional Rice-Fish Farming Research and Development Workshop, June 6-11, 1993, SURIF, Sukamandi, Suang, West Java, Indonesia.

Kangmin, L. (1988). Rice-fish culture in China: A review. *Aquaculture*, 71(3), 173–186.

Kathiresan, R.M., Anbhazhagan, R. & Padmapriya, S.P. (2005). Weed management in integrated rice + fish + poultry farming system. In Proceedings of the 20th Asian Pacific Weed Science Society Conference. Ho Chi Minh: Cuu Long Delta Rice Research Institute, 624–628 pp.

Kathiresan, R.M. (2007). Integration of elements of a farming system for sustainable weed and pest management in the tropics. *Crop Protection*, 26(3), 424-429.

Kathiresan, R.M. & Ramah, K. (2000). Impact of weed management in Rice-Fish farming systems. *Indian Journal of Weed Science*, 32(2), 39-43.

Kaushik, S.J., Gouillou, M.F. & Cho, C.Y. (1998). Applications of the recommendations on vitamin requirements of finfish by NRC (1993) to salmonids and sea bass using practical and purified diets. *Aquaculture*, 161(1-4), 463–474.

Khoo, K.H. & Tan, E.S.P. (1980). Review of rice-fish culture in Southeast Asia. In R. S. V. Pullin & Z. Shehadeh, H. (1980). Proceedings of the ICLARM-SEARCA Conference on Integrated Agriculture-Aquaculture Farming Systems (pp. 1–14). Manila: ICLARMC inf. Pro., 24.

Koesoemandinata, S. (1980). Pesticides as major constraints to integrated agriculture-aquaculture farming systems. In R.S.V. Pullin & Z.H. Shehadeh (Eds.), Proceedings of the ICLARM-SEARCA Conference on Integrated Agriculture-Aquaculture Farming Systems. Manila, Philippine, 54-69 pp.

Krogdahl, Å., Berg-Lea, T. & Olli, J.J. (1994). Soybean proteinase inhibitors affect intestinal trypsin activities and amino acid digestibilities in rainbow trout (*Oncorhynchus mykiss*). *Comparative Biochemistry and Physiology*, 107A, 215–219.

Kropff, M.J., Cassman, K.G., Vanlaar, H.H. & Peng, S. (1993). Nitrogen and yield potential of irrigated rice. *Plant and Soil*, 156(1), 391–394.

Kumar, S., Sahu, N.P., Pal, A.K., Choudhury, D. & Mukherjee, S.C. (2006). Studies on digestibility and digestive enzyme activities in *Labeo rohita* (Hamilton) juveniles: effect of microbial a-amylase supplementation in non-gelatinized or gelatinized corn-based diet at two protein levels. *Fish Physiology Biochemistry*, 32, 209-220.

Kunda, M., Azim, M.E., Wahab, M.A., Dewan, S., Roos N. & Thilsted, S.H. (2008). Potential of mixed culture of freshwater prawn (*Macrobrachium rosenbergii*) and self-recruiting small species mola (*Amblypharyngodon mola*) in rotational rice-fish/prawn culture systems in Bangladesh. *Aquaculture Research*, 39: 506-517.

Lackey, J.B. (1938). The manipulation and counting of river plankton and changes in the some organisms due to formalin preservation. *Public health reports* 53: 2080-2098.

Ladha, J.K., Pathak, H., Tirol-Padre, A., Dawe, D. & Gupta, R.K. (2003). Productivity trends in intensive rice-wheat cropping systems in Asia. In: Ladha JK, Hill JE, Duxbury JM, Gupta RK, Buresh RJ (eds) Improving the productivity and sustainability of rice-wheat systems: issues and impacts, ASA special publication 65. American Society of Agronomy, Crop Science Society of America, Soil Science Society of America, Madison, pp. 45–76.

Lawrence, C., Best, J., James, A. & Maloney, K. (2012). The effects of feeding frequency on growth and reproduction in zebra fish (*Danio rerio*). *Aquaculture*, 368:369, 103-108.

Lee, D.K. & Lee, W.J. (2003). Biological control of mosquito larvae by using indigenous fish predator, *Misgurnus mizolepis*in Republic of Korea. Abstract book of the 52nd annual meeting of the American Society of Tropical Medicine and Hygiene. 3 to 7 December, Philadelphia.

Lee, K. & Dabrowski, K. (2003). Interactions between vitamins C and E affects their tissue concentrations, growth, lipid oxidation, and deficiency symptoms in yellow perch (*Perca flavescens*). *British Journal Nutrition*, 89, 589–596.

Lightfoot, C., Van Dam, A. A. & Costa-Pierce, B. A. (1992). What's happening to the rice yield in rice-fish systems? In C.R. De la Cruz, C. Lightfoot, B.A. Costa-Pierce, V.R. Carangal and M.P. Bimbao (eds.), Rice-fish research and development in Asia, ICLARM Conference Proceeding (pp. 24-41), 457 pp.

Little, D.C., Surintaraseree, P. & Taylor, N.I. (1996). Fish culture in rain fed rice fields of northeast Thailand. *Aquaculture*, 140, 295-321.

Liu, C.C. (1995). Rice-azolla-fish cropping system, p. 210-208. InK.T. MacKay (ed.) Rice-fish culture in China. International Development Research Centre (IDRC) Ottawa, Canada, 276 p.

Lu, J. & Li, X. (2006). Review of rice-fish-farming systems in China-one of the Globally Important Ingenious Agricultural Heritage Systems (GIAHS). *Aquaculture*, 260,106–113

Mridha, M.A.R., Hossain, M.A., Azad Shah, A.K.M., Uddin, M.S. & Nahiduzzaman, M. (2014). Effects of Stocking Density on Production and Economics of All-Male Tilapia (*Oreochromis niloticus*) Culture in a Rain Fed Rice-Fish Ecosystem, *Journal of Applied Aquaculture*, 26:1, 60-70,

MacKay, K.T. (1995). Rice-fish culture in China. International Development Research Centre (IDRC), Ottawa, Canada, 276 p.

Mamun, S.A., Nasrat, F. & Debi, M.R. (2012). Integrated farming system: prospects in Bangladesh. *Journal of Environmental Science and Natural Resources*, 4: 127-136.

Matteson, P.C. (2000). Insect-pest management in tropical Asian irrigated rice fields. *Annual Review Entomology*, 5, 549-574.

Mazurais, D., Darias, M.J., Gouillou-Coustans, M.F., Le Gall, M.M., Huelvan, C., Desbruyères, E., Quazuguel, P., Cahu, C. & Zambonino-Infante, J.L. (2008). Dietary vitamin mix levels influence the ossification process in European sea bass (*Dicentrarchus labrax*) larvae. *American Journal of Physiology-Regulatory, Integrative and Comparative Physiology*, 294(2), R520–R527.

Mazurais, D., Glynatsi, G., Darias, M.J., Christodoulopoulou, S., Cahu, C.L., Zambonino- Infante, J.L. & Koumoundouros, G. (2009). Optimal levels of dietary vitamin A for reduced deformity incidence during development of European sea bass larvae (*Dicentrarchus labrax*) depend on malformation type. *Aquaculture*, 294, 262–270.

Miah, M.S., Uddin, M.S. & Shah, M.S. (1997). Effect of stocking ratios on the growth and production of fishes in mixed polyculture system. *Bangladesh Journal of Fisheries*, 20(1-2), 135-138.

Middendorp, H.A.J. (1992). Contribution of stocked and wild fish in rice fields to fish production and farmer nutrition in northeast Thailand. *Asian Fisheries Science*, 5 (2), 145-161.

Mihelakakis, A., Tsolkas, C. & Yoshimatsu, T. (2002). Optimization of feeding rate for hatchery-produced juvenile gilthead sea bream *Sparus aurata*. *Journal of the World Aquaculture Society*, 33, 169– 175.

Mishra, A., Ghorai, A. K. & Singh, S. R. (1997). Effect of dike height on water, soil and nutrient conservation and rice yield (Report No. 5). Water Technology Centre for Eastern Region Indian Council of Agricultural Research, Bhubaneswar, India.

Mohanty, R. K. (1995). Comparative evaluation of growth and survival of Indian major carp fry in aerated and non-aerated ponds under different stocking densities (M.F.Sci. Thesis). Orissa University of Agriculture and Technology, Bhubaneswar, India.

Mohanty, R.K. (1999). Growth performance of *Penaeus monodon* at different stocking densities. *Journal of Inland Fisheries Society of India*, 31(1), 53–59.

Mohanty, R.K. (2001). Feeding management and waste production in semi-intensive farming of *Penaeus monodon* (fab.) at different stocking densities. *Aquaculture International*, 9(4), 345–355.

Mohanty, R.K. (2004). Density dependant growth performance of Indian major carps in rainwater reservoirs. *Journal of Applied Ichthyology*, 20(2), 123–127.

Mohanty, R.K. (2010). Impact of phased harvesting on population structure, feed intake pattern and growth performance of *Macrobrachium rosenbergii* DeMan (giant freshwater prawn) in polyculture with carps in concurrent rice–fish culture. *Aquaculture International*, 18(4), 523–537.

Mohanty, R.K. (2015). Effect of feed restriction on compensatory growth performance of Indian major carps in a carp prawn polyculture system: a response to growth depression. *Aquaculture Nutrition*, 21(4), 464–473.

Mohanty, R.K., Kumar, A., Mishra, A., Panda, D.K. & Patil, D. (2014). Water budgeting and management: enhancing aquacultural water productivity (Report No. 63). Directorate of Water Management (ICAR), Odisha, India, 62 pp.

Mohanty, R.K., Verma, H.N. & Brahmanand, P.S. (2004). Performance evaluation of rice–fish integration system in rainfed medium land ecosystem. *Aquaculture*, 230, 125–135.

Mohanty, R. K., Jena, S. K., Thakur, A. K. & Patil, D. U. (2009). Impact of high-density stocking and selective harvesting on yield and water productivity of deep-water rice–fish systems. *Agricultural Water Management*, 96(12), 1844-1850.

Mondal, M.A.I., Kader, M.A., Choudhury, A.H., Mustafa, M.G., Nabi, M.R.U., Billah, M.M., Asif, A.A. Siddiqui, A.A.M. (2018). Socio-economic uplifting analysis of ESBN fishery of the coastal villages, Kumira and Kattoli, Chittagong, Bangladesh. *International Journal of Research-Granthaalayah*, 6(8), 248-263.

Moody, K. (1992). Fish-crustacean- weed interactions. In C.R. De la Cruz, C. Lightfoot, B.A. Costa-Pierce, V.R. Carangal & M.P. Bimbao (Eds.), Rice-fish research and development in Asia ICLARM Conference Proceedings (pp. 185–192). Manila, Philippines, 457 pp.

Munsiri, P. & Lovell, R.T. (1993). Comparison of satiate and restricted feeding of channel catfish with diets of varying protein quality in production ponds. *Journal of World Aquaculture Society*, 24, 459–465.

Mustow, S.E. (2002). The effects of shading on phytoplankton photosynthesis in rice fish fields in Bangladesh. *Agriculture, Ecosystem and Environment*, 90(1), 89–96.

Nabi, R. (2008). Constraints to the adoption of rice-fish farming by smallholders in Bangladesh: a farming systems analysis. *Aquaculture Economics and Management*, 12(2), 145–153.

Nahar, A. (2010). Impacts of different rice-fish-prawn culture systems on yield of rice, fish and prawn and limnological conditions. *Journal of the Bangladesh Agricultural University*, 8(1), 179-185.

Naranjo, P.J., Hernandez-Llamas, A., & Villarreal, H. (2004). Effect of stocking density on growth, survival and yield of juvenile redclaw crayfish *Cherax quadricarinatus* (Decapoda: Parastacidae) in gravel-lined commercial nursery ponds. *Aquaculture*, 242(1-4), 197–206.

National-Research-Council. (1993). Nutrient Requirements of Fish. National Academy Press, Washington DC.

Naylor, R. (1996). Invasions in Agriculture: Assessing the cost of the golden apple snail in Asia. *Ambio*, 25, 443–448.

Neng, W., Guohou, L. & Gemei, Z. (1995). The role of fish in controlling mosquitoes in rice fields. In: MacKay, T.K. (Ed.), Rice-Fish Culture in China. International Development Research Centre (IDRC), Ottawa, Canada.

Newell, G.E. & Newell, R.C. (1973). Marine Plankton: A Practical Guide, revised edition. London: Hutchinson Educational Ltd. pp: 244.

Ng, W.K., Lu, K.S., Hashim, R. & Ali, A. (2000). Effects of feeding rate on growth, feed utilization and body composition of tropical hibrid catfish. *Aquaculture International*, 8, 19–29.

Nguyen, V.S., Truong, Q.P., Villaneuva, F. & Dalsgaard, J.P. (1993). Integrated rice-prawn farming in the Mekong Delta: a route towards sustainable and profitable farming systems. *NAGA, ICLARM Quarterly*, 16, 18–20.

Nikki, J., Pirhonen, J., Jobling, M. & Karjalainen, J. (2004). Compensatory growth in juvenile rainbow trout, *Oncorhynchus mykiss* (Walbaum), held individually. *Aquaculture*, 235, 285–296.

Oehl, F., Sieverding, E., Ma¨der, P., Dubois, D., Ineichen, K., Boller, T. & Wiemken, A. (2004). Impact of long-termconventional and organic farming on the diversity of arbuscular mycorrhizal fungi. *Oecologia*, 138; 574-583

Ogello, E., Mlingi, F., Nyonje, B., Chectarero-Karisa, H. & Munguti, J. (2013). Can integrated livestock fish culture be a solution to East Afircan's food insecurity? A Review. *African Journal of Food, Agriculture, Nutrition and Development*, 13, 8058–8078.

Okumus, I. & Bascinar, N. (2001). The effect of different numbers of feeding days on feed consumption and growth of rainbow trout (*Oncorhynchus mykiss*). *Aquaculture Research*, 32, 365–367.

Panda, M.M., Ghosh, B.C. & Sinhababu, D.P. (1987). Uptake of nutrients by rice under rice-cum-fish culture in intermediate deep water situation (upto 50-cm water depth). *Plant Soil*, 102, 131-132.

Philips, A.M., Podoliak, H.A., Poston, H.A., Livingston, D.L., Booke, H.E., Pyle, E.A. & Hammer, G.L. (1964). The production of anemia in brown trout. Fisheries Research Bulletin No. 27. State of New York Conservation Department, Albany N.Y, pp. 66–70.

Pimentel, D., Houser, J., Preiss, E., White, O., Fang, H., Mesnick, L., Barsky, T., Tariche, S., Schreck, J. & Alpert, S. (1997). Water resources: agriculture, the environment, and society. *Bioscience*, 47 (2), 97-106.

Pouomogne, V. & Ombredane, D. (2001). Effect of feeding frequency of the growth of tilapia (*Oreochromis niloticus*) in earthen ponds. *Tropicultura*, 19, 147-150.

Prein, M. (2002). Integration of aquaculture into crop-animal systems in Asia. *Agricultural Systems*, 71, 127– 146.

Purba, S. (1998). The economics of rice-fish production systems in North Sumatra, Indonesia: An empirical and model analysis. University of Göttingen, Diss, 178 pp.

Qin, L., Liu, Y., Li, F.B., Feng, J.F., Wu, D.X. & Fang, F.P. (2016). Impacts of rice-fish co-culture on the physical and chemical variables of the micro profiles at sediment-water interface in an intensive culture pond. *Chinese Journal of Rice Science*, 30(6): 647–652.

Rahman, S., Barmon, B. K. & Ahmed, N. (2011). Diversification economies and efficiencies in a blue-green revolution combination: a case study of prawn-carp-rice farming system in Bangladesh. *Aquaculture International*, 19(4), 665-682.

Rahman, H., Mirza, J.A., Hossain, A., Asif, A.A., Haq, E., Chwakravorty, P. & Rahman, M. (2017b). Economics of fish production in paddy fields in Bangladesh. *Asian Journal of Medical and Biological Research*, 3(3), 379-390.

Rahman, M.A., Kang, S., Nagabhatla, N. & Macnee, R. (2017a). Impacts of temperature and rainfall variation on rice productivity in major ecosystems of Bangladesh. *Agriculture and Food Security*, 6, 1-11.

Razzak, M.A. M. Frel, M.A.M., Khan, K., Becker & Dewan, S. (2007). Impact of common carp, *Cyprinus carpio* (L) and Nile tilpia, *Oreochomis nilaticus* (L) on anthropods population, zoobenthos and weeds in rice-fish culture. *Bangladesh Journal of Fisheries Research*, 11:19:28.

Razeim, M.A., Farouque, M.G., Sarker, M.A., Asif, A.A. & Ahmed, M. (2017). Attitude of farmers towards Pangas farming for their livelihood improvement. *Asian-Australasian Journal of Bioscience and Biotechnology*, 2(1), 106-119.

Riche, M.A. (2008). Food for thought: feeding management strategies (Part 2). *Global Aquaculture Advocate*, 11, 68–70.

Riche, M.A., Haley, D.I., Oetker, M., Garbrecht, S. & Garling, D.L. (2004). Effect of feeding frequency on gastric evacuation and the return of appetite in tilapia (*Oreochromis niloticus*). *Aquaculture*, 234, 657–673.

Robertson, L., Lawrence, A.L. & Castille, F.L. (1993). Effect of feeding frequency and feeding time on growth of *Penaeus vannamei* (Boone). *Aquaculture Research*, 24: 1-6.

Robinson, E.H. & Li, M.H. (1999). Effect of dietary protein concentration and feeding rate on weight gain, feed efficiency, and body composition of pond-raised channel catfish *Ictalurus punctatus*. *Journal of the World Aquaculture Society*, 30, 311–318.

Roger, P.A. (1996). Biology and management of the floodwater ecosystem in rice fields. International Rice Research Institute, Los Banos, Laguna, Philippines, 250 p.

Roosta, H.R. (2014). Comparison of the vegetative growth, eco-physiological characteristic and mineral nutrient content of basil plants in different irrigation ratios of hydroponic: aquaphonic Solutions. *Journal of Plant Nutrition*, 37, 1782–1803.

Rosenthal, H. & Gessner, J. (1991). Status and prospects of sturgeon farming in Europe. In: Rosenthal, H., Grimaldi, E. (Eds.), Efficiency in Aquaculture Production. Proc. 5th Int. Conf. on Aquafarming "Acquacoltura'90" Verona, Italy, pp. 143–192.

Rothuis, A.J., Nhan, D.K., Richter, C.J.J. & Ollevier, F. (1998a). Rice with fish culture in the semi-deep waters of the Mekong Delta, Vietnam: Interaction of rice culture and fish husbandry management on fish production. *Aquaculture Research*, 29, 59–66.

Rothuis, A.J., Duong, L.T., Richter, C.J.J. & Ollevier, F. (1998b). Polyculture of silver barb, *Puntuis gonionotus* (Bleeker), nile tilapia, *Oreochromis niloticus* (L.), and common carp, *Cyprinus carpio* L., in Vietnamese rice fields: Feeding ecology and impact on rice and rice field ecology, semi-deep waters of the Mekong Delta, Vietnam: interaction of rice culture and fish husbandry management on fish production. *Aquaculture Research*, 29, 649–660.

Rothuis, A.J., Nhan, D.K., Richter, C.J.J. & Ollevier, F. (2008). Rice with fish culture in the in the semi-deep waters of the Mekong Delta, Vietnam: a socio-economical survey, *Aquaculture Research*, p: 59-66

Rothuis, A.J., Vromant, N., Xuan,V.T., Richter, C.J.J. & Ollevier, F. (1999). The effect of rice seeding rate on rice and fish production and weed abundance in direct-seeded rice-fish culture. *Aquaculture*, 172, 255–274.

Roy AK, Ghosh A.K., Arafat S.T. & Huq K.A. (2013). Fish-paddy crop rotation practice in South-West coastal region of Bangladesh: A profitable technology for the poor farmers. *Bangladesh Journal of Agricultural Research*, 38: 389-399.

Roy, B., Das, D.N. & Mukhopadhyay, P.K. (1990). Rice-fish-vegetable integrated farming: towards a sustainable ecosystem. *Naga*, 13(4), 17-18.

Sayeed, M.A., Alam, M.T., Sultana, S., Ali, M.S., Azad M.S. & Islam, M.A. (2007). Effect of inorganic fertilizer on the fish growth and production in polyculture system of Bangladesh. *University Journal Zoology*. Rajshahi Univ., 26: 77-80.

Saikia, S.K. & Das, D.N. (2004). 'Aji gnui assonii' – a practice of organic hill farming among the Apatani tribe of Eastern Himalaya. *International Journal of Sustainable Development and World Ecology*, 11(2), 211–217.

Saikia, S.K. & Das, D.N. (2009a). Feeding ecology of common carp (*Cyprinus carpio* L.) in a rice–fish culture system of the Apatani plateau (Arunachal Pradesh, India). *Aquatic Ecology*, 43(2), 559– 568.

Saikia, S. K. & Das, D. N. (2009b). Potentiality of periphyton-based aquaculture technology in rice-fish environment. *Journal of Scientific Research*, 1(3), 624-634.

Sampaio, C.M.S. & Valenti, W.C. (1996). Growth curves for *Macrobrachium rosenbergii* in semi-intensive culture in Brazil. *Journal of the World Aquaculture Society*, 27:353–358.

Samonte, S.O.P., Wilson, L.T., Medley, J.C., Pinson, S.R.M., McClung, A.M. & Lales, J.S. (2006). Nitrogen utilization efficiency: Relationships with grain yield, grain protein, and yield-related traits in rice. *Agronomy Journal*, 98(1), 168.

Sastradwirja, F. (1992). Resource Utilization in Rice-Fish Farming. In: Rice-Fish Research and Development in Asia, Dela Cruz, C.R., C. Lightfoot., B.A. Costa-Pierce, V.R. Carangal and M.P. Bimboo (Eds.). ICLARM, Manilia, Philipines, pp: 201-206.

Shekhar, J., Mankotia, B. S. & Dev, S.P. (2009). Productivity and economics of rice (*Oryza sativa*) in system of rice intensification in North-Western Himalayas, *Indian Journal of Agronomy*, 54(4) pp.423:427.

Sevilleja, R.C., Cagauan, A.G., Lopez, E.A., dela Cruz, CR. & van Dam, A.A. (1992). Component technology research in rice-fish systems in the Philippines. In: dela Cruz, C.R., Lightfoot, C., Costa-Pierce, B.A., Carangal. V.R., Bimbao, M.P. (Eds.1, Rice-Fish Research and Development in Asia. ICLARM Conf. Proc. 24, pp. 373-384.

Shailender, M., Suresh Babu, C., Srikanth, B., Kishor, B., Silambarasan, D. & Jayagopal, P. (2012). Sustainable culture method of giant black tiger shrimp, *Penaeus monodon* (Fabricius) in Andhra Pradesh, India. IOSR, *Journal of Agriculture and Veterinary Science*, 1(3), 12–16.

Shajib, M.S.H., Sarker, B., Asif, A.A., Rahman, M.M., Zafar, M.A. & Hossain, A. (2017). Effects of stocking density on the growth rate of gold fish fry reared in hapa. *Asian Journal of Medical and Biological Research*, 3(4), 504-515.

Shakir, C., Lipton, A.P., Manilal, A., Sugathan, S., & Selvin, J. (2014). Effect of stocking density on the survival rate and growth performance in *Penaeus monodon*. *Journal of Basic and Applied Sciences*, 10: 231–238.

Shang, Y.C. (1990). Aquaculture Economic Analysis: An Introduction. World Aquaculture Society, Baton Rouge, LA, USA, 211pp.

Shankar, B., Halls, A. & Barr, J. (2004). Rice versus fish revisited: On the integrated management of floodplain resources in Bangladesh. *Natural Resources Forum*, 28(2), 91–101.

Shekar, M., Kakietek, J., D'Alimonte, M., Sullivan, L., Walters, D., Rogers, H., Dayton, Eberwein, J., Soe-Lin, S. & Hecht, R. (2015). Investing in nutrition: the foundation for development – an investment framework to reach the global nutrition targets. Report No. 104865. Washington, D.C.: World Bank.

Shimeno, S. (1991). Yellow tail, *Seriola quinqueradiata*. Handbook of Nutrient Requirements of Finfish, pp. 181–191.

Shoko, A.P., Getabu, A., Mwayuli, G. & Mgaya, Y.D. (2011). Growth performance yield and economic benefits of Nile tilapia *Oreochromis niloticus* and Kale *Brassica oleracea* cultured under vegetable-fish culture integration. *Tanzania Journal of Science*, 37, 37–48.

Shugen, P., Zhechun, H. & Jicheng, Z. (1995). Ecological mechanisms for increasing rice and fish production. In: MacKay KT; Rice-fish culture in China. *International Development Research Centre* (IDRC), Ottawa, 195–200pp.

Siegrist, M. (1998). Belief in gene technology: the influence of environmental attitudes and gender. *Personality and Individual Differences*, 24, 861–66.

Siikavuopio, S.I., Knudsen, R., Amundsen, P.A., Saether, B.S. & James, P. (2012). Effects of high temperature on the growth of European whitefish (*Coregonus lavaretus* L.). *Aquaculture Research*, 44(1): 8–12.

Singh, R.K., Balange, A.K. & Ghughuskar, M.M. (2006). Protein sparing effect of carbohydrates in the diet of *Cirrhinus mrigala* (Hamilton 1822) fry. *Aquaculture*, 258(1-4), 680-684.

Singh, V.P., Early, A.C. & Wickham, T.H. (1980). Rice agronomy in relation to fish culture, p. 15-34. In Pullin, R.S.V. & Shehadeh, Z.H. (eds.) Proc. of the ICLARMSEARCA Conf. on Integrated Agriculture-Aquaculture Farming Systems, 6-9 August 1979, Manila, Philippines, 258 p.

Sinhababu, D.P., Sanjoy Saha, S. & Sahu, P.K. (2013). Performance of different fish species for controlling weeds in rainfed lowland rice field. *Biocontrol science and technology*, 23(12), 1362-1372.

Smith, S.E. & Read D.J. (2008). Mycorrhizal Symbiosis. Academic Press, London, UK.

Snow, A.M., Ghaly, A.E. & Snow, A. (2008). A comparative assessment of hydroponically grown cereal crops for the purification of aquaculture waste water and the production of fish feed. *American Journal of Agricultural and Biological Sciences*, 3(1): 364–378.

Sukhanova, Z.N. (1978). Settling without the inverted microscope. In: Sourina A, editor. Phytoplankton Manual. Norwich, UK: UNESCO, Page Brothers Ltd. pp: 97.

Sultana, P. (2012). Implications of floodplain aquaculture enclosure. *Journal of Environmental Planning and Management*, 55(9), 1159-1174.

Taylor, F.J.R. (1976). Dinoflagellates from the international Indian expedition. A report on material collected by the RV Anton Bruun 1963-1964. Bibliotheca Botanica Left, 132: 1-226.

Takeuchi, T., Watanabe, K., Satoh, S. & Watanabe, T. (1992). Requirement of grass carp (*Ctenopharyngodon idella*) fingerlings for alpha-tocopherol. *Bulletin of the Japanese Society for the Science of Fish*, 9 (58), 1743–1749.

Talbot, C. (1985). Laboratory methods in fish feeding and nutritional studies. In: Tytler P. And Calow P. (eds). Fish *Energetics*: New Perspectives, The Johns Hopkins University Press, Baltimore, MD, pp. 125–154.

Thang, N.V. (1996). A Manual for Culture of Giant Freshwater Prawn. Agriculture Publisher, Ho Chi Minh, Vietnam 120pp.

Thilsted, S.H. (2013). Fish diversity and fish consumption in Bangladesh. Diversifying food and diets: Using agricultural biodiversity to improve nutrition and health, 270.

Tian, X.L. & Qin, J.G. (2003). A single phase of food deprivation provoked compensatory growth in barramundi *Lates calcarifer*. *Aquaculture*, 224, 169–179.

Tsuruta, T., Yamaguchi, M., Abe, S. & Iguchi, K. (2011). Effect of fish in rice-fish culture on the rice yield. *Fisheries Science*, 77, 95–106.

Tung, P.H. & Shiau, S.Y. (1991). Effects of meal frequency on growth performance of hybrid tilapia, *Oreochromis niloticus, O. aureus*, fed different carbohydrate diets. *Aquaculture*, 92, 343-350.

Vromant, N., Duong, L.T. & Ollevier, F. (2002a). Effect of fish on the yield and yield components of rice in integrated concurrent rice-fish systems. *Journal of Agricultural Science*, 138, 63–71.

Vromant, N., Nam, C.Q. & Ollevier, F. (2002b). Growth performance and use of natural food by *Oreochromis niloticus* (L.), in Polyculture systems with *Barbode sgonionotus* (Bleeker) and *Cyprinu scarpio* (L.) in intensively cultivated rice fields. *Aquaculture Research*, 33, 969–978.

Vromant, N., Nhan, D.K., Chau, N.T.H. & Ollevier, F. (2002c). Can fish control plant hopper and leafhopper populations in intensive rice culture? *Biocontrol Science and Technology*, 12, 695–703.

Uddin, M.J., Dewan, S., Ashrafuzzaman, M. & Haque, M.M. (2001). Growth and yield of GIFT (*Oreochromis niloticus*) and Thai silver barb (*Barbodes gonionotus* Bleeker) in rice fields and their effects on the yield of rice. *Bangladesh Journal of Fisheries Research*, 5(1): 29-35.

Wahab, M.A., Ahmed, Z.F., Haq M.S. & Begum, M. (1994). Compatibility of silver carp in the polyculture of cyprinid fishes. *Progress Agriculture*, 5: 221-227.

Wang, B. & Zhang, Q. (1995). Cultivating different breeds of fish in rice fields, p. 139-146. In K.T. MacKay (ed.) Rice-fish culture in China. International Development Research Centre (IDRC), Ottawa, Canada, 276 p.

Wang, N., Hayward, R.S. & Noltie, D.B. (1998). Effect of feeding frequency on food consumption, growth, size variation, and feeding pattern of age-0 hybrid sunfish. *Aquaculture*, 165, 261-267.

Wilson, C. & Tisdell, C. (2001). Why farmers continue to use pesticides despite environmental, health and sustainability costs. *Ecological Economics*, 39, 449–462.

Woodward, B. (1994). Dietary vitamin requirements of cultured young fish, with emphasis on quantitative estimates for salmonids. *Aquaculture*, 124, 133–168.

Wu, L. (1995). Method of Rice-Fish Culture and their Ecological Efficiency: In Rice-Fish Culture in China, Mackay K.T. (Ed.). International Development Research Centre (IDRC), Ottawa, Canada, pp: 91-96.

Xie, S., Zhu, X., Cui, Y., Wootton, R.J., Lei, W. & Yang, Y. (2011). Compensatory growth in the *gipel* carp following feed deprivation: temporal patterns in growth, nutrient deposition, feed intake and body composition. *Journal of Fish Biology*, 58, 999–1009.

Xie, J., Liu, L., Chen, X., Chen, J., Yang, X. & Tang, J. (2009). Control of diseases, pests and weeds in traditional rice-fish ecosystem in Zhejiang, China. *Bulletin of Science and Technology*, 25(6), 801-805.

Xu, Q., Yang, L. & Dong, Y. (1998). Rice-field Ecosystem in China. Press of China, Beijing, China, (In Chinese).

Yamazaki, M., Ohtsuka, T., Kusuoka, Y., Maehata, M., Obayashi, H., Imai, K. & Kimura, M. (2010). The impact of nigoro-buna crucian carp larvae/fry stocking and rice-straw application on the community structure of aquatic organisms in Japanese rice fields. *Fisheries Science*, 76(2), 207-217.

Yang, G., Xiao, Q. & He, T. (1995). Techniques adopted in rice-azolla-fish system with ridge culture, p. 107-116. In K.T. MacKay (ed.) Rice-fish culture in China International Development Research Centre (IDRC), Ottawa, Canada. 276.

Yaro, I., Lamani, S.L. & Oladimeji, A.A. (2005). Effect of different fertilizer treatments on water quality parameters in rice-cum-fish culture system. *Journal of Applied Ichthyology*, 21(5), 399–405.

Yinhe, P. (1995). Ecological effects of rice-fish culture. In: Mac-Kay KT (ed) Rice-fish culture in China. International Development Research Centre (IDRC), Ottawa, pp 189–194.

Yunus, M., Hardjamulia, A., Syamsiah, I. & Suriapermana, S. (1992). Evaluation of rice-fish production systems in Indonesia, p. 131-138. In De la Cruz, C.R., Lightfoot, C., Costa-Pierce, B.A., Carangal, V.R. and Bimbao, M.P. (eds.) Rice-fish research and development in Asia. ICLARM Conf. Proc. 24, 457 p.

Zafar, M.A., Hasan, M.Z., Ali, M.M. & Asif, A.A. (2017). Growth and production performance of Vietnamese koi (*Anabas testudineus*) with Magur (*Clarias batrachus*) at different stocking densities. *Asian-Australasian Journal of Bioscience and Biotechnology*, 2(3), 226-237.

Zhang, Z. & Wang, S. (2006). Analysis to development history of rice-fish culture and the driving factors. *Journal of Nanjing Agricultural University*, 6, 79-83.

Zhou, Q.C., Wang, L.G., Wang, H.L., Wang, T., Elmada, C.Z. & Xie, F.J. (2013). Dietary vitamin E could improve growth performance, lipid peroxidation and non-specific immune responses for juvenile cobia (*Rachycentron canadum*). *Aquaculture Nutrition*, 19 (3), 421–429.

Zolfaghari, M., Imanpour, M.R. & Najafi, E. (2011). Effect of photoperiod and feeding frequency on growth and feed utilization of fingerlings Persian sturgeon (*Acipenser persicus*). *Aquaculture Research*, 42, 1594–1599.

Zonneveld, N. & Fadholi, R. (1991). Feed intake and growth of red tilapia at different stocking densities in ponds in Indonesia. *Aquaculture*, 99(1-2), 83–94.