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MORPHOLOGICAL DEVELOPMENT OF HILSA SHAD [Tenualosa ilisha (F. HAMILTON, 1822)] LARVAE FROM MEGHNA ESTUARY, BANGLADESH

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By

MD. GOLAM SAJED RIAR

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfillment of the Requirement for the Degree of Master of Science

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DEDICATION

To my wife, Nur- A- Raushon and my beloved son, Zayan Ibn Sajed who sacrificed their golden time for my study abroad. And my mother, Shahida Mostafa who always keep praying for me day and night to achieve my goal

and

To all my friends, teacher and colleague who supported me all those past years

Abstract of thesis was presented to the Senate of Universiti Putra Malaysia in fulfillment of the requirement for the degree of Master of Science

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Chairman: Prof. Aziz Arshad, PhD
Faculty: Agriculture

Hilsa shad (*Tenualosa ilisha*) locally familiar as ilish or hilsa is a national fish of Bangladesh. Despite its popularity, many biological aspects of this fish are still unknown. Morphometric characteristics, mouth and gut morphological development are the important factors to be identify the fish larvae and informs us the type of foods taken as well as its feeding range. In larval fish, the food size and types is closely related with the mouth and gut morphology. So far, there was limited information available on hilsa larvae identification and no information available on larval mouth and gut morphology of Hilsa shad, which are the limiting factor for its own larvae culture and rearing. Therefore, this study was conducted to identify the hilsa larvae based on its morphomeristic characteristics and observe the morphological changes of mouth and gut during different larval stages of *T. ilisha.* Methodology of this study was different from other larval study. For this study larvae was collected by sampling from the wild breeding and nursing ground, not from hatchery breeding. Weekly sampling was performed to collect the sample from Meghna estuary, Bangladesh between August 2016 and January 2017. Collected samples were preserved in 5% formalin and transported to the laboratory. Morphological characteristics of the larvae and the mouth and gut morphology of larvae and early juvenile stages were examined using Keyence Digital Microscope (VHX-500). Larvae of *T. ilisha* were characterized by their distinguished elongated body, moderately high numbers of myomere; small to moderate mouth, short-based dorsal and anal fin (never overlaps the anal fins). The body depth increased more than body length at metamorphosis stage (larvae to juveniles). The smallest mouth size was found at 45^{o} mouth gap while largest found was at 90^{o}. It was observed that the length of lower jaw was higher than the upper jaw length. There were four larval stages observed in this experiment viz. yolk sack stage, pre flexion stage, flexion stage, post flexion. The mouth was initially closed at yolk sac stage. In pre flexion stage, the mouth gap of the larvae ranged between 177 ± 25 and 367 ± 47 µm, while in flexion stage it ranged between 241 ± 31 and 497 ± 59 µm. As for post flexion stage, it ranged between 307 ± 38 and 621 ± 74 µm and in early juvenile stage it ranged between 393 ± 61 and 788 ± 119 µm. It is revealed that there was a significant relationship between standard length (SL) and upper jaw length (R^2 = 0.941, $P < 0.05$) similarly with the lower jaw (R^2 = 0.931, $P < 0.05$). Significant relationship was also found between SL and mouth gap at 90^{o} (R^2 = 0.938, $P < 0.05$).

Digestive tract was transparent and formed a straight tube at the yolk sac stage. At pre flexion stage, the digestive tract was differentiated into mouth opening, buccopharyngeal cavity, oesophagus, stomach, intestines and rectum. Development of digestive tract was almost completed during pre flexion stage. The length of the digestive tract did increase along with the length of the body. During pre flexion stage, food particles were observed in the gut of the larvae. Gut loop was clearly observed at post flexion stage. The percentage of gut length compared with the standard length was 84.87 ± 4.87%, 85.64 ± 4.47%, 82.29 ± 6.18%, 77.99 ± 4.98%, 74.02 ± 3.27% at yolk sac, pre flexion, flexion, post flexion and juvenile stages, respectively. There was a strong linear relationship between the gut length and standard length (R^2= 0.97, $p < 0.05$). This study was a first attempt which investigated the mouth and gut morphological changes of hilsa larvae collected from the Meghna estuary, Bangladesh. Overall, these finding can be used to identify the hilsa larvae in wild and considered base line information for size and types of larval food in culture and management of *T. ilisha*.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk Ijazah Master Sains

PERKEMBANGAN MORFOLOGI LARVA TERUBOK HILSA [*Tenualosa ilisha* (F. HAMILTON, 1822)] DARIPADA MUARA MEGHNA, BANGLADESH

Oleh

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Mac 2018

Pengerusi: **Prof. Aziz Arshad, PhD**
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Terubok Hilsa (*Tenualosa ilisha*) dikenali umum sebagai 'ilish' atau 'hilsa' di Bangladesh. Kajiselidik ini dijalankan bagi memperihal mengenai morfologi luaran, perkembangan struktur mulut dan saluran pencernaan semasa pelbagai peringkat larva dan awal juvenil. Sampel larva *T. ilisha* dikumpul daripada muara Sungai Meghna di Bangladesh setiap minggu antara bulan Ogos 2016 hingga Januari 2017. Sampel yang sedia dikumpul telah dipindahkan ke Malaysia dam semua kerja makmal bekaitan projek dilakukan di Jabatan Akuakultur, Universiti Putra Malaysia. Larva *T. ilisha* dapat dicirikan dengan bentuk badannya yang memanjang, bilangan miomer dan 'vertebrae' yang sederhana tinggi, struktur mulut yang kecil hingga sederhana saiz dan tanpa gigi, sirip dorsal yang berpangkal pendek, dan sirip anal dan dorsal posterior yang tidak mertindih dengan sirip anal. Larva dan juvenil dapat dibahagikan kepada lima kumpulan iaitu larva pundi yolka (3.83 ± 0.57mm), larva pra fleksion (8.07 ± 1.83mm), larva fleksion (11.50 ±1.55mm), larva pasca fleksion (14.72 ±1.70mm) dan juvenil (18.75 ±3.02mm). Bilangan miomer dan 'vertebrae' masing-masing berada di antara julat 34 – 45 dan 40 – 46. Bagi ruji sirip, bilangan ruji sirip dorsal adalah 16 -19, ruji sirip anal 19 – 21, ruji sirip pectoral 14 – 16, ruji sirip pelvik 8 – 9 dan ruji sirip ekor adalah 21 – 23. Perkaitan di antara nilai min kedalaman badan dan panjang piawai berbeza dengan signifikan ($p < 0.05$) di kalangan peringkat larva dan juvenile. Saiz mulut terkecil didapati pada 45° jarak bukaan manakala yang terbesar adalah pada 90°. Adalah diperhatikan yang rahang bawah adalah lebih panjang daripada rahang atas. Struktur mulut pada awalnya tertutup semasa peringkat kantung yolka. Pada peringkat pre-fleksion, jarak bukaan mulut larva adalah di antara 177 ±25 dan 367 ±47 µm, manakala di peringkat fleksion ianya berjulat antara 241 ±31 dan 497 ±59 µm. Bagi peringkat pasca-fleksion dan juvenil, ianya direkod masing-masing antara 307 ±38 dan 621 ±74 µm serta 393 ±61 dan 788 ±119 µm. Adalah didapati yang terdapat perkaitan signifikan antara panjang piawai (SL) dengan panjang rahang atas ($R^2 = 0.941$, $P < 0.05$) dan juga panjang rahang bawah ($R^2 = 0.931$, $P < 0.05$). Perkaitan signifikan juga didapati di antara SL dan jarak bukaan mulut pada 90° ($R^2 = 0.938$, $P < 0.05$). Salur peecernaan kelihatan lutsinar dan membentuk seperti satu tiub lurus pada peringkat kantung yolka. Pada peringkat pre-fleksion, salur pencernaan telah dibezakan menjadi bukaan mulut, rongga bukofarinks, esofagus, perut, usus dan rectum. Perkembangan salur pencernaan hampir keseluruhan lengkap semasa peringkat pre-fleksion. Panjang

salur pencernaan bertambah mengikut pertambahan panjang badan. Semasa peringkat pre-fleksion, partikel makanan dapat diperhatikan pada bahagian dalam perut larva. Pusingan perut dapat diperhatikan jelas pada peringkat pasca-fleksion. Peratus panjang perut dibandingkan dengan panjang piawai badan adalah masing–masing 84.87 ±4.87%, 85.64 ±4.47%, 82.29 ±6.18%, 77.99 ±4.98%, 74.02 ±3.27% bagi peringkat kantung yolka, pre-fleksion, fleksion, pasca-fleksion dan juvenil. Terdapat perkaitan langsung yang tinggi di antara panjang perut dan panjang piawai ($R^2 = 0.97$, $P < 0.05$). Kajian ini merupakan cubaan pertama dalam mengkaji perubahan morfologi mulut dan perut larva hilsa yang didapati di muara sungai Meghna Bangladesh. Secara keseluruhannya, segala penemuan ini boleh digunakan bagi mengenalpasti larva ikan hilsa dan boleh dianggap sebagai data-asas bagi kultur dan pengurusan *T. ilisha*.

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I certify that a Thesis Examination Committee has met on 7 March 2018 to conduct the final examination of Md. Golam Sajed Riar on his thesis entitled "MORPHOLOGICAL DEVELOPMENT OF HILSA SHAD [*Tenualosa ilisha* (F. HAMILTON, 1822)] LARVAE FROM MEGHNA ESTUARY, BANGLADESH" in accordance with the Universities and University Colleges Act 1971 and the Constitution of the Universiti Putra Malaysia [P.U.(A) 106] 15 March 1998. The Committee recommends that the student be awarded the Master of Science.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

%	Percentage
µm	Micron
^{O}C	Degree Celsius
ACFL	Anal to caudal fin length
BD	Body depth
BFRI	Bangladesh Fisheries Research Institute
DoF	Department of Fisheries
ED	Eye diameter
FL	Flexion
GL	Gut length
HD	Head depth
HL	Head length
JV	Juvenile
LJL	Lower jaw length
MG	Mouth gap
Mm	Milliliter
PAL	Pre-anal length
PDL	Pre-dorsal length
PF	Pre flexion
PO	Post flexion
PPCL	Pre-pectoral length
PPVL	Pre-pelvic length
SL	Standard length
Tk	Taka, Currency of Bangladesh
TL	Total length
UJL	Upper jaw length
UPM	Universiti Putra Malaysia
YS	Yolk sac

CHAPTER 1

INTRODUCTION

1.1 Background of the Study

Bangladesh is blessed with rich and extensive inland and marine fisheries resources with a wide variety of indigenous and exotic fish fauna. This riverine system has tributaries flow through the country constituting a waterway of the total area about 8, 53,863ha (Bangladesh Economic Review, 2015). These water bodies are offering huge scope and potentiality for enhancing the fish production and socio-economic status of the people living in the villages.

Fisheries play a major role in the economy of agriculture based developing country like Bangladesh. The role of this sector in the country's economy is increasing day by day. The total annual fish production of Bangladesh was 3.89 million MT at 2016 (DoF, 2017). In national GDP, fisheries sector contributes 3.69% and agriculture contributes 23.12% GDP; and 2.01% of foreign exchange has been earned by exporting fisheries products (Bangladesh Economic Review, 2015). Fish supply 60% protein to the people of the nation. It is a good source of high-quality protein, thus can make an outstanding contribution to reduce the malnutrition problem of Bangladesh. Fisheries sector also plays an important role in the employment generation and poverty alleviation. About 11% of the total population directly or indirectly depends on Fisheries related business (DoF, 2014).

Fisheries in Bangladesh, falls broadly into four categories: (i) inland capture fisheries (open water), (ii) freshwater culture (close water), (iii) marine, industrial or trawl fishing, and (iv) marine artisanal or small-scale fishing. Fishing techniques are mainly categorized into traditional, artisanal and commercial. Traditional and artisanal fisheries in rivers, beels, haor and baor as well as in freshwater are primarily inshore which is developed by independent fishermen in small fishing boats using simple gear including traps, gillnets, beach seines, purse seines, dip nets, cast nets and small long lines. Most of the catch has been consumed locally either as processed or fresh. There is no effective central marketing agency in the villages. There is a wide variety of fish species are available in Bangladesh which can be categorised as follows: hilsa, carp, catfish, prawn and other species. In the inland open water system, there are 260 native species, 13 exotic fish species and 20 shrimp species was reported (Rahman, 1989). Also, there were 31 species of tortoises and turtles have been found; among them 24 species were live in fresh water system (Sarker and Sarker, 1988). In the upper Bay of Bengal, 475 species of finfish were discovered; among them about 65 species were commercially important. Further, in the upper zone, 38 species of marine prawn were discovered (Ali, 1992). Among all the fish species, the most important species is Hilsa Shad or *Tenualosa ilisha* (commonly known as Hilsa).

Hilsa, *Tenualosa ilisha* (Hamilton, 1822) is also locally called ilish and/or ellis in a different regions of Bangladesh. It is a national fish of Bangladesh as well as the most popular edible species preferred by all areas of Bangladesh. In addition, two more species of hilsa was also available in Bangladesh named *T. toli* and *Hilsa kelee* (Bhaumik, 2016). *Tenualosa ilisha* is the most popular and largest catch among all hilsa in Bangladesh (Islam, 1989). Its marine distribution extends from Iran and Iraq in the Persian Gulf to the west coast of India in the Arabian Sea and the Bay of Bengal (Pillay and Rosa, 1963). Hilsa is an anadromous fish, migrating from sea to freshwater riverine environments for spawning. It is distributed in rivers, tributaries and channels extending over 9,390 km^2 as well as in the 118,813 km^2 area of the northern Bay of Bengal (Hasan *et al*., 2013). More than 60% of the hilsa catch comes from marine sources and the total annual harvest was about 0.39 million MT; thus, the hilsa fishery alone contributes 12% of the nation's total catchment (DoF, 2017). In total, it is nearly half of the total marine catches, and about 12% of total fish production of Bangladesh which contributes 1% of the current GDP to the country. The average annual production of hilsa was 0.39 million MT, which is worth for Tk. 80,000 million (Tk. 200/kg). It has also contribution to earn the foreign exchange nearly Tk. 500 – 1,000 million/year (DoF, 2015). The peak fishing season extends from June to March, with a major peak between September and October; and the least peak is February - March (Islam, 1989). The catchment is based on artisanal and use mainly drift and gill nets that was practiced from traditional non-mechanized and mechanized wooden boats (Islam, 1989). About 460,000 fishers of 148 Upazilas (Lowest administrative unit of Bangladesh) were directly employed in hilsa fishing with an indirect employment about 2.5 million in the wider hilsa sector (trading, processing, etc.). Thus, the hilsa fishery is playing one of the most important roles in employment, foreign currency earnings and poverty eradication of the country. 50 - 60% of global hilsa catch was reported from Bangladesh, 20 - 25% from Myanmar, 15 - 20% from India and 5 - 10% from the rest of the countries *viz.,* Iraq, Kuwait, Malaysia, Thailand, and Pakistan (BOBLME, 2010). Majority catchment has been reported from Bangladesh followed by India and Myanmar (Bhaumik, 2015).

For aquaculture, hilsa spawn were collected from wild and stocked in pond, but due to poor larval management system, most of them died in the larval stage itself. For this purpose, development of a comprehensive larva culture protocol including a proper feeding management program for this fish is urgently needed.

1.2 Problem Statement

The demand of hilsa is expanding rapidly and exceeding the supply due to a steady increase in population and income. Aquaculture is the logical answer to meet that demand as wild resources which are declining due to overfishing, pollution, etc., while the cost of fishing is increasing. For the many years hilsa harvested from nature and it's increasing day by day in Bangladesh for good management practices. Now it is important to introduce hilsa in aquaculture but the technology was a failure due to lack of knowledge on larval management. Kulkarni (1950) has first reported the controlled breeding in hilsa. In Malaysia, the Sarawak Fisheries Department succeeded in artificial breeding of *T. toli.* But there was no establish protocol for hilsa breeding, still it was collected from nature. So, now it is important issue to find out a proper

identifying protocol for hilsa larvae and develop knowledge its larval feed types and range. Therefore, one of the most important factors in fish larva culture is the provision of a suitable food. In some cases, good quality feeds can also give poor results unless proper food size and types. Food size and types mostly depend on the mouth size and alimentary tract development. In the absence of adequate food, fish larvae have eventually reached a point of no return (Blaxter and Ehrich, 1974); at the point of which only 50% of larvae are still being able to feed if sufficient food is available. Even under optimum conditions, the remaining 50% are no longer capable of taking up food. Feeding of fish is strongly influenced by food particle size in relation to mouth size and gut structure of larvae. Mouth size appears to be the limiting factor in the larval feeding of both natural and artificial diets; once the prey has been located, it must be captured and the first problem to overcome is getting the food item into the mouth. Strong relationships between the mouth size and the food particle during larval stages was well documented by Blaxter and Ehrich (1974).

There was also a relationship between the structure of alimentary tract and the nature of feeding. The poor growth of some fish larvae was due to the under development of their digestive tract (Kaushik and Luquet, 1993). There may be a marked difference in the morphology and histology of the gut among fishes. However, it needs to be need clear and specific information is required to identify the hilsa larvae and find out the relationship among food with mouth gap and alimentary tract of *T. ilisha* larvae, which is necessary for the development of hilsa culture practices. So far, no comprehensive description regarding mouth and digestive tract development of *T. ilisha* have been published.

Therefore, the present study was undertaken to observe and describe the larval morphomeristic characteristic and morphological development of the mouth and alimentary tract of *T. ilisha* larvae.

1.3 Specific objectives

1. To describe the morphomeristic characteristics of *T. ilisha* larvae and early juveniles from wild
2. To observe the external mouth morphological development of *T. ilisha* until early juvenile stages.
3. To examine the alimentary tract development of *T. ilisha* larvae and early juvenile.

REFERENCES

Ali, S. 1992. Chingree: Bangladesher chingree utpadon o chasah (in Bengali) (Cultivation and production of prawn in Bangladesh). Bangla Academy: Dhaka.

Aljetlawi, A. A., Sparrevik, E. and Leonardsson, K. 2004. Prey-predator size-dependent functional response: derivation and rescaling to the real world. Journal of Animal Ecology 73, 239–252.

Avila, E. M. and Juario, J. V. 1987. Yolk and oil globule utilization and developmental morphology of the digestive tract epithelium in larval rabbitfish, *Siganus guttatus* (Bloch). *Aquaculture,* 65:319-331

Azadi, M. A. and Rahman, A. S. M. S. 2008. Morphometric and Meristic Study of *Gudusia chapra* (Ham. 1822) And *Gonialosa manmina* (Ham. 1822) (Clupeidae) From the Kaptai Lake, Bangladesh. The Chittagong Univ. J. B. Sci., Vol. 3(1 - 2):pp. 21-31.

Bangladesh Bureau of Statistics. 1991. Report of the Upazila Development Monitoring Project 1990, Vol. - II, June.

Bangladesh Economic Review. 2015. Finance Division. Ministry of Finance. Peoples Republic of Bangladesh.

Bensam, P. 1990. A synopsis of the early developmental stages of fishes of the genus *Sardinella* Valenciennes from Indian waters with keys for their identification. *Indian Journal of Fisheries* 37: 229 - 35.

Bhaumik, U. 2015. Perspectives of reproductive biology and spawning behaviour of Indian Shad (*Tenualosa ilisha*)–A global review. International Journal Current Research and Academic Review. 3(8):229-241.

Bhaumik, U. 2016. Stock Profile of Hilsa Shad Population in Bay of Bengal Region- A Review. Int. J. Curr. Res. Aca. Rev. 4(6): 22 – 38.

Blaber, S. J. M. and Mazid, M. A. 2001. Hilsa Fishery Research in Bangladesh. ACIAR Project 9430, Final Report, August 2001, 123+20 pp.

Blaxter, J.H.S. and Ehrlich, K.F. 1974. Changes in behaviour during starvation of herring and plaice larvae in the early life history of fish (ed. J.H.S. Blaxter), pp. 575-588, Springer-Verlag, Berlin.

BOBLME. 2010. Status of hilsa *(Tenualosa ilisha)* management in the Bay of Bengal, BOBLME-2010-Ecology-01

Bremigan, M. T. and Stein, R. A. 1994. Gape-dependent larval foraging and zooplankton size: implications for fish recruitment across systems. Can J Fish Aquat Sci 51:913-922.

Busch, A. 1996. Transition from endogenous to exogenous nutrition: larval size parameters determining the start of external feeding and size of prey ingested by Ruegen spring herring *Clupea harengus.* Marine Ecology Progress series. 130: 39-46.

Chen, B. N., Qin, J. G., Kumar, M. S., Hutchinson, W. and Clarke, S. 2006. Ontogenetic development of the digestive system in yellowtail kingfish *Seriola lalandi* larvae. *Aquaculture, 256*(1-4), 489-501.

Chowdhury, S.R. 1993. Study on Tidal behaviour along the coast of Bangladesh with specialemphasis on the seasonal variations in mean sea level. MSc Thesis. Institute of Marine Sciences, Chittagong University, Bangladesh.

Conides, A. J. and Glamuzina, B. 2001. Study on the early larval development and growth of red progy, *Pagrus pagrus* with emphasis on the mass mortalities observed during this phase. Sci. Mar., 65 (3): 193-200.

Crockford, T. and Johnston, I. A. 1993. Developmental changes in the composition of myofibrillar proteins in the swimming muscles of Atlantic herring. *Clupea harengus*. Mar Biol. 115:15-22.

Cushing, D. H. 1975. Marine ecology and fisheries. Cambridge University Press, Cambridge.

DoF. 2014. Department of Fisheries. Fish Catch Statistics, various issues Department of Fisheries, Government of the People's Republic of Bangladesh.

DoF. 2015. Department of Fisheries. Fish Catch Statistics, various issues Department of Fisheries, Government of the People's Republic of Bangladesh.

DoF. 2017. Department of Fisheries. Fish Catch Statistics, various issues Department of Fisheries, Government of the People's Republic of Bangladesh.

Economou, A. N.1991. Food and feeding ecology of five gadoid larvae in the northern North Sea. J Cons int Explor Mer 47.339-351.

Ferraris, R. P., Tan, J. D. and Delacruz, M. C. 1987. Development of the digestive tract of milkfish, *Chanos chanos* (Forsskal): Histology and histochemistry. *Aquaculture,* **61**:241-257.

Fraser, J. H. 1970. The ecology of the ctenophore *Pleurobrachia pileus* in Scottish waters. ICES J Cons 33:149-168.

Govoni, J. J. 1980. Morphological, histological, and functional aspects of alimentary canal and associated organ development in larval *Leioslornus xanrhurus.* Rev. Can. Biol. 39:69-80.

Hag, G. A. E., Kamarudin, M. S. Saad, C. R. and Daud, S. K. 2012a. Mouth Development of Malaysian River Catfish, *Mystus nemurus* (C and V) Larvae. Journal of American Science, 8(1); 271-276.

Hag, G. A. E., Kamarudin, M. S. Saad, C. R. and Daud, S. K. 2012b. Gut Morphology of Developing Malaysian River Catfish *Mystus Nemurus* (Cuvier and Valenciennes) Larvae. Journal of American Science, 8(2); 116-121.

Haldar, G. C. 2004. Present status of the hilsa fisheries in Bangladesh: completion report of the studies conducted under the ARDNCS, GEF Component, FFP. Report no 38.8, December 2004, Fourth Fisheries Project, Department of Fisheries, Aquatic Resources Development, Management and Conservation Studies (Global Environment Facility/World Bank), i-ix + 70 pp. 34.

Haldar, G. C. and Islam, M. S. 2008. Hilsa fisheries conservation, development and management technique. Department of Fisheries (DoF). Dhaka, Bangladesh; 1-40.

Hamilton, F. 1822. An account on the fishes found in the river Ganga and its branches. Edinburgh and London. i-vii+1-405. 1-39 pp.

Haniffa, M. A., Raj, A. J. A. and Sridhar, S. 1999. Weaning diet for Striped Murrel *Channa striatus*. Fishery technology. Vol.36 (2). Pp: 116- 119.

Hasan, M.N., Hossain, M.S., Bari, M.A. and Islam, M.R. 2013. Agricultural Land Availability in Bangladesh. Dhaka: SRDI, 42 pp.

Hasan, K.M.M., Ahmed, Z.F., Wahab, M.A. and Mohammed, E.Y. 2016. Food and feeding ecology of hilsa (*Tenualosa ilisha*) in Bangladesh's Meghna River basin. IIED Working Paper. IIED, London.

Hassan, M. A. and Macintosh, D. J. 1992. Optimum food particle size in relation to body size of common carp (*Cyprinus carpio*) fry Aquaculture and Fisheries Management 23; 315- 325.

Hepher, B. 1988. Nutrition of pond fishes. Cambridge University Press, New York. pp 1845-1874.

Hunter, J. R. 1980. The feeding behavior and ecology of marine fish larvae: fish behavior and its use in the capture and culture of fishes. ICLARM Conference Proceedings 5, 287–326.

Hyatt, K. D. 1979. Feeding strategy. In Fish physiology.pp. 77-119. London.

Islam, M.S. 1989. The life history and fishery of hilsa in Bangladesh and their implication for management. Fishbyte 7 (1): 3-4

Kaji, T., Kodama, M., Arai, H., Tagawa, M., and Tanaka, M. 2002. Precocious development of the digestive system in relation to early appearance of piscivory in striped bonito *Sarda orientalis* larvae. Fish Sci 68, 1212-1218.

Kamali, A., Kordjazi, Z. and Nazary, R. 2006. The effect of the timing of intial feeding on growth and survival of ship sturgeon (*Acipenser nudiventris*) larvae: a small-scale hatchery study.Journal of Applied Ichthyology.22 (1), 294-297.Aquaculture 109, 187-205.

Kamler, E. 1992. Early life history of fish. An energetic approach. Chapman and Hall, London, 183 pp.

Kaushik, S.J. and Luquet, P., 1993, Fish nutrition in practice, INRA, Paris.

Keast, A. and Webb, D. 1966. Mouth and body form relative to feeding ecology in the fish fauna of small lake, Lake Opinicom, Ontario. Journal of the Fisheries Research Board.

Kendall, A. W., Ahlstrom, E. H. and Moser, H. G. 1984. Early life stages of fishes and their characters. In: Ontogeny and Systematics of Fishes. Moser HG, Richards WJ, Cohen DM, Fahay MP, Kendall AW and Richardson SL, eds. Allen press, Lawrence, US, pp. 11-22.

Kulkarni, C. V. 1950. Breeding habits, eggs and the early life history of Indian Shad, *Hilsa ilisha* (Ham.), in Narbad River. Zoological Survey of India, 169-176.

Leis, J. M. and Carson-Ewart, B. M. 2000. The Larvae of Indo-Pacific Coastal Fishes: An Identification Guide to Marine Fish Larvae. Australian Museum, Sydney. 67-69 pp.

Leis, J. M. and Trnski, T. 1989. The larvae of Indo-Pacific shore fishes. New South Wales University Press, Sydney, and University of Hawaii Press, Honululu: 371 pp.

Lovell, R. T. 1989. Digestion and metabolism. In Nutrition and Feeding of Fish (Ronald, H.& Chorn,L., eds.), pp.73-80, Van Nostrand Reinhold. New York.

Mahmud, H., Mirza, A.T.M., Rahman, T., Saha, B. and Kamal, A. K. I. 2002. Status of Heavy Metals in Water and Sediment of the Meghna River, Bangladesh. *American Journal of Environmental Sciences.* 11. 6. 427-439 pp.

McGowan, M. F. and F. H. Berry. 1984. Clupeiformes: development and relationships. Pp. 108-126.

Mohanty, B. P., Paria, P., Mahanty, A., Behera, B. K., Mathew, S. and Shankar, T. V. 2012. Fatty acid profile of Indian Shad, *Tenualosa ilisha*. National Academy of Science Letter 35(4): 263–269.

Mome, M. A. 2007. The Potential of the Artisanal Hilsa Fishery in Bangladesh: An Economically Efficient Fisheries Policy. Final project, UNU, Fisheries training program.

Moteki, M., Ishikawa, T., Teraoka, N. And Fushimi, H. 2001. Transition from endogenous to exogenous nutritional sources in larval sea bream, *pagrus major*. Suisanzoshoku, 49: 323-328.

Munk, P. 1992. Foraging behaviour and prey size spectra of larval herring *Clupea harenqus*. Mar Ecol Prog Ser 80:149-158.

Munroe, T. A. 2000. An overview of the biology, ecology and fisheries of the clupeid fishes occurring in the Gulf of Main. Northeast Fisheries Science Canter reference documents 00-02.

Nakatani, K., Agostinho, A. A., Baumgartner, G., Bialetzki, A., Sanches, P. V., Makrakis, M. C. and Pavanelli, C. S. 2001. Ovos e larvas de peixex de agua doce: desenvolvimento e manual de identificacao. Maringa, Eduem, 378p.

Nizinski, M. S. and Munroe, T. A. 2002. Engraulidae, the living marine resources of the western central Atlantic. Vol. 2. Bony fishes part 1. FAO species identification guide for fishery purpose and American society of Ichthyologist and herpetologist. Species publication no. 5. FAO, Rome. 764-794.

O'Connell, C.P. 1981. Development of organ systems in the northern anchovy, *Engraulis mordux,* and other teleosts. Amer. Zool. 21: 429-446.

Park, S. J., Lee, S. G and Gwak, W. S. 2015. Ontogenetic Development of the Digestive System in Chub Mackerel *Scomber japonicus* Larvae and Juveniles. Fisheries and Aquatic Sciences, 18(3), 301-309.

Peter, C.W. 1996. Ecology explanation through functional morphology: The feeding biology of sun fishes. Ecology 77(5), 1336-1343.

Pillay, T. V. R and Rosa, H. J. 1963. Synopsis on biological data on Hilsa, *Hilsa ilisha* (Hamilton) 1882. *FAO Fisheries Biology Synopsis,* 25**,** pp. 1–6.

Rahman, A.K.A. 1989. Freshwater Fishes of Bangladesh. Zoological Society of Bangladesh. Department of Zoology, University of Dhaka. Bangladesh

Rahman, A. K. A. 2005. Freshwater fishes of Bangladesh. Zoological Society of Bangladesh, University of Dhaka, Dhaka, Bangladesh. 394 pp.

Ramezani-Fard, E., Kamarudin, M. S., Harmin, S. A. Saad, C. R. Abd Satar M. K. and. Daud, S. K. 2010. Ontogenic development of the mouth and digestive tract in larval Malaysian mahseer,*Tor tambroides* Bleeker. Journal of Applied Ichthyology, 27,920-927.

Robb, A. P. and Hislop, J. R. G. 1980. The food of five gadoid species during the pelagic O-group phase in the northern North Sea. Journal of Fish Biology 16, 199–217.

Sarker, M.S. and Sarker, N.J. 1988. Wildlife of Bangladesh – A Systematic List. Rico Printers. Dhaka.,Bangladesh

Scharf, F. S., Juanes, F. and Rountree, R. A. 2000. Predator size–prey size relationships of marine fish predators: interspecific variation and effects of ontogeny and body size on trophic-niche breadth. Marine Ecology Progress Series 208, 229–248.

Segner, H., Rösch, R., Verreth, J. and Witt, U. 1993. Larval nutritional physiology: studies with *Clarias gariepinus, Coregonus lavaretus* and *Scophthalmus maximus.* J. World Aquacult. Soc., 24: 121-139.

Severi, W. and Verani, N. F. 2006. Morphological development of Pellona flavipinnis post yolk sac larvae and juveniles (Clupeiformes: Pristigasterdae). Zootaxa, 1126: 21- 33.

Silva, A. C. G. D., Severi, W. and Maviael F. D. C. 2010. Morphological development of *Anchoviella vaillanti* (Steindachner, 1908) (Clupeiformes: Engraulidae) larvae and early juveniles. Neotropical Ichthyology, 8(4):805-812.

Swarup, K. 1959. The morphology and histology of the alimentary tract of *Hilsa ilisha* (Ham.). *Proceedings of the National Academy of Science*, India 29:109-126.

Usman, B. I., Amin, S. M. N., Arshad, A. and Kamarudin, M. S. 2016. Morphometric relations in the grey eel catfish *Plotosus canius* in the coastal waters of Port Dickson, Peninsular Malaysia. *Journal of Environmental Biology*, Vol. 37, 573-578.

Walford, J. and Lam, T. J. 1993. Development of digestive tract and proteolytic enzyme activity in seabass (*Lates calearifer*) larvae and juveniles.

Watanabe, Y. and Sawada, N. 1985. Larval development of digestive organs and intestinal absorptive functions in the freshwater goby *Chaenogobius annularis.* Bull. Tohoku Reg. Fish. Res. Lab. 47: 1-10.

Wikipedia. 2017. Hilsa. [26 November, 2007] < http://en.wikipedia.org/wiki/Hilsa>

Zar, J.H. 1974. Biostatistical Analsis. Prentice-Hall International, Inc.,London.