

Review Paper

THE FRESHWATER MUD EEL, *MONOPTERUS CUCHIA* – A REVIEW

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Abstract

The freshwater mud eel *Monopterusuchia* is a tasteful, nutritionally rich and medicinally valuable fish with high export demands which can play a unique role for socio-economic welfare of the area. This fish was rich in nature of Bangladesh, however, the populations of the freshwater eel are declining at an alarming rate from the natural water bodies due to several reasons specially for overfishing while increasing the population of this fish completely depends on natural reproduction, and thus this fish are recorded as rare species in Bangladeshi habitats. Due to its high market demands and this fish is now a red listed species in Bangladesh, so, different steps should be taken for conserving this fish. As no positive responds of this fish with artificial breeding for seed production it is necessary to learn more about its life history in details. Therefore, this review was made considering its distribution, populations, taxonomy, habit and habitats, morphology, physiology, biology including reproduction strategies, genetics and molecular biology, biochemical compositions, toxicological observations, health concern, culture practice, capture fishery, consumable status in Bangladesh, marketing and business as well as socio-economic conditions of this freshwater mud eel in Bangladesh. This review is considered from the literature review of the PhD work of first author.

Key words: *Monopterusuchia*, Life History, Ecology, Diseases, Fisheries, Socio-economy.

INTRODUCTION

The freshwater mud eel, *Monopterusuchia* (Figure 1) is leading amphibious life and found in plenty commonly in stagnant waters in mud-holes in shallow beels and boro-paddy fields with low oxygen content throughout the country of Bangladesh [1]. The mud eel (*M. cuchia*) is a carnivorous and nocturnal prefers animal based food like small fishes, mollusks and worms etc. This fish is very tasty, nutritionally rich with medicinal

value and highly priced in foreign markets. This fish thrive on the small fishes, prawns, molluscs, aquatic insects, small frogs, etc. [2]. This fish can play a unique role for socio-economic welfare of the area and thus social fishery could be developed [3]. Although, this fish have quite a large economic demand, the populations of this freshwater eel are declining at an alarming rate from the natural water bodies due to several reasons specially for overfishing while population increase completely depends on natural reproduction [2, 4], and thus, this fish are recorded as rare species in Bangladeshi nature [5]. In addition, no culture system is developed in Bangladesh [3] and unsuccessful artificial breeding was observed through inducing agents [6]. Due to the risk of this fish in Bangladesh it is more necessary to conserve. Thus, this review is important to know about the fish in details to find out the specific reason which will be contributed for artificial breeding, higher production, diseases resistance and conservation strategy etc.



Figure 1. External feature of the freshwater mud eel, *Monopterus albus*

DISTRIBUTION OF THE FRESHWATER MUD EEL

The freshwater mud eel *M. albus* is distributed in Bangladesh, India (Northern and Northeastern), Pakistan, Nepal and Myanmar etc. [7].

CONSERVATION STATUS OF THE FRESHWATER MUD EEL

This fish is now vulnerable in Bangladesh due to loss of habitats, changes in habitats and overexploitation [5].

TAXONOMY OF THE FRESHWATER MUD EEL

The freshwater mud eel, *Monopterus albus* [8], belongs to the family synbranchidae of the order synbranchiformes [9, 10]. It has some synonyms such as *Amphipnous albus* [8], *Pneumabranchnus albinus* [11], *Pneumabranchnus leprosus* [11], *Pneumabranchnus striatus* [11] and *Unibranchapertura albus* [8], etc. It is commonly known as Cuchia, Rice eel or Swamp eel etc. Though former researchers identifies this fish morphologically, however, recently molecular based identification is mostly used for

authentication and this fish is already identified through molecular basis by using mtDNA and glutamine synthetase gene [12].

Scientific classification of *Monopterusuchia*

Kingdom: Animalia

Phylum: Chordata

Sub-Phylum: Vertebrata

Class: Osteichthyes

Infraclass: Actinopterygii

Order: Synbranchiformes

Family: Synbranchidae

Genus: *Monopterus*

Species: *M.uchia*

Taxonomic formula of this fish was designed where B= VI, D=very rudimentary, P1. P2. A. and C= absent [1, 5, 13, 14, 15]. Maximum Length of this fish was recorded 20cm, [13], 66cm [1, 15], 60cm [5, 7] and 82cm [16].

HABIT AND HABITAT OF THE FRESHWATER MUD EEL

The habitat of this fish is freshwater and brackish water and found in shallow, well vegetated water and mud [5]. They are inhabits plenty in mud holes in shallow beels and boro paddy field throughout the Bangladesh especially Sylhet, Mymensing, and Tangail regions [1, 13, 15]. However, recently this fish was also recorded from Chalan beel, Bangladesh [16]. Shafi and Quddus [14] stated that this fish live in ponds, canals, rivers, beel, baor shallow water comparatively rich with aquatic plants. Also found in flooded rice fields. They can live in holes without water by the help of respiratory organs. Some fishery scientist says that they pass entire summer in hole, but sometimes coming out from the hole to take oxygen. Most of the time in hole of water their mouth position is kept straight upper position and return into the hole completely when found any enemy.

The fish *M.uchia* is common in freshwater and likes muddy environments. They often spend their daytime hiding under stones and mud or having a burrowing habit [17]. This fish resides in the mud holes in the shallow beels along with the dykes of paddy field, pits and swamps during the winter season. The freshwater mud eel, *M.uchia* is also an evasive nocturnal animal. This fish has versatile motility and is even capable of moving over dry land for short distances. This behavior is used for relocation according to resource availability. In the absence of water and food, this Asian swamp eel is able to survive long periods of drought by burrowing in moist earth [18]. If its home becomes unsuitable, *M.uchia* simply crawls ashore and make its way to a more suitable home by slithering over the land in a snake-like fashion. These characteristics enhance the ability of *M.uchia* to disperse widely. Like other eels, freshwater mud eel provide various values for the ecosystem and for the human beings. The unique adaptation that allows mud eel to be successful in their environments, primarily for wedging through small openings, while some are adapted to burrowing into soft substrates or living a pelagic existence [19].

MORPHOLOGY OF THE FRESHWATER MUD EEL

The body of the freshwater mud eel, *M.uchia* is a slender shaped streamline with a tapering tail [20]. They do not have pectoral, pelvic and dorsal fin. The dorsal and anal

fins are fused with caudal or tail fins forming a single ribbon along the whole length of the fish. The gills of *M. cuchia* are reduced and the fish has a pair of air breathing organ in the form of a sac on two sides of the head [7]. A pair of supra branchial chambers are present and each contain a complicated labyrinthine organ [21]. The pharyngeal pouches starts developing at an early stage but become functional quite late in its life history [22]. The main feature of the body is slimy. According to the Shafi and Quddus [14], elongated and cylindrical body form caudal at the posterior part with sequentially narrow. Ventral fins are reduced, sometimes skin folds are seen. Only gill openings are situated antero-lateral part of the body. Anus is posteriorly situated than normal position. Barble is absent however rib and one row of palatine teeth are present. Gill filaments are distributed up to isthmus. Wety and slippery skin are found. Very small, round and indistinct scales longitudinally arranged. Body color is deep brown whereas abdominal part is comparatively opaque. Eyes are small, head not conspicuous, gill-opening crescentic of which gills greatly reduces. A pair of suprabranchial pouces (respiratory organ) is large. The structure of the air-breathing organs were observed by the examination with light, scanning and transmission electron microscopy and the morphological basis for buccopharyngeal, aerial as well as aquatic respiration while respiratory islets were found well distributed over the surface of the buccopharynx, hypopharynx and branchial arches extending deep into the gill clefts but occupy only the anterior two-thirds of the air sacs, the remaining posterior one-third part seems to be non-respiratory in function and may serve as a reservoir for residual air [10, 23]. Munshi *et al.* also found that arterioles penetrate deep into the epithelial region of air sacs and buccopharynx in spiral-like fashion to form the characteristic vascular papillae of the respiratory islets [10].

PHYSIOLOGY OF THE FRESHWATER MUD EEL

Some exceptional physiological activities particularly respiratory adaptations were observed in *M. cuchia* [24, 25] where areas of the air-breathing surface of *Amphipnous cuchia* were indicated [26]. The gills of *M. cuchia* are reduced and the fish has a pair of air breathing organ in the form of a sac on two sides of the head [7]. The species has dual systems of oxygen uptake for respiration: aquatic respiration by uptaking dissolved oxygen through the gills and aerial respiration by uptaking air directly through the skin [27]. These mechanisms enable it to survive in oxygen-depleted conditions or in areas where water is scarce. Aerial respiration performed by the fish with the aid of a pair of supra branchial chambers each containing a complicated labyrinth organ [21]. The pharyngeal pouches starts developing at an early stage but become functional quite late in its life history [22]. For this special modification, this fish can survive 90 to 132 days without water and food burrowing in moist earth [18] and can be stored large number in a small sample container as well as transported in live in a small earthenware or plastic jar to distant places [28]. This fish release excessive body slime for escaping from the predators. The freshwater mud eel, *M. cuchia* has versatile motility and is even capable of moving over dry land for short distances.

BIOLOGY OF THE FRESHWATER MUD EEL

Population biology of the freshwater mud eel, *M. cuchia* was studied [29] and this fish is observed as a voracious general predator that feed during the night on small fish, amphibians, crustaceans, echinoderms, insect larvae, aquatic invertebrates etc. The natural foods such as fish fingerlings, earthworms, tubifex, snails, aquatic insects, insects pupae, slaughter house waste (liver, intestine, viscera, skin of livestock animals)

etc. were recorded. The fish *M. cuchia* showed significantly highest growth rate in terms of increase in weight with receiving dead small fish as feed and lowest growth was recorded in fed with pellet feed [4]. The growth rate might be associated with the size of fingerlings stocked, quality of feed supplied, culture period and season. The survival rate of fish with different food items ranged from 80 ± 10.0 to 94 ± 6.0 [4]. The length-weight relationship and relative condition factor (Kn) of this fish were observed and the relationships were found significantly at 0.1% level indicating isometric growth pattern [30]. Relative condition factor was found to be high during the monsoon months (spawning period) from April -June reflecting the maturity of the fish. First maturity was found to attain at 25.2 cm in total length. The length-weight relationship and condition factor showed that the growth of *M. cuchia* is quite satisfactory. The effect of different feeds and shelters on growth, survival and production of this freshwater mud eel, *M. cuchia* were also observed in the cemented sisterns considering different feeds where they found better growth, survival rate and production through the supply of dead small fish [31, 32]. On the basis of survival rate and production, they were also suggested that the water hyacinth is suitable shelter for the culture of *M. cuchia* in the cemented sisterns. However, it was found the best growth and survival of this fish in a cemented tank with live food (Fish fry and earthworms) as well as in earthen ditches with supplement food than other tanks where dead fish was supplied (part of the PhD research of first author in 2013).

REPRODUCTION AND BREEDING OF THE FRESHWATER MUD EEL

Taxonomically the freshwater mud eel, *M. cuchia* was identified by the study of some important morphometric characteristics. Identification of male or female fish is so difficult but some external characteristics are helpful to observe sexual differentiation during breeding season. It was recorded that the mature female was larger than male fish and the abdomen of female fish is swollen and brownish in colour with rough abdominal skin [12]. Anus and genital pore was observed as tubular in male and round shape in female. Internally, single gonad of both sexes comprised of a white, smooth, ribbon-like structure extending longitudinally below the gut and above the kidney for the entire length of the abdominal cavity [12]. In male two equal, very thin, narrow and long sperm ducts were observed which is extended from anus to liver. However, single tubular oviduct was found in female with eggs from urinogenital opening to anterior part of the gall bladder. In an average 600 round eggs were found in the experimental females and the egg size was ranged between 0.1mm to 0.7 mm in diameter. Histologically, the testis and ovary was also studied and easily separated from male to female [12].

M. cuchia is a rare species of air breathing teleostean fish in Bangladesh and India with spawning period confined down to peak summer and this fish lays its eggs in especially prepared nest-holes and keeps a guard on the developing young ones [33, 34]. The yolk reserve persists till about 22 to 24 days of development and larvae respond to direct feeding even before yolk-absorption where the young ones feed actively on chironomus larvae [33]. Surface breaking habit for aerial respiration apparently commences around 15th–16th day of larval life and adult characters are almost attained in about a month's time [33]. In the case, the fish shows obligate sedentary nature because of the persisting heavy yolk mass would not permit an easy drift during the course of heavy floods. It is, therefore, a safe ecological adjustment for *M. cuchia* to spawn in the peak of summer with its nest-hole built just near the sub-surface level of the water [35]. Low dissolved oxygen in the water, a possible disadvantage of the summer breeding, is adequately met

in this species by the relatively large yolk mass, rich in carotene as indicated by its deep orange-yellow hue, yolk with such characteristics is known to be involved in respiratory functions. High vascularization of the body surface of the young ones of *M. cuchia*, particularly on its finfolds and yolk sac, indicates well developed skin respiration [26]. This explains the tendency of the parent fish to keep the brood in an amphibian environment.

Artificial propagation of eels has long been attempted not only to address fundamental questions on the reproductive biology of this fish, but also from a fisheries management and eel aquaculture perspective. Increasing fishing pressures on this eel has led to reduce recruitment of juveniles, limiting the industry and potentially leading to ecological impacts. However, captive breeding of this fish has not yet been achieved. Sexual development in freshwater eels is halted when this fish is held in captivity [36], but this arrest can be overridden by hormonal treatment. Though reproductive biology this fish has been described in terms of sex dimorphism, gonadosomatic index, ova diameter and fecundity while peaks of Gonadosomatic Index (GSI) recorded during April to June for female (7.52 ± 1.15) and male (5.50 ± 1.25) indicated that the fish has only one breeding season during summer [37] where the ova diameter from 0.30 mm to 4.0 mm and the number of ova per gram body weight were found 4.61 and the number of ova present per gram of ovary weight was recorded 74.27. Recently the reproductive biology and gonad histology of freshwater mud eel *M. cuchia* was also performed considering gonadosomatic Index (GSI) and ova diameter, fecundity, vitellogenesis and this study may contribute to have successful breeding program and seed production technology of this fish species in captivity [38]. Mass seed production and conservation of the available populations through proper management of the populations is recommended to save this threatened species from extinction, though practically no work either in private level or government or institutional level so far been done in Bangladesh on the artificial breeding of this fish [3].

POPULATION STATUS OF THE FRESHWATER MUD EEL IN BANGLADESH

The freshwater habitat of Bangladesh is very suitable for living this fish and the population of this fish is very high. But due to this fish have quite a large economic demand the populations of the freshwater eel are declining at an alarming rate from the natural water bodies due to water obstruction, habitat destruction, pollution, excessive use of pesticides, industrial flow, over exploitation and destructive fishing etc. [2]. The freshwater mud eel is recorded as rare species from floodplains and beels due to attack by several diseases [39].

GENETICS AND MOLECULAR BIOLOGY OF THE FRESHWATER MUD EEL

Very limited research regarding genetics and molecular biology has been performed of this freshwater mud eel in Bangladesh as well as in other countries. Although some works have so far been done on this fish, however, no researches were carried out on genetic biotechnology or population genetic structure of this fish, while only DNA fingerprinting were observed in narrow sense using RAPD marker in China [40] and Bangladesh [41, 42]. Different eels were identified by RFLP using mitochondrial DNA [43], but molecular identification and genetic characterization were not available for this species, only mtDNA and glutamine synthetase gene were used for first time identification [12]. As this fish is vulnerable in Bangladesh, it is required to maintain high level of biodiversity to develop natural and artificial breeding, and to increase high production. Glutamine synthetase (GS) is an enzyme that plays an important role in the metabolism of nitrogen by catalyzing the condensation of glutamate and ammonia to form glutamine [44]. Due to the key role of GS in detoxifying ammonia, particularly in

the brain, and in ammonia excretion in the kidney in fish, therefore, this gene of freshwater mud eel was sequenced [45]. On the other hand, comparative mitochondrial DNA sequence and amino acid analysis of the cytochrome C oxidase subunit I (COI) from two eel species, *M. cuchia* and *M. albus* were also studied [46]. Fishing and aquaculture activities pose potential threats to genetic diversity of wild fish populations in different ways. For instance, over-exploitation may reduce population sizes to levels where inbreeding and loss of genetic diversity through random events become serious problems, or may result in extinction of local populations or population segments. In recent years, this species has been declining over much of its range and therefore, careful monitoring and molecular genetic research will be vital to its survival and conservation.

BIOCHEMICAL COMPOSITIONS OF THE FRESHWATER MUD EEL

Though biochemical and nutritional components of the freshwater mud eel were not recorded strongly, however, it was recorded that different eels including *M. cuchia* contain high nutritional compounds (Table 1). The average protein content per 100g of eel flesh is 14g and the caloric value of eel flesh is as high as 303 Kcal/100g compared to 110 Kcal/100g in other average fishes [17]. Besides, the freshwater mud eel *M. cuchia* has medicinal value and some ethnic tribal group use the fish for few diseases. Some haematological parameters of this freshwater mud eel including haemoglobin concentrations, haematocrit values, red blood cell counts, red blood cell diameter, erythrocyte sedimentation rate and plasma haemoglobin concentration have been measured [47].

Table 1: Nutritional elements in different eels

Nutrients	Amounts	Nutrients	Amounts
Minerals		Vitamins	
Selenium	13.3mcg	Choline	133 mg
Manganese	0.1mg	Pantothenic Acid	0.1 mg
Zinc	3.3mg	VitaminB12	6.1 mcg
Sodium	104mg	Folate	30.6 mcg
Potassium	555mg	Vitamin B6	0.1 mg
Phosphorus	441mg	Niacin	7.1mg
Magnesium	40.8mg	Riboflavin	0.1mg
Iron	1.0mg	Vitamin E	8.2mg
Calcium	40.8mg	Vitamin C	3.7mg
Fatty acids		Other components	
Total omega -6 fatty acids	400mg	Ash	2.9mg
Total omega -3 fatty acids	1332mg	Water	139mg
Poly unsaturated Fat	1.9g	Proteins	38mg
Monounsaturated Fat	14.7g	Sodium	104mg
Saturated Fat	4.8g	Cholesterol	257mg
Total Fat	23.8g		
Calories			
Calories from Protein		161	
Calories from Carbohydrates		0.2	
Total calories		375	

TOXICOLOGICAL OBSERVATION IN THE FRESHWATER MUD EEL

The adaptive strategies against ammonia toxicity in the amphibious mud eel, *Amphipnous cuchia* were observed whereas the freshwater mud eel, *A. cuchia* faces the problem of ammonia toxicity in its natural habitats due to build up of high ammonia during exposure to high external ammonia (HEA) and also during desiccation stress [48]. The mud eel is primarily ammoniotelic while living in water excreting ammonia as the major nitrogenous excretory end product. The glutamine enzyme (GS) was found to be widely distributed at relatively high levels in different tissues of the mud eel, with maximum activity in brain, followed by stomach, intestine, kidney, liver and muscle whereas a high level of GS enzyme activity was found in stomach and intestine of this fish. The mud eel, *A. cuchia* is found uniquely adapted to nitrogen metabolism using multiple strategies to tackle the problem of ammonia toxicity, and thus this fish can survive in extreme habitats [48]. Acute toxicity study of retinoic acid in the freshwater eel, *M. cuchia* was also examined [49] where all-trans retinoic acid (RA) is found as an active metabolite of vitamin A and its administration may prevent most of the defects generated by vitamin A deficient. It was also found out the LD50 value of RA in *M. cuchia* through intramuscular injection resulting the impact of RA may be used in managing fish farms to increase the immunity.

DISEASES OF THE FRESHWATER MUD EEL

The health conditions of freshwater mud eel, *M. cuchia* was investigated through clinical and histopathological observations [50] where the water temperature and total hardness were found at reduced level for fish during the months of November to January that might have played role in the occurrence of clinical and pathological changes in fish. Clinically weak body, rough skin, deep ulcer and grey brownish colour of the body were noticed. Major pathology in the skin and muscle such as loss of epidermis and dermis, necrosis of myotoms, huge vacuum spaces, marked melanomacrophage and fungal granuloma were found [50]. Melanomacrophages, severe haemorrhage, vacuums, hepatic necrosis, fat droplets in the liver and kidney of this fish were also marked [50]. The fishes were affected by EUS, with the evidence of development of fungal granuloma in skin, muscle and kidney. As a result, health condition was deteriorated during the winter season generally.

Very low parasitic affect was observed in the freshwater mud eel *M. cuchia*. The overall gill parasites and stomach parasites of *M. cuchia* were poor [4]. A gill parasite (*Argulus* sp.) was found in freshwater mud eel, *M. cuchia* while no stomach or visceral parasites were available. Two species of parasites were found in this fish, viz. *Argulus* sp. (Family - Argulidae) and *Ergasilus* sp. (Family - Ergasilidae) [4]. Only unicellular protozoan parasite, *Chloromyxum amphlovi* are mentioned in the gall bladder of this fish [14]. On the other hand, thirty specimens of *M. cuchia* were examined for observing parasitic cestode fauna and out of these fourteen specimens were found to be infected with cestodes and they were restricted to the intestine of the fish [51]. It was also found that the female fish show higher prevalence than the male fish whereas the fish specimen with intermediate weight group shows highest prevalence of infestation.

CONSUMABLE INFORMATION OF THE FRESHWATER MUD EEL

The freshwater mud eel, *M. cuchia* is used as food fish in Bangladesh but many people do not take it as food where only some tribal people accept this flesh. Some people are believed to have medicinal value.

CULTURE PRACTICE OF THE FRESHWATER MUD EEL

The freshwater mud eel culture is a low-cost system compared to other small-scale fish culture projects and it is presumed a low-cost enterprise to the farmers. This fish culture does not necessarily require large bodies of water and specific expensive formulated feed. The mud eel, *M. cuchia* is quite hardy and pollution resistant. It can be profitably raised with aquatic crops like swamp cabbage [17]. Raising this species is easy to do and achieves a more profit than some other small size fish culture activities [52, 53]. This fish can be easily cultured in a small tank, aquarium and other vessels while the species adjust well to life in captivity and are very hardy inhabitants. A larger aquarium with adequate hiding places and a well-sealed lid is essential for maintaining this fish. Though the effect of different feeds and shelters on growth, survival and production of freshwater mud eel, *M. cuchia* in Bangladesh was studied [31, 32] whereas it was found a potentiality of this fish culture in Bangladesh but no productive culture system is developed for commercial purposes. Rearing practice was also done by first author in different environments in 2013 and found high production through simple culture. In addition, production potential of this mud eel was observed in participatory semi-intensive culture systems considering rice field and ponds [54]. Rice field and pond habitat was improved by installing mud-compost hips, bamboo roots; plastic and bamboo-made hollow pipes, and aquatic vegetations. The feed was supplied with dead fish, dry fish, live carp fry and flesh of snails and bivalves. Though, lower growth performance of *M. cuchia* was observed in rice field than pond, however, it was said that semi-intensive culture both in rice fields and ponds are a good proposition as an aquaculture technology to save the mud eel from decline and enhance the nutritional status and socio-economic improvement of the Adivasi (Ethnic) people.

CAPTURE FISHERY OF THE FRESHWATER MUD EEL

As no commercial culture practice is available in Bangladesh, the freshwater mud eel, *M. cuchia* business is completely depends on natural capture only. Fish catchers are capturing this fish throughout the year but it is easy to capture during summer and the fish is found abundantly at this period. Due to the complexities of its habitat, behavior and life history, makes it difficult to catch the fish, therefore, the fishing methods for catching the mud eel is scanty and different techniques employed traditionally by the ethnic communities where they use wounding gears including spear, knives and sickle, ichthyotoxic plants such as *Derris elliptica* and *Milletia pachycarpa* etc., handlines, spindle shaped and cubical traps etc. [55]. Other methods including bunding and digging, and light fishing are also documented.

MARKETING AND BUSINESS OF THE FRESHWATER MUD EEL

The freshwater mud eel from the business side is promising because the demand from within and outside the country until the current unmet demand and the growing number of day let alone there is increasing recognition by some countries that Indonesia, especially the eels came from Java island has the highest quality. Its demand for export is increasing day by day. Though, in Bangladesh very few amounts of tribal people consume this fish, a lot of foreign currency would be earned by exporting this fish which will help to improve the national economy of Bangladesh [31].

This eel fish is popular across the world and are consumed and prepared in many different ways, in different countries. This fish has tremendous demand in foreign countries like Japan, Korea, China, Thailand, Thaiwan, Honkong, New Zealand, Australia,

Europe etc. [56]]. The freshwater eel, *M. cuchia* trade, a high-value export fishery involving nearly 15 countries in the world, with high demand in China, Malaysia, Singapore, Japan and Taiwan [57]. This mud eel is exported from the Laos, Cambodia and Vietnam and Indian part of Assam and Meghalaya. But in recent years, a scope has been established to export this fish from Bangladesh. Now-a-days the freshwater mud eel is a commercially important fish in Bangladesh [58]. The annual landing of the freshwater mud eel is about 1.85 Metric tons [50]. This freshwater eel comprise only 1.5% of the total fish landing centre at different parts of the country [59].

The marketing system passes through a number of channels from catcher to exporter. A different grading system is involved for marketing of this freshwater eel in Bangladesh. It is varied according to the sex and size of the eel in the international market. Freshwater eel marketing was considered as a profitable business by most of the marketing operators. The social and religious restriction on consumption of freshwater eel was also reported as a problem that hinders the business and prevents obtaining realistic prices in the domestic market [57]. In marketing systems of this fish, there are a number of people involved in Bangladesh. The market chain from collector to consumers passes through a number of intermediaries like local agents, wholesalers, suppliers, exporters and buyers [57, 60]. The demand of freshwater eel is high for export but supply is not enough because freshwater eel is now in vulnerable condition. Farmers never can directly communicate with consumers, market communication normally being made through supplier or local agent. The supplier usually buys the freshwater eel from the local agent but do not seem to have formal agreements with particular producers. Collectors directly sell their fish to wholesalers or through local agents. Local agents are normally based in local markets near to fish farming communities. Local agents or sellers usually sell the freshwater eel to the wholesale markets. Local agents have informal agreements with wholesalers obliging them to supply certain quantities in spite of the lower profit margins. Local agents used to carry freshwater eel from remote village where the rate is low. Sometimes seller or supplier take small amounts of *dadon* which is a system of tied credit through which the wholesalers advance money to the suppliers in exchange to ensure the supply of fish from farmers. Wholesaler commonly use mechanical vehicles (trucks, pickups and microbus) to transport fish from local area to Dhaka packing center which takes 7-10 hours depending on the communication system. Aluminum containers, bamboo baskets with polythene covers are commonly used for keeping the freshwater eel during the transport. Then suppliers use plastic basket and foam box for the preparation of export, they use ice and ginger during packaging to decrease mortality. Finally exporter exports this fish as live by cargo plane in amount 40-50 tons.

Bangladesh began exporting freshwater eel around 1987-88 and since 1992 the value of export earnings has been steadily increasing. In 2002, freshwater eel ranked 4 in terms of frozen food export items [57]. Price fluctuation, lack of buyers and market information, credit problems, high mortality and poor transportation systems in the marketing of freshwater eel have been reported by some researchers in Bangladesh. All of these problems have negative effects on the international markets. To achieve an efficient marketing system in a competitive manner it is necessary to identify the existing problems and to solve these wherever they occur in the chain. It will also be useful for the policy makers to identify the existing weaknesses, by providing them with the necessary information for formulating strategies towards improvement of the eel

fishery. Two types of domestic market, nearer to local markets in the vicinity of the fishing village and the consumer markets away from fishing areas have been reported [61]. The market price varies with the size and with the season and the selling price is normally fixed through bargaining between the seller and consumers. Besides live eel, many East Asian and South East Asian countries export different forms of eel and eel products throughout the world.

The freshwater mud eel is an exported item in Bangladesh and its export is increasing yearly [62]. According to the information of fisheries department, 7157 tons of freshwater mud eel is exported from Bangladesh in 2013-2014 fiscal year, 6817 Tons in 2012-2013, 5057 tons in 2011-2012, 3295 tons in 2010-2011 and 1782 tons by 2009-2010. According to the information of Export Development Bureau (EDB), Bangladesh has been earned 1, 49, 78, 000 USD by exporting this fish in 2013-2014 and 1, 09, 21, 000 USD in 2012-2013. That means the scope of exporting this fish is increased in both amount and foreign currency earning. According to the exporter, a large amount of this fish is exporting in China, Honkong, Taiwan, USA, South Korea, Singapore, UAE, Canada, Japan and some other countries. According to the EDB, 95% of freshwater eel is exported last year in China with around 1,41,62,000 USD, in USA 3,25,000 USD, in Honkong 2,71,000 USD, in South Korea 69,000 USD and in Taiwan 64,000 USD. Consulting with the Managing Director of Seba Aqua Resources is an eel exporter of the country in year 1995, it was known that the freshwater mud eel and crabs are most potential export item in Bangladesh. If Government is giving a good concern regarding this fish and crabs like other frozen fish it would be a very possibility to earn foreign currency like shrimps. Exporters said that, they collect this fish from Laksham, Chandpur, Sylhet, Moulvi Bazar, Habiganj and Sunamganj of Bangladesh in summer season, and they collect this fish in large amount from Gopalganj, Faridpur, RaajBari, Narail and North Bengal of Bangladesh in winter season. It is also known that market value is fluctuated by seasonal supply and size of this fish. The price of the freshwater mud eel is ranged from 150 taka to 280 taka per kg in the field level from wholesaler stake holders. Stake holder sells this fish to the exporters as rate 250 taka to 450 taka per kg. Exporters export this fish as 500 taka to 800 taka per kg [4, 62]. Three unknown eel export company said that every week 150 to 200 tons of this eel is exported. However, out of this amount lot of this fish is exporting by some awful businessmen while Government is unknown [62]. Considering the total export earnings from freshwater eel the fishery shows future potential.

SOCIO-ECONOMIC CONDITIONS OF THE EEL FISHERS IN BANGLADESH

Socio-economic potential of the freshwater mud eel is immense in Bangladesh. This fish can play a unique role for socio-economic welfare which will be developed social fishery in Bangladesh [3]. It has been observed that this fish can meet the increasing demand of animal protein in Bangladesh as well as to collect foreign currencies that will help to improve the national economy of Bangladesh [58]. It has revealed in a report that this fish economically important in various groups of people, especially the Hindu and Christian communities and some ethnic tribal group. The fishery of freshwater mud eel can generate employment directly and indirectly in terms of people employed in the marketing and other associated business. More than 8,000 fishers, collector, depot owner, supplier/agent, traders, transporters and exporters were found to be involved in this sector [57]. Most marginalized segment of population especially land less people, widow and children are involved in eel collection for their livelihoods earning. Domestic

demand needs to increase through increasing social awareness and promoting awareness of the nutritive value of this export oriented species.

Capturing this fish play a unique of some poor people for their livelihood. Though, it has no demand in local markets and majority of the people do not eat this fish in Bangladesh some fishermen release this fish in nature, but rarely people eat this fish as medicine. Along fishermen sometimes tea labours are engaged in capturing this fish. Due to the business of this fish is promising day by day with high economic potential and the interest of this fish is completely depends on natural breeding while no steps is taken by Government or NGOs for production and development of this fish in Bangladesh, this review would be very important for the development and conservation. If this fish are cultured commercially it must be play a vital role to the national economy including creation of work facility and hope for jobless people as well. Therefore, to develop and conserve this valuable fish in the nature of Bangladesh support from government and different nongovernmental organizations needs to be greater and perceptions regarding the activity need to show attention for the culture system of freshwater mud eel and marketing in Bangladesh.

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