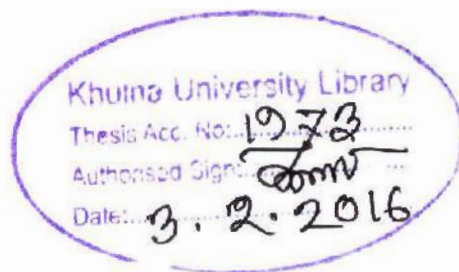


MUD CRAB RESOURCE DEVELOPMENT IN BANGLADESH: A REVIEW



**A Thesis
By
MST. MUSLIMA KHATUN
Roll No. MS-010623
Session: 2006-2007**

**The thesis submitted to Fisheries and Marine Resource Technology Discipline in
partial fulfillment of the requirements for the degree of Science in
Fisheries and Marine Resource Technology**

February 2008

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Approved as to style and contents by



(Dr. Khandaker Anisul Huq)

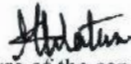
Head

**Fisheries and Marine Resource Technology Discipline
Khulna University, Khulna
Bangladesh**

Declaration

Mud crab resource development in Bangladesh: A review

The results presented in the project work with the above mentioned title are entirely of the candidate's own investigations and no part of the results has been accepted for any degree nor is being concurrently submitted for any degree.



(Signature of the candidate)

Mst. Muslima Khatun

Examination Roll No.: MS 010623

Session: 2006-2007



(Signature of the supervisor)

Dipak Kamal

Professor

Fisheries and Marine Resource Technology Discipline
Khulna University, Khulna, Bangladesh.

February 2008

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Mst. Muslima Khatun
Khulna University

ABSTRACT

This paper reviews the current status of, and future potential for, mud crab resources in Bangladesh. Among 16 reported species, mud crab (*Scylla* sp.) is the most potential aqua-resources of Bangladesh which, however, has remained in a primitive stage. It remains absolutely as export oriented artisanal fishery based on harvest from wild sources of coastal tidal water bodies of Bangladesh. High international demand with comparatively good return in short period of time has triggered its fattening of rejected male and female crabs in small earthen ponds using locally available trash by the coastal poor. High demand and price, however, resulted in overfishing of undersize crabs by increasing numbers of new catchers throughout the coastal zone of Bangladesh which may lead to a collapse of this potential aqua-resources in near future. In order to overcome this problem and to allow further development of this potential resource, a sustainable management plan has been suggested considering the eco-biological, socio-economical, business, policy and legal aspects.

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LIST OF SYMBOLS AND ABBREVIATIONS

e.g.	As for example
NGO	Non Government Organization
WSBV	White Spot Bacullo Virus
No.	Number
USD	United States Dollar
Fig.	Figure
L	Liter
h	Hour
kg	Kilogram
°C	Degree centigrade
‰	Parts per thousand
FAO	Food and Agriculture Organizaton
COFI	FAO Committee on Fisheries
CPU	Catch Per Unit Effort
MSY	Maximum Sustainable Yield
GSI	Gonadosomatic Index
CL	Carapace Length
CW	Carapace Width
BW	Body Weight



1.1 Introduction

Mud crabs (*Scylla* sp.) are widely distributed in the Indo-West Pacific region (Macintosh *et al.*, 2002). Among four species (*Scylla serrata*, *S. tranquibarica*, *S. paramamosain* and *S. olivacea*) of mud crabs the red mud crab (*Scylla olivacea*, Forskal 1775) is widely distributed in the coastal waters of Bangladesh (Kamal *et al.*, 2003). It is a member of a group of swimming crab, portunid, characterized by a flattened hind pair of legs, olive-green to brown, rounded frontal-lobe teeth and one or possibly two blunt spines on both the dorsal propodus and ventral carpus (Keenan *et al.*, 1998). Mud crabs are predominantly estuarine, but depend on the marine environment for spawning and early larval life (Arriola, 1940).

Bangladesh has a coast line of about 710 km and about 628,780 ha of potential mangrove tidal flats (Mac-Nac, 1974) where capture of mud crab has been practiced by the artisanal fishers over the last three decades as an export commodity. Although shrimp is at the top of the coastal resources with export potential and income to the fry collectors to processors, but recent outbreak of diseases in cultured shrimp and other negative environmental and socio-economic impacts such as conversion, expropriation and privatization of land, salinity intrusion, vulnerability in food security, marginalization of coastal communities, unemployment, urban migration and land use conflicts (Deb, 1998, Monzu, 1998) have posed a threat to the sustainability of brackish water shrimp farming in Bangladesh.

A large intertidal mud-flats, the Sundarbans mangrove swamps, tidal rivers and canals across the coastal zone of Bangladesh are the suitable habitats for a number of crustacean species including shrimps and crabs. Under this situation, development of mud crab resources would be a partial alternative to replace brackish water shrimp culture in future (Love and Chandra, 2005). Therefore, the current physical settings allow us to take attempts for the development of mud crab culture practice at large scale aside by brackish water shrimp farming in these large areas (Fig. 1.1) (Salam *et al.*, 2003).

Unfortunately, mud crab fishery in Bangladesh is not well established. No management regime has ever been practiced for mud crab fishery. Therefore, its fishery based on wild harvest of mud crab by traditional, sometimes by destructive gears and methods is being continued over the last three decades under a few unorganized landing centers at Cox's Bazar, Chittagong, Noakhali, Bhola, Barisal, Patuakhali, Bagerhat, Khulna and Satkhira districts (Fig. 1.2).

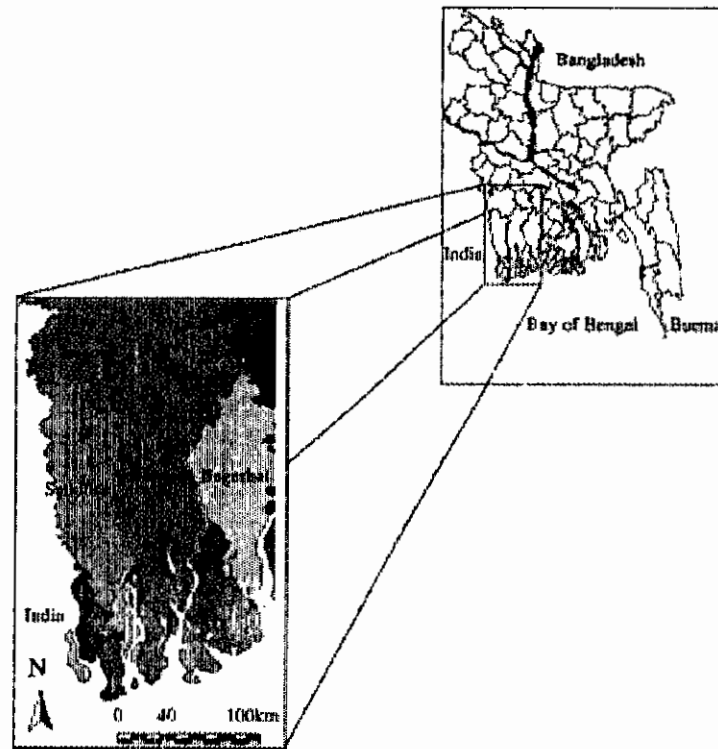


Fig. 1.1 Coastal areas potential for mud crab culture.

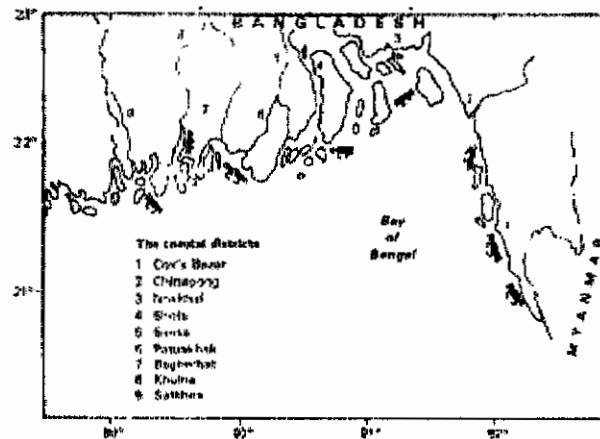


Fig. 1.2 Coastal areas where mud crab is being harvested currently.

The present study, therefore, aimed at to assess the present status of, and future potential for mud crab resource development in Bangladesh considering the context of policy, legal, management and its eco-biology, socio-economic and business aspects. For example, different aspects of culture and post harvest handling of mud crab in Bangladesh reviewed and identified possible strategies to improve culture and management approaches as well as product development of mud crab with a view to poverty alleviation through sustainable development in Bangladesh. Post-harvest handling of mud crab includes activities related

to spoilage and quality control of crab from harvesting to consumption or export. Hence, harvesting, transportation, marketing, grading, quality control, export and so on are the essential component of post-harvest handling. Mud crab culture also includes fattening, pond, cage, pen and integrated culture of mud crab.

1.2 Objectives

Overall Objective

- Resource development of mud crab for alleviation poverty of coastal poor communities.

Specific objectives

- i. To assess current research activities and future research needs in order to develop mud crab as a resource in Bangladesh;
- ii. To assess current status of and future scope for mud crab fattening in Bangladesh;
- iii. To assess current status of and future scope for mud crab culture (seed production, larval rearing; and culture in various systems) in Bangladesh;
- iv. To assess current status of and future scope for mud crab fishery management in Bangladesh;
- v. To assess current status of and future scope for domestic market of mud crab in Bangladesh;
- vi. To assess current status of and future scope for mud crab export (live, frozen, and cooked condition) in Bangladesh;
- vii. To assess current status of and future strategies for people involved in mud crab.
- viii. To assess current status of and future scope for policy, legislation and management regimes for mud crab resource development in Bangladesh.

2. Review of Literatures

i. Mud Crab Research in Bangladesh:

Bhuyain and Das (1976) made a taxonomic investigation and reported 15 species of crab from the intertidal zone. Mahmood (1977) reported 16 crab species from the coast of Bangladesh. Islam (1977) worked on the Brachyura of Bangladesh, with special reference to the biology of *Scylla serrata*. However, Ahmed *et al.* (2005) have given first time the record of *Scylla olivacea* through overviewing descriptive accounts and illustrations and key to identification.

Saha and Ahmed (1999), Saha *et al.* (1999, 2000), Kamal (2002) and Zafar (2003) reported on broodstock development and various methods of fattening the species. Mia *et al.* (2006) described the meristic characteristics and gonadal development of mud crab, *S. serrata* in the Sundarbans. Carapace and body width of both the male and female crabs are strongly correlated, and abundance of male is highest in November and female in August-October. GSI values for male varies from 8.04 – 10.53 and that of female from 9.68-17.52, indicating that mud crab breeds throughout the year. In addition, GSI values of male and female mud crabs shows peaks in February and January, respectively.

Although crab fattening in ponds started by farmers in 1993 (Kamal, 2002), while fattening in both cages and ponds was developed recently (Zafar, 2005 and Kamal, 2004). Khatun (2007) studied on optimum sex ratio of mud crab in pen culture in mangroves.

ii. Mud Crab Fattening in Bangladesh:

Zafar (2003, 2004) and Kamal (2002) developed mud crab fattening in ponds, cages and brackishwater ponds.

iii. Mud Crab Culture in Bangladesh:

Kamal (2004) and Zafar (2003) developed mud culture in cage, pot and earthen pond. Recently, appropriate stocking density of mud crab (*Scylla olivacea*) has developed in the Sundarbans mangrove (Khatun, 2007).

iv. Mud Crab Fishery Management in Bangladesh:

A few studies are also conducted by Islam (2003) and Islam (2006) on comparison of mud crab production from the Sundarban and shrimp ghers and status of crab collectors, respectively. Ahmed (1992) and Khan and Alam (1992) briefly reported on the fishery,

production and bio-economics of mud crab resources in Bangladesh. In addition, Hossain *et al.* (2006) studied on crafts and gears used in mud crab catching in Bangladesh.

v. *Domestic Market of Mud Crab in Bangladesh:*

Regarding post harvest activities, Ahmed (1992) briefly described handling, transportation and marketing of mud-crab in Bangladesh. Kamal *et al.* (2003) and Kamal and Tapadar (2003) reported on the production, transportation and marketing of mud crab from southwest Bangladesh. Zafar and Ahsan (2006) studied on marketing and value chain analysis of mud crab (*Scylla* sp.) in the coastal area of Bangladesh. In spite of its increasing demand and great export potential, crab marketing system has not yet been established in Bangladesh.

vi. *Mud crab export from Bangladesh:*

Kamal and Tapadar (2007) studied on production, marketing and transportation of mud, while Uddin (2002) studied on marketing and transportation of mud from the south-west region of Bangladesh. Zafar and Ahsan (2006) also describe the marketing and value chain analysis of mud crab in Bangladesh. In addition, Hossain and Ahmed describes different aspects of post harvest approaches of mud crab in Bangladesh.

vii. *Communities involved in mud crab*

Zafar and Ahsan (2006) first studied on socio-economic status of crab collectors in Bangladesh.

viii. *Policy, Legislation and Management Related to Mud Crab in Bangladesh:*

In Bangladesh, Hoq (2007) discussed crab fishery management briefly as a potential resource of SRF.

3. Materials and Methods

Information related to culture, feed management, marketing and post harvest handling of mud crab in Bangladesh and other countries were collected from books, journals, proceedings, thesis papers, internet, and publications of DoF, and reviewed.

Chapter 1

3.1 Research on Mud Crab Resources in Bangladesh

3.1 Biology: Species identification; distribution and abundance estimation; sex ratio; L-W relationship; reproductive biology (size at first maturity; fecundity, spawning migration of females, breeding season, spawning area, larval distribution and migration etc.); population dynamics (estimation of age-growth-mortality-recruitment).

Research in overseas countries

Species identification and in differentiating stocks of a single species^a and distribution allozyme electrophoresis is considered to be the most reliable genetic marker method for *Scylla* species and their stocks and distribution^b, larval identification^c, distribution^d, length-weight relationship^{h,i,j,k}, recruitment of *S. serrata* has been reported throughout the year in most habitats with two peaks for female (January-May and June-July)^l, grow during intermoult periods^m, reproductive biology^{n,o}, description of male and female reproductive system of *S. serrata*^p, female reproductive structure^q, sex ratio in *S. serrata* varied by size and season^r, overall sex ratio of male to female is found to vary between 1:0.82 and 1:3^s, basic characteristics of ovarian development^t, gonadal development in *S. serrata*^u, fecundity is found to be varied from 1.5 to 7 million depending on CW^v; size at sexual maturity varies with sex, temperature and latitudes, and size at first maturity and M₅₀ in *S. olivacea* and *S. paramamosain* have been found to be 83 and 91.2, and 101 and 110.5 mm ICW respectively^w; age at 1st maturity in female is 1 yr in Chinese marine water^x and 1st maturity in male in tropical water is 1.5 yr^y. Most of the workers reported that *S. serrata* mate either in the mangroves^{aa} or the brackishwater estuaries^{ab} before starting migration to the spawning ground^{ac}; spawning in the high seas/offshore areas^{ad}; eggs are extruded in batches of up to 1-7/2.5 million at a time and hatches within 12-28 days/30 days^{ae}; larval development^{af};

Research in Bangladesh

Distribution of mud crab in coastal region and the Sundarban mangroves^e, length-weight relationship^f, First record of mud crab based on the characters as olive green colour, round frontal teeth with shallow interspaces, reduced spines to blunt prominences of cheliped palm, absence of two spines on the carpus and no polygonal pattern in both sexes^{ag}, meristic characteristics and gonadal development^{ah}.

Keenan *et al.*, 1998^{a,b}; Macintosh *et al.*, 2002^{b,c}; Lin *et al.*, 1994^c; Overton, 2000^d; Azam *et al.*, 1998^e; Khan & Alam, 1992^e; Prasad & Neelakantan, 1988a,b,c^h; George *et al.*, 1986ⁱ; Cheewasedtham, 1990^j; Poovachiranon, 1992^k; (Chandrasekaran and Natarajan, 1994; Srinivasagam *et al.*, 1988; Jayamanne, 1992; Kathirvell, 1983; Jones and Sujansinghani, 1950; Cheewasedtham, 1990; Forbes and Hay, 1988; Hoq *et al.*, 2001; Lee, 1992; Robertson, 1996; Tiensongrussmee and Pratoomchat, 1999; Macintosh *et al.*, 1999; Hasek and Rabalais, 2001)^l; (Khan & Alam, 1992; Ayub and Ahmed, 2001)^m; Moser *et al.*, 2002ⁿ, Overton and Macintosh, 2002^o; (Ahilan, 1999; Delathiere, 1988 and 1990)^p, (Quinn and Kojis, 1987; Kang *et al.*, 2000a, 2001)^q, (Jayamanna and Jinadasa, 1993; Quinn and Kojis,

1987)^f, (Lari, 1995; Cheewasedtham, 1990; Kathirvel and Srinivasagam, 1992)^g; Quinn and Kojis, 1987^h; (Poovachiranon, 1992; Robertson and Kruger, 1994)^u; (Varikul *et al.*, 1972; Lee 1992; Jayamanna and Jinadasa, 1993; Ahilan, 1999; Tiensongrussmee and Pratoomchat, 1999; Onyango and Kudoja, 1995; Wu *et al.*, 1998)^v; Overton and Macintosh, 2002^w; Wu *et al.*, 1998^v; Luo and Wei, 1986^w; (Cheewasedtham, 1990; Devi, 1985; Le Reste *et al.*, 1976; Akil and Jiddawi, 1999)^{aaa}; (Hill, 1975; Heasman *et al.*, 1985; Robertson and Kruger, 1994)^{ab}; (Arriola, 1940; Hill, 1975)^{ac}; (Hill, 1975; Le Reste *et al.*, 1976; Prasad and Neelakantan, 1989; Cheewasedtham, 1990; Akil and Jiddawi, 1999)^{ad}; (Varikul *et al.*, 1972; Lee, 1992)^{ae}; (Delathiere, 1988, 1990; Wu, 1991; Hill, 1974; Ong, 1964, 1966)^{af}; Ahmed *et al.*, 2005^{ag}; Mia *et al.*, 2006^{ah}.

3.2 Ecology: Natural food and feeding habit; breeding behaviour (breeding habit and habitat); predator-prey relationship; trophic interaction; cannibalism; autotomy and regeneration.

Research in overseas countries

Mangrove offers the most suitable habitat for *S. serrata*^a; mangrove swamps as nursery ground^b; mangroves of the Sundarban is enriched with estuarine rivers, creeks and provide a congenial habitat for the mud crab, *S. serrata*^c; soft bottom areas of tidal wetlands from 0-6 m depth provide unique habitat for *S. serrata*^d; habitats that provide shelter and food for the juvenile, sub-adult and adult *S. serrata* include- estuaries^e; tidal lakes^f; lagoons^g; Chin and Amandakoon, 1992^h; tidal rivers^h; and mangrove swampsⁱ; absolute abundance of *S. olivacea* in the Ranong mangrove ecosystem of Thailand at 22-33 crabs/ha^j, 0.806 crabs/100m² in the Kleinmond estuary of South Africa^k, 0.006 crabs/m² in Kowie estuary, South Africa^l; abundance of juvenile^m; exploitation – table 3.1.1; overfishing of *S. serrata* in Thailandⁿ, Malatsia^o.

Research in Bangladesh

Yield-375 tons and MSY-283 tons^p; (crab production from Sundarbans Reserve Forest: 1987-88 – 200 MT, 1988-89- 10MT, 1989-90-40MT, 1990-91-120MT, 1991-92-270MT, 1992-93-490MT, 1993-94-530MT, 1994-95-700MT, 1995-96-640MT, 1996-97-1000MT, 1997-98-820MT, 1998-99-420MT, 1999-2000-370MT)^q; nocturnal in habit and most active at dusk and dawn period^r; omnivorous animal^s; feed on dead animals and slow moving and sessile benthic invertebrates^t; having stalk eyes^u.

(Macnae, 1968; Hill, 1979a,b; Hill *et al.*, 1982; Chandrasckaran and Natarajan, 1994; Kuthalingam *et al.*, 1982)^a; Forbes and Cyrus, 1998^b; Mahapatra *et al.*, 1996^c; Tien *et al.* 1996^d; Thia-Eng, 1973^e; Forbes and Cyrus, 1998^f; Loneragan and Bunn, 1999^h; Macnae, 1968ⁱ; Moser, 2001^j; Hill, 1975; Robertson, 1996^l; (Ahmed and Abbas, 1999a,b, Ayub and Ahmed, 2001, Kuthalingam *et al.*, 1982, Forbes and Hay, 1988; 1992 and Hoq *et al.*,

2001)^m; Tiensoongrasmee and Pratoomchat, 1999ⁿ, Kosuge, 2001^o; Chantarasri, S., 1994^p; (Joel and Raj, 1986; Lee, 1992)^r; Arriola, 1940^s; (Hill, 1976, 1979b)^t; Warner, 1977^u.

Table-3.1.1 The CPUE and production of *S. serrata* from different habitats.

Habitat	Area/Size (CW, cm)	CPUE	Production (MT/year)	Source
Mangrove areas of Segara Anakan-Cilacap, Java, Indonesia.		bamboo trap: 4.5 kg/trip/day Lift net: 3.2 kg/trip/day.	--	Suwarso (1991)
Ennore estuary, East coast of India	6 Km ²	--	5.86 in 1963	Raj (1992)
Godavari estuary, East coast of India	211 Km ²	--	337.46 in 1974	Raj (1992)
Sundarmangrove (Indian part), East coast of India	(353645.16 ha)	15-20/hoor&line/day	33.60 in 1959	Raj (1992)
Chilika Lake, East coast of India	906 Km ²	3-4crabs/trap/day (45x30x25cm)	64.53 in 1974	Raj (1992)
Pulicat Lake, East coast of India	461 Km ²	--	907.18 in 1959	Raj (1992)
Vembanad Lake, East coast of India	300	--	24.53 in 1964-67	Raj (1992)
Killai backwaters, East coast of India	6.68	--	12.05 in 1974	Raj (1992)
Gulf of Thailand & Andaman sea	--	0.5 Kg/ trap/day 0.2 Kg/liftnet/day	4.3 in 1984 4.5 in 1985 4.6 in 1986 5.0 in 1987 4.5 in 1988 5.0 in 1989	Tookwinas <i>et al.</i> (1992)
Negombo lagoon, Sri Lanka	7-28	0.0022 /trap/hr in 1985 0.0015 /trap/hr in 1986 0.0014 /trap/hr in 1987	35 43 40	Jayamanne (1992)
Coastal areas of Bangladesh	8.1-14.5	Hook: 5-6 Kg/day/man in winter & 15-20 Kg in wet season	1937-2085 in 1991	Khan and Alam(1992)
Tuticorin, India	11.5	--	9.461 in 1974-75	Shanmugam and Bensam (1980)
Jaffna lagoon in Northern Sri Lanka*	6.3 -19.0	3.5 to 17.5 (8.7) in 1991 3.9 kg to 14.6 (7.8) in 1992		Chitravadivelu (1994)
Negombo Lagoon, Sri Lanka	--	Declined	1422 in 1980 2309 in 1983 1973 in 1984*	Jayamanne (1992)
Pala Lagoon of Territory of American Samoa.		2.0 lb/gear-hour/cast net 0.02 lb/pot-hour/ crab pots		Ponwith (1992)
Korapuzha estuary, Kerala, India	5.1-21.5 F 4.6-19.5 M (8.6-12)	11.3 kg	14 in 1987-89	Sarada (1997)
Eastern Cape estuaries, South Africa	8-18	0.007-0.129 crab/trap/hr		Robertson (1996)
Klong Ngao mangrove forest, Ranong Province, Thailand	9-10	--	109	Cheewasedtham, (1990)
Coastal waters of Thailand	50% at <9 cm	--	5,900 in 1955	Tiensoongrasmee and Pratoomchat (1999)

*Fishing Unit: Parik Koodu (Baited trap)

3.3 Physiology: Tolerance to environmental parameters (Salinity, pH, temperature).

Temperature has considerable effects on feeding and duration of emergence and movement activity in *S. serrata*. The emergence time and movement were maximum at 25°C and minimum at than 12°C. At 25°C, 65% of crabs fed, but none did so at 12°C Hill (1980). Mud crab larvae possess a low tolerance to lower salinity (Hill, 1974). Experimental studies confirmed that 1st zoeal larvae of *S. serrata* cannot survive at above 25°C or below 17.5 ppt salinity (Hill, 1974). Therefore, zoea larvae are unsuited to estuarine conditions. The larvae can tolerate temps down to 5°C, but they are inactive below 10°C. It is suggested that 10°C is probably a lower limit and that female crabs which migrate to sea to release their eggs do not enter water with a temp less than 12°C (Hill, 1974). However, they are essentially euryhaline but died over 70 ppt (Motoh, 1979). Devenport and Wong (1987) reported that *S. serrata* can tolerate a wide range of salinity from 1-42 ppt. *S. serrata* can survive at sudden fluctuations in salinity, but prolonged exposure to lower salinities below 10 ppt results in poor feeding and reduced growth (Manjulatha and Babu, 1998).

Temperature has also a profound effect on intermoult duration (Heasman, 1980). Manjulatha and Babu (1998) reported that crabs could survive at sudden fluctuations in salinity, but prolonged exposure to lower salinities below 10 ppt in *Scylla oceanica* resulted in poor growth. Incubation period of *S. serrata* eggs is 12 days at 27°C temperature and 32 ppt salinity (Varikul *et al.*, 1972; Lee, 1992). Larvae metamorphose into megalopa in 30 days and at first crab stage in 37 days of age.

3.4 Fishery: Fishing crafts and gears (Diversity of fishing crafts and gears; CPUE by gears, destructive gears; efficient gears; fishing season and areas, identification of fishing hot-spot areas.

Research in overseas countries

old bamboo-tube traps^a; fishing gear in Indonesia^b; Srilanka^c; Thailand^d; China^k.

Research in Bangladesh

Crafts and gears used in catching mud crab, *S. olivacea*^a; fishery management in the Sundarbans; marketing, transportation and export^{cdef}.

Hossain and Ahmed, 2006^a; Hoq, 2007^b; Uddin, 2002^c; Kamal and Tapadar, 2007^d; Ahmed, 1992^e; Zafar and Ahsan, 2006^f; Maitland, 2002^g; Cholik and Hanfi, 1992^h; Jayamanne, 1992ⁱ; Tookwinas *et al.*, 1992^j; Anon. 2007a^k

3.5 Fishing communities: (Geographic location of mud crab fishing communities in the coastal zone; Socio-economics of mud crab fishers).

Research in Bangladesh

Social and economic status of mud crab collectors (Zafar and Ahsan, 2006)

3.6 Fisheries economics: (Cost-benefit analysis of mud crab harvest from different wild habitats and gears).

Research in overseas countries

Cost-benefit analysis of crab culture^c.

Research in Bangladesh

Investment-return analysis of fattener and farmer^a; economic analysis based on sex in pen culture in mangroves^b.

Zafar and Ahsan, 2006^a; Khatun, 2007^b; (Triño *et al.*, 1999^e; Mwaluma, 2002; Triño and Rodriguez, 2002)^c

3.7 Fisheries management: (Stock assessment; estimation of estimation of MSY, MEY, MSY; estimation of harvest size).

Research in overseas countries

Estimated size at sexual maturity for female in Thailand (Overton and Macintosh, 2002), exploitation in India (Kathirvel and Srinivasagam, 1992)

Research in Bangladesh

Fishery management in SRF (Hoq, 2007);

3.8 Culture: Types of culture (pen, cage, cell); culture season, pond size and depth; pond management; stocking size, time, sex and density; harvest methods (single harvest, continuous harvest, harvesting gears; supplementary food and feeding regimes (feed types, feeding rate, feeding method); water quality management; aquaculture economics.

Research in overseas countries

Culture environments^f; culture in mangroves^g; culture in ponds^h; (protein requirements - 30% to 35% and dietary lipid levels - 5.3 to 13.8%)ⁱ; artificial diet^j.

Research in Bangladesh

Cage, pot and earthen pond culture^{ab}; integrated culture^c; pen culture in mangroves^d; culture environments^e; culture systemⁱ; negative effect of integrated culture^j.

Zafar, 2003^a; Kamal, 2004^b; (Tapadar, 2003 and Uddin, 2002)^c; Khatun, 2007^d; Islam & Bhuiyan, 1982^e; (Lee and Wickins, 1992; Cowan, 1984; Davenport and Wong, 1987; and Overton and Pushpakumara, 1999)^f; Triño *et al.*, 1999^g; (Mwaluma, 2002; Triño and Rodriguez, 2002)^h; (Overton and Pushpakumara, 1999; Liong, 1993; Williams and Primavera, 2001; and Wickins and Lee, 2002)ⁱ; Johnston *et al.*, 2000^j; Djuwito *et al.*, 1992ⁱ; Catacutan *et al.* 2003^j.

3.9 Fattening: Types of fattening (pen, cage, cell); sources of seeds; fattening season, pond size and depth; pond management; stocking size, time, sex and density; harvest methods (single harvest, continuous harvest, harvesting gears); supplementary food and

Chapter 2

3.2 Mud Crab Fattening and Culture

3.2.1 History of mud crab culture

3.2.1.a. Bangladesh: Although mud crab culture has been proved to be highly profitable aquaculture venture in many SE Asian countries, virtually there is no activity of mud crab in Bangladesh. However, a few research studies have been done in recent years in the SW and SE part of coastal Bangladesh (Zafar, 2004; Saha *et al.*, 2000; Kamal, 2004, Kamal *et al.*, 2007 and Khátun, 2007).

3.2.1.a.1. Introduction of mud crab business

Crabs were a virgin stock in the past in Bangladesh. The Hindus, Buddhists and tribal were the traditional consumers of crab in Bangladesh; the majority Muslim population did not favour them as a food item as a traditional convention based on preference and belief. But it might have been primarily because of the existence of extensive inland fish resources. These attitudes, however, are slowly beginning to change. After independence, in 1971, the importance of utilizing sea fish, and non-traditional items like crab, as a source of animal protein supply, was emphasized (Tookwinas *et al.*, 1992). The crab consumption habit of the coastal people helped to develop crab fishing in the country. Due to declining inland fishes, mud crab is now finding more consumers in Bangladesh. Live mud crab first appeared as an export item in 1977-78 and, from 1982, exports have been increasing (Ali *et al.*, 2004). Due to huge profit from crab fishing, immense pressure on this fishery reduces catch as well as stock for recent years (Anon. 2005). Realizing the situation, attempts have already been taken in some countries to reduce the rate of fishing pressure through implanting management schemes and also by releasing hatchery produced mud crab seeds into mangrove habitats. On the other hand, emphasis has been given in large scale commercial larvae production and rearing, and development of low cost supplemental feeds to meet the nutritional requirements of different life stages, i.e. larvae, juvenile, adult and brood mud crab. All the issues need precise information on the biology (moulting, growth, reproduction), ecology (behaviour, cannibalism, habitat quality etc), physiology (nutritional requirements, digestibility of supplemental feed ingredients, water quality requirements etc.), fishery, post harvest handling, value and supply chain, market development of value added products etc. in order to ensure sustainable development and management of mud crab resources in Bangladesh context.

3.2.1.a.2. Culture environment

Islam & Bhuiyan (1982), while working on the distribution of mud crabs in Karnafully River estuary, found *Scylla serrata* to be extremely eurythermic, and in aqueous media, with a tolerance range of 3–45°C. The most favourable regime of salinity for *Scylla serrata* is from 10–50 ‰ (Bhuiyan and Islam, 1981). Khatun (2007) stated that salinity, DO and pH in all pens ranged from 10 to 24.5 ppt, 3.84 to 7.90 mg/L and 6.1 to 9.7, respectively are suitable for pen culture, while water temperature 20°C are unsuitable for crab culture.

3.2.1.a.3. Culture system

Only fattening is practiced scientifically in Bangladesh (Zafar, 2003 and Zafar, 2006), although pond, cage, pen and integrated culture is now going on.

Pond culture

Fattening of mud crab (*S. serrata*) started unscientifically in 1993 in earthen ponds of the coastal area of Bangladesh. Obayed (1998) first studied on fattening of mud crab in earthen pond in great Khulna region and stated that mud crab culture is feasible in ponds. However, Zafar (2003) and Kamal (2004) introduced economically feasible mud crab cage, pot and earthen pond culture.

Farmers usually do not maintain particular stocking density for mud crab fattening (Kamal *et al.*, 2007). They usually supply feed at the rate of 5–8% of body weight in every alternate day and mainly prefer tilapia as the feed of crabs. Usually 15–16 days are required to fatten a batch of mud crab. The survival rate and production rate in case of traditional mud crab practice in Paikgacha is 78.55 % and 0.304 Kg/m² accordingly. The net income of a farm in an average size of 310.77 m² was Tk. 21,525 yr⁻¹.

Kamal (2002) developed a fattening technology for female mud crab (*S. olivacea*) in small brackish water ponds using bamboo pens in Kopilmuni. Paikgacha in Khulna district. In the first experiment thin females of 170–240 g were fattened with tilapia feeding rate of 10% biomass/per day for 21 days. The best survival rate and FCR were found with 1 crab m⁻² as 91% and 2.2, while the production rate was maximum at 0.325 kg m⁻² for 4 crabs m⁻² and minimum at 0.18 kg m⁻² for 1 crab m⁻². Stocking density was correlated positively and significantly with production rate and FCR. The water temperature, salinity and pH of the experimental fattening ponds varied from 23–31°C, 10.4–17.7 ppt and 8.4–10, respectively.

Traditional mud crab culture is a common practice in Bangladesh since 1992 (Kamal *et al.*, 2007). Most of the fattening farms, rectangular in shape with a common inlet and outlet made of PVC pipes are established near the bank of river or canal where brackish water is available throughout the year. The size of mud crab fattening ponds varied between 809.7-8097 m² in the study area. Usually a single pond is divided into 3-4 components by using bamboo fences/*bana* of 1 to 2 m in height. The pond depth varies from 0.25 to 1.5 m with the depth of water available in the pond between 0.5 to 0.75 m. Some fatteners use fine meshed nylon mosquito net (locally called '*Moshari jal*') around the bamboo fencing in order to prevent escapement of stocked animals from the ponds.

Obayed (1998) also conducted an experiment on fattening and culture of mud crab (*S. olivacea*) in Mitakhali of Bagerhat district for 120 days. The size of the pond was 600 m² for fattening with a stocking density (SD) of 0.8 crab m⁻² while two ponds of 600 and 1,450 m² were used for grow-out culture with a SD of 1 crab m⁻². Water temperature, salinity, dissolved oxygen (DO) and pH were reported during the culture period from September to December 1995 were 9.2-31 °C, 4.8-9.5 ppt, 3.5-6.0 ppm and 6.2-8.52, respectively. The survival rate was 55% from the fattening pond and 63-64% from grow-out ponds. The food conversion ratio (FCR) and specific growth rate (SGR) from the crab fattening pond were 1.8 and 2% per day, respectively, while 2.1-2.5 and 1.9 % per day, respectively for grow-out ponds. Saha *et al.* (1999) recommended the application of cow manure in addition to feed at a rate of 500 kg ha⁻¹ per 2 weeks in pond culture of mud crab.

Cage culture

Zafar (2004) reported the results of a comparative fattening study of mud crab (*Scylla serrata*) for 14-15 days in bamboo cage (30 cells/cage) and earthen ponds and concluded the mud crab fattening in bamboo cage as sustainable and economically viable for the poor and landless coastal people. The stocking sizes for male and female crabs were varied from 160-400 g and 140-250 g respectively in cage system. The average daily rate growth of growth was higher in cage system (1.12g/crab/day) than the earthen pond (0.51g/crab/day). Mortality was also lower in cage (307%) than the earthen pond (8-12%). Male crabs showed comparatively higher growth than the females. The gross profit was also higher in cell-cage (Tk. 350/cage/15 days) than the earthen pond (Tk. 224/pond/15 days). The mortality of female mud crabs was lower (0-6.66) than the males (3.33-6.66%). The growth and mortality was also found to be related to seasonal variation (salinity and

temperature). However, information on pond size or stocking density, stock size, and fattening period for earthen pond system were not reported.

Integrated culture

In Bangladesh, there is no research in integrated culture of mud crab, although integrated culture of mud crab with shrimp is common in the coastal areas (Tapadar, 2003 and Uddin, 2002). Crabs usually enter into shrimp farm with inlet water, grows there and finally adult are harvested from the *gher*.

Pen culture

The mangrove forest of Bangladesh has been under intensive pressure of exploitation, direct clearance of forest and conversion for the last few decades (Islam and Wahab, 2005). Shrimp farming is one of the most destructive forms of mangrove conversion that contributes significantly to destruction of biological resources as well as mangroves (Islam and Wahab, 2005). Shrimp fry collectors along in coastal areas also destroy a lot of larvae and post larvae of other species, causing biodiversity reduction. Hence, pen culture of mud crab is potential for sustainable development of aquaculture as well as poverty alleviation. In this regard, Zafar (2007) and Khatun (2007) studied on optimum stocking density and sex ratio, suitable environment and economic analysis of pen culture of mud crab in Bangladesh.

Khatun (2007) stated that all-female culture in rich water in mangroves could be suitable in commercial pen culture of mud crabs in Bangladesh. Specific growth rates by weight and internal carapace width of all-male crabs are significantly ($P < 0.05$) higher than those of all-female crabs, while specific growth rates of the mixed-sex crabs are not significantly different from those of all-male and all-female crabs ($P > 0.05$) (Table 3.2.1). Feed conversion ratio (FCR) of all-male crabs is significantly ($P < 0.05$) better than that of all-female and mixed-sex crabs. In contrast, payback period of all-female as well as mixed-sex crab culture is significantly lower than all-male crab culture. However, there are no significant ($P > 0.05$) differences in final body weight, internal carapace width, daily weight gain, survival rate, gross and net yields among all-male, all-female and mixed-sex crabs. No cannibalistic nature of mud crab is observed throughout the culture period.

The area of rich water in mangroves give significantly ($P < 0.05$) better results in terms of FCR, survival rate, gross and net yields, net margin, revenues/costs ratio and production

Table 3.2.1 Partial budget analysis for monosex and mixed-sex pen culture of mud crab based on one ha area per crop. (n=3) (Khatun, 2007).							
Item	Unit	Price (USD)	All-male		All-female		Mixed
			Quantity	Value (USD)	Quantity	Value (USD)	Value (USD)
Gross revenues (A)							
Crab	kg	Depend on size and sex	586±125.95 (n=47)	900.48±186.1	590.33±117.85 (n=48)	2,268.57±452.86	558.61±129.62 (n=45) 1,517.64±434.85
Total costs (B)							
Variable costs							
Crab seed	kg	0.17	518.52	88.15	518.52	88.15	88.15
Feed	kg	0.16	1,361.71±65.75	217.88±10.52	1,385.04±29.72	221.60±9.17	1,374.33±13.12 219.89±10.10
Labor	person/day	2.14	45	96.43	45	96.43	18 38.57
Night guard	person	114.3	2	228.6	2	228.6	2 228.6
Interest	%	11		52.65±14.59		44.68±0.52	38.13±1.11
Subtotal				683.98		639.46	613.34
Fixed costs							
Depreciation of pen	pcs	1.31	167	218.03	167	218.03	167 218.03
Interest	%	11		24.06		24.06	24.06
Subtotal				242.09		242.09	242.09
Total				926.54		922.24	855.17
Net margin (A-B)				-26.06 ^c		1346.27 ^a	661.47 ^b
Revenues/costs				0.97 ^c		2.46 ^a	1.77 ^b
Production cost	USD/kg			1.62		1.61	1.59
Payback period	Year			17.12 ^b		1.46 ^a	2.90 ^a

*Depend on size and sex: F1 (Female) 200g – 5 USD/kg, D2 (Female carrying egg) 120g – 1.14 USD/kg, SM (Small male) 200g – 0.86 USD/kg, M (Male) 250g – 1.43 USD/kg, L (Large male) – 2 USD/kg.

* Mean values with different superscript letters in the same row were significantly different ($P<0.05$).

Table 3.2.2 Partial budget analysis for pen culture of mud crab in different water level based on one ha area per crop. (Khatun, 2007).

Item	Unit	Price (USD)	rich water		little water		moderate water	
			Quantity	Value (USD)	Quantity	Value (USD)	Quantity	Value (USD)
Gross revenues (A)								
Crab	kg	Depend on size and sex	709.61±22.90 (n=56)	1,943.55±815.04	478.94±52.92 (n=40)	1,241.48±545.51	546.39±43.80 (n=44)	1,501.65±705.14
Total costs (B)								
Variable costs								
Crab seed	kg	0.17	518.52	88.15	518.52	88.15	518.52	88.15
Feed	kg	0.16	1,267.89±13.46	212.86±2.95	1,335.77±163.41	213.88±10.15	1,416.43±20.06	226.63±3.21
Labor	person/day	2.14	45	96.43	45	96.43	45	96.43
Night guard	person	114.3	2	228.6	2	228.6	2	228.6
Interest	%	11		50.64±16.54		41.71±4.27		43.11±3.49
Subtotal				682.68		668.77		682.92
Fixed costs								
Depreciation of pen	pcs	1.31	167	218.03	167	218.03	167	218.03
Interest	%	11		24.06		24.06		24.06
Subtotal				242.09		242.09		242.09
Total				924.77		910.86		925.01
Net margin (A-B)				1018.79 ^a		330.62 ^b		576.64 ^{ab}
Revenues/costs								
Production cost	USD/kg			2.10 ^a		1.36 ^b		1.62 ^{ab}
Payback period	Year			1.30 ^a		1.90 ^b		1.69 ^{ab}
				2.73		10.19		8.55





*Depend on size and sex: F1 (Female) 200g - 5 USD/kg, D2 (Female carrying egg) 120g - 1.14 USD/kg, SM (Small male) 200g - 0.86 USD/kg, M (Male) 250g - 1.43 USD/kg, L (Large male) - 2 USD/kg.

* Mean values with different superscript letters in the same row were significantly different ($P<0.05$).

Table 3.2.3 Growth and production performance of all-male, all-female and mixed-sex culture in pens (Khatun, 2007).

Item	All-male	All-female	Mixed-sex	Male	Female
Initial body weight (g)*	97.4 ± 12.3 ^b	105.4 ± 12.1 ^a	100.6 ± 12.3 ^{ab}	95.8 ± 12.6	105.4 ± 11.4
Final body weight (g)	224.4 ± 26.9 ^a	221.4 ± 24.8 ^a	223.4 ± 25.5 ^a	233.4 ± 23.9	214.0 ± 23.6
Initial ICW (cm)*	7.34 ± 0.42 ^c	8.03 ± 0.52 ^a	7.69 ± 0.50 ^b	7.40 ± 0.47	8.00 ± 0.34
Final ICW (cm)	10.17 ± 0.89 ^a	10.19 ± 0.10 ^a	10.19 ± 0.68 ^a	10.55 ± 0.62	9.84 ± 0.54
SGR _w (% day ⁻¹)*	0.83 ± 0.04 ^a	0.74 ± 0.02 ^b	0.79 ± 0.04 ^{ab}	0.89 ± 0.01	0.70 ± 0.07
SGR _{ICW} (% day ⁻¹)*	0.32 ± 0.03 ^a	0.23 ± 0.02 ^b	0.28 ± 0.02 ^{ab}	0.36 ± 0.04	0.21 ± 0.03
DWG (g day ⁻¹)	1.27 ± 0.09 ^a	1.15 ± 0.04 ^a	1.22 ± 0.08 ^a	1.37 ± 0.07	1.08 ± 0.11
FCR*	1.46 ± 0.33 ^a	1.95 ± 0.42 ^b	1.96 ± 0.47 ^b	1.67 ± 0.27	2.34 ± 0.76
Survival rate (%)	52.22 ± 10.18 ^a	53.33 ± 10.00 ^a	50.00 ± 10.00 ^a	48.89 ± 7.70	51.11 ± 13.88
Gross yield (kg ha ⁻¹ 100 days ⁻¹)	586.00 ± 126.00 ^a	590.33 ± 117.98 ^a	558.67 ± 129.62 ^a	285.22 ± 53.99	273.39 ± 80.73
Net yield (kg ha ⁻¹ 100 days ⁻¹)	99.11 ± 136.52 ^a	60.78 ± 113.10 ^a	55.67 ± 125.92 ^a	45.67 ± 48.30	10.00 ± 82.62

* Values with different superscript letters in the same row were significantly different ($P < 0.05$)

Table 3.2.4 Growth and production performance of crabs cultured in area of rich water, little water and moderate water in pens (Khatun, 2007).

Item	Block 1 (rich water)	Block 2 (little water)	Block 3 (moderate water)
Initial body weight (g)	101.66 ± 5.9	100.12 ± 5.3	102.10 ± 3.2
Final body weight (g)	228.09 ± 2.5	215.60 ± 4.9	223.92 ± 6.5
Initial ICW (cm)	7.73 ± 0.37	7.60 ± 0.41	7.72 ± .30
Final ICW (cm)	10.2 ± 0.24	10.0 ± 0.29	10.2 ± 0.08
SGR _w (% day ⁻¹)	0.81 ± 0.07	0.77 ± 0.04	0.78 ± 0.06
SGR _{ICW} (% day ⁻¹)	0.29 ± 0.06	0.27 ± 0.06	0.28 ± 0.03
DWG (g day ⁻¹)	1.26 ± 0.09	1.16 ± 0.03	1.22 ± 0.09
FCR*	1.46 ± 0.11 ^a	2.22 ± 0.34 ^b	1.69 ± 0.42 ^a
Survival rate (%)*	62.22 ± 1.92 ^a	44.44 ± 5.09 ^b	45.55 ± 6.94 ^b
Gross yield (kg ha ⁻¹ 100 days ⁻¹)*	709.67 ± 22.81 ^a	479.00 ± 53.00 ^b	546.33 ± 44.07 ^{ab}
Net yield (kg ha ⁻¹ 100 days ⁻¹)*	201.33 ± 43.36 ^a	-21.67 ± 71.01 ^b	35.89 ± 42.99 ^{ab}

* Mean values with different superscript letters in the same row were significantly different ($P < 0.05$)

cost of mud crab than the area of little water, while gross and net yields, net margin, revenues/costs and production cost of mud crab in the area of moderate water (block 3) are not significantly different from those in little water and rich water area ($P>0.05$) (Table 3.2.4). There are no significant differences of payback period among area of little, moderate and rich water. Both all-female and mixed-sex culture of mud crab in pens are economically feasible, however, all-female crab culture is more profitable than mixed-sex crab culture due to the higher market price of female crabs than male crabs (Table 3.2.3 and Table 3.2.4).

Kamal and Uddin (2004) also studied the technical and commercial feasibility of female mud crab (*Scylla olivacea*) culture in small (100 m²) bamboo pens in terms of growth, survival, production, FCR and return on investment (ROI). through three stocking densities (SD) (0.25, 0.5 and 1.0 crab/m²) with three replicates for a period of 60 days at Munshiganj of Satkhira district (22°12'19.7" N; 89°09'1.8" E), Bangladesh between October and December, 2003. The average body weights of crabs at stocking and harvesting were 102.69 to 141.69g, and 147 to 193 g. The crabs were fed with low cost trash fish at 5% of their biomass per day during morning and evening. Total water of the pens was changed during spring tide phases fortnightly. The average water temperature, salinity, pH and DO were recorded at 30 °C, 7 ppt, 7.7 and 6.2 ppm, respectively. The best average growth both by length and weight (7.79±1.04 mm and 62.73±2.19 g), FCR (1.69±0.12), ROI (172.91%) were attained with SD 0.5, while the highest survival rate (79.33±1.53%) was found for SD 0.25 followed and the highest production (8.29±0.14kg/100m²) was achieved at SD 1 crab/m². A negative but significant correlation was found for growth rate and survival with SD, while production and FCR showed significant positive correlation with SD. However, ROI showed negative and insignificant relationship with SD. The survival and production were found to be better with SD 0.25 and 1 respectively. While comparatively better performance of growth, FCR and ROI were achieved with SD 0.5 over the 0.25 or 1 crab/m². Therefore, a stocking density of 0.5 crab/m² could be most suitable for commercial farming practice of mud crab through bamboo pen system in Bangladesh.

3.2.1.b. Other countries:

3.2.1.b.1. Culture environments of mud crabs

Scylla species are commonly called mud crabs or mangrove crabs found in Southeast Asia and Mauritius. Culture temperature and salinity ranges from 23-30 °C and 18-34‰. Its growth rate is 8-9 cm CW (200+ g) in 3-4 months with of 30-70% survival rates and yields of 340-1800 kg/ha/crop in summer (in Taiwan) and 5 to 6 month in winter (Lee and Wickins, 1992).

Cowan (1984) suggests a salinity range of 5 to 21 ‰ with 10–12‰ being the most appropriate. Davenport and Wong (1987) reported that *Scylla serrata* can tolerate salinities between 1 and 42‰, and the crabs survived for more than 6 hrs in freshwater. The crabs were found to be oxyconformers with limited physiological capacity to survive hypoxic conditions.

Overton and Pushpakumara (1999) reported that mud crabs can tolerate a wide range of temperature and salinity as 12-35 °C and 2 to 50 ppt, respectively. *S. serrata* is reported to rear at approximately 30°C with salinities in the range of 10-25 ppt in order to achieve maximal production (Ruscoe *et al.*, 2004). Khatun (2007) stated that salinity, DO and pH in all pens ranged from 10 to 24.5 ppt, 3.84 to 7.90 mg/L and 6.1 to 9.7, respectively are suitable for pen culture, while water temperature 20°C are unsuitable for crab culture.

3.2.1.b.2. Culture systems

Aquaculture of the mud crabs has been conducted for at least 100 years in China and for 40 years throughout Asia (Overton and Pushpakumara, 1999). In Japan, sea-ranching of hatchery reared mud crab seed has been employed but seed production has not been proved reliable (Shokita *et al.*, 1991). Almost all crab aquaculture production relies on wild-caught stock, as larval rearing has not yet reached a commercially viable level for stocking into aquaculture farms. The traditional trade in mud crabs is for hard-shelled crab products, namely meat crab and egg crab. However, in recent years the market for mud crab products has extended to soft-shelled crabs and processed crab meat.

In general, two types of meat crab culture are practiced all over the world, that is, fattening and grow-out (Overton and Pushpakumara, 1999). Fattening is the holding of fished crabs that have recently molted (also known as thin or "watery" crabs) for 10 - 30 days until meat weight has increased (Overton and Pushpakumara, 1999). On the other hand, grow-out is the

process of stocking juvenile crabs (10 g to 100 g) and allowing them to molt and grow. Usually the crabs are harvested after 3-8 months or once they reach 200 g to 500 g size (personal communication with the fattener and depot owner). Four types of culture systems namely pond culture, cage culture, pen culture and integrated culture are found all over the world (Overton and Pushpakumara, 1999). However, in Bangladesh, scientific method of pond and cage culture has already been introduced (Zafar, 2003 and 2005; Kamal, 2004) and pen culture system is now going to be introduced (Khatun, 2007).

Pond culture: Earthen ponds are the most commonly used in small-scale culture of mud crabs (Overton and Pushpakumara, 1999). Small ponds are built in the homestead. Sometimes, fattening or grow-out ponds from 0.25 to 1 ha in surface area may be concreted or brick-powdered (Williams and Primavera, 2001). Farmers usually build a fence made of a range of materials, e.g., roofing tiles in Vietnam, concrete slabs in Sri Lanka, polyethylene sheets in the Philippines or mesh in Vietnam/Thailand around the perimeter of the pond to prevent crabs from escaping and to keep away predators. A simple sluice gate is used to allow water exchange. Shelters are provided by building trenches, canals, islands and by stocking seaweeds in ponds (Liong, 1993). The method of stocking, feeding and harvesting as well as the level of pond maintenance varies widely from farmer to farmer. Larger crabs are selectively harvested starting at 2 to 3 months (Williams and Primavera, 2001). In pond culture, berried females in particular, try to escape to the sea to spawn (Wickins and Lee, 2002).

Cage culture: Cage culture of mud crabs facilitates the use of estuaries, lagoons and brackish water ponds (Overton and Pushpakumara, 1999). Floating cages, made of bamboo or polyethylene/galvanized wire net are mainly used for mud crab fattening. The cage culture of mud crabs has been used in the Philippines and Indonesia. These cages can include those that are divided into compartments for individual crabs, thus reducing the mortalities due to aggression and cannibalism. The cages are floated using plastic floats and empty oil barrels to keep the upper side at surface level. A mesh screen is needed on top of the cages to prevent the crabs from escaping. Cages will allow individuals who do not have access to land to farm mud crabs. Grow-out cages of 3 x 3 x 2 m in Malaysia are stocked at 30 to 60 kg/cage (Williams and Primavera, 2001). Crabs for fattening in Indonesia are stocked in 2 x 1.5 x 1 m at 70 to 110/cage or in individual compartments in 2 x 0.5 x 2 m cages.

Pen culture: Pen culture has been used for grow-out of mud crabs in the Philippines and Sarawak, East Malaysia (Overton and Pushpakumara, 1999). This method integrates the system of crab rearing with the coastal mangrove forests, which does not involve the clearing of mangroves to construct ponds because the value of mangrove ecosystem should not be overestimated. Instead, the mangrove forest is penned-off and stocked with crabs. The pens can be made of plastic netting supported with a bamboo network as in the Philippines or made of wood as in Sarawak (Overton and Pushpakumara, 1999). Small (160 to 1,200 m²) and bigger (2,000 m²) pens are rectangular, square or irregular in shape. Canals to hold water during the low tide occupy 20 to 30% of total pen area; optional gates provide better water exchange. The natural mounds constructed by the mud crabs are retained (Williams and Primavera, 2001) rely on tidal water exchange and supplemental feeding. Pens for culturing mud crabs may also be constructed within ponds. Crabs for fattening in Indonesia are stocked at 100 crabs/pen with 4 x 4 x 2.5 m bamboo pens.

Vay *et al.* (2005) recommended mud crab pen culture for mangrove sites with mature trees, but not newly planted or newly colonized (wild) areas structure after evaluating that crab culture do not affect mangrove trees, although it reduced species diversity and also numbers and biomass of seedlings. However, in Asia, pen culture of mud crab is practiced in the Philippines and Malaysia. In the Philippines, Trino and Rodriguez (2001) conducted an experiment on growth and survival of mixed sex mud crabs *Scylla serrata* (Forsk.) grown in 200 m² pens located in reforested mangrove tidal flats for 160 days (Table 2.3). The pens were enclosed with nylon net (12-mm mesh and 2-mm nylon twine diameter) stretched over a bamboo framework. The bottom margins of the net enclosures were buried 60 cm into the mud, while the inner side of the upper net margin was lined with 30-cm-wide polythene film (gauge #18–20) to prevent crabs from escaping. Peripheral and central canals of 50 cm deep and 50–100 cm wide representing about 20–30% of the pen area were dug inside the pens. Canals were dug between rows of mangrove trees without destroying their roots. The pens were flooded during high tide but a dike with a crown approximately 40–50 cm wide and 50-cm high was built around the enclosure to maintain minimum water depths of 30–50 cm over the entire pen during the lowest tides with a screen of larger mesh (5 mm) to allow entrance of juvenile fish and crustaceans into the pens. Each pen had draining facility through two 50-cm-wide and 50-cm-high drain gates, and drained for three consecutive nights weekly to mangrove roots. The values for water quality parameters of the area were temperature at 27–32 °C, salinity at 18–32 ppt, DO at 4.2–11 ppm and pH at 8.5–9.

The seeds collected from natural habitat were stocked at 0.5 and 1.5 m⁻² and fed with salted fish bycatch or a mixed diet of 75% salted brown mussel flesh and 25% salted fish bycatch at 5-10% body weight. Crude protein contents of the feed ingredients were 47.1% for salted fish bycatch that consisted mainly of *Mirogobius* spp., and 32.2% for salted brown mussel (*M. metcalfei*) flesh, while crude fat contents were 5.1% and 3.5%, respectively. The experiment revealed that regardless of feed, the FCR of 5.30±0.34 and survival of 56.00±1.90% at 0.5 m⁻² stocking densities were significantly better ($P<0.05$) than those at 1.5 m⁻² of the stocking density (7.6±0.63 FCR and 33.00±3.61% survival), while the growth was not significantly affected by stocking density. However, cost-benefit analysis showed that crabs stocked at 1.5 m⁻² and fed a mixed diet of 75% salted brown mussel flesh and 25% salted fish bycatch was more profitable.

In Sarawak of Malaysia, the pen culture system of *S. olivacea* and *S. tranquebarica* introduced in 1992 becomes popular among local fishers or culturists (Ikhwannuddin and Oakley, 1999). Usually crabs of about 100 g are stocked in pens and harvested after 4-6 months when they reached marketable size as 3-4 pieces/kg with carapace width of more than 9.0 cm. The crab pen dimension is normally 18 m × 9 m with 2.4 m high fence made of palm (*Oncosperma tigillaria*) or wooden plank strips of about 10 cm × 4 m × 6 cm thickness. To avoid crab escape by burrowing, the strips are piled about 1.5 m deep into the soil with practically no gaps in between strips, which are supported by posts at 3 m interval and 3 levels of horizontal cross beams made of the same palm or hardwood materials. Main perimeter drains of about 0.8 m wide × 0.8 m deep were usually constructed in the internal area of pens. While tertiary drains of 0.3 m wide × 0.3 m deep are sometimes constructed across pens to connect the perimeter drain. A range of 4-5 small crabs/m² is stocked during the early morning and late afternoon for the culture operation. Crabs are fed with chopped trash fish once a day during high tide or nighttime at 2-4 kg per feeding daily. The farm size is 0.5 ha. A unit of 12 pens unit of 0.2 ha costs \$23,620 to build and makes a yearly profit of \$1,6000, the return on investment is over 40% and total production is over 4.5 tonnes per year.

Pen culture was also introduced to Mtwapa mangrove creek (intertidal area), situated 20 km north of Mombasa city of Kenya during 2000-2001 (Mwaluma, 2002) with the aim of finding an alternative source of income and food for the local communities, who practice artisanal fishery in the creek. The site was a naturally occurring pond of 800 m² (Table 2.3), which was

flushed during high tide up to 2 m in depth, while during low tide it is 1 m deep. *Uzio* (fish traps) made by the local fishermen each measuring 4 x 2 m was used for fencing. Crab seeds were obtained by contracting local fishermen and other villagers and by beach seining at Mtwapa creek using technical support from Kenya Marine and Fisheries Research Institute (KMFRI). Stocking density was 2 crabs/m² with a ratio of females to males of 1:1.75 (Table 3.1.7). Before stocking, the crabs were allowed to acclimatize in cool water from the pond. Crabs were fed with trash fish (fish heads, fish skin, broken fish, fish entrails and squid heads) once a day during high tide. Majority of the crab seeds ranged from 20 – 39.9 mm carapace length and weighed < 19.9 g, where the maximum size was 99.9 mm CW as 100 g crabs were not available and harvested after 4 months. The pond was well flushed with a salinity and temperature range inside from 12.8 to 35‰ and 25 to 36°C, respectively, and pH and DO were 7.95 – 8.25 and 2.65 - 4.00 mg/l, respectively. SGR and TWG at 60 – 79.9 mm and 80 – 99.9 mm size group were 4.3 and 50.0 g and 4.0 and 24.0 g, respectively that indicating slower growth rate towards maturity.

Integrated culture of mud crabs

Mud crabs have been shown to be a good polyculture species, particularly with finfish species (milkfish and tilapia) and seaweeds (*Gracilaria* spp.) (Overton and Pushpakumara, 1999). An example of the integrated culture is the rice cum fish farming in Thai Binh Province, North Vietnam. Mud crabs also have the potential to be farmed in coastal rice fields during the dry season.

Although integrated shrimp culture with rice is popular in Southeast Asia, it has several negative effects (Johnston *et. al.*, 2000). Firstly, greater leaf-litter fall and rotting organic matter on the pond bottom at farms, overhanging mangroves quickly foul the pond water to create an anoxic environment for the shrimp. Heavy rainfall during the wet season also washes a considerable amount of organic material into the ponds from the forest floor as well as increasing the levels of mangrove tannins in the ponds through leaching. Secondly, shading effects of the mangrove particularly with older forests increase heterogeneity in water quality conditions in ponds that have significantly negative correlation between shrimp yields and mangrove density (Johnston *et. al.*, 2000). On the other hand, mud crabs have several benefits over shrimp including higher survival, higher profits, and faster growth rates. This is achieved with little or no capital or feed input, with crabs either cultured in ponds or mangrove forests. Cash crops such as bananas, Indian taro, pineapples and cherry trees planted on pond levee

banks, particularly during the wet season when freshwater is plentiful, also increase total farm production. Therefore, integrated crab culture is now becoming popular, especially in North Vietnam (Overton and Pushpakumara, 1999).

3.2.2 Stocking density and feeding practices of mud crabs

Stocking density of 0.25 to 0.5 crab/m² are suitable for female crab culture in bamboo pen system in Bangladesh (Kamal, 2004). The best growth rate and FCR are obtained from stocking density of about 61 mm for female and 69 mm carapace width for male in bamboo cage. In Srilanka, India and Thailand, large crabs of 150 g stocked at 2 m² are cultured and harvested after 3-4 weeks as 250 g (Wickins and Lee, 2002). In China, 5-25 g juvenile crabs are stocked during February to March in modified rice fields at densities 0.4-0.8 m² (4,000-8,000/ha) to grow to 125 g in 6-9 months. Feed is given at 5% body weight three to four times per day (Wickins and Lee, 2002).

Analysis of data of the survey cruise by the research vessel "Anusandhani" in the year 1997 shows that 12 species of juveniles of commercially valuable fishes and 15 species of adult small size fish were also caught and considered as trash (Ahmad, 2005). Two other fish species, *Tetraodon patoca* and trigger fish (Balistidae) are also considered as trash fish. Of the total catch, true trash fish and commercially juvenile species were 6.44% and 28.50% respectively, whereas adult species was 65.05%. A lot of trash fish especially small size tilapia and puti from fresh water culture is also available to use for crab feed (Table 3.2.5 and 3.2.5). Hence, trash fish popular and economic to use in feed of crab (Table 3.2.5). However, continuous exploitation of trash fish may give immense pressure on natural stock. Therefore, recently Khatun (2007) and Zafar (2007) stated that some mollusk species are also potential for crab feed as molluscs are also abundant during new moon and full moon. However, Small-size trash fish including small tilapia (*Oreochromis mossambica*), puti (*Puntius stigma*) and bele (*Glossogobius giuris*) was cheaper than mollusk which have more than 60% protein (Table 3.2.5). Dry fish and trash fish provide the best survival rate and FCR over mussel, and mixed of mussel and trash fish for female and male in bamboo pens in Bangladesh (Kamal, 2004).

Table 3.2.5 Prices of supplementary feeds of mud crab (Khatun, 2007).

Category	Total weight (g)	Meat weight (g)	Meat (%)	Price (USD/kg)	Meat price (USD/kg)
Cockle	58.53	13.183	22.131	0.14	0.65
Snail	67.57	11.357	16.967	0.06	0.34
Trash fish					0.15-0.17

Traditionally, mud crabs have been viewed as carnivores that show a preference for natural diets containing molluscs, crustaceans and dead fish (Hill, 1979). In pond fattening of *Scylla serrata* in the Philippine, the crabs were fed a mixed diet of 75% brown mussel (*Modiolus metcalfei*) flesh and 25% fish bycatch (consisting of *Leiognathus* sp) at a rate of 10% of the crab biomass daily until final harvest (Trino and Rodriguez, 2001, Table 3.2.7). The effects of three diets (diet 1 – formulated feed with vitamin and mineral supplements, diet 2 – formulated feed without vitamin and mineral supplements, and diet 3 – fish bycatch) and monosex culture (male or female) on the growth, survival, feed conversion ratio, and production of mud crab (*Scylla serrata*) was evaluated by Trino *et al.* (2001). The crabs were fed the formulated diets a day after stocking at the rate of 5% of the crab biomass daily at CL < 6 cm, and 2% at the CL $\geq$ 6 cm (Table 3.2.7). Fish bycatch was given at 5 - 10% on wet weight basis. The highest growth and economic return was obtained from fish bycatch. The diet without vitamins and minerals was more economic than the diet with vitamins and minerals as the crab growth with the diet of vitamins but minerals was slightly higher than that with the diet without vitamins and minerals but vitamins and minerals consists a major part of feed cost. Hence, the formulated diet without vitamin and mineral supplements was economically viable.

In the Philippines, 2-3 cm CW juveniles were stocked in traditional intertidal ponds during May-August and fed trash fish at 6-10% of the body weight/day during high tide to reduce pollution, and crabs grew to 200 g or 8 cm in 4-6 months (Lee and Wickins, 1992).

In Taiwan, crabs were stocked in 0.2-0.5 ha earth ponds at 0.5 to 3 m⁻² and fed live snails and trash fish at 10-15 g m⁻² daily and crabs grew to 8-9 cm CW in three to four months in summer and five to six months in winter with 30-70% survival (Lee and Wickins, 1992).

Usually mud crabs are fed with locally caught fish species, which have a low market value (Table 3.2.7). These low-value fish species are harvested by farmers themselves or are bought locally from other fishermen (Overton and Pushpakumara, 1999). Rodriguez *et al.* (2003) reported that regardless of diet, the survival rate and net production of mud crabs were significantly higher ($P < 0.05$) when crabs were subjected to bimonthly selective harvesting than those at single terminal harvest, and higher profits could be earned by using a bimonthly selective harvesting and a mixed diet of 75% fresh or fresh-frozen brown mussel flesh and 25% cooked cracked corn.

A study was also conducted to identify production and nutritional values of local raw materials available in Central Java, and to develop feeds using selected raw materials for mud crab fattening (Hutabarat, 1999). The low-cost local raw materials for protein sources found

in abundance in Central Java throughout the year include trash fish, mysid, squid, blood meals, worm-meals and shrimp head meals as animal protein sources, and saga and soy beans as plant protein sources. The protein levels of selected raw materials are high (41.1–80.3%) and the highest level is found in blood meal, followed by squid, trash fish and shrimp head meals. Recently artificial feed production for crab is blooming worldwide to reduce pressure on natural resources. In Thailand, artificial crab feed is now going to be introduced to farmers in both fattening and grow-out farms (personal communication with Miss Pam, researcher, Department of Fisheries, Thailand, Table 3.2.6). Crabs are first acclimatized with artificial feed in small containers made of net, then release them to the pond. However, the feed ingredients are as follows

Table 3.2.6 Ingredients of artificial feed (personal communication with Miss Pam, researcher, Department of Fisheries, Thailand)

Name of ingredients	Amount (g/kg)
Soybean meal	82.7
Fish meal	210
Squid powder meal	84
Shrimp head meal	42
Lecithin	5
Tuna oil	30
Palm oil	30
Wheat Glutin	60
Wheat flour	155
Vitamin mixed	20
Mineral mixed	40
Vitamin C 100%	3
Rice bran	238.3

Artificial feed is made based on the nutritional requirements of mud crabs. Djuwito *et al.* (1992) showed that protein requirements for 'fattening' and mud crab culture ranged from 30% to 35%. Dietary lipid levels ranging from 5.3 to 13.8% appear to meet the lipid requirement for juvenile crabs (Sheen and Wu, 1999). Catacutan (2002) reported that juvenile *S. serrata* grows well when fed diets containing 32–40% dietary protein with either 6% or 12% lipid at dietary energy ranging from 14.7–17.6 Milijoule/kg.

Crustaceans are particularly proficient at digesting proteins, and protein/energy ratio is about 35-40mg protein/Milijoule energy (D'Abramo *et al.*, 1997). However, lipid is not digestible, and fiber in the form of cellulose or chitin has a negative effect on feed digestibility. Therefore, the recommended levels of lipid and fiber in crustacean feed are less than 10% lipid and less than 5% fiber (D'Abramo *et al.*, 1997). The optimal dietary cholesterol requirement of juvenile *S. serrata* is approximately 0.51% (Sheen, 2000). Diets with high P/E ratios (31.1 mg protein/Kilojoule) or high dietary energy (18.7 MJ/kg) were not well utilized by the crabs.

Sheen and Wu (1999) investigated the effect of dietary lipid levels on growth of juvenile crabs by using a mix of cod liver oil and corn oil, and determined that dietary levels between 5.3% to 13.8% appeared to meet the needs of the crabs. Interestingly, the upper level found was the highest tested, showing no reduction in growth compared to that in *Penaeus monodon* reported by Glencross *et al.* (2002). It is quite possible that mud crabs can tolerate, or actually require, a higher level of dietary lipid than does *P. monodon*. The cholesterol requirement of mud crabs was studied by Sheen (2000) using diets with varying cholesterol levels, and the author found that crabs fed on diets without added cholesterol had low weight gain, and the lowest moulting frequency and survival among all treatments. Dietary cholesterol levels over 1.12% had an adverse effect on growth. The optimal dietary level of cholesterol was determined to be 0.51% (5.1 g/kg) (Sheen, 2000).

Millamena and Quintio (2000) investigated the effects of diets on reproductive performance of female mud crabs. Using three diets including a natural diet (meat from squids, mussels and fish), a formulated artificial diet, and a 50:50 mixture of the two diets, they concluded that the mixture diet gave the best results in terms of fecundity, egg hatchability and larval survival. A study on digestibility of nutrients in feed components of mud crab diets indicated that mud crabs can digest a wide range of nutrients, including animal products such as fish meal, squid meal, *Acetes* sp. and meat and bone meal, as well as some plant products such as soybean meal, corn meal, wheat flour, rice bran and copra meal (Catacutan *et al.* 2003). The study showed that ADC of dry matter was between 88.3 and 93.6%, except for meat and bone meal (85.2%) due to high ash content (34% by weight). In all cases, protein digestibility was high, between 94.3% (copra meal) and 97.6% (squid meal), and fat digestibility was largely varied, and generally higher in the plant diets, while ash ADC ranged from 64.4% (meat and bone meal) to 82.2% (squid meal). The encouraging aspects of the study was that fibre

digestibility in all the plant feedstuffs was very high in the range from 94.4% to 96.1%. This may indicate that the crabs have certain capacity to digest fibre, either by metabolising as energy source, or breaking down plant cellular structures to liberate the cell contents for better digestion. Similarly, the high levels of NFE digestibility in the plant diets suggest the notion that the crabs can efficiently use starch and perhaps other carbohydrate materials. These diets contained 31.3 to 42.5% by dry-weight NFE, with digestibility ranging from 91.6% to 95.8%.

Table 3.2.7 Size of culture area, stocking size, stocking density, harvesting size, sex ratio, feed type, feeding rate, SGR, DWG, FCR, survival rate and production rate of mud crab cultured in pond and pen. (** indicate culture in mangroves and * indicate pond culture).

Source	Size (m ²)	Stocking g size (g)	Stocking density (g/m ²)	Harvesting size (g)	Sex	Feed type	Feeding rate (%)	Culture period (day)	SGR (%/day)	DWG (g/day)	FCR	Survival rate (%)	Production rate (kg/100m ²)
Triño <i>et al.</i> , 1999**	150	7.3-110	0.5 1.5 3.0	M-475.4, 428.8, 408.7 F- 327.1, 331.8, 325	M:F=1:0 M:F=0:1	Mussel trash fish	8	120	M: 3.47, 3.33, 3.03 F: 3.0, 2.93, 2.97	-	M: 2.1, 3.94, 6.3 F: 2.3, 4.01, 5.99	M: 97.3, 56.4, 27.5 F: 99.1, 57, 33.6	M: 34.7, 54.4, 50.5 F: 24.3, 42.9, 49.2
Triño and Rodriguez, 2001**	150	338	0.25	M-520, F-484, Mixed-517	M:F=1:0 M:F=0:1 M:F=1:1	Mussel+fish bycatch	10	30	M-1.1 F-0.73 Mix.-0.81	-	-	M-100 F-100 Mix.-86.9	M-17.9 F-15.9 Mix.-14.2
Zafar, 2003**	483.92	F=140-160 M=160-180 20- >100	0.5 0.33 0.5	-	M:F=1:1 M:F=0:1 M:F=1:0 M:F=1:1.7 5 and other species	Fresh eel+ salted eel	5-10	21	-	M-0.6, F-0.34 F-0.36 M-0.66	-	85 88 91.5	-
Mwaluma, 2002*	800	>100	0.5	>300	-	Trash fish	-	120	1.47-4.00	-	-	7	-
Triño and Rodriguez, 2002*	200	17-20	0.5 1.5	308.4-326.4 311.5-321.2	-	Mussel+fish bycatch	5-10	160	1.75-1.72 1.75-1.83	-	5.3 7.6	56 33	49 68
Kamal, 2004*	100-130	100-130	0.25-1	163-204	M:F=0:1	Trash fish	5	30	0.25:3.38	-	0.25:1.95	0.25:88.33	-
Kamal <i>et al.</i> , 2007	-	-	-	-	-	Trash fish	5-8%	15-16	-	-	-	78.55	30.4
Khatun, 2007*	60	80-120	0.5	>180	M:F=1:0 M:F=0:1 M:F=1:1	Trash fish	5-10	100	M-0.83 F-0.74 Mix-0.79	M-1.27 F-1.15 Mix.-1.22	M-1.46 F-1.95 Mix.-1.96	M-52.22 F-53.33 Mix.-50.00	M-586.00 F-590.33 Mix.-558.67

The selected raw materials generally contained 10 essential amino acids and long chain EFA (n-3 HUFA and n-6 HUFA) which are required by mud crabs for their growth (Hutabarat, 1999). It is also found from the experiment that there is significant difference between crabs fed with mussel meat and the crabs fed with moist prawn pellet, and the diet containing mussel meat resulted in the highest SGR and highest moulting frequencies (Marasigan, 1999).

Refinement of mangrove pen on-growing systems for mud crabs by partially replacing the fish requirements with low-cost pellets in Vietnam and Philippine has been shown to be cost effective, with a 55% return on investment and 1.8 yr payback period (Vay *et al.*, 2005).

Problems

- Price of trash fish is going to be increased day by day.
- Crab is known as carrier of viral disease.
- Unscientific harvesting of crab from shrimp *ghers*.

3.2.3 Seed production

3.2.3.a. Bangladesh: Though mud crab fattening is practiced widely practiced, pre-adult crab is collected from nature as seed production technique of mud crab is not available in Bangladesh. Hence, timely availability and abundance of crab seed can be a limiting factor for expansion of this industry (Chong, 1993). However, Saha *et al.* (2000) concluded that high stocking has inverse effect on brood development. Stocking density of 6000/ha give the best performance in growth and survival. Seasonal influences were detected for a number of characteristics with highly significant differences in fecundity, time to spawn, egg size, zoea size and proportion of non-viable zoea.

3.2.3.b. Other countries: Seed production of mud crab is a burning issue worldwide. Table 3.2.8 illustrates various seed production research conducted in other countries

3.2.3.b.1. Larva production

Table 3.2.8 Studies related to seed production of mud crab.

Source and subject	Finding
Mann <i>et al.</i> , 1999 (reproductive performance of broodstock)	Crabs collected in autumn are larger in size and weight and have significantly larger, more developed oocytes than those collected in winter or summer. Spring crabs spawn significantly smaller eggs than crabs collected in the other seasons. However, fertilization rate of the eggs do not vary significantly by season. Unilateral eyestalk ablated crabs produce larger eggs and has a lower production of non-viable eggs.
Millamena and Quintio, 1999 (reproductive performance and broodstock diet)	Feeding with combination diet consists of natural food (mussel, squid, fish by-catch) and formulated diet improves the reproductive performance. Latency period from stocking to maturation and spawning is shorter in ablated than in unablated females. Prematurations are observed both in unablated and ablated females in all dietary

Li <i>et al.</i> , 1999; Zeng 1987; Zeng <i>et al.</i> , 1991; Lin <i>et al.</i> , 1994 (reproductive biology)	treatments. The local mud crab has two annual spawning peaks and embryo development of the crab can be divided into 10 stages. The temperature range for embryo development is found to be 15–35 °C, while the optimal range is 20–30 °C. The embryonic stage 2 (gastrula) of the crab is the most susceptible to low temperature during which diapause occurs when temperature falls below 15 °C. Changes in protein, lipid, carbohydrate content and activity of four hydrolytic enzymes during the embryonic development is also measured. The result suggested that protein is the most important energy source for supporting embryo development. Specific activities of four hydrolytic enzymes increase rapidly at embryo stage 9 (immediately before hatching), reflecting the preparation for upcoming larval feeding. The embryo hydrolytic enzyme activity is suggested as an indicator for the viability of larvae. Lipid may be transferred from hepatopancreas to the ovary during crab gonad maturation. Triglycerides and phospholipids is the major lipids in the ovary of the crab.
Shangguan <i>et al.</i> , 1991; Yan <i>et al.</i> , 1994 (histology) Shangguan and Li 1994b (morphology and ultrastructure of mature sperm) Zeng and Li 1992a (larval culture biology)	Oogenesis of the crab is divided into 3 stages and ovarian development is divided into 6 stages. Crab sperm consisted of an acrosome, nuclear cup and radial arms. The rotifer, <i>Brachionus plicatilis</i>, is a suitable diet for early larval development, though its density significantly affects survival and development of the larvae. Larval survival rate is shown to steadily increase with density of rotifers and at 60 ind./mL, the highest survival rate to Z3 can be reached. However, for late larvae, rotifers are not a complete diet due to mass mortality and delay in moulting. In contrast, Z1 larvae fed with <i>Artemia</i> nauplii usually results in lower survival, but for later zoea, <i>Artemia</i> proves to be a good diet. Larvae initially fed with a high density of rotifers, but then shifted to <i>Artemia</i> at Z2/Z3 or fed a mixed diet at Z3 have the best overall zoeal survival as <i>Artemia</i> have apparently higher dry weight and C, H, N content and the gaps grew wider as larvae developed. Poor nutritional status during the zoeal stages appears to have a delayed effect on survival of megalopa. During larval development, C, H, N percentages reach their highest levels at late Z5, and newly moulted megalopa have the highest daily growth rate.
Zeng, 1987 (larval development) Li 1990; Li and Li 1995 (digestive system of larvae)	The basic form of the gastric mill appears at Z3 and is nearly complete at Z5. The cuticle cells of the midgut also shows differentiation at Z3. Accumulation of glycogen, lipid and protein in larval alimentary tract reach their highest levels at Z5 and the megalopal stage, but generally showed a significant increase at Z3.
Tang <i>et al.</i> , 1995 (digestive enzymes of larvae)	The level of larval digestive enzyme activities is associated with both larval developmental stage and nutriticnal composition of the diets. The specific activity of protease is high in Z1 larvae, indicating an immediate diet requirement after hatching but the low protease activity in Z5 larvae may relate to high mortality at that time.
Zeng and Li, 1992b; Zeng, 1987 (environmental factors)	25–30 °C is optimal temperature range for zoeal development. However, early larvae appeared generally more tolerant to lower temperatures, while megalopa can survive well at temperatures as high as 35 °C). For early larvae (Z1–Z3) and later stages (Z4–M), the most suitable range of salinity is 27–35 ppt and 23–31 ppt, respectively. The most optimal salinity for the duration of larval development appears to be 27 ppt. A short period of starvation after hatching can affect larval survival and development. On the other hand, if larvae are fed for only one day after hatching, there is a possibility of moulting into Z2 without further feeding. The PNR50 (Point-of-No-Return) for the Z1 larvae of the crab is estimated to be about 1.3 days, and PRS50 (Point-of-Reserve Saturation) 123 about 2.3 days (Zeng and Li 1998). Daily feeding rates of early larvae is significantly affected by the diet density, and newly metamorphosed megalopa has significantly high daily feeding rate which lasted for 2–3 days after metamorphosis.
Quinitio <i>et al.</i> , 1999 (feeding schemes of larvae)	2.0 mg/L/day + 0.25 mg increment/substage and natural food give high survival rate survival (3.71% - 1.33%).

culture) Williams <i>et al.</i> , 1999 (feed of larvae) Baylon and Failaman, 1999 (larval rearing)	The diets containing <i>Artemianauplii</i> can produce consistently high survival rates from megalopae to first crab instar. A combination diet of <i>Artemia</i> and <i>Brachionus</i> is ideal for the rearing of mud crab larvae, giving a high survival (69%) up to zoea 5 stage, high metamorphosis to megalopa (56%) and the shortest time to produce megalopa (17 days from hatching). As megalopa are already benthic in behavior and stays in the bottom of the container most of the time, minced or frozen <i>Artemia</i> should be given instead of live <i>Artemia</i> which actively swim about and hence are difficult for the megalopa to catch. From instar 1 to instar 4 stage, crablets prefer a diet composed mainly of bivalves and crustaceans, which must also be the diet of adult crabs. Higher density of 50 larvae/L can be used in larval rearing of the mud crab, although further studies should be done to determine effect of higher stocking densities of up to 200 larvae/L, on survival of larvae reared in bigger containers. Mud substrate can be provided to prevent cannibalism
Dat, H.D., 1999 (larval rearing)	The incubation period of the berried female crab is 10 days. The most suitable range of temperature is 28–30 °C, salinity 30 ppt (29–31) for the period of embryonic development and larval zoea stages; megalopae adapt to a salinity of 22–25 ppt. The food for zoea from stages 1 to 3 was diatoms, chlorella, rotifer (<i>Brachionus plicatilis</i>) and, in the final stages, it is rotifers and <i>Artemia</i> nauplii. The maximum survival rate of larvae attaining the first crab stage was 24%.
Zeng and Li, 1999 (feed of larvae)	Larval survival and development is steadily increased with density and at 60/mL, the highest survival of 94.7% to Z3 can be reached. Larvae initially fed with rotifers but then substituted with <i>Artemia</i> at Z2/Z3 or mixed at Z3 gave best overall zoeal survival. As larvae entered Z3, those fed with <i>Artemia</i> have significant higher DW and C, H, N values.
Parado-Esteva and Quintio, 1999 (salinity tolerance of larvae)	The highest LT50 for Z1, Z2, Z3, Z4 and Z5 are 20–32 ppt, 20–32 ppt, 20–24 ppt, 24–32 ppt and 20–32 ppt, respectively. When the larvae is transferred to test salinities at Z3, the highest percentages of larvae metamorphosed to the megalopa stage at salinities of 20–28 ppt, and when transfer to at Z4 or Z5, the highest percentage of larvae moulted to the megalopa stage at 24–28 ppt or at 28 ppt, respectively.
Macintosh <i>et al.</i> , 1999. (transport mechanism of larvae)	The brachyuran megalopae of at least four families including the portunidae, utilize floating mangrove leaves as an apparent transportation mechanism that help to protect megalopae from predators and may also provide a cue for their development into the benthic crab stage.
Marasigan, 1999 (feed of grow-out)	The diet containing mussel meat (<i>Perna viridis</i>) for mud crab (<i>S. serrata</i>) give the highest SGR and highest average moulting frequencies rather than moist prawn pellet, dry prawn pellet, squid and trash fish (<i>Alepes</i> sp).

3.2.3.b.2 Hatchery system

Mann *et al.* (1999) described a practical hatchery system for the mass culture of the mud crab *Scylla serrata* developed at the Bribie Island Aquaculture Research Centre. The system encompasses the main phases of the hatchery cycle from broodstock management through to harvest of megalopae or juvenile crabs from culture tanks. However, the overall system is described as follows

Broodstock

A standard circular broodstock tank with sandcovered bottom and flow through seawater is originally used to house broodstock through the maturation phase to spawning. This system is

then modified to allow greater control over water quality; a diagram of the maturation system is included in fig. 3.11. Characteristics of the system include:

- Chemical pre-treatment of new broodstock. Crabs are disinfected at an average of 100 ppm formalin overnight.

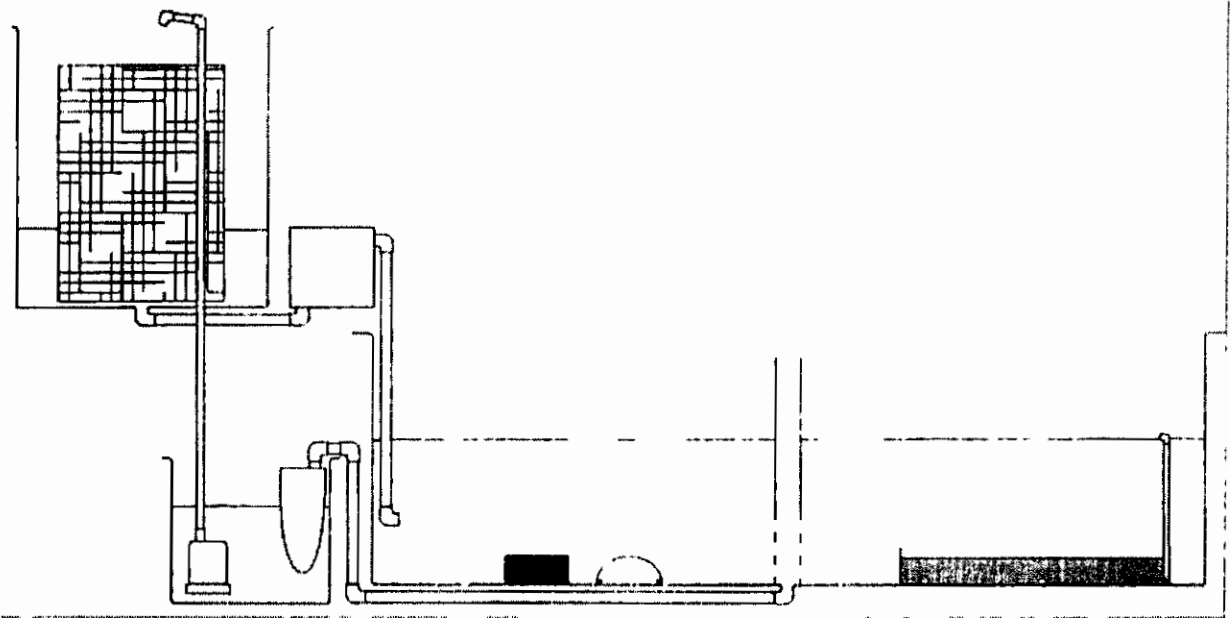


Fig. 3.2.1 Maturation and spawning system for mud crabs used at BIARC (Mann *et al.*, 1999).

- Use minimum volume of sand that allows for easier cleaning and replacement of the sand substrate, which is important, as crabs extrude eggs while partially buried in the sand.
- The system holds large volume (8 tonnes) of water.
- Broodstock are held at low stocking density i.e. no more than $1.5/\text{m}^2$ and disinfected with 10 ppm formaldehyde for 12 h.
- Recirculation of water. Dependence on inflowing seawater is reduced by using a recirculation system incorporating a mechanical and biological filter and UV disinfection. Inflow of new seawater is reduced to 0% to 20% per day.
- The appropriate feeding level is assessed daily to prevent over-feeding and fouling of the system.
- The broodstock are fed a varied diet containing food groups that reflect their natural diet and includes prawns, bivalves, fish and squid. In addition, mixed diet or special formulated diet (SEAFDEC) or mixed diet with high mollusk component can be used (Fielder and Heasman, 1999). Females should be free of lesions and have a full complement of limbs.

3.2.3.b.3 Larva culture

Table 3.2.9a Larval culture (Fielder and Heasman, 1999)

<i>Steps</i>	<i>Time required</i>	<i>Remarks</i>
Egg incubation	13–14 day incubation period	Avoid feeding during 8–12 days incubation period. High rate of flow-through of UV disinfected water.
Hatch	-	Filtered (1µm), disinfected (UV) water with 700 and 1000% exchange per day. Best practices are to avoid bilateral ablation during spawning incubation and aerated sand substrate in (0.8 m ²) spawning tray. All females provided with individual shelters and stocked at low density.

Stocking culture tanks

After hatching, the aeration in the hatch tank is turned off for several minutes to allow the vigorously swimming, photo-positive larvae to aggregate at the surface, where they are collected. The larvae are then transferred to a plankton mesh screen, where they are slowly flushed for 20 to 30 minutes with culture tank water. The flushing reduces the amount of potentially contaminated hatch tank water that will be eventually transferred into the culture tank and also slowly acclimatized the larvae to the new water. Care is taken to reduce the physical and chemical shock, and therefore stress, that the larvae encounter in the handling and transfer process. However, the best practices are to collect only vigorous positively phototropic larvae and immediately flush with 1 µm filtered, UV disinfected seawater, and transfer larvae to culture tank in 5 L dish allowing 45 minutes of water blending and acclimation (Fielder and Heasman, 1999).

Hatch tank and culture tank temperature is manipulated so that temperatures are within half of a degree and other water quality parameters are similar. Gentle handling reduces the physical turbulence that the larvae are subjected to. Although there are no supporting data available, it is expected that reducing the stress to the larvae at all times will reduce the incidence of stress-mediated susceptibility to disease. Temperature shock causing larval stress and mortality has been surmised when unintentional temperature fluctuations due to equipment failure has lead to abnormally high mortality rates. Temperature fluctuations of 5 °C over the range 23–28 °C within a daily cycle have been typically followed by dramatic mortality events. To ensure larvae are stocked into the culture tank at the required density, counts are made of larval density

in the flushing screen. The required volume of larvae concentrate is then transferred directly to the culture tank.

Culture tank design

The larval culture unit used at BIARC incorporates a primary culture tank and a recirculation tank. Seawater is circulated between the primary tank and the recirculation tank via an airlift and gravity flow. The advantages of using the double tank system are:

- Manipulation of water quality takes place remote from the larvae and changes can be slowly infused into the culture environment.
- Heating of the culture takes place remote from the larvae. Experiments at BIARC demonstrated that even low watt density heaters ($<35 \text{ k W/m}^2$) positioned in the culture tank cause larval mortality.
- Addition or removal of live feeds takes place in the recirculation tank, reducing the disturbance to the culture tank. For example, uneaten *Artemia* can be collected in a plankton bag secured over the inlet to the recirculation tank.
- Water exchanges can be introduced gradually into the culture tank to lessen shock to larvae and reduce the possibility of stress mediated infection and mortalities. The recirculation tank is 20% of culture tank volume, which allows up to 20% water exchange to be made at a time. When water exchanges are performed, the tank can be completely drained and cleaned if necessary.
- The recirculation tank acts as a settlement area for particulate material which can then be easily removed.
- A surface skimmer to remove organic pollutants or a biofilter can be added to the recirculation tank to treat water before it returns to the culture tank.
- The airlift pipe between the two tanks provides for extra gas exchange and no electrical pumps are required in the system.
- In smaller culture tanks of 1000 litres or less, aeration rates can be relatively low with most turbulence coming from a predominantly lateral flow generated by water flowing into the tank from the recirculation tank. This allows larvae more stability within the water column and the larvae are able to aggregate in areas where food density is highest. Water velocity can be adjusted for different larval stages. However, salinity tolerance of mud crab larvae is given as follows

Table 3.2.9b Salinity tolerance of mud crab zoea larvae recorded at SEAFDEC (Fielder and Heasman, 1999).

Stage	20	21	22	23	24	25	26	27	28	29	30	31	32
Z1	-	-	-	-	-	-	-	-	-	-	-	-	-
Z2	-	-	-	-	-	-	-	-	-	-	-	-	-
Z3					-	-	-	-	opt				
Z4					-	-	-	-	opt	-	-	-	-
Z5									opt				

Algae: A green water culture is maintained throughout the culture cycle. *Nannochloropsis oculata* is maintained at 5×10^5 cells/mL by addition of new algae on a daily basis. The algae are added for their water 'conditioning' properties and for continuous enrichment of the live food in the system.

Tahitian *Isochrysis* is added to supplement *Nannochloropsis* in the culture from Z3 onwards to give further enrichment to the *Artemia* nauplii. *T. Isochrysis* is chosen as it is complementary to *Nannochloropsis* in its levels of the two critical fatty acids DHA and EPA, (*T. Isochrysis* is high in DHA and low in EPA while *Nannochloropsis* is the opposite) (Dunstan et al., 1993). All algae in mass production are cultured in filtered seawater disinfected with chlorine overnight. This reduces the potential for contaminants affecting the algae and of introducing bacterial or other potential pathogens into the culture system.

Table 3.2.10 Food and Feeding regime of mud crab.

	Rotifer		<i>Artemia</i> nauplii
Zoea 1	10/mL and 500–1000/larva ¹	40/mL ²	
Zoea 2	-	30/mL ²	1–5/mL and 50/larva ¹
Zoea 3	10–15 /mL ¹	16.7/mL ²	0.5 to 3 /mL ¹
Zoea 4		8.9/mL ²	-
Zoea 5		3.3/mL ²	larger on-grown ¹
Megalopa			sub-adult ¹
Crab 1			

¹ Fielder and Heasman, 1999; Rabbani, 2006²

Culture management

Bacteriological surveys of larval cultures at BIARC have determined that the bacterial community is very unstable during the first days of culture. Typically, levels of both total heterotrophic and presumptive *Vibrio* (TCBS counts) rapidly increase from culture initiation to day 2. From day 2 to around day 3 or 4, bacterial levels rapidly decline to reach a low base level. It is better to start the cultures 3 days before hatching of the crab larvae to be used. This way the larvae are not stocked into the cultures until the bacterial community has established. The

influence of this procedure on larval growth and survival has not yet been investigated through experimentation. Further management strategies used in the culture of larvae are designed to maintain stability of the culture environment and reduce the potential for opportunistic pathogens to invade the system. While cultures are running well, water exchanges are kept at a low level that is sufficient to keep ammonia and nitrite within safe limits and is typically 10% to 20% per day. Exchange rates need to be increased up to 40% per day near the end of the larval cycle in order to maintain acceptable water quality. The use of a biofiltration medium in the recirculation tank is investigated and found to act as an accumulator of particulate organic material. This is an advantage as it increases the ability to remove polluting organic material from the system and improve culture quality. The nitrification ability of the substrate is, however, limited due to the need to regularly clean it.

After larvae have metamorphosed to the megalopa stage, additional substrate is suspended within the culture tank to provide a surface for settlement of megalopa and crabs. The substrate is constructed of strips of shade cloth and flyscreen mesh, which is suspended vertically along a length of twine weighted at one end and with a float at the other.

Harvest: The settlement substrate added to the culture tank during the megalopa stage also acts as a convenient way to harvest settled megalopae and first stage crabs from the tank. Late stage megalopa and crab stages tend to remain clinging to the fibres as the substrate is gently removed from the tank and placed in a nursery tank. The remaining megalopae or crabs are drain harvested into a mesh cage. The most appropriate time for harvesting from the larval culture tank that maximises survival has still not been rigorously investigated. Whether to harvest at megalopa or crab stage will also depend on the conditions to which they will be transferred.



Chapter 3

3.3 Mud Crab Fishery Management

Mud Crab Fishery Management in Bangladesh

3.3.a. Bangladesh:

3.3.a.1 Crab fishery in the Sundarbans

There are a few studies on management practices of mud crab in Bangladesh, especially in the Sundarbans as it is the major source of mud crab in Bangladesh. Recently Hoq (2007) studied on fisheries exploitation and management practices on Sundarbans where mud crab has little concern. The mud crab (*S. serrata*) is harvested on an increasing scale from the Sundarbans and has become into an export oriented lucrative business commodity (Hoq, 2007). The crab fishery has been come under heavy fishing pressure in recent years and considered to be overexploited. There is a significant price variation of this species in the market, which promoting some selectivity of the capture: berried females are more valuable than female without eggs, while males are of least value. Females without egg are sold for fattening in ponds which then export as berried females. Mud crab fishing takes place round the year throughout the SRF of which 30% are berried females. The potential of crab fishery seems to be vast and the prospects of its culture, just as with shrimp, need to be explored. During shrimp fry collection, crab seed are indiscriminately destroyed. The presence of a high abundance of crab megalopa in Sundarbans water would allow for a new mud crab aquaculture grow-out industry to develop the current small-scale crab fattening practices.

3.3.a.2 Catch Per Unit Effort (CPUE)

Fishers are issued a pass from the Forest Department prior to entering the SRF where each crabber harvests about 10-15 kg of mud crab per day (personal communication with crab fisher and forest officers). Each boat with two crabbers harvests about 70-200 kg of mud crab of different sizes and sex in 7 days. Most crabbers in the SRF do agricultural labour and/or fish inside the SRF for white fish or shrimp during off-season.

The CPUE has declined significantly over the last few decades in the SRF based on a field survey conducted in 2003-2004 due to following reasons:

- Increase in the number of crabbers due to unavailability of alternate income options;

- Use of small meshed marine set bag nets (*behundi jal*) in the shallow sea areas of the Bay of Bengal from October to March which trap berried females of mud crab in large quantities;
- Recent increase of fishing with poison in small canals that makes canals unsuitable for aquatic fauna including mud crab.

3.3.a.3 Crafts and gear used in crab harvesting

The fishermen use indigenous fishing craft and gear to trap crab. A craft locally called *nowka* (wooden boat, with or without engine) is operated manually by these fishermen (Uddin, 2002; and Kamal and Tapadar, 2007 and Ahmed, 1992). It measures approximately 7-8 m in length, 0.9 - 1.2 m in breadth and 0.3-0.5 m in depth and is operated by one or two fishermen (Ahmed, 1992). Mechanized devices have not yet been developed for crab fishing. Small boat, with or without engine is also used in Thailand (Tookwinas *et al.*, 1992).

Generally, fishermen use the local gear suited to a particular habitat to trap crab. Rope line, hook line, long metal hook and set bagnet are widely used along the tidal river and mangrove area, whereas iron hooks, cast net and bamboo trap are used to catch crab in shrimp farms. The rope line used in the Sundarbans is the most effective of these methods.

The principal gears, the *daon* (baited line/ rope line), the bamboo traps or *boom*, iron hook and the *chip* (pole) are employed for capture of crab (Hossain and Ahmed, 2006). Various nets used for collection of crabs either as main or the secondary catch, and some accessory implements are required for handling and transport of crabs. However, the types of gear and their ways of use are described below:

Rope line

Crab are extensively fished in the estuarine and mangrove swamps of the Sundarbans using this method. A rope line of about 100-200 m coir rope with branching line is stretched across the estuary or swamp (Ahmed, 1992). One end of the rope is tied to a pole fixed on the bank, while the other end is towed by boat to the extent as the rope permits. This line is weighted at regular interval with bricks. The rope line is operated at the depth of 4-8 ft (Uddin, 2002 and Kamal and Tapadar, 2007). Pieces of eel meat are suspended as bait having nose to attract crabs (Ahmed, 1992). When the crab tugs at the bait, the noose tightens around the crab, which then clings to the line with its claws. After becoming the line sufficiently heavy with crab, the fishermen lift the rope to within 5-8 cm of the water surface. The crab are then captured with a scoopnet and stored in a basket to prevent their escape.

In Chittagong region, baited line are locally called *daon*, consists of a long rope made of jute fibre or nylon ranging from 400 to 1200 m in length and 5 to 10 mm in thickness. The length of *daon* depends on the stretch of the fishing site. Usually a *daon* of 600 m is used having 1200 baited substrings of 5 to 15 cm length (Table 3.3.1). The substrings are hanged at regular interval of 40 - 50 cm. A burnt earthen circular disc-shaped weight or a piece of brick is tied to that rope as sinker at the 5 m apart.

Operation of *daon*: All the substrings are tied with a small piece of fish meat of sharks, rays, catfishes or eels as bait. A boat is often used for the operation of *daon*. A suitable creek is selected for placing the *daon*. Then one end of the line is tied to a bamboo pole of 3 - 5 m height or more. The pole is driven into the mud and the fishermen row to the other bank of the creek by releasing the line. In wide rivers and estuaries the fishermen often use weight instead of bamboo pole. The other end is fastened to a post in the boat. The bait is tied with the substring by means of slip noose. If the bait is pulled, the slip noose becomes tighter round the bait. Crabs are attracted to the fish bait and cling to it with their strong claws. The fishermen reel the line when they assess a good number of crabs to have clings to it. Normally it is done at about 1 hour interval. A fishing unit of at least three is required for the purpose. One reels the line, the other fixed bamboo pole. Sometimes the same person reels the line and operates the scoop net. When a crab clung to the bait is visible it is scooped out by the scoop net and stored in the basket or directly in the hold of the boat.

Long metal hook

Long metal hook is used to catch crabs from the hole (Ahmed, 1992). This technique is used by the small-scale fishermen of Noakhali, Barisal and Teknaf districts (Ahmed, 1992). When a hole is detected, this gear is used to corner the crab. Once the retreat of the crab is cut off, it rises on its hind legs, waving its large claws to frighten away the assailant. When it grips the rod with its powerful claws, it does not let go. It can thus be easily taken out along with the rod.

Bamboo trap

Bamboo trap, locally known as *chui*, or *tonga* is used to catch crabs in shrimp farm, tidal rivers, estuaries and mangrove areas (Hossain and Ahmed, 2006; Uddin, 2002; and Kamal and Tapadar, 2007). It has two openings or eyes, which are funnel-shaped (Ahmed, 1992). The mouth is being wide for entry and the inner end narrow to prevent escape. Usually eel fish (Zafar and Ahsan, 2006, Kamal and Tapadar, 2007 and Uddin, 2002), frog and tilapia (Kamal

Table 3.3.1 The principal gears used for fishing of mud crab in Bangladesh (Hossain and Ahmed, 2006).

Name of gear	Type of gear (local name)	Length of line (m)	Rows of interval (m)	Length of stick (m)	Material used	Name of bait used	Fishing area	Types of mud crab caught	Fishing period
Baited line	Baited line (<i>daon dori</i>)	400-1200	0.4-0.5	-	Coir, jute, nylon rope, brick, sinker	Eel, shark, ray and trash fish	Creeks, estuaries and rivers etc	Male and female	All season
Length (cm) Diameter (cm) Mesh size (cm)									
Bamboo trap/boom	a) One mouth opening (<i>bang chai</i>)	60-65	35-40 (mouth)	5	Split of bamboo	Eel, shark, ray and trash fish	River channel	Maximum female	All season
	b) Two mouth opening (<i>lamba chai</i>)	85-90	35-40 (mouth)	5	Split of bamboo	Eel, shark, ray and trash fish	Shrimp pond	Both male and female	All season
Name of hook (local name)	Size (m)	Materials used	Fishing area						
Iron hook (<i>gaij</i>)	Length 1.8-2.0	Iron and wood	Intertidal zone of shrimp ponds, mangrove swamps and river channel						

Table 3.3.2 The secondary gears used for fishing of mud crab in Bangladesh (Hossain and Ahmed, 2006).

Name of net (local name)	size	Mesh size (cm)	Materials used	Fishing area	Fishing period
Behundi net (<i>Behundi jal</i>)	Length 20 m, wide 6 m, Wings 9m	Mouth - 10.0 Codend -1.0	Nylon and cotton	River	All season
Charpata net (<i>Gira jal</i>)	Length 70-90 m Depth 4-5 m	1.0	Nylon and cotton	Intertidal zone of river	All season
Cash net (<i>Jhaki jal</i>)	Diameter 4-5 m	1.5-2.0	Nylon and cotton	Shrimp pond and river channel	All season

and Tapadar, 2007 and Uddin, 2002) is used for bait. At the beginning of high tide, 60-100 *ckai* are placed in rows across a canal, tied with a rope or fixed individually with a stick. Some fishermen also operate the trap in the channels during low tide. After the crabs are collected, the *ckais* are rebaited and set again. Trapping crab by this method is practiced for 5-7 days at a stretch mainly by the fishermen of Chokoria and Cox's Bazar.

Iron hooks

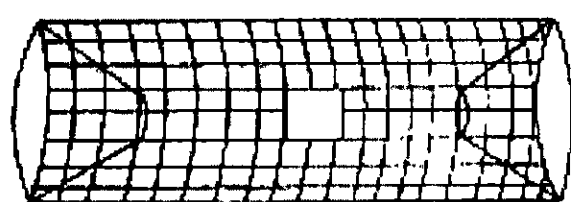
Iron hooks made of an iron rod of 3-4 ft in length is used to make a hook and fitted with a wooden or bamboo handle, usually used in shrimp gher to collect crabs (Uddin, 2002 and Kamal and Tapadar, 2007).

Castnet

This gear is generally used to catch shrimp and fish (Ahmed, 1992). During such fishing, a small quantity of crab are also entrapped. In semi-intensive shrimp culture farms, the culturists spread pieces of fish in a definite area where crab concentrate. Then they use the castnet to entrap the crab, which are considered pests by the shrimp farmer.

Set bagnet

Set bagnet is used to trap crabs in shrimp gher during water exchange (Ahmed, 1992). During the regular water exchanges through the sluice gates in shrimp farms, indigenous set bagnets are installed by the gates to prevent the shrimp from escaping. During this activity, some crab are entrapped in the nets.



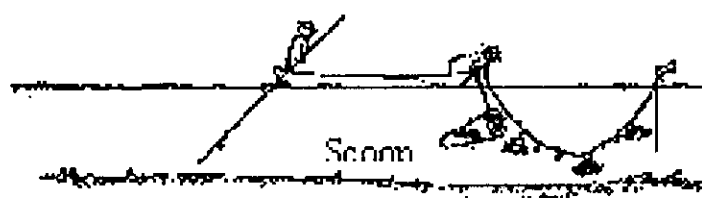
Boom



Scoop net

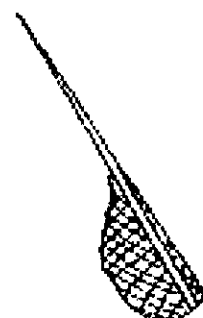


Rai

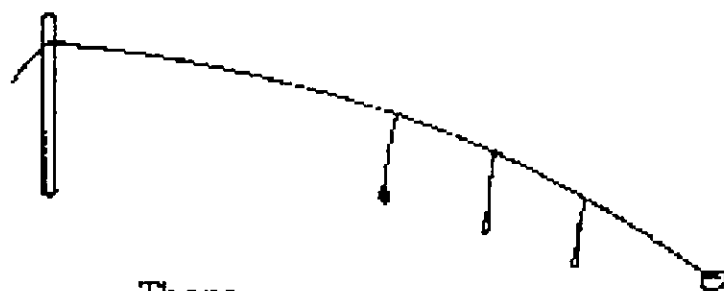


Scom

Rope line



Bait strike



Thopa



Iron hook

Fig.3.3.1 Gears used for harvesting mud crab in the SW region of Bangladesh (Kamal, 2003)

Impact

The Mud Crab Fishery seems to have little impact on the ecosystem due to passive fishing methods that effectively target large mud crabs, although crocodiles, turtles and sharks may feed on mud crabs. Due to the steady growth in demand and price of live mud crab in export markets, the species has already been overfished from various natural sources. The current ban on shrimp fry collection (Frankenberger, 2002) and enforcement of a ban on the use of destructive fishing gear in the Sundarbans have resulted in a huge entry of fish and shrimp fry fishers into mud crab harvesting in the Sundarbans (Anon, 2000). The catch per unit effort (CPUE) production and export earnings has also declined significantly over the past few years (Anon, 2005). Moreover, the fishery of mud crab (*Scylla olivacea*) from the Sundarbans is over-exploited with a MSY of 283 tons and yield is 375 tons (Zafar *et al.*, 2006).

3.3.a.4 Harvesting area and season

Harvesting area

There are three major sources of mud crab harvesting in Bangladesh. The main sources of crabs are the Sundarban mangrove forest and tidal rivers, whereas during rainy season crabs are harvested from the Sundarban, tidal rivers, shrimp farms and fattening ponds (Uddin, 2002) as crab mortality significantly increases during winter due to low temperature (Khatun, 2007). However, production of mud crab from the Sundarban is higher than shrimp ghers (Islam, 2003). About 90% of exportable crab come from natural sources and the rest being come from the fattening centers (Zafar and Ahsan, 2006). Although crab harvesting from the Sundarban from December to February and May to June is prohibited, crab harvesting are carried out throughout the year (Islam, 2003 and personal communication with the fisherman in Munshigong) showing permit of fishing during breeding season (personal communication with the fisherman in Munshigong). Crab seeds enter into shrimp farms through inlet, naturally grows and it is harvested after maturation (Uddin, 2002). The maximum catching attains during spring tide and neap tide.

The unregulated exploitation has depleted mud crab populations in many parts of the world (Overton and Macintosh, 2002; Checwasedtham, 1990) including Bangladesh (Azam *et al.*, 1998).

Harvesting season

Wet season (June-October) is the peak harvesting season from shrimp ghers, and the dry season (early and late winter, October-March) is the peak crabbing season from the SRF (Uddin, 2002).

Juvenile crabs enter traditional shrimp *ghers* with tidal water and grown until harvest. In contrast, crabbing continues year round in tidal rivers and canals throughout the coastal zone of Bangladesh.

The peak crabbing season in the SRF is the winter months in December and January (Uddin, 2002). However, Mia et al. (2006) reported that abundance of male is highest in November and abundance of female is highest in August-October. In winter most shrimp *ghers* are dried out, but if not, crabs living inside the *ghers* go down to the river and mangroves to avoid winter or to migrate for breeding into the sea. The maximum catch is during spring tides of the full moon and the new moon phases, locally called *goon*.

Problems

In Bangladesh, there's no scientific study on development of efficient craft and gear for crab, although high mortality during transportation from harvesting area to depot is due to prolonged period for transportation and fishing as fishing mortalities are 0.35/yr and 0.38/yr for male and female, respectively in Bangladesh (Zafar *et al.*, 2006). On the otherhand, legs of crabs are sometimes broken during harvesting by hand, cast net etc. Hence, the major problems are

- Unscientific and inefficient harvesting methods.
- Lack of efficient harvesting gear.
- Lack of assessment of current harvesting level.

3.3.b Other countries: A collapsible crab trap, which can be very easily transported, has been developed by the Department of Fisheries in Thailand (Tookwinas *et al.*, 1992). Fishermen can carry many more of these traps than other types when they go fishing. The efficiency is also higher than other gear. The catch per unit of effort (CPUE) is about 0.5 kg/day, while the crab liftnet is about 0.2 kg/day.

After the fattening period, mud crab are also harvested individually by hand. The crab are then bound with straw or string to enable easy handling. A skilled labourer is hired to bind the pincers of the crab. However, fishing gear used in other countries are described below

Table 3.3.3 Fishing gear used in other countries

Country	Gear
India.	Line with baited hooks, traditional craft (boat), hoopnet/basket/trap, barrier net/stakenet, gillnet, dragnet/pushnet, castnet, shore seine (Kathirvel and Srinivasagam, 1992).
Indonesia	Dragnet/Pushnet, set bagnet (Cholik and Hanfi, 1992), crab pot (Anon., 2007a).

Sri Lanka	Traditional craft (boat), hoopnet/basket/trap, barrier net/stakenet, gillnet, castnet, shore seine (Jayamanne, 1992).
Thailand	Traditional craft (boat), hoopnet/basket/trap, barrier net/stakenet, gillnet, dragnet/pushnet, wing set bagnet, set bagnet (Tookwinas <i>et al.</i> , 1992).
Malaysia	Traditional craft (boat), hoopnet/basket/trap, barrier net/stakenet, gillnet, dragnet/pushnet, trawl (otter and pair).
Madagascar	Wooden gaff, dipnet, line with baited hooks, traditional craft (boat), gillnet, dragnet/pushnet (Sivasubramaniam and Angell, 1992).
Philippine	Fish pot, cast net, baby trawl, push net, beach seine, fish coral, gill net, setnet, crab lift net (Ladra and Mondragon, 1992).
China	Aluminium square crab net, anti seaweed crab trap, semi-oval crab trap, folded crab net, elastic crab net, round crab net (Anon. 2007a).
Singapore	Round crab trap (Anon. 2007a)
Italy	Crab square cage (Anon. 2007a)
Chile	Heart shaped crab net (Anon. 2007a)

In Phipplipine, Tobagonian bamboo-tube traps has been introduced instead of old bamboo-tube traps (Maitland, 2002). Tobagonian bamboo-tube traps are baited with local fruits and are positioned on the surface adjacent to crab burrow entrances, while Old World bamboo-tube traps are reportedly used unbaited and are inserted into the mouths of crab burrows. The new traps' simple design and ability to catch land crabs alive and unharmed make them a viable research tool in population studies of land crabs. Similar traps could be made from modern plastic drainage piping.

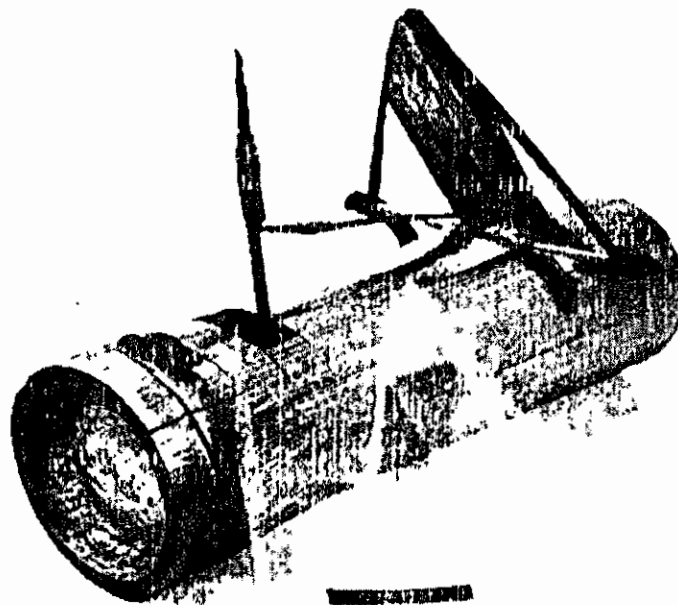


Fig. 3.3.2 Tobagonian bamboo-tube traps used for medicinal harvesting (Maitland, 2002).

The trap is baited by skewering a piece of firm fruit (e.g., guava) onto the tip of the trigger if the trigger is made of bamboo. Crabcatchers in Tobago, craft the trigger stick from the stem of a freshly cut banana leaf. Thus, the trigger also acts as the bait. A crab that enters the trap and pushes or pulls against the trigger tip in an effort to consume the bait is likely to dislodge the trigger from its hold on the edge of the trigger hole. This done, the spindle is released allowing the bow to slam the trap-door shut. The crab is trapped. These bamboo traps are extremely efficient. Fifty traps set overnight in a banana grove in Kendall, Tobago, yielded 25 crabs the next morning that were subsequently 'russed up in "strings" of 20 and sold at the side of the road or in the market in Scarborough.

Chapter 4

3.4 Domestic Market and Export of Mud Crab in Bangladesh

3.4.1 Post harvest handling

Live mud crabs are transported from one place to another. The fact that mud crab survive in air for about 4-5 days (under optimum conditions) has enabled their shipment to distant markets. Improved packaging and handling techniques have also significantly contributed towards the increase in regional trade (Angell, 1992).

As mud crabs are highly cannibalistic animals, the crab have to be bound with coarse twine to render their claws immobile immediately after capture. Thus, the claws of live mud crab are tied with plastic rope or coir rope to prevent human injury and physical damage or mortality of harvested crabs (Kamal and Tapadar, 2007 and Uddin, 2013).

Harvested mud crabs from both wild sources (Sundarban mangrove swamps, Tidal rivers and canals) and shrimps farms are transported to Dhaka by various means within 7 hours to 7 days. Sometimes, the collectors have to stay 7 to 15 days in the Sundarban only for collection (Zafar and Ahsan, 2006). Hence, 81% of crab collectors are male.

3.4.2 Grading for marketing

Grades of XXL, XL, L, M and SM for male and FF1, F1, KS1, F2, F3 and KS3 for female are considered for export in Bangladesh. However, grading system of mud crab in local market differs from international market (Zafar and Ahsan, 2006). In Khulna region, XXL for male and KS3 in female are not considered in local market, whereas SSM for male and KS2 for female are considered in addition to the grades of international market in Chittagong region. The grades of mud crab depend on sex, size, body weight, gonadal maturation and hardness of the carapace of the animal (Kamal and Tapadar, 2007). Experienced farmers can tell whether the ovaries are full by examining the crab against the light and also by pressing its shell to feel if the crab is firm and full. The same practice of examining female gonad is found in Philippine (Ladra and Lin, 1992). In Philippine, crabs are marketed live in all cases and females with mature ovaries are particularly expensive (Ladra and Lin, 1992). Although grading system is

different for male and female, some fixed categories are considered for grading in all cases (Table 3.4.1).

Table 3.4.1 Overall grading system of mud crab in local in Khulna region and international market (Hasan, 2006 and Kamal and Tapadar, 2007).

		Local market					
Criteria		XL	L	Grade M	SM		
Male	Weight (gm)	>400	>300	>250	>200		
	Gonad condition	Full	Nil	Nil	Nil		
	Shell condition	Hard	Hard	Hard	Hard		
Female	Weight (gm)	F1	KS-I	F2	F3		
	Gonad condition	>180	>180	>150	>120		
	Shell condition	Full	Partial	Poor	Nil		
		Hard	Hard	Hard	Hard		
		International market					
		XXL	XL	L	M	SM	
Male	Weight (gm)	>500	>400	>300	>250	>200	
	Gonad condition	Full	Full	Nil	Nil	Nil	
	Shell condition	Hard	Hard	Hard	Hard	Hard	
Female	Weight (gm)	FF1	F1	KS1	F2	F3	KS3
	Gonad condition	>200	>180	>180	>150	>120	>120
	Shell condition	Full	Full	Nil	Full	Full	Nil
		Hard	Hard	Hard	Hard	Hard	Hard

There seems to be significant fluctuations in the market price of mud crab due to the wide seasonal variations in the landings. Price of crab is highly variable among seasons. Price is relatively high in winter, especially during Chinese festival due to high demand (Table 3.4.2), which is the main obstacle of fish processing center in freezing of as the buyer fix price and quantity at the beginning of contact (personal communication with Prof. Dipak Kamal, Khulna University). Hence, increasing production through culture and fattening can contribute to a more stable situation (Angell, C.A., 1992). However, this seasonal variation of market demand and price of crabs in Bangladesh is almost similar with that in the Philippine (Balio *et al.*, 1999) and Queensland (Lee, C., 1992). Price of crabs is high in the Philippine during Christmas season and in Queensland during the Christmas or New Year and Chinese New Year.

Table 3.4.2 Grading and prices of mud crab during winter (Khatun, 2007).

Grade/ size	Weight (g)	Prices (USD/kg)	
		During Chinese festival	Winter except Chinese festival
XXL (Double extra large)	500	8.57	5
XL (Extra large)	400	7.14	3.57
L (Large male)	300	4.57	2
M (Male)	250	3.86	1.43

SM (Small male)	200	3.14	0.86
F1 (Female)	180	14.29	5
D2 (Female carrying egg)	120	2.86	1.14
PS (Pieces: male and female)	100	1.43	0.14

Problems

- Supply of mud crab mostly depends on natural resource, so buying unstable price, on the otherhand, fixed selling price;
- Different grading system in local and international market;
- Unsuitable infrastructure in depot;
- No control of crab fishermen, depot owner over price fixation;
- The social and religious customs binder the development of domestic market or any other value added product development.

3.4.3 Transportation

3.4.3.1 Transport to local landing centre

Harvested mud crabs are transported to the depots from tidal rivers and mangrove swamps by small wooden boats and sometimes by mechanized trawlers and transported to the local depots by bi-cycle or Van (Kamal and Tapadar, 2007), while in India, crabs are generally sent to major cities by train (Kathirvel and Srinivasagam, 1992). From farms, the mud crabs are carried in bamboo baskets, plastic pots, while cane baskets moistened with brackish water are used for packing and transport of crab in Srilanka (Jayamanne, 1992).

The overall condition of crabs from shrimp farms are found more stable and fetched higher prices than the crabs harvested from the Sundarban mangrove swamps. As fishers with small non-traditional boats usually stay 6-9 days in each fishing trip, the crabs caught in the first days reached at depots after 9 days. Crabs from shrimp farms usually took 3-4 hours to reach at local depots by the *forias* and middle men. Fishers in Bangladesh kept the harvested crabs in the hole of the boat and sprayed river or canal water of the crabs to keep them moist (Kamal and Tapadar, 2007), whereas in Australia, commercial fishermen either pack their catch immediately or, in more remote locations, store them under water in holding structures of net-

pens or floating steel cages until enough have accumulated for a full shipment, either by road or by light plane (Gillespie and Burke, 1992).

3.4.3.2 Transport to Dhaka

Long-necked shaped bamboo baskets of different sizes are used to transport mud crabs from local depots to Dhaka. The baskets are covered with sackcloth or gunny bags and the bottom is lined wet with betel-nut leaf (Kamal and Tapadar, 2007 and personal communication with depot owner in Munshigong), while mangrove leaves are used to line bottom and side of basket in Australia (Gillespie and Burke, 1992) to keep low temperature and to prevent dehydration. In India, crabs are packed in bamboo baskets for domestic marketing (Kathirvel and Srinivasagam, 1992).

Live crab should be handled minimally after capture. They should not be handled by their claws, as they readily shed them. Crab should also be protected from exposure to intense sun and wind. While crab are being packed, they should be packed as close together as possible; spaces can lead to movement, fighting and damage. In Australia, individually tied crab are arranged neatly inside the baskets and these are covered with plastic sheets and placed in the coolest part of the vessel (Gillespie and Burke, 1992). However, in Bangladesh, different grades of crabs together in the same baskets containing about 70-90 kg crabs are transported to Dhaka by bus, and mini-truck (Pick up) at night hours depending on the quantity and availability of suitable vehicles when the ambient temperature is lower (Kamal and Tapadar, 2007). It takes 6 to 12 hr to reach Dhaka. However, it takes few days to transport crab to Dhaka during civil disobedience due to political unrest situation.

3.4.3.3 Domestic marketing

Two types of markets exist for crab in Bangladesh such as (a) local markets in the vicinity of fishing villages, and (b) consumer markets away from the fishing areas (Ahmed, 1992 and personal communication). The non-Muslims and the tribal people of the Chittagong hill tracts are the major consumers of crab from Chokoria and Cox's Bazar. The non-Muslims of Da Koop, Koira and adjacent areas are the main consumers of the Sundarbans crab. 15.3% muslim, 97.61% Hindu and 100% Christian people consume mud crab at weekly, monthly and occasionally, respectively (Hasan, 2006). About 72.7% consumers purchase crabs from directly from market (Hasan, 2006). In addition, a good portion of the catch from Chokoria and the Sundarbans is sold in Chittagong and Khulna local market respectively. On the otherhand, in

Srilanka (Jayamanne, 1992), India (Kathirvel and Srinivasagam, 1992), crab are consumed locally in hotels, restaurants and households. Crabs are purchased through intermediate vendors for hotels and restaurants. But households usually buy directly from fishermen.

In most of the countries of south-east Asia like Srilanka (Jayamanne, 1992), Philippine (Ladra and Lin, 1992), India (Kathirvel and Srinivasagam, 1992), even Bangladesh (Nahid, 2006 and Zafar and Ahsan, 2006), crabs with low meat content or weighing less are sold locally. Of them, 93.83% of male crabs are between 40 to 200 g, and 76.67% female crabs are within 70 to 120 g in body weight (Hasan, 2006). However, 86.4% consumers preferred large crabs which are not available in local market. Price varies from 10 to 60 Tk/kg. Direct sale by fishermen in the local market or in consumer markets is the general mode of marketing (Zafar and Ahsan, 2006). Sometimes a member of the fisherman's family participates in marketing. Previously, there were no middlemen in this trade and the retailer sells crab in fish markets or, sometimes, door to door, keeping them in the bamboo baskets. But now a few purchasing centers have been set up. Crab are purchased at these centers by retailers, for supply to the consumer market. Selling and purchasing are generally determined by bargaining. Customers tend to buy crabs instead of fish during wet season as the price of fish become higher due to the scarcity of fish (Hasan, N., 2006).

3.4.3.4 International marketing

There is a growing demand for crab worldwide. Most of the harvested crabs are exported to the foreign countries through airfreight. Immediately after reached in Dhaka at early morning hours, crabs are again graded following international grades and packed in small bamboo baskets containing 15 kg of crabs (Kamal and Tapadar, 2007). The baskets are stacked one over another. Major export markets of mud crabs are Singapore, Hong Kong, Malaysia, Thailand, China, India and Taiwan (Kamal and Tapadar, 2007, Uddin, 2003 and personal communication with depot owner in Munshigong). Besides this the crabs are also exported to UK, Japan, Germany, Belgium, China, France, Korea, South-Africa, Netherlands, Saudi Arabia, India, Austria, Qatar, Kuwait, Mexico, UAE, Uganda, Oman, Bahrain, Honduras, Malawi (Kamal and Tapadar, 2007).

Although mud crab are in great demand in foreign markets, they must arrive at their destination alive and in good condition. It is recommended to prolong the shelf life of the mud crab is to pack them in polystyrene boxes with ice placed at the bottom of the box and chicken-wire mesh used to separate the crab from the ice (Gillespie and Burke, 1992). Several layers of newspaper

placed in the bottom to absorb fluid lost by the crab. Mud crab kept in this manner may have a better survival rate compared to those packed basket. It is best to put the crab in a cool area which has a temperature of 18-22°C. Crab stored at 32°C also died earlier, due to dehydration. Cannibalism during transport can be prevented by feeding the crab 12-24 hours prior to shipment abroad. Handling conditions after harvest should be such that the crab are not subjected to drying winds. Exposure to direct sunlight for long periods also has a negative effect on survival.

3.4.4 Mortality export handling

Mortality of crab during handling is a major concern of post harvest losses in Bangladesh. Mortality rate varies from 20 -30% depending on season as the highest being found in summer (30%), then 24% in monsoon and 21% in winter (Kamal and Tapadar, 2007, Table 3.4.3). This seasonal variation may be attributed due to the highest temperature in summer and the lowest in winter. However, the mortality rate is found to be the highest during packing in depot (10 - 14%), then catcher to depot as (8 - 11%), and the lowest during transportation (4 - 5%) (Kamal and Tapadar, 2007). This may happen for hot environment, rough handling and unsuitable physical structure in depot, and long time trip during catching crab due to unsuitable vehicle, inefficient harvesting gear and poor storage capacities during bringing from catcher to depot. On the other hand, crabs are transferred to Dhaka at night when cool environment may decrease mortality rate.

Table 3.4.3 Mortality (%) of mud crab during handling in 2001 (Kamal and Tapadar, 2007).

Season	Catcher to depot	Packaging in depot	Transportation to Dhaka	Total
Summer	11	14	5	30
Monsoon	9	11	4	24
Winter	8	10	3	21

Another important concern is rejection of crab in depot. About 10-15% of the harvested crabs are rejected in depots for poor quality (Kamal and Tapadar, 2007). As a result, when collectors sell crab to traders, additional 10% crabs are taken from them or they are given 10% less money (Zafar and Ahsan, 2006). Male crabs of soft shell and poor meat, female of absent of hepatopancreas, both male and female of broken chela, 2 swimming leg and shell are considered as poor quality and rejected (Kamal and Tapadar, 2007). Soft shell and poor meat

crabs can be improved by fattening. However, broken chela, swimming leg and shell are attributed due to poor handling and cannibalism. Less space as much as possible among crab in bamboo baskets reduces cannibalism. Keep crab in depot in some holding arrangements include the use of pumps and above-ground swimming pools established on the river bank or holding the crab out of water, keeping them moist by covering them with moist jute sacks or mangrove leaves reduce stress to crab (Gillespie and Burke, 1992), thus reduces mortality rate.

Problems

- Inadequate number of suitable vehicles for crab transportation to the local market through riverine way;
- The roads are not well constructed at local areas. Delay at Dauldia-Paturia ferry terminal is one of the major concerns to mortality during transportation from local depots to Dhaka;
- High mortality due to mishandling and poor transport system at different level of transportation. The buyers arbitrarily decided to set mortality 30% (Zafar and Ahsan, 2006);
- Size of mud crab basket for transportation from local depots to Dhaka is too large and causes stress to the mud crabs.

3.4.5 Marketing channel

Marketing is an important and challenging competitive instrument for small-scale quality food producers. Marketing pattern of mud crab involves of collectors, depot owners, exporters and consumers (Fig. 2). A series of intermediaries or middle man (*Forias*) such as local agents, local markets, fatteners and so on are found in crab marketing channel in Bangladesh. As a result, the final price of the product depends on the marketing network and fisherman get very low price, which is similar to India (Kathirvel and Srinivasagam, 1992). The greater the number of intermediaries, the higher the price of crab (Ladra and Lin, 1991). Middlemen who collect the crab from the fishermen often mark up the price depending on the size, when reselling them to the retailer at the market in India. In Srilanka, export quality crab are also purchased and transported daily through the intermediate agents of various exporters (Jayamanne, 1992).

The intermediaries are reported to take extra margin intentionally. The value chain analysis revealed that the value addition at fatteners' level is the highest among all intermediaries (Zafar and Ahsan, 2006). The most disadvantaged group are the coastal people who collect crab from

wild and sell them to the local traders (Zafar and Ahsan, 2006). About 52% of depot owner take loan from local agent of exporters (Zafar and Ahsan, 2006) and most of the crab collector take loan (Tk. 100 to 5000) from depot owners with the condition that loan owners have to sell crabs to the specific person (Kamal and Tapadar, 2007). Sometimes, local traders and brokers also take loan (Tk. 1000 to 10000) from *aratters*. About 66% crab collectors in Khulna and 60% in Satkhira take loan from depot owners (Zafar and Ahsan, 2006). There is no government policy of giving loan to crab traders (personal communication).

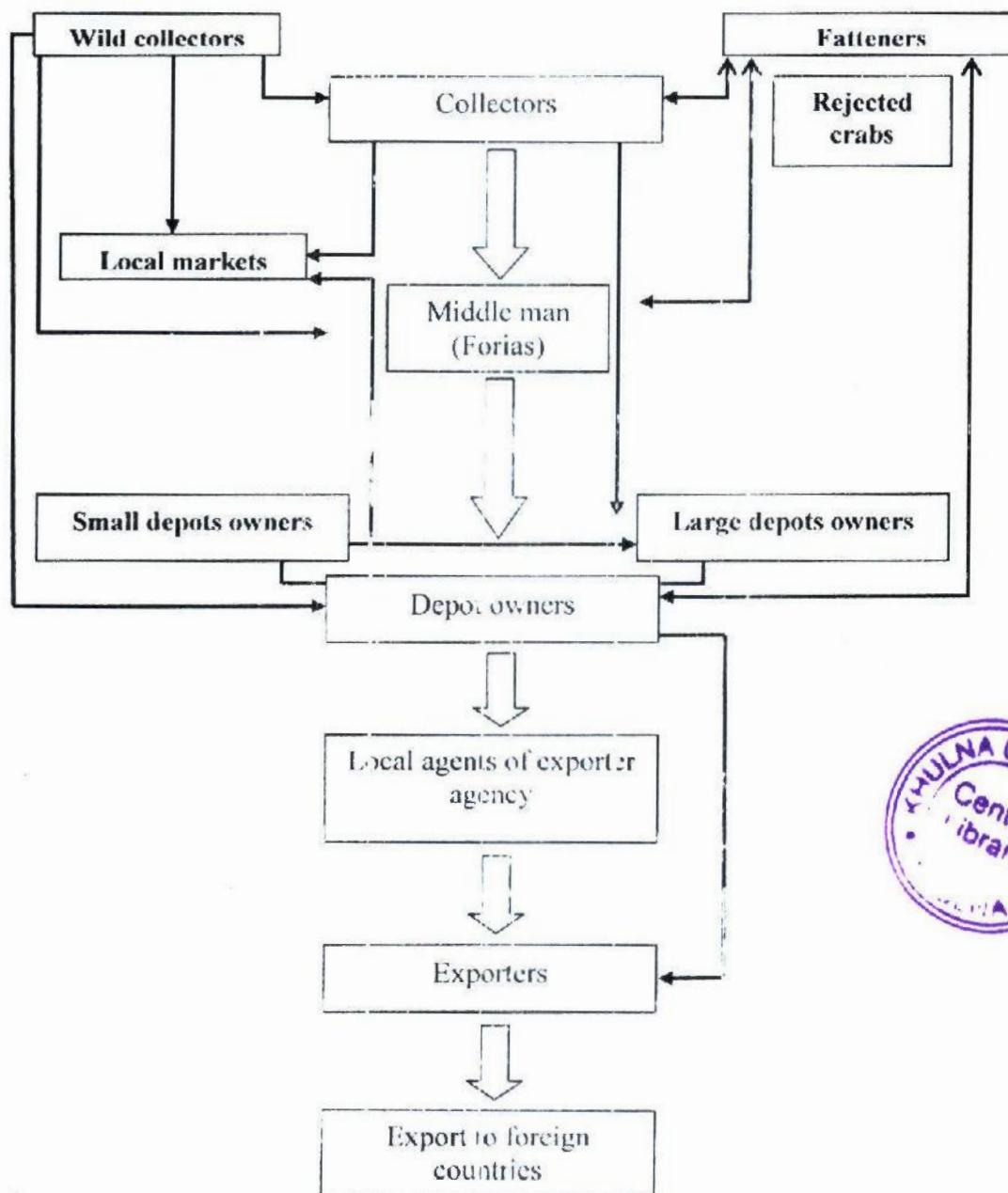


Fig. 3.4.1 Crab marketing channel (Zafar and Ahsan, 2006; Kamal and Tapadar, 2007 and Uddin, 2002)

The harvesters harvest crabs from the sources and sold to small depot or to broker or directly to the supplier. The marketable crabs from the small depot owner are sold to suppliers (Fig.3.4.1). The exporter purchase crab directly from the supplier located at the Upazilla level. Sometimes, the exporters directly collect crabs from the catcher by employing agents. On other hand, harvested crabs are also transferred to another place supplier (Fig. 3.4.2). A big chunk of the profit goes to middleman or brokers, who act as a middleman between catcher and supplier (Fig. 3.4.2). The rejected crabs (under grade and broken claws or legs) are transferred to the local market for domestic consumption at low price and the immature crabs are transported to gher for fattening. The fatteners get benefit as 19% to 71 % of their investment (Table 3.4.4). However, culture of small crab is not yet fully developed.

3.4.6 Crab depot

Mud crab trading depots are situated in 15 upazillas namely Paikgacha, Koyra, Dumuria, Batiaghata, Dacope, Ashasuni, Shamnagar, Kaligong, Debhata, Tala, Bagerhat sadar, Rampal, Mongla, Morelgong, Shoronkhola (Kamal and Tapadar, 2007), Kutubdia, Moheskhali, Banskhali, Chittagong city, Noakhali and Voia (Zafar and Ahsan, 2006). The size of crab depot varies from 40 to 320 sq. ft. made of *kucha* (bamboo, bamboo fence and Nypa-leaves with earthen floor), *semi-pacca* (bamboo, wood and tin roof with concrete floor) and *pacca* (brick, RCC and concrete). Thus, infrastructure facilities for the depots are in a poor shape. The markets are not satisfactory with regard to space, shade, sanitation, water supply, drainage, electricity and telecommunication. Due to poor roads and the absence of them in some remote areas of crab collection, long time to reach product in airport causes deterioration and mortality of crab.

Problems in marketing

1. Lack of buyer and market information;
2. Insufficient market facilities;
3. Credit problem (bank);
4. Lack of registration practice of depot owners and fatteners;
5. Involvement of unproductive middle man in trading;
6. Muscle power by local leaders;
7. Social and religious problem.

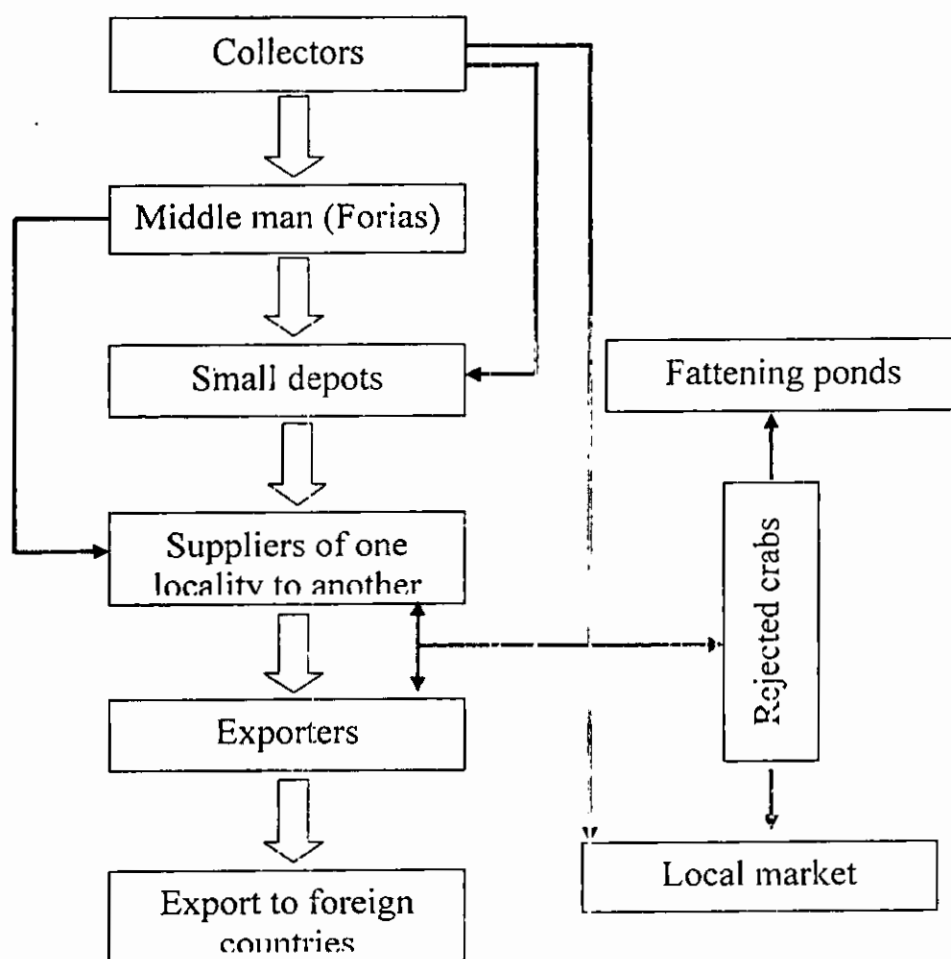


Fig. 3.4.2 Crab marketing channel (Zafar and Ahsan, 2006. Kamel and Tapadar, 2007 and Uddin, 2002)

Table 3.4.4 Investment-return analysis of fattener or farmer in Khulna region (Zafar and Ahsan, 2006).

Stakeholder	Product		Buying price (Tk./kg)	Investment (Tk./kg)		Land cost			Average (Tk./kg)	Selling price (Tk./kg)		Margin (Tk./kg)	Benefit (%)
	Sex	Grade		Description	Land rent (lease value)	Own	lease	Both		Grade	Average price (Tk./kg)		
Fattener	Male	XXLPD	28		0.00	2.92	1.93	XXL	204	15.75	141.17	19.13	
				Permanent labor cost	8.00	8.00	8.00	XL	134	15.75	71.11	36.56	
		LPD	19	Transport cost	2.06	2.06	2.06	L	109.5	15.75	57.85	32.84	
				Feed cost	2.06	2.06	2.06	M	92.5	15.75	50.65	71.20	
		SMPD	28	Other operational cost (fencing, pond maintenance, harvest)	2.01	2.01	2.01			15.75			
				Total	14.13	17.05	16.06	F1	194.5	15.75	142.16	16.88	
	Female	KS1	24						F2	109	15.75	61.75	35.63
		KS2	22						F3	68.5	15.75	28.37	45.82
		KS3	13										

Table 3.4.5 Investment-return analysis of depot owner in Khulna region (Kamal and Tapadar, 2007).

Name of the Upazilla	Khulna	Satkhira	Bagerhat
Annual Production (Kg)	14,348.47±3,861.684	35,673±27,930.33	35,110±52607.46
Debt (Tk)	1,41,000±1,79,677.5	53,000±38,665.23	18,27,200±4009752
Depot size (Sq.ft)	135.2±93.31	223.2±117.08	214.8±304.1097
Man power (Person)	2	2.6±1.14	2.6±1.52
Sales (Tk)	22,18,415±5,97,837.5	52,45,071.8±41,54,893	6,704,679.8±10,133,537
Cost of goods sold (Tk)	17,98,772±4,97,100.8	41,07,516.4±32,52,448	34,99,062.6±53,14,959
Gross benefit (Tk)	4,29,643.3±1,38,202.2	11,37,555.4±9,02,483.3	32,05,617.2±48,18,636
Commercial expenses			
Depot rent (Opportunity cost) (Tk)	4,800	5,520±1609.969	6,240±3219.938
Salaries (Tk)	48,000	62,400±27364.21	62,400±36397.8
Packaging (Tk)	1,3635.93±3715.96	31,213.876±24439.04	30,721.261±46031.55
Utilities and services expenses (Tk)	2,208±384	2,928±1766.896	3,120±1609.969
Transportation (Tk)	58,439.99±15,925.89	1,33,773.76±104738.8	1,31,662.5±197278
Miscellaneous (Tk)	12,000	12,000	14,400±5366.563
Total cost (Tk)	1,39,083.9±21,713.27	2,47,835.64±154884.4	24,8543.77±240488.7
Net Benefit (Tk)	2,90,559.3±1,43,584.5	8,89,719.98±748335.9	29,57,073.4±4583014
Cost-Benefit ratio	2.07±0.86	2.96±1.3	7.91±5.72
Return on investment (ROI)	4.76±3.14	16.33±13.33	21.53±9.94

3.4.7 Nutritional value of mud crab

Mud crabs are rich in high protein and fat content, although there are variations in proximate composition of different body parts. The female mud crabs showed a comparatively higher value in shell moisture, gill protein, shell protein, shell fat, meat fat and hepatopancreas fat contents than the male crabs, while male crabs showed higher values in shell ash, meat ash and hepatopancreas ash contents (Kamal, 2002). The protein content was found highest in the body meat (76.89%) followed by ovary (60.49%), gill tissue (59.24%), hepatopancreas (31.45%) and carapace shell (16.59%) (Table 3.6). The fat content was found to be highest in the hepatopancreas (44.53%) followed by ovary (8.98%), gill tissue (3.88%), body meat (3.36%) and carapace shell (2.34%). The maximum ash contents was found in carapace shell (65.04%) which was followed by gill tissue (23.28%), body meat (11.02%), hepatopancreas (9.66%) and ovary (4.98%). The highest moisture content was noticed in the gill tissue at 83.91% that was followed by body meat at 79.63%, hepatopancreas at 68%, ovary at 53% and the carapace shell at 45.04%. A significant variation in proximate composition was found between different body parts.

Table 3.4.6 The proximate composition in different body parts of male and female mud crabs (Kamal, 2002).

Body parts	Moisture	Protein	Fat	Ash
Gill	83.91	59.24	3.88	23.28
Shell	45.04	16.59	2.34	65.04
Meat	79.63	76.89	3.36	11.02
HP	68.0	31.45	44.53	9.66
Ovary	53	60.49	8.98	4.98

HP: Hepatopancreas.

However, the proximate composition of body meat is more or less similar to the results provided by the previous workers which indicates that the proximate composition of mud crab do not vary significantly among geographical localities but varies significantly between sexes (Table 3.7). Particularly, females possess a higher fat content than the males and that is why the test and hence the demand and price of female mud crab is much higher than the males.

Table 3.4.7 Proximate composition of body meat in the mud crab *Scylla serrata* from different geographical locations.

Source	Protein (%)	Fat (%)	Moisture (%)	Ash (%)
Srinivasagam, 1979	16.65*	F>M	78.38	--
George and Gopakumar, 1987	20.92*	F>M	80.19 M	5.09*
Das et al., 1995	19.98* F	0.48* F	77.45 F	1.23* F
Kamal, 2002	76.89**	3.36	79.63	11.02

M= Male; F= Female. *= Values are in % wet weight basis. ** Wet weight basis.

3.4.8 Microbial quality of harvested crab

The coastal waters of Bangladesh are under the influence of chemical and biological pollution through numerous river systems of Bangladesh and their upstream countries (Haque *et al.*, 2005, 2004; Faruque *et al.*, 2003; Biswas *et al.*, 1999; Ipe, 1995; Hossain *et al.*, 1994). Kamal *et al.* (2005) studied on microbial load from different edible part of crabs. Seasonal, spatial and sexual variation in bacterial flora of public health significance in the flesh of live mud crab (*Scylla olivacea*) was enumerated collected in different season (wet and dry winter) from three geographic locations (Khulna, Satkhira and Bagerhat) of the Sundarban mangrove swamps of Bangladesh. Total viable count (TVC) of bacterial flora was significantly higher in the meat of crab collected from Bagerhat ($8.7 \times 10^5 \pm 1.6 \times 10^6$ CFU g⁻¹) over Khulna ($2.5 \times 10^5 \pm 2.6 \times 10^5$ CFU g⁻¹) and Satkhira ($1.2 \times 10^5 \pm 1.3 \times 10^5$ CFU g⁻¹) regions (Table 3.8 and 3.9). Samples collected from Khulna region had significantly higher levels of TC (717.8 ± 1141.8 MPN g⁻¹) and FC (1207.3 ± 1377.3 MPN g⁻¹) than the samples from Bagerhat (TC: 63.3 ± 528.2 , FC: 63.3 ± 98.2 MPN g⁻¹) and Satkhira (TC: 17.0 ± 215.2 , FC: 17.0 ± 13.5 MPN g⁻¹) regions. Male mud crab meat contained higher but insignificant level of TVC ($6.8 \times 10^5 \pm 1.3 \times 10^6$ CFU g⁻¹) and TC (677.7 ± 941.8 MPN g⁻¹) over the female crab, however female crab had higher TC count (440.7 ± 963.3 MPN g⁻¹) over the males. Crab meat showed significantly higher TC and FC counts during wet season (TC: 1089.0 ± 1081.6 ; FC: 526.0 ± 933.6) over dry-winter season (TC: 24.8 ± 34.2 ; FC: 6.0 ± 4.6 MPN g⁻¹) (Table 3.7 and 3.8). However TVC did not show any significant seasonal variation (wet TVC: $7.7 \times 10^5 \pm 1.3 \times 10^6$; dry-winter TVC: $5.4 \times 10^4 \pm 2.3 \times 10^4$ CFU g⁻¹). Neither *Salmonella* sp. nor *Vibrio cholerae* were detected in any samples collected from the studied area.

Table 3.4.8 Microbiological load in male and female mud crabs (*Scylla serrata*) from the SW region of Bangladesh during summer (Kamal *et al.*, 2005).

Parameter	Unit	Chaina, Khulna		Munshigonj, Satkhira		Vaga, Bagerhat	
		M	F	M	F	M	F
TVC	Cfu/gm	3.4×10^5	5.8×10^5	3.1×10^5	3.2×10^4	3.3×10^6	7.1×10^4
TC	MPN/gm	>2400	>2400	460	150	1100	24
FC	MPN/gm	460	>2400	42	20	24	210
<i>Salmonella</i> sp.		Nil	Nil	Nil	Nil	Nil	Nil
<i>Vibrio cholerae</i>		Nil	Nil	Nil	Nil	Nil	Nil

Table 3.4.9 Microbiological load in male and female mud crabs (*Scylla serrata*) from the SW region of Bangladesh during winter (Kamal *et al.*, 2005).

Parameter	Unit	Chalna, Khulna		Munshigonj, Satkhira		Vaga, Bagerhat	
		M	F	M	F	M	F
TVC	Cfu/gm	4.3x10 ⁴	3.9x10 ⁴	6.9x10 ³	5.1x10 ³	2.7x10 ⁴	9.2x10 ⁴
TC	MPN/gm	9	20	4	<3	93	20
FC	MPN/gm	4	7	<3	<3	15	4
<i>Salmonella sp.</i>		Nil	Nil	Nil	Nil	Nil	Nil
<i>Vibrio cholerae</i>		Nil	Nil	Nil	Nil	Nil	Nil

3.4.9 Production and export

Crab catches have fluctuated considerably from year to year. Over-exploitation of juveniles (Samaranayake, 1986) and environmental degradation could be a major threat to the natural population. Domestic waste, urban sewage and increasing industrial effluents all contribute to the deterioration of water quality and the reduction of the crab population, as reported in Cochin, India (Devasia *et al.*, 1985). Aromatic petroleum hydrocarbons (Kulkarni and Masurekar, 1983) and heavy metals such as mercuric chloride, arsenic trioxide and lead nitrate are toxic to mud crab (Krishnaja *et al.*, 1987). However, export earnings have been increasing recent years (Fig. 3.3).

The annual average production of mud crab from three districts of the southwest region has been estimated to be 6,946 t in 2001. The production was maximum (1,134 t) in July and minimum (224 t) in March. The share of mud crab production was 2,513 t in Khulna, 1,777 t in Satkhira and 2,656 t in Bagerhat district. The maximum (2,656 t) production was found in Bagerhat district and the minimum (1,777 t) in Satkhira district.

A domestic market for mud crabs has not yet been developed in the southwestern region of Bangladesh because of high price and religious prohibition among Muslims (Anon, 2005). Hence, all harvested crabs are exported to foreign countries by airfreight. Crabs are now exported from Srilanka to many countries in Asia and Europe. Singapore receives more than 90 per cent of the export. Malaysia, Hong Kong, Japan, Taiwan, U.S.A, U.K, Pakistan, Syria, Saudia Arabia, South Korea, Switzerland, Australia and the Maldives take the balance (Jayamanne, 1992).

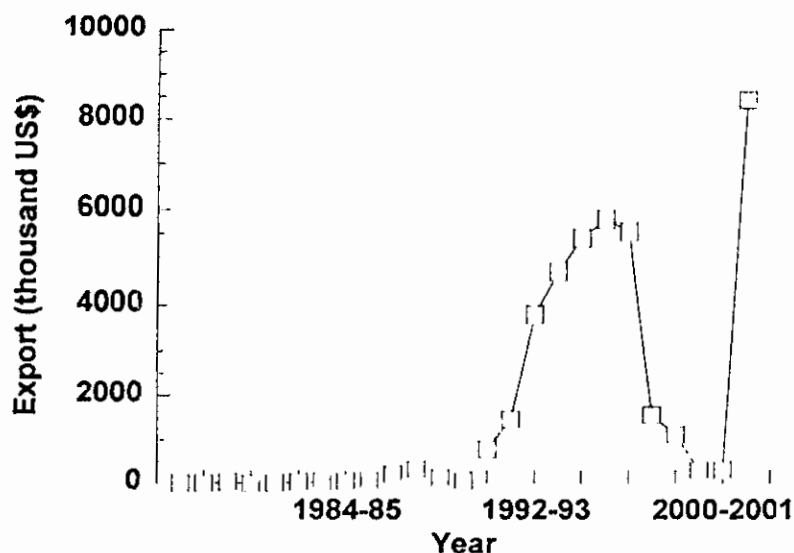


Fig. 3.4.3 Yearly export earnings from mud crab

The highest percentage of mud crab exported in Taiwan from 1990-91 to 1999-2000 fiscal year. Whereas Singapore 28%, Hong Kong 16%, Malaysia 10%, Thailand 9%, USA 4% and the other countries 4% (Kamal and Tapadar, 2007). In 1995-96 fiscal years Bangladesh earned US\$ 5792 thousand, which was the highest from 1990-91 to 1999-2000 fiscal year (BEPB, 2001). The growth of mud crab export was high during 1990-91 to 1995-96 then, the mud crab export has declined from 1996-97 to 1999-2000 (Kamal and Tapadar, 2007). The reason for the decline could be attributed to be a severe fall in the abundance of wild stocks in the Sundarbans as a result of over fishing.

Mud crab trade in south-east Asia has shown a consistently increasing trend in the past few years. Malaysia and Singapore are the main markets in the region (Angell, 1992). Although crab fishing in Bangladesh is prohibited in winter due to breeding, unemployed local coastal people harvest huge crabs illegally during winter (personal communication with fisherman, Munshigong, Satkhira).

In Bangladesh, maximum crab production is achieved during rainy season (July to October) and minimum during winter (December to March) (Kamal and Tapadar, 2007). There's also seasonal and monthly variation of crab production (Kamal and Tapadar, 2007) that causes problem in crab processing as the buyers like to contract for about 6 months to 1 year (Personal communication). Monsoon season is the peak time of crab production followed by winter and summer season (Kamal and Tapadar, 2007). Maximum production of F1, F2, XL, L and SM are found in July, KS1 in August, F3 and M grade in October, while minimum production of F1, XL, M and SM is achieved in March, KS1, F2, F3 and L in April.

Mud crabs are at present a good export item, either in the form of meat frozen in a block or in a cooked condition or alive. Hong Kong, Malaysia and Singapore are the principal buyers of live crab from Bangladesh. Crab have also been exported to Thailand, Taiwan, Sweden, Pakistan and Kuwait (Ahmed, 1992). Crab processing is also important in domestic market for its demand as 44% consumers want to buy cooked crab (Hasan, 2006).

Table 3.4.10 Different crab products produced in the world.

Country	Product
China	Crab juice, Spicy crab flavor coated broad beans, Frozen crab stick, Frozen crab claw meat, frozen soft shell crab, crab shell meal as organic fertilizer, Sauce
Indonesia	Frozen crab, Boiled frozen crab, soft shell crab, Pasteurized crab meat, chitosan from crab shell, crab chips,
Hong Kong	IQF crab
Japan	Live and frozen crab.
Australia	Frozen raw crab body meat
Philippine	Chitin and chitosan from crab shell. Live crab.
Bangladesh	Live crab, Frozen crab.
United states	Fresh pasteurized crab meat, crab extract, live and frozen crabs, crab stick, frozen soft shell crab,
Spain	Live crab,
Singapore	Live crab, Canned crab meat
India	Frozen crab, Live mud crab
Madagascar	Live crab
Thailand	Soft shell crab, crab pickle, crab stick, chips, sausage
Vietnam	Frozen crab meat, Soft shell crab,
Chile	Crab claw

However, crab products are exported in various processed forms such as salted, dried and smoked meat in airtight containers. In Thailand, they mostly exported swimming crab Fresh and frozen mud crabs are exported to France, West Germany, Hong Kong, Italy, Japan, Malaysia, Singapore, Taiwan, USA and others, while salted, dried and smoked crab to Australia, Belgium, Hongkong, Japan, Singapore, England, America and others (Tookwinas *et al.*, 1992). A large percentage of crab caught in Queensland is sent live to the major cities in Australia

where they command high prices (Lee, 1992). Frozen crab meat from India has been exported in large quantities to Malaysia, Singapore and some other countries (Kathirvel and Srinivasagam, 1992).

Quality control is also important in food industry. Although pesticides are chemicals used to enhance food production, these are also known to induce toxic effects in humans and animals (Om and Chung, 1998). The highest values were observed in molluscs and crustaceans as 117.4 ng g^{-1} in marine environment (Karavoltzos, 2002). In crab fishery of Bangladesh, there's no study or practice of pesticides contamination. However, Zafar et al. (2004) first studied on radionuclides in Bangladesh.

There are huge scope for exporting value added crab products for poverty alleviation in Bangladesh. However, the major areas of crab product development are

1. Soft-shelled crabs;
2. Canned crab meat, egg;
3. Frozen crab (whole) and
4. Frozen crab claw as these products have high export demand and easy to develop in the context of Bangladesh.

As labor is very cheap especially female workers have the practice to work in shrimp processing industry as well as culture of crab, it may be pioneer in poverty alleviation. Crab bearing eggs is cheaper than other grades. Hence, processing of eggs and dead crab will be helpful for the export.

Problems

- Lack of public awareness of the real situation and of aspects of conservation;
- Lack of technical knowledge and proper management systems to culture of mud crab;
- Lack of practice of quality control of crabs for export.

Chapter 5

3.5 Manpower Involved in Crab Fishery

3.5.1 Manpower involved in mud crab harvesting and marketing

No detailed information is available on the number of manpower involved in crab harvest, trade and export in Bangladesh, even the number of fishers involved in collecting crabs from tidal rivers, the Sundarbans Reserve Forest (SRF) and tide-fed shrimp *ghers* or the people involved in crab export. However, mud crab fishery supports the livelihood of more than 50,000 fishers, traders, *farias* (brokers), transporters and exporters (Acharya and Kamal, 1994; Kamal, 2002). No detailed information is available on how many people are particularly involved in crab fattening or culture, harvest, trade and export in Bangladesh. No information is available on the number of fishers involved in collecting crabs from tidal rivers, the Sundarbans Reserve Forest (SRF) and tide-fed shrimp *ghers*. Although there are 14 private enterprises involved in mud crab export in Dhaka (Mirpur and Uttara) by air, the number of workers involved in mud crab export activity in Dhaka is not known. Kamal *et al.* (2003) estimated the number workers in mud crab landing centres and the number of crab depots in Bagerhat, Khulna and Satkhira Districts at 702 and 292, respectively.

3.5.1.1 The crabbers

There is no information on the number of crabbers in the SRF, tidal rivers and canals and from traditional tide-fed shrimp *ghers* in Bangladesh. Most capable women and children are involved in crabbing from shrimp *ghers* close to their houses using baited sticks during the shrimp cultivation period (April-December). Commercial crabbers also harvest mud crab from shrimp *ghers*, tidal rivers and canals and from the SRF at different seasons depending on the abundance of mud crabs in the various habitats. Many crabbers from Bagerhat, Barisal, Borguna, Khulna, Pirozpur, Satkhira and Sharupkathi districts harvest mud crab in the SRF during dry winter and summer months (October to March) using baited long line and bamboo traps. Some crabbers living at the edge of the SRF harvest mud crab from the northern peripheral areas of the SRF year-round. A few women crabbers enter the Sundarbans from nearby villages and return home by evening every day.

3.5.1.2 Socio-economic condition

Recently Zafar and Ahsan (2006) describes social and economic status of crab collectors which are given below

Table 3.5.1 Social and economic status of crab collectors (Zafar and Ahsan, 2006; Ahmed, 1992).

Social Status of mud crab collectors	
Factors	Description
Age structure	Khulna: most of the crab collectors (35%) are in the age group of 33-41 years, whereas 14%, 25%, 18% and 8% of the collectors belonged to age groups 15-23, 24-32, 42-50 and above 50 years, respectively. Satkhira: most of the crab collectors (39%) are in the age group of 33-41 years, whereas 11%, 19%, 23% and 8% were in the age groups of 15-23, 24-32, 42-50 and above 50, respectively. Chittagong: dominated by males (10-40 yrs)
Sex ratio	Khulna: 81% of the crab collectors are male and the rest (19%) are female. Satkhira: 82% of the crab collectors are male and the rest (18%) are female. Reason: The main sources of crabs are the Sunderbans and the rivers far from the locality. Therefore, the crab collectors had to stay there 7 to 15 days that was usually impossible for the female crab collectors. As a result, females are mainly involved in collecting crabs from ghers and bank of the rivers. Another reason for less involvement of female in crab collecting localities is social restriction.
Religious status	Hindus - 89% and Muslims - 11% (Zafar and Ahsan, 2006). Fishermen in different parts of the country are Hindus (Ahmed, 1992). Religious restriction on eating crab might also discourage the Muslims to be involved in catching crabs.
Educational status	About 58% - educated at the level of class one to two About 10% - at the level of class five to nine, the rest were completely illiterate. The non-formal education facilities provided by different NGOs in other parts of the country are not found in these communities.
Family size	Khulna: 52% of the collectors have above 6-7 members in their family, whereas 29%, 12% and 7% of them have 4-5, above 7 and 2-3 members in their family, respectively. Satkhira: 41% of the collectors have above 6-7 members in their family, whereas 27%, 13% and 21% of them have 4-5, above 7 and 2-3 members in their family, respectively.
Drinking water facilities	64%- use filtered pond water, 5% - use ponds water directly and 8% - use rainwater for drinking purpose, whereas none of them had their own tube-well. 23% collectors used tube-well provided by the local government or those belonging to serloois or neighbours.
Sanitation facilities	Two types of toilet such as 1) Katcha toilet-made of bamboo with leaf shelter and inadequate drainage system and 2) Sanitary toilet- made of bamboo walled, ring slave with good drainage system are found to be used by the crab collectors. Only 32% of the crab collectors afford sanitary toilet provided by local government office.
Use of electricity	Only 18% of the crab collectors in Khulna and Satkhira districts have electricity facility.
Housing condition	Four types of houses i.e. i) Wooden wall with tin shed (2%), ii) Mud wall with tin/asbestos shed (6%), iii) Mud wall with golpata shed (31%) and iv) Mud wall with straw shed (61%).
Health care facilities	Most of the crab collectors (50%) are found to be dependent on village doctors (unqualified practitioners, homeopathy, kabiraj, etc.) for their treatment, while only 10% got health

services from qualified doctors from local government health centre

Economic Status of Mud Crab Collectors

Ownership of land	23% of the crab collectors have no own land, while 39%, 27%, 8% and 3% of them have 0-5, 6-10, 11-15 and above 15 decimal lands, respectively.
Occupation	Primary occupation of collector - to earn their livelihoods, and the fattener collect crabs from depot that had no export value. Secondary occupations of the crab collectors in Khulna district are labour (67%), fishing (15%), craft and gear making (5%), wood collection from the Sundarbans (4%) and van pulling (9%) while those in Satkhira district are labour (64%), fishing (19%), craft and gear making (3%), wood collection from the Sundarbans (4%) and van pulling (10%).
Daily expenditure in crab collection	Crab collection from gher, rivers etc. Crab collection expenditure is found to depend mainly on the amount of baits. Baits are available in the local markets. Baits may be fresh or formulated and dried. The collectors need Taka 20-60 for purchasing the baits.
Expenditure for harvesting crabs from the Sundarbans	About 59% of the crab collectors collect crabs from the Sundarbans in groups each usually consisting of three members where Tk. 1001-1100 is spent by 38% groups followed by Tk. 801-900, 901-1,000, and 1,101-1,200 by 19%, 23% and 20% groups, respectively for a 12 days' crab collection voyage to the Sundarbans. Boat, bait and license fees are required for the purpose. The collectors who do not own any boat are found to hire boat from other fishermen.
Daily income from crab collection	Khulna: most of the crab collectors (49%) earn Tk. 31-60/day by selling their collected crabs, whereas 25%, 24%, 9% and 3% of them earn Tk. 61-90, 91-120, 121-150 and more than 150/day, respectively. Satkhira: about 39% earn Tk. 31 - 60/day by selling their collected crabs, whereas 33%, 16%, 9% and 3% of them earn Tk. 61- 90, 91-120, 121 -150 and more than 150/day, respectively.
Credit facilities and Dadon system	Crab collectors usually have no access to any institutional credit. 66% of the crab collectors Khulna and 60% in Satkhira are found to go to the money lenders for dadon with a high interest rate. Usually the depot owners act as the money lenders and compel the collectors to sell their harvest at a fixed price much lower than the market price. The poor crab collectors have nothing to do with such conditional trading as they are unable to invest for boat rent, bait costs, license fees and food cost during long days fishing in the Sundarbans.

Problems

- Lack of sufficient information of people involved with crab fishery.
- Alternative income source in off season.
- Lack of institutional credit facilities. Illegal harvesting of crabs.
- Lack of statistics of different categories people involved.
- Violence of forest law in crab fishery management.

Chapter 6

3.6 Policy, Legislation and Management Regimes for Mud Crab Resource Development in Bangladesh

3.6.1 Crab Resource Management in Bangladesh

After reviewing the present status and management of mangrove habitat resources in Bangladesh, Islam and Wahab (2005) stated that the mangrove has been under intensive pressure of exploitation for the last few decades due to direct clearance and conversion of the mangrove under extreme threat, and reported shrimp farming is the most destructive form of resource use the mangrove has been converted to, and contributed significantly to mangrove destruction with a corresponding loss of biological resources. Depending on the present status, it is suggested that the management options and the policy aspects should be critically reviewed and amended accordingly; beneficiaries and stakeholders at all levels of resource exploitation must take part and contribute to conservation and management (Islam and Wahab, 2005).

Salam *et al.* (2003) reported that 43% of the land of coastal area is classified as very suitable, and a further 5% is moderately suitable for brackish water shrimp and crab culture. Areas with very suitable or moderately suitable water chemistry are widely distributed in the lower part of the region because of uniform salinity, temperature and dissolved oxygen. However, in the south and northeastern part of the region, by-product inputs are potentially insufficient for shrimp farming due to low crop yields and less cattle and poultry rearing. Similarly, the areas with potential for shrimp and crab farming at an optimum level are patchily distributed except for a few areas in the Khulna and Bagerhat districts, where most of the NGOs and government offices are located, far away from the farming sites. Most of the area is marginal to unsuitable due to the absence of major roads and distance from processing plants. Image interpretation showed that crab culture had much more suitable land in terms of infrastructure (40%) than shrimp (3%) due to the abundance of crab postlarvae inside and surrounding the Sundarbans mangrove forest and their higher survival rate during transportation. Also, adult crabs are not as perishable as shrimp and can travel long distances for marketing. A comparison of the results for the two species revealed that the salinity, water availability and infrastructure strongly influenced the outcome. Some northern areas are only marginally suitable for both species because of the lack of saline water. A greater area is suitable for farming crab than shrimp because the former is more tolerant of environmental stress and little processing is needed prior to export (Salam *et al.*, 2003).

Amin *et al.* (2006) reported that the catch per unit effort of shrimp reduced from 592.78 kg/day (1992-93) to 284.23 kg/day (52% less) although fishing effort has been increased. Hence, attempts are needed to culture some other species specially those, which have market price and growth fast.

In Bangladesh, the mangrove is now going to be destroyed due to conversion into shrimp farm and the value and sustainability of converting the forest into aquaculture ponds are overestimated (Ronback and Primavera, 2000). On the otherhand, crab can be cultured profitably in mangroves without destroying mangrove forest (Khatun, 2007). In addition, recruitment of this species into the fishery takes place throughout the year (Zafar *et al.*, 2006). The exploitation level for *S. serrata* was found to be 0.41 for the male and 0.39 for the female. The stocks of male and female *S. serrata* were not under fishing pressure ($E < 0.50$) in the Southeastern part of Bangladesh.

This is the time of expansion cultivated areas through income growth and ecological consideration. As the Government of Bangladesh imposed regulation to stop shrimp seed collection to protect the fisheries resources notorious image for being ecologically destructive, alternative employment opportunities is important for sustainable development of coastal resources (Azadi *et al.*, 2007). Hence, crab is an important candidate in coastal areas. A crab collector earn Tk. 800-1100/week and Tk. 20-80/day from the Sundarbans and gher/river/canal (Islam, 2006). A community-based fattening project of *Scylla serrata* and blue swimming crab, *Portunus pelagicus* is also adopted by the womenfolk of Vellapatti fishing village in Tuticorin, Southeast coast of India (Patterson and Samuel, 2005).

3.6.2 Law on Fish in Bangladesh

Although crab is an important export commodity, this valuable resource is not considered with care for its management and development. As for example, still now yield and export crabs are often given with other crustacean groups, even in the statistics of Department of Fisheries (DoF), whereas accurate statistics is essential for any kind of management measures. In Fisheries law, there's no special attention to crabs (Table 3.6.1).

Table 3.6.1 Explanation of crabs in law on fish (Mashud, 1999)

Definition of fish/fisheries	Law/Ordinance
'Fish' means any aquatic animal, whether piscine or not, and includes any shellfish, crustacean, turtle or aquatic mammal, and the young, fry, eggs and prawn thereof.	Marine Fisheries Ordinance.

'Fishery' means one or more stocks of fish that can be treated as a unit for the purpose of conservation and management.

Fish includes all cartilaginous, bony fishes, prawn, shrimp, amphibians, tortoises, turtles, crustacean animals, mollusks, echinoderms and frogs at all stages in their life history.

The protection and
Conservation of fish
(Amendment) Act, 1995.

Fishery means any water body, natural or artificial, open or closed, flowing or stagnant (such as river, haor, beel, flood plain, canal etc.) where activities for growing fish or for conservation, development, demonstration, breeding, exploitation or disposal of fish or of living organism related to such activities are undertaken, but does not include an artificial aquarium of fish used as decorative article, pond or tank.

'Fish' includes all cartilaginous and bony fishes, prawn, shrimp, amphibians, tortoise, turtles, crustacean animals, coelenterates, molluscs, echinoderms and frogs at all stage of their life history.

The Fish and Fish Products
(Inspection and Quality
Control) Ordinance, 1983



3.6.3 Management practices in the Sundarbans Reserve Forest (SRF)

Scientific management of forest resources was first initiated in the Sundarbans in the 1870s when a Forest Management Division was established exclusively for the management of Sundarbans in the Gangetic Delta. The FD exercises its control on fisheries resources in SRF through collection of tolls, taxes and revenue from fishing boats, fishermen and fishery products. Every fishing unit/party needs to get a license at the rate of Tk 1500, which is renewable each year at Tk 750. Failure of renewal of license within 2 years of issuing license, a new license must have to be taken. At the time of issuing permits from the forest stations, tax for fishing and staying in the forest is determined at the rate of Tk 3/person/week for fishing and Tk 0.25/person/week for staying in the forest. In failure to come back with the designated time, a penalty of Tk 3/person/week is charged. Fishing is permitted for 3 weeks in a month. After fishing, the fishermen return through the same forest station they enter and pay tax for their catch.

The fisheries status and management of SRF was scientifically studied in 1994 through a FAO-assisted project (BGD/84/056) (Chantarasri, 1994), from which fisheries structure of Sundarbans was understood, although Rabanal (1984) under another FAO-assisted project (FO:TCP/BGD/2309) observed some basic fisheries of SRF. In depth study on fisheries of Sundarbans was first conducted by Chantarasri (Chantarasri, 1994), where description and MSY of major fisheries resources of Sundarbans were estimated and some management issues were addressed. The data produced by that study were very comprehensive 1-year data and

after that no long-term data collection was done, which could provide more information and ensure the sustainable exploitation of the resources. In Sundarbans, the major problem for fisheries management is the absence of fishery experts with overall responsibility of fisheries in SRF.

To sustainable yield management of mangroves for coastal fisheries, the mangroves are kept for providing nutrients, breeding grounds and nursery grounds as permanent habitat. Mangrove forest management is based on the sciences and skills of geology, petrology, climatology, hydrology, botany, ecology, silviculture, forest technology and economics-in the selection and treatment of both wood and non-wood resource (FAO, 1984). About 46% of the mangrove forests of the world are in Asia (Akseerkeac, 1993). Many Asian countries have established many tools that can provide better baseline information which include remote sensing, GIS and environment impact assessment studies. Sundarbans is still lagging behind in using such techniques.

The Sundarbans mangrove forest was declared as "Reserve Forest" in 1875-76 under the first "Forest Act" of the British India. As a reserve forest, control of fishing within Sundarbans is exercised by the Forest Department (FD) and the output from the fishery being regarded as "minor forest products" (Anon, 1994). As with other forest products, FD exercises their control by issuing of boat/transportation and fishing permits. Activities of the FD on fisheries are exclusively focused on revenue collection. The fisheries resources are exploited on the basis of maximum sustainable yield (MSY), which is not ideal for sustainable management for the fisheries resources of Sundarbans (Pana, 1994). The UNESCO has declared the Sundarbans as a World Heritage Site in 1999. No comprehensive fisheries management system has ever been existed in the Sundarbans, although currently Asian Development Bank is supporting a project "Biodiversity conservation in the Sundarbans" and some management options are in the process of implementation (Anon, 2002).

3.6.4 Crabbing pass, rules and real situation

The Sundarbans Forest Division allow crabbing activities inside the SRF through a boat license certificate (BLC), fishing permit, and revenue for harvested crabs at a rate of Tk. 300/boat/year, Tk. 3/day/fisher and Tk. 100/40 Kg harvested crab respectively (US\$1 = Tk 60 approximately) (personal communication with forest officers). Mud crab fishing is prohibited inside the two protected areas (Sundarbans East and West Sanctuaries) along the sea side and during December - February and May -June months to protect brood mud crabs during the peak breeding season. However, there is no scientific evidence through field studies that mud crab

breeds during the closed season. Illegal crabbing, however, both in the protected areas and during closed season is a common practice. Crabbers usually collect a permit for white fish using baited hooks (*borshi*) but catch mud crab with baited long line.

Problems

- Timely availability and abundance of crab seed.
- Over harvesting of crab seed as natural seed is the only one option of crab collection.

3.6.5 FAO Code of Conduct for Responsible Fisheries

Fisheries, including aquaculture, provide a vital source of food, employment, recreation, trade and economic well-being for people throughout the world, both for present and future generations and should therefore be conducted in a responsible manner. National and international fisheries policies and management practices that better reflect the principles of the Code of Conduct will lead to an improved and sustainable economic, social and environmental contribution of the fisheries sector. The optimization of the contribution of fisheries to achieving benefits in terms of food, employment, recreation and trade as well as ecosystem and socio-economic well-being will benefit populations throughout the world. To promote long-term sustainable fisheries, in 1995 the FAO Conference adopted the Code of Conduct for Responsible Fisheries.

To assist with the wider dissemination of the Code of Conduct as requested by the FAO Committee on Fisheries, a booklet, entitled "What is the Code of Conduct for Responsible Fisheries?" has been produced. It describes, in a non-technical manner, important aspects of the Code of Conduct. The purpose of the publication is to create greater awareness of the goals and purpose of the Code and to encourage its effective application in all capture fisheries and in aquaculture. The booklet does not replace the Code of Conduct but simply presents some of the complex information contained within the Code in a simplified form in an attempt to make it more accessible to all users of fisheries.

This project supports the implementation of the Code, which involves, in varying degrees, all units of the Fisheries Department and associated regional teams. The Code sets out principles and international standards of behaviour for responsible practices with a view to ensuring the effective conservation, management and development of living aquatic resources, with due respect for the ecosystem and biodiversity. The Code recognizes the nutritional, economic, social, environmental and cultural importance of fisheries and the interests of all those

concerned with the fishery sector. The Code takes into account the biological characteristics of the resources and their environment and the interests of consumers and other users.

Strategies:

- At the invitation of FAO's Director-General, Ministers responsible for fisheries met in Rome as a sign of their attachment to the implementation of the Code of Conduct for Responsible Fisheries. Inter alia, the Ministers were especially appreciative of FAO's role in promoting the application of the Code of Conduct and the increasingly wide adoption of the Code by States and concerned organizations. The Rome Declaration on the Implementation of the Code of Conduct for Responsible Fisheries, unanimously adopted by the FAO Ministerial Meeting, was attended by 126 Members of the Organization

- FAO has been widely disseminating the Code in various languages and is actively promoting its implementation. The Code has been published by FAO in Arabic, Chinese, English, French and Spanish. In addition, FAO has been advised that, in a number of instances, governments, industry or NGOs have taken the initiative to translate the Code into other languages. The Code is now available in more languages than any other FAO document.

- The promotion and implementation of the Code is being addressed at all sessions of FAO fishery bodies. FAO regards the implementation of the Code and the strengthening of regional fishery bodies as being intrinsically linked.

- Resolution 4/95 of the FAO Conference, recalling Article 5 of the Code, urged that the special requirements of developing countries be taken into account in implementing its provisions. It also requested that FAO elaborate an inter-regional assistance programme for external assistance. The purpose of this programme would be to upgrade the fisheries capabilities of developing countries so that they would be better placed to meet their obligations under the Code. The Interregional Programme of Assistance to Developing Countries for the Implementation of the Code of Conduct (FISHCODE) includes several component projects.

Implementation

FAO has a responsibility to facilitate the implementation of the Code and, where possible and appropriate, to technically support national and regional initiatives towards this end. However, primary responsibility for the Code's implementation rests with governments since it involves difficult, and sometimes sensitive, national policy decisions.

FAO's global initiatives

FAO's global role in promoting the implementation of the Code centres on a number of different, but related, activities. These initiatives accord with instructions from the FAO Governing Bodies and COFI concerning activities to support the dissemination and implementation of the Code. These initiatives, many of which are inter-related, include:

- The dissemination of the Code in official FAO languages (Arabic, Chinese, English, French, and Spanish) through a range of channels;
- The implementation of the Code has been placed on the agendas of all FAO regional fishery bodies for consideration and follow-up action. In this way awareness about the importance of the Code and the need to promote and facilitate its implementation has been heightened;
- FAO staff routinely promote the implementation of the Code when country visits are undertaken;
- The elaboration and distribution of technical guidelines to assist with the national implementation of the Code. Currently six guidelines have been printed and distributed, and other guidelines are in the pipeline;
- Training related to, and in support of, the implementation of the Code is planned through TRAINFISH, a training methodology based on TRAIN-X which is promoted by the United Nations Development Programme for use within the UN system. TRAINFISH will have a strong focus on national capacity building and in promoting programme sustainability. A video concerning the Code will be developed and distributed in support of this training initiative;
- An inter-regional programme to support activities relating to the implementation of the Code has been elaborated. The programme has been presented to the international donor community to determine funding interest. The Government of Norway has committed itself to fund at least two components of the programme relating to fisheries monitoring, control and surveillance, and fisheries research;
- The monitoring of progress with the Code's implementation, and reporting to COFI, will be primarily facilitated through the provision of national information provided to FAO through a questionnaire. Information provided by countries will be consolidated for COFI reporting; and

- An internet site for the Code has been established on the FAO Page on the web. The site is updated regularly, providing information about developments with the Code.

Regional facilitation and adaptation of the Code

At the regional level, fishery bodies have an important role to play in facilitating the implementation of the Code, and for this reason the draft FAO strategy to support implementation underscores the importance of regional action. The strategy recognizes that because of its global, and in some cases generalised nature, the Code would be better implemented if some of its provisions were adapted to meet different fishery (e.g. inshore and offshore fisheries, small-scale and industrial fisheries, marine and inland fisheries, and aquaculture) and regional circumstances (e.g. tropical and temperate fisheries) as far they are consistent with its basic purposes and principles. Moreover, it is further recognized that in regions where there are shared fisheries, or common management problems in non-shared fisheries, regional cooperation as expressed through the co-ordination of management policies and other forms of cooperation (e.g. sharing of training and research institutes and other forms of technical cooperation), can be best achieved through the programmes of regional fishery bodies.

The mounting of regional workshops to assist in the adaptation of the Code so that it might more appropriately meet the needs of particular fisheries and different regional situations is being fostered by FAO and some of its projects.

National responsibilities

With respect to national implementation of the Code, governments are encouraged to work with all stakeholders to facilitate structural adjustment and change in the fisheries sector. In large-scale fisheries, industry will have a prominent role in implementing the Code; this role will essentially involve ensuring that industry complies voluntarily with measures adopted by governments to facilitate the long-term, sustainable use of fisheries. Such compliance will reduce government enforcement costs in achieving national goals. In contrast, in artisanal and small-scale fisheries, the fishing communities themselves (through community-based management) and possibly NGOs (given their grass-roots fisheries connections in many developing countries), will be expected to be closely involved in facilitating and supporting the implementation of the Code.

Conclusion and recommendation

Mud crab resources are an asset to the country and can be developed to the status of a major foreign exchange earner if culture and proper management measures are implemented. Mud crab culture is a growing sector in the world, and which is still in a primitive stage Bangladesh. Legal prohibition of capturing of crab during breeding season is essential to maintain the resource. This could be achieved by enclosure of breeding area in winter and by awareness building and educating the fishing community on the 'gainful' aspects of resource management of which they are the immediate beneficiaries. This warrants in-depth investigations on the mud crab resource in all parts of the country in order to achieve maximum utilization while sustaining the resource. Techniques for mass breeding, culture and fattening, processing, marketing, export and quality control is also important areas which should be developed and strengthened. Transportation techniques will have to be developed to get maximum earnings from the exports. In order to achieve this success, following recommendation should be taken under consideration

Researchable issues

Nutrition and feed management

- Establish the nutritional requirements of mud crabs (*Scylla olivacea*) at various phases of their life cycles to enable the development of suitable formulated diets.
- Assessment of stock and present status of utilization of trash fish in Bangladesh.
- Production of low cost formulated diets by replacing fish meal to alternative local materials for various phases of life cycle.
- Food and feeding habit in natural environment.

Seed production

- Environmental and nutritional requirements of larval stages that will provide basic information for mud crab larval rearing in the hatcheries to increase survival.
- Morphological, behavioral and growth rate differences at various stages and among species of mud crabs.

- Identify different life stages of four mud crab species to allow field identification of zoea, megalopae and juvenile stages of these animals.
- Develop suitable artificial breeding technique of mud crab.

Reproductive biology and population dynamics

- Reproductive biology (size at maturity, population fecundity, spawning periodicity and locality) of all mud crab species, namely *S. tranquebarica*, *S. pareamamosain* and *S. olivacea* as a few studies have been conducted on *S. olivacea*.
- Population dynamics parameters (e.g. recruitment, growth, and mortality rate of different stages).

Culture

- Feasibility of integrated mud crab culture in coastal region.
- Assessment of appropriate stocking density of mud crab (*Scylla olivacea*) for the development of pen culture in the vicinity of mangrove forests of Bangladesh.

Health management

- Determine the current status of health management of crabs in Bangladesh.
- Establish appropriate culture techniques to ensure that the crabs produced are healthy.

People involved with crab fishery

- Detailed socio-economic analysis of crab fishers
- Alternate option for income generation, especially in lean period.

Post harvest handling

- Assessment of the stock size and sustainable yield of mud crab in inshore and offshore waters to assess.
- Appropriate technology to culture and processing of soft shell crab.
- Introduction of suitable techniques for crab meat processing.
- Development of efficient craft and gear to catch crabs.
- Efficient transport to carry crabs quickly during transportation.
- Suitable techniques to control or decrease temperature in depot.
- Appropriate techniques of processing to prepare product from dead crabs.

- Suitable boxes of crab's transportation to increase survival rate and quality of crabs.
- Quality control – microbial and biochemical test, pesticide test.
- Status of different categories people involved in crab fishery.

Management issues

Culture

- A strategy to exploit the natural crab seed resource on a sustainable basis has to be formulated in parallel with recommendations on how the culture sites should be managed to minimize possible pollution effects.
- Site selection for long term basis and introduction of mud crab pen culture in mangroves.
- Overall long term planning for the development of mud crabs aquaculture in Bangladesh.
- Amendment of fisheries law to promote crab fishery.
- An exchange of technical information can be initiated by networking and utilizing the resources of NACA, DANCED, ACIAR, SEAFDEC and AAHRI through newsletters, a networked news group, bulletin board, broadcast e-mail and the publication of occasional papers are possible options.
- Establish a standardized protocol for estimating production yields.
- Establish community-based crab fishery management to ensure sustainable management.
- Alternate income generation in off season and provide credits for both crab business and alternate income.
- Measures should be taken and implemented to stop the current rate of mangrove habitat destruction to allow suitable living condition for the re-stocked mud crab larvae into the mangroves.

Post harvest handling issues

- Government participation in internal crab promotional activities.
- Training of professional crab fishermen in capture, culture and other relevant activities with the help of international agencies.

- Technical and financial support to the farmer in crab culture to maintain year round supply.
- Government and non-government initiatives for efficient transportation of crabs.
- Infrastructure development and management approach to control temperature in depot.
- Quality control – microbial and biochemical test, pesticide test.
- Proper management and legal approach to stop illegal and over harvesting of crabs.

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