EFFECTS OF DIFFERENT FISH SIZES, STOCKING DENSITIES AND FEEDING RATES OF TILAPIA, *OREOCHROMIS* SP. CULTURE IN *CHLORELLA* SP. PRODUCTION

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2011

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DEGREE : **MASTER OF SCIENCE**

VIVA DATE : **3RD MARCH 2011**

DECLARED BY

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ACKNOWLEDEMENTS

I would like to express my sincere grateful acknowledgement to my supervisor, Prof. Dr. Shigeharu Senoo, Borneo Marine Research Institute, for his invaluable suggestions, guidance and encouragement throughout study period. I thank Univeristi Malaysia Sabah for the assistantship. I would like to express my gratitude to Prof. Dr. Saleem Mustafa, Former Director of Borneo Marine Research Institute, Brig. Gen. Prof. Datuk Seri Panglima Dr. Kamaruzaman Hj. Ampon, Vice-chancellor, Universiti Malaysia Sabah, Associate Prof. Datin Dr. Mariam Bte Abdul Latip, Dean of Center for Postgraduate Studies and Prof. Dr. Ridzwan Abdul Rahman, Present Director of Borneo Marine Research Institute for their encouragement and assistance.

I would like to express my special thanks to Prof. Mitsuru Eguchi, Head of Fisheries Department, Faculty of Agriculture, Kinki University, Japan for giving a very special opportunity to study in Universiti Malaysia Sabah before starting my postgraduate study. Without this opportunity, I would not have been able to start and completing my postgraduate study in Malaysia. I also extend my thanks to all the Hatchery staff, research assistants, my friends, colleagues and well-wishers of the Borneo Marine Research Institute for their assistance, for their valuable input directly or indirectly for the successful completion of the thesis. From deepest of my heart, I would like to express my thanks to my family for their assistance, encouragement and support, for throughout four years experiences in Hatchery of Borneo Marine Research Institute, Universiti Malaysia Sabah.

Hiroko Matsubara
28th September 2011

ABSTRACT

EFFECTS OF DIFFERENT FISH SIZES, STOCKING DENSITIES AND FEEDING RATES OF TILAPIA, *OREOCHROMIS* SP. CULTURE FOR *CHLORELLA* SP. PRODUCTION

To establish a suitable technique *of Chlorella* sp. production in tilapia culture tank, eight experiments were conducted. The recommendable stocking density (kg/m^3) and feeding rate (%BW) of tilapia were investigated for different sizes of tilapia; 0.5 g (Super Small, SS), 9.1 g (Meddle, M), 46.0 g (Large, L) and 160.6 g (Extra large, LL) in body weight for *Chlorella* sp. production. All of experimental tilapia culture water was regulated to 10 ppt salinity by mixed freshwater and filtered seawater for the purpose of producing euryhaline rotifer, *Brachionus* spp. by using this *Chlorella* sp. In the SS size tilapia culture, the optimum stocking densities and feeding rates for *Chlorella* production were 3 kg/m^3 and 4 %BW, respectively. In the M size tilapia culture, the densities of *Chlorella* were not significant difference amonth the stocking densities 2 to 6 kg/m^3 and feeding rates 1 to 3 %BW. In the L size tilapia culture, the optimum stocking density and feeding rates for *Chlorella* production were 4 kg/m^3 and feeding rate 1 %BW, respectively. In the LL size tilapia culture, the optimum stocking density and feeding rates for *Chlorella* production were 10 kg/m^3 and 1 %BW, respectively. For the *Chlorella* production in tilapia culture, it was necessary to culture the tilapia under the optimum stocking densities and feeding rates according to the tilapia sizes. The M size tilapia culture with stocking density, 4 kg/m^3 and feeding rates, 1 %BW is the most recommendable combination of tilapia rearing combination for *Chlorella* production in tilapia culture under 10 ppt.

ABSTRAK

Untuk menubuhkan teknik yang sesuai bagi penghasilan *Chlorella* di dalam tangki ternakan tilapia, 8 kajian telah dijalankan. Kadar kepadatan dan pemakanan optimum oleh tilapia telah dikenalpasti ke atas 4 tilapia yang berbeza saiz; 0.5 g (Super Kecil, SS), 9.1 g (tengah, M), 46.0 g (besar, L) dan 160.6 g (tambahan besar, LL) bagi penghasilan *Chlorella*. Kesemua air ternakan tilapia telah diselaraskan menjadi 10 ppt tahap kemasinan menggunakan air laut yang ditapis bagi tujuan penghasilan rotifer eurihalin, *Brachionus* spp. menggunakan *Chlorella* tersebut. Di dalam penternakan tilapia bersaiz SS, kadar kepadatan dan pemakanan optimum bagi penghasilan *Chlorella* adalah 3 kg/m^3 dan 4 % berat badan. Di dalam penternakan tilapia bersaiz M, kepadatan *Chlorella* tidak menunjukkan sebarang perbezaan signifikan di antara kepadatan 2 hingga 6 kg/m^3 kadar pemakanan dan 1 hingga 3 % berat badan. Di dalam penternakan tilapia bersaiz L, kadar kepadatan dan pemakanan optimum untuk penghasilan *Chlorella* adalah 4 kg/m^3 dan 1 % berat badan. Manakala bagi penternakan tilapia bersaiz LL, kadar kepadatan dan pemakanan optimum untuk penghasilan *Chlorella* adalah 10 kg/m^3 dan 1 % berat badan. Untuk penghasilan *Chlorella*, tilapia diternak dibawah kepadatan dan pemakanan optimum bergantung kepada saiz tilapia. Tilapia bersaiz M dengan kepadatan 4 kg/m^3 dan kadar pemakanan 1 % berat badan adalah gabungan yang paling sesuai dicadangkan untuk penghasilan *Chlorella* di dalam tangki ternakan tilapia di bawah tahap kemasinan 10 ppt.

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LIST OF ABBREVIATIONS

am	Morning
pm	Evening
h	Hour
RM	Ringgit Malaysia
spp.	Plural of species
sp.	Species
μm	Micrometer
L	Litter
SL	Standard Length
TL	Total Length
million cells/ml	Million Cells Per Milliliter
rotifer/ml	Rotifer Per Milliliter
ml/min	Milliliter Per Minute
mg/l	Milligram Per Litter
cm	Centimeter
g	Gram
%	Percentage
ppt	Part Per Thousand
lux	Lux
g/m^3	Gram Per Meter Cubic
kg/m^3	Kilogram Per Meter Cubic
g/fish	Gram Per Fish
mean±SD	Mean Plus Minus
TSD	Tilapia Stocking Density
FR	Feeding Rate
SR	Survival Rate
N.D.	No Date
HDPE	High-density Polyethylene Round Tank
FRP	Fiber-reinforced plastic Tank

SS	Super Small
M	Middle
L	Large
LL	Extra Large
BW	Body Weight
BOD	Biochemical Oxygen Demand
DO	Dissolved Oxygen
FCR	Feed Conversion Ratio
FAO	Food and Agriculture Organization of the United Nations
°C	Degree Celsius
TAN	Total Ammonia Nitrogen
NO_3^-	Nitrate
NH_3-N	Ammonia Nitrogen
HUFA	Highly Unsaturated Fatty Acids
EPA	Eicosapentaenoic Acid
DHA	Docosahexaenoic Acid
U. S. A.	United States of America
BMRI	Borneo Marine Research Institute
UMS	Universiti Malaysia Sabah
UMS Hatchery	Fish Hatchery, Borneo Marine Research Institute, Universiti Malaysia Sabah

KEY WORDS

Chlorella sp., Tilapia, *Oreochromis* sp., 10 ppt Salinity, Tilapia Size, Stocking Density, Feeding Rate, Growth, Survival,

CHAPTER 1

INTRODUCTION

1. 1. Phyto- and Zooplankton (e.g. *Chlorella* spp. and Rotifer spp.) Production as Live-Feed for Aquaculture

Phytoplankton are microscopic aquatic plants that form the base of the food chain in an aquaculture or natural aquatic ecosystem (Ken, 2003). Phytoplankton is eaten by zooplankton, which is then eaten by fish larva. The fish larva is then eaten by a small fish fry, and the small fish fry is then eaten by bigger and bigger fish in the food chain (Ken, 2003, Sugita, 2006). In aquaculture, phytoplankton such as *Chlorella* (Photo 1), *Nannochloropsis, Tetraselmis* and *Isochrysis* spp. are used as feed for zooplankton. Rotifer, *Brachionus* spp. (Photo 1), is a common zooplankton used for feeding fish larvae (Ester and Odi, 2006).

Mass production of rotifer and phytoplankton is necessary for aquaculture (Ester and Odi, 2006). *Chlorella* can be self-produced to feed rotifer for aquaculture, but it requires high laboratory skills and large area for culturing (Yoshiwara at al. 1997, Ester and Odi, 2006). Both rotifer and phytoplankton must be tolerant to the same environmental condition, especially the salinity of the water, where they are reared (Hagiwara, 2008). Hence, optimal mass production of rotifer and/or phytoplankton involves the understanding of the delicate balance of their environmental conditions.

Now days, *Chlorella* are mass produced or "factory made" and sold as concentrates (Ester and Odi, 2006, Chlorella Co. Ltd, Fresh Chlorella V-12). The price of concentrated *Chlorella*, however, is relatively more expansive in Malaysia (at approximately RM140/L at the time when this study started at 68 billion cells /ml) as they are imported from Japan, Korea, Taiwan, the U.S.A., and Europe. Bulk purchase can reduce the cost of concentrated *Chlorella*, but, requires refrigeration space for storage. Hence, in order to minimize the cost of aquaculture production and not to depend on using "factory made" concentrated live feed, there is a need to study a more economical technique of mass producing of self-produced *Chlorella* and rotifer.

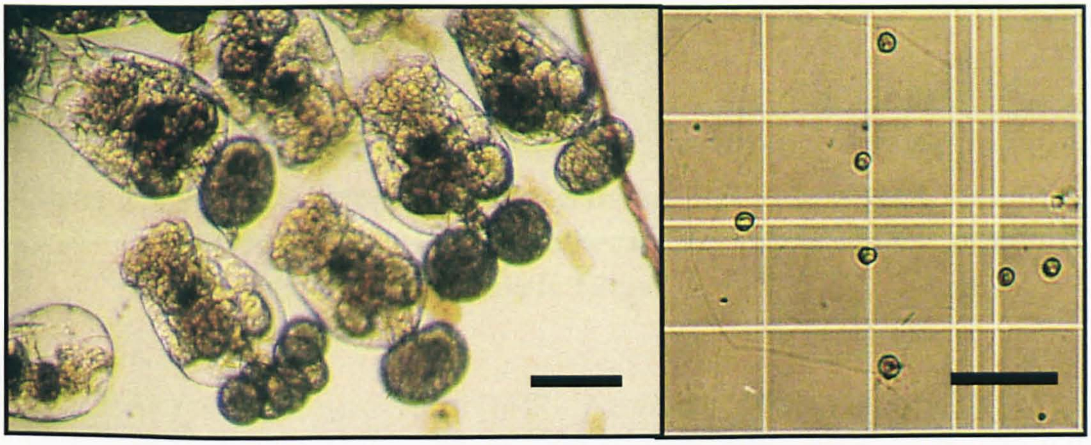

Photo 1: Rotifer, *Brachionus* spp. (left) and *Chlorella* sp. (right) cultured in the Fish Hatchery of Borneo Marine Research Institute, Universiti Malaysia Sabah. Scale is 50 µm.

Self-produced *Chlorella* requires maintenance of strain and pure culture in the laboratory. Mass production is then achieved by gradually increasing the volume in outdoor culture tanks. However, the production of self-produced *Chlorella* tend to be inconsistent due several reasons, namely: contamination with other phytoplankton such as *Scenedesmus* spp. and *Coelastrum* spp (Photo 2) through mishandling, netting materials, fish fecal material, weather, salinity, and/or water temperature (Ester and Odi, 2006, Hagiwara, 2008). Apparently, a lot more effort

REFERENCES

Abeliovich, A. & Azov, Y. 1976. Toxicity of Ammonia to Algae in Sewage Oxidation Ponds. *Apply Environmental Microbiology* **31 (6)**: 801-806.

Al-Haribi, A. H. & Siddiqui, A. Q. 2000. Effects of Tilapia Stocking Density on Fish Growth and Water Quality in Tanks. *Asian Fisheries* **13**: 391-396.

Allanson, B. R., Bok, A. Q. & VabWyk, N. I. 1971. The Influence of Exposure to Low Temperature on *Tilapia mossambica* Peter (Cichidae) 2. Changes in Serum Osmolarity, Sedium and Chloride Ion Concentrations. *Journal of Fish Biology* **3**: 181-185.

Arnaud, M-F., Moal, J. & Kaas, R. 2006. The Microalgae of Aquaculture. *In* Josianne, G. S. & Lesley, A. M. (eds.) *Live Feeds in Marine Aquaculture*, pp. 206-243. Backwell Publishing, Oxford, UK.

Bailey, D. S., Rakocy, J. E., Martine, J. M. & Shults, M. R. 2000. Intensive Production of Tilapia Fingerlings in a Recirculating System. *In* Fitzsimmons, K. & J. C. Filho (eds.) Tilapia Culture in 21 Century. *Proceedings from the Fifth international symposium on Tilapia aquaculture*, pp. 328-333. Rio de Janeiro, Brazil. American Tilapia Association, Charles Town, West Wirginia, and ICLARM, Penang, Malaysia.

Bowen, S. H. 1982. Feeding, Digestion and Growth-qualitative Conderations. *In* Pullin, R. V. S. & Lowe-McConnell, R. H. (eds.) *The Biology and Culture of Tilapias*, pp.141-156. ICMLARM Conference Proceedings No. 7.

Burune, D. E., Schearts, G., Eversole, A. G., Collier, J. A. & Schwedler, T. E. 2004. Partitioned Aquaculture Systems. Southern Regional Aquaculture Center, SRAC Publication No. 4500.

Caulton, M. C. 1976. The Importance of Pre-digestive Food Preparation to *Tilapia rendalli* Boulenger When Feeding on Aquatic Macrophytes. *Transaction of Rhodesian Scientific Association* **57**: 22-28.

Chervinski, J. 1982. Environmental Physiology of Tilapias. *In* Pullin, R. V. S. & Lowe-McConnell, R. H. (eds.) The Biology and Culture of Tilapias. *ICMLARM Conference Proceedings* 7, pp. 119-128, ICLARM, Manila, Philippines.

Chlorella Co. Ltd. Accessed, 26.8.2011, Products information for Aquaculture, Home Page Address: http://www.chlorella.co.jp/products/suisan.html (in Japanese)

Coward, K. & Bromage, N. R. 2000. Reproductive Physiology of Female Tilapia Broodstock. *Reviews in fish biology and fisheries* **10**: 1-25

De Silva, S. S., Gunasekera, R. M. & Keembiyahetty, C. 1986. Optimum Ration and Feeding Frequency in *Oreochromis niloticus* Young. *In* Mclean, J. L., Dizon, L/B. & Hosillos, L. V. (eds.) *Proceedings of the First Asian Fisheries Forum*. pp. 559-564. Asian Fisheries Society, Manila, Philippines.

Eguchi, M. & Yoshikawa, T. 2008. Culturing Environment of Farm. *In* Sugita, M. (ed.) *Feed and Water for Aquaculture –Backyard Star in Production-*. pp105. Kouseisya kouseikaku (in Japanese).

El-Sayed, A. –F. M. 2002. Effects of Stocking Density and Feeding Revels on Growth and Feeding Efficiency of Nile Tilapia, *Oreochromis niloticus* Fry. *Aquaculture Research* **33**: 621-626.

El-Sayed, A. –F. M. 2006a. Current State and Future Potential. *In* El-Sayed, A. –F. M. (ed.) *Tilapia Culture*. pp1-3. CABI Publishing.

El-Sayed, A. –F. M. 2006b. Environmental Requirements. *In* El-Sayed, A. –F. M. (ed.) *Tilapia Culture*. Pp34-46. CABI Publishing.

El-Sayed, A. –F. M. 2006c. Semi-intensive Culture. *In* El-Sayed, A. –F. M. (ed.) *Tilapia Culture*. pp47-69. CABI Publishing.

El-Sayed, A. –F. M. 2006d. Intensive Culture. *In* El-Sayed, A. –F. M. (ed.) *Tilapia Culture*. pp70-94. CABI Publishing.

El-Sayed, A. –F. M. 2006e. Nutrition and Feeding. *In* El-Sayed, A. –F. M. (ed.) *Tilapia Culture*. pp95-111. CABI Publishing.

El-Sayed, A. –F. M. 2006f. Reproduction and Seed Production. *In* El-Sayed, A. –F. M. (ed.) *Tilapia Culture*. pp112-138. CABI Publishing.

El-Sheekh, M. M. & Fathy, A. A. 2009. Variation of Some Nutritional Constituents and Fatty Acid Profiles of *Chlorella vulgaris* Beijerinck Grown under Auto and Heterotrophic Conditions. *International Journal Botany* **5**: 153-159.

Endo, M. & Takeuchi, T. 2004. Reduction of Nutrient in Fish Culture Waste by using Green-algae, *Senedisumus* sp. *Eco-Engineering* **16 (3)**: 195-201.

Esther, L. & Odi, Z. 2006. Production and nutritional value of rotifers. *In* Josianne, G. S. and L. A. McEvoy (eds.) *Live Feeds in Marine Aquaculture*. Pp43, Blackwell Science.

FAO (Food and Agriculture Organization of the United Nations). 2004. Fishstat Plus. FAO, Rome.

Foss, A., Imaland, A. K., Roth, B., Schram, E. & Stefansson, S. O. 2007. Interactive Effects of Oxygen Saturation and Ammonia on Growth and Blood Physiology in Juvenile Turbot. *Aquaculture* **271**: 244-251.

Getachew, T. 1987. A Study of an Herbivorous Fish, *Oreochromis niloticus* L., Diet and its Quality in two Ethiopian Rift Valley lakes, Awasa and Zwai. *Journal of Fish Biology* **30**: 439–449.

Gonzales, Jr. J. M., Hutson, A. H., Rosinski, M. E., Wu, Y. V., Powless, T. F. & Brown, P. B. 2007. Evaluation of Fish Meal-free diets for first feeding Nile tilapia, *Oreochromis niloticus*. *Journal of applied aquaculture* **19 (3)**. Available online at http://jaa.haworthpress.com

Grover, J. J., Olla, B. L., O'Brien, M. & Wicklund, R. I. 1989. Food Habits of Florida Red Tilapia Fry in Matured Seawater Pools in the Bahamas. Progressive Fish Culturist **51**: 152-156.

Guiry, M. D. & Guiry, G. M. 2008. AlgaeBase. *World-wide electronic publication, National University of Ireland.* Available online at http://www.algaebase.org

Hagiwara, A. 2008. Zooplankton as live foods for fish larvae. *In* Sugita, M. (ed.) Feed and Water for Aquaculture –Backyard Star in Production-. pp.59-80 Kouseisya kouseikaku (in Japanese).

Hofer, S. C. & Watts, S. A. 2002. Cold Tolerance in Genetically Male Tilapia (GMT registered), *Oreochromis niloticus. World Aquacultrue* **33 (2)**: 19-21.

Hotos, G. N. 2003. Growth, Filtration and Ingestion Rate of the Rotifer *Brachionus plicatilis* Fed with Large, *Asteromonas gracilis* and Lmall, *Chlorella* sp. Celled Algal Species. *Aquaculture Research*: 793-802.

Huang, W. –B. & Chiu, T. –S. 1997. Effects of Stocking Density on Survival, Growth, Size Variation, and Productivity of Tilapia Fry. *Aquaculture Research* **28**: 165-173.

Kaufman, L. and Liem, K. F. 1982. Fishes of the Suborder Labroide (Pesces: Perciformes): Phylogeny. *Ecology and Evolutionary Significance.* Breviora 472: 1-19

Ken, S. 2003. Ken Schultes's Fild Guide to Freshwater Fish, John Wiley and Sons, ISBN 0471449946, 9780471449942, United States of America, P21

Kreger, D. R. 1962. Cell wall. *In* Lewin, B. J. D. (ed.), *Physiology and Biochemistry of Algae.* pp. 315– 336. Academic Press, New York.

Lu, J., & Takeuchi, T. 2002. Taste of Tilapia *Oreochromis niloticus* Fed Solely on Raw *Spirulina. Fisheries Science* **68**: 987–988.

Magid, A. M. A. & Babiker, M. M. 1975. Oxygen Consumption and Respiratory Behaviour of Three Nile Tishes. *Hydrobiologia* **46**: 359-367.

Martin, J. 2009. Greenwater Tank Culture of Tilapia. *In* Aquaponic Journal, The Voice of the Aquaponic Industry, Nelson and Pade, Inc., Available Online at http://www.aquaponicsjournal.com/articlegreenwater.htm

Maruyama, I., Nakao, T., Shigeno, I., Ando, Y. & Hirayama, K. 1997. Application of Unicellular Algae *Chlorella vulgaris* for the Mass- culture of Marine Rotifer *Branchionus. In* Hagiwara, A., Snell, T. W., Lubzns, E. & Tamaru, C. S. (eds.), *Live Food in Marine Larviculture.* Kluwer Hydrobiologia 358: 133-138. Academic Publishers.

Matsubara, H. & Senoo, S. 2007. Effects of Different Body Weights of Tilapia, *Oreochromis niroticus* for *Chlorella* Production, Abstract of Seminar and Workshop on Aquaculture Biotechnology -Prospects for Blue Revolution-

Matsubara, H. & Senoo, S. 2008. Effects of Different Body Weights of Tilapia, *Oreochromis niroticus* for *Chlorella* Production, Abstract of 5th World Fisheries Congress

McDonald, M. E. 1987. Interaction between a Phytoplanktivorous Fish, *Oreochromis niloticus* and two Unialgal Forage Population. *Environmental Biology* Fisheries **18**: 229–234.

Meyer-Burgdorff, K., Osman, M. F. & Funther, K. D. 1989. Energy Metabolisum in *Oreochromis niloticus. Aquacutlure* **79**: 283-291.

Mok, W. J. 2006. Mass Production of Rotifer using Self-production Concentrated *Nannochloropsis* sp., Universiti Malaysia Sabah (Master thesis).

Morgan, P. R. 1972. Causes of Mortality in the Endemic Tilapia of Lake Chilwa (Malawi). *Hydrobiologia* **40**: 101-119.

Muir, J. F., Van Rijn, J. & Hargreaves, J. 2000. Production in Intensive and Recycle Systems. *In* Beveridge, M. C. M. & McAndrew, B. J. (eds) *Tilapia.* pp.405-445. Biology and exploitation, Kluwer Academic Publishers.

Naas, K. E., Naess, T. & Harboe, T. 1992. Enhanced First Feeding of Halibut Larvae (*Hippoglossus hippoglossus*) in Green Water. *Aquaculture* **105**: 143-156.

Nakase, G., Nakagawa, Y., Miyashita, S., Nasu, T., Senoo, S., Matsubara, H. & Eguchi, M. 2007. Association between *Bacterial* Community Structures and Mortality of Fish Larvae in Intensive Rearing Systems. *Fisheries Science* **73**: 784-791.

Okauchi, M. 2008. Microalgae. *In* Sugita, M. (ed.) Feed and Water for Aquaculture – Backyard Star in Production-. pp.40-58. Kouseisya kouseikaku (in Japanese).

Philippart, J. C. L. & Ruwet, J. C. L. 1982. Ecology and Distribution of Tilapia. *In* Pullin, R. V. S. & Lowe-McConnell, R. H. (eds.) *The Iiology and Culture of Tilapias.* pp.15-59. ICMLARM Conference Proceedings No. 7.

Rana, K. J. 1990. Reproductive Biology and the Hatchery Rearing of Tilapia Eggs and Fry. *In* Muir, J. F. & Roberts, R. J. (eds.) *Recent Advances in Aquaculture.* pp.343-406. Croom Helm, London and Caberra.

Senoo, S. 2007. Rotifer Culture for Fish Larval Rearing-1. *In* Fish Culture in Southeast Asia, *Aquanet* **66 (4)**: 44-45 (in Japanese).

Siddiqui, A. Q., Al-Harbi, A. H. & Al-Hafedh, Y. S. 1997. Effects of Stocking Density on Patterns of Reproduction and Growth of Hybrid Tilapia in Concrete Tanks in Saudi Arabia. *Asian Fisheries Science* **10**: 41-49.

Suresh, A. V. & Lin, C. K. 1992. Tilapia Culture in Saline Waters: a review. *Aquaculture* **106**: 201-206.

Tamaru, C. S., Murashige, R. & Lee, C. S. 1994. The Paradox of using Back Ground Phytoplankton during the Larval Culture of Striped Mullet, *Mugil cephalus. Aquacutlure* **119**: 167-174.

Trewavas, E. 1982. Taxonomy and Speciation. The Biology and Culture of *Tilapias. In* Pullin, R. V. S. & Lowe-McConnell, R. H. (eds.) *Tilapia.* pp.3-13. ICLARM Conference Proceedings No. 7.

Tsadic, C. G. & Kutty, M. N. 1987. Influence of Ambient Oxygen on Feeding and Growth of the Tilapia, *Oreochromis niloticus.* UNDO/FAO/NIOMR, Port Harcourt, Nigeria, 13pp.

Tuker, H., Eversole, G. & Brune, D. E. 2003. Filtration of Green Algae and Cyanobacteria by Nile tilapia, *Oreochromis niloticus,* in the Partitioned Aquaculture System. *Aquaculture* **215**: 93-101.

Turnbull, J., North, B. & Knowles, T. 2006. Project-stocking Density. *In* LINK Aquaculture Sal 18 and Dafra AW 1203. *Fishwelfare.* Available online at http://www.fishwelfare.net/projects/stocking-density.php

Turner, G. F. & Robinson, R. L. 2000. Reproductive Biology, Mating Systems and Parental Care. *In* Beveridge, M. C. M. & McAndrew, B. J. (eds.) *Tilapia Biology and Exploitation.* pp.33-58. Kluwer Academic Publishers.

Yada, Y. 1982. Study on the Feeding Habit of *Oreochromis nilotica*: I. The Change in Feeding Habit of *Oreochromis nilotica* in Feeding and no Feeding Pond. *Suisanzoshoku* **29**: 229–233.

Yoshimatsu, K., Hagiwara, A., Yoshimatsu, T. & Kitagima, C. 1996. Culture Technology of Marine Rotifers and Implication for Intensive Culture of Marine Fish in Japan. *Journal of Marine and Freshwater Research* **47**: 217-222.

Yoshiwara, K., Usuki, K., Yoshimatu, T., Kitajima, C. & Hagiwara, A. 1997. Recent Developments of a High Density Mass Culture System for the Rotifer *Branchionus rotundiformis,* Tschugunoff, *Hydorobiologia* **358**: 139-144.

Wangead, C., Greater, A. & Tansakul, R. 1988. Effects of Acid Water on Survival and Growth Rate of Nile Tilapia, *Oreochromis niloticus. In* Pullin, R. S. V., Bhulaswan, T., Tonguthai, K. & Maclean, J. L. (eds.) *Proceedings of the second international symposium on Tilapia in Aquacultur.* pp.433-438. ICLARM Conference Proceedings No. 15.

Watanabe, W. O., Ellingson, L. J., Wicklund, R. I. & Olla, B. L. 1988. The Effects of Salinity of Growth, Food Consumption and Conversion in Juvenile, Monosex Male Florida Red Tilapia. *In* Pullin, R. S. V., Bhulaswan, T., Tonguthai, K. & Maclean, J. L. (eds.) *Proceedings of the second international symposium on Tilapia in Aquacultur.* pp. 515-523. ICLARM Conference Proceedings No. 15

Watanabe, W. O., Cleark, J. H., Dunhkam, J. B., Wicklund, R. I. & Olla, B. L. 1990. Culture of Florida Red Tilapia in Marine Cages: Effects of Stocking and Dietary Protein on Growth. *Aquaculture* **90**: 123-134.

Watanabe, W. O., Ernst, D. H., Chasar, M. P., Wicklund, R. I. & Olla, B. L. 1993. The Effects of Temperature and Salinity on Growth and Feed Utilization of Juvenile, Sex Reversed Male Florida Red Tilapia Cultured in a Recirculating System. *Aquaculture* **112**: 309-320.