1. GENERAL INTRODUCTION

The food from land is so limited that it may not be able to satisfy even the basic requirement of the ever increasing population. One of the alternatives to overcome this problem of food shortage is to tap the vast resources of the ocean which could cope of with the population explosion and nourish them in maximum extend as possible. To encourage the fishery is necessary for ever increasing demands for protein rich food to earn valuable foreign exchange and to provide employment opportunities to the coastal rural populations. India with its vast costal line has tremendous potential for marine food resources. Consumption of fish and other marine products have always been a major factor in the economy and nutrition of the coastal population. The traditional importance of seafood is its high quality protein. It compares favorably with chicken, beef, egg and cheese by supplying all the amino acids needed for tissue building and repair. Seafood is easily digestible because it has very little connective tissue. For that reason fish is recommended in many special diets. Seafood has protein; carbohydrates and wide assortment of minerals without much fat and cholesterol or sodium.People that customarily eat seafood are less likely to develop heart diseases, diabetes, arthritis, bronchial asthma and psoriasis. Eating fish regularly can help to fight heart disease.

In ancient times peoples were a kind of carnivorous due to lack of knowledge and awareness but today they are naturally eliminate animal's meat considerably because health problems like heart related diseases.So human beings are great crazy about seafood because it has rich amount of polyunsaturated fatty acids (PUFA) than saturated fatty acids.So the seafood has a great demand today. Among varies seafood crab is considered to be more healthy and delicious.Thirty years ago in some areas, the crabs had no demand, but today the crab and the seafood have been highly attractive due to high consumer preference ultimately the demand is shooting up both national and international markets. For the last two decades crab resources have been exploited to the maximum extend by using high-tech gears and crafts.The demand almost always exceeds supply in many parts of the world thus encouraging people to go for aquaculture. The economically important portuid crabs found along east coast of India are *Scylla serrata, S.tranquebarica, Portunus sanguinolentus, P. pelagicus, Charybdis feriata, C. lucifera, C.natator* and *C. truncata*.

In India, millions of people are suffering from malnutrition.Protein deficiency may be minimized for some extent by making available cheaper fish meal items like crabs, which are rich in protein, minerals and vitamins A & D. Their meat contains considerable amount of glycogen and free amino acids, rendering their flesh sweet and tasty. It also serves as a good source for iodine, phosphorus, magnesium, iron, copper, sulphur and calcium which are essential to keep up the health and stamina (Joel and Raj, 1980).The crab meat has got medicinal value for curing asthma and chronic fevers (Raja, 1981).

Reproduction is the main mechanism to maintain species proliferation and continuity and in brachyuran crabs is extremely diversified ultimately shaped to maximize egg production and offspring survivorship (Hartnoll and Gould, 1989; LopezGreco *et al.,* 2000). The reproductive cycle of crustaceans has been widely studied, mainly of those species that have commercial value or ecological potential (Reigada and Negreiros-Fransozo, 1999; Pinheiro and Fransozo, 2002; Castiglioni and Negreiros-Fransozo, 2006). Many works have been conducted on various aspects of the reproductive biology of many marine animals ('O' Brien, 1999; Duran Munoz *et al.*, 2000; Morita and Morita, 2002). Study of gonads, size at sexual maturity and fecundity are important aspects of reproductive biology of crab. This information is often required to manage crab fisheries on sustainable basis. The knowledge on mating strategies and behaviour is essential for the production of broodstock round the year. Since broodstock is not available throughout the year from natural resources.

During development the colour of the egg changes through brown to grey as the yolk is used up and the outline of the embryo becomes visible. The eyes and pigment spots appear first, followed by the outlines of the abdomen and cephalothorax. As the embryos develop and absorb yolk the sponge darkens, turning black just prior to hatching. The embryonic stages are very much useful in recognizing the stages of development of species. When the larvae hatched out from the eggs, they undergo a series of developmental stages before metamorphosing to juvenile stage.During this process; they exhibit marked variations in morphological features. These variations are unique for each and every species according to their developmental stages.

In marine invertebrates, the degree of tolerance to salinity variations often varies during ontogeny. Within the zone of tolerance, environmental conditions have been shown to affect development rate, intermoult duration and growth of many brachyuran larvae. Complete development of all the larval stages has been affected by salinity for several species of Brachyura (Costlow and Bookhout, 1968).

A major barrier to develop crab aquaculture is an insufficient supply of seeds which are presently collected from the wild. However, the techniques of mass production of these larvae are not yet standardized. Besides the above, due to the increasing demand for the crabs in the market, they were extensively fished and which lead to decrease in the wild stock. So, further it becomes imperative to maximize the larval production in controlled conditions, not only for ranching to improve the natural stock but also to cater the needs of the aquafarmers to increase the production of crabs to supply and fulfill the requirements of the consumer.

1.1. SCOPE OF THE STUDY

The focus of the present day aquaculture was increasingly shifted towards the development of hatchery technology and crab farming to meet the human protein demand.Mass larval culture experiments were carried out on both commercial and non-commercial crabs all over the world. But, the percentage of survival at the end of the larval cycle is very low.Studies on the mass seed production technology were under experimentation for mud crabs with low survival rates, but such studies are scanty in the sea crabs in general and *C.feriata* in particular especially in Indian perspective.Hence the present study was aimed to investigate the reproductive biology and mass seed production of *C.feriata* with following objectives;

Information about the reproductive biology and mating behavior of any species is important for the successful seed production in captivity.Study of gonads, stages of gonad development, size at maturity and fecundity are important aspects of the reproductive strategies of a crab.This information is often required to manage crab fisheries on sustainable basis and also prevent the depletion of the natural sources.Hence the present study was aimed to investigate the reproductive system and mating behaviour of *C.feriata.*

The quality and survival of newly hatched zoeae will depend primarily on the embryonic development.So an attempt has been made to study the embryonic development in the portunid crab, *C.feriata.*

The salinity is particularly important because it represents ecological master factor for many aquatic organisms.The objective of this work was to study the effect of salinity on larval development of *C.feriata* in relation to survival and duration of larval stages.

To develop aquaculture activities mass seed production technology is essential. If we collect seeds from natural environment, identification is a major problem and also the seeds are not uniform in size. If farming activities are introduced year round seed availability is essential.This is not possible from the natural resources because the berried female's availability restricted in certain seasons only. So seed production in controlled condition is very much needed.Hence an attempt was made to produce seeds in controlled condition.

1.2 DESCRIPTION OF THE COLLECTION AREA

In the present study the animals were collected from Annankovil landing centre in Parangipettai coastal waters situated along southeast coast of India. Parangipettai (Lat. 11˚ 29'N and Long. 79˚46'E) coast with its sheltered shoreline support a lucrative fishery in Tamilnadu.The fisher folks of Annankovil are involved in fishing activities.They are bringing their catches and are finally transported to the local markets, companies and to nearby places (Map 1).

Map 1. Description of the collection area

1.3. DESCRIPTION OF THE STUDY ANIMAL

Crabs are members of Crustacea, a class of invertebrate phylum Arthropoda that includes the animals with jointed legs and a hardened outer covering or exoskeleton. Crabs are belonging to the order Decapoda a name which refers to this fact that the members of this order have 5 pairs of legs. The true crabs are placed in the infraorder Brachyura an appropriate name for this group, as their shortened flap-like abdomen or tail is folded under the body.

Taxonomic Hierarchy of *C.feriata* (Plate 1)

Kingdom: Animalia
Phylum: Arthropoda
Subphylum: Crustacea
Class: Malacostraca
Subclass: Eumalacostraca
Superorder: Eucarida
Order: Decapoda
Suborder: Pleocyemata
Infraorder: Brachyura
Superfamily: Portunoidea
Family: Portunidae
Genus: *Charybdis*
Species: *C. feriata*

Common Name: Siluvai Nandu, Cross crab, X-mass crab.

FAO Name: Crucifix crab, Coral crab.

Vernacular Name: Siluvai Nandu**,** X-mass crab, Yeasu nandu.

Synonyms

Cancer feriatus, Linnaeus -1758.

Charybdis cruciata, Herbst- 1794.

C. (Goniosoma) crucifera, Alcock, 1899,-No new locality

Ganiosoma cruwferum, Lanchester, 1901, -Malay Peninsula.

C. cruciatus, Stebbing, 1910, -No new locality.

C. cruciata, Rathbun, 1910, -Gulf of Siam.

C. crucifera, Balss, 1922, -Formosa

C. (Goniosoma) crucifera, Gordon, 1931, -Coast of China.

C. (Goniosoma) cruciata, Shen, 1932, -Hong Kong.

C. cruciatus, Chopra, 1935, - Gulf of Bengal.

C. (Goniosoma) cruciata, Shen, 1937, -Singapore.

C. (Charybdis) cruciata, Leene, 1938, -Java Sea.

C. (Charybdis) cruciata, Stephensen, 1945, -Gulf of Iran.

C. (Charybdis) cruciata, Stephenson, Hudson and Campbell, 1957 -Australia.

C. (Charybdis) cruciata, Miyake, 1961, - Japan.

C. cruciata, Miyake, 1962 - Japan.

C. cruciata, Takeda and Miyake, 1969, -Formosa.

C. (Charybdis) feriatus, Stephenson, 1972, -Australia.

Distinguishing Characters

1. Anterolateral teeth broad at base, first anterior lobe bifid.
2. Three spine on anterior borders of arm.
3. Across on the carapace.
4. Carapace broad, slightly convex and smooth, length much less than its width.

5. Antero-lateral borders with six spines, the first one truncated and notched anterioly and the rest acuminate.
6. Fingers as long as the palm.
7. Propodus of the last pair of legs with one or two denticles near distal end of its posterior border.
8. Chelipeds stout, asymmetrical.
9. Merus armed with 3 strong teeth on the distal half of anterior margin and with granules or denticles on the proximal half.

Colour

Sexually not dichromatic; overall colouration of fresh specimen purplish red; clear distinct creamy white longitudinal cross on carapace beginning from the frontal region and extending up to cardiac region; laterally on each side a creamy white inverted shaped markings beginning from the border of orbit and extends up to posterior border of carapace; creamy white colouration found between the base of antero lateral spines; chelae reddish brown and mottled with creamy white; tip of the chelae dark brown, under surface creamy.

Size

Maximum carapace width is 45 mm and length of carapace is 65mm.

Habit and Habitat

Marine, rocks, rocky or stony coast, in 10-30 m deep waters or coral reef flats, stones and sandy muddy substratum.

Distribution

The Indo-Pacific portunid crab, *C. feriata* was recorded for the first time from the Mediterranean Sea, almost throughout the Indo-pacific and its distribution over South Africa, Hong Kong - Southern Waters, Tolo Harbour; China - Guangxi, Guangdong, Taiwan, Fujian; Japan, Australia, India, Tanzania, East Africa, South Africa and Madagascar.It is also distributed in China Sea, Arabian sea, Indian Ocean, Japan and Australia, In India, it is reported from West Bengal, Tamil Nadu, Parangipattai (Portonovo, south east coast), Kerala, Karnataka, Maharastra and Andaman and Nicobar Islands.

Plate 1.*C. feriata*

1.4. REVIEW OF LITERATURE

Reproductive System

Cronin (1947) studied the anatomy and histology of the male reproductive system of *Callinectes sapidus*.Estampador (1949) has compared the spermatogenesis and oogenesis in *S.serrata*. George (1963) demonstrated the anatomy of the reproductive system and embryological studies of *Neptunus sanguinolentus*. Ryan (1967) studied the structure and function of the reproductive system of *P. sanguinolentus*.Hartnoll (1974) observed some secondary sexual characters in crabs.The histology of reproductive system in the blue crab *C. sapidus* was observed by Johnson (1980). Batoy *et al*. (1980) studied the breeding season, sexual maturity and fecundity of blue crab, *P. pelagicus* in selected coastal waters in Leyte and Vicnity, Phillippines. Smith (1982) reported the potential status and biology of blue crabs in South Australia.Hines (1982) studied the allometric constraints and variables of reproductive effort in brachyuran crabs.Hartnoll and Gould (1989) registered brachyuran life history strategies and the optimization of egg production. Ingles and Braum (1989) observed the reproduction and larval ecology of the blue swimming crab *P. pelagicus* in Ragay Gulf, Philippines. Krol *et al*. (1992) have reported the reproductive components and microscopic anatomy of decapods crustacean. Minagawa *et al.*

(1993) investigated the female reproductive biology and oocyte development of the red frog crab, *Ranina ranina*, off Hachijojima, Izu Islands, Japan**.**

Emmerson (1994) reported the seasonal breeding cycles and sex ratios of eight species of crabs from Mgazana, a mangrove estuary in Transkei, South Africa.Sumpton *et al.* (1994) studied the reproduction and growth of the commercial sand crab, *P. pelagicus.* Haddon (1994) observed the size-fecundity relationships, mating behaviour and larval release in the New Zealand paddle crab, *Ovalipes catharus.* Mounton and Felder (1995) investigated the reproduction of the fiddler crabs *Uca longisignalis* and *U. spinicarpa* in a Gulf of Mexico salt marsh. Jensen *et al.* (1996) reported the structure of the female reproductive tract in the Dungeness crab (*C. magister*) and implications for the mating system. Kumar *et al.* (2000) have been studied the reproductive biology and distribution of the blue swimmer crab (*P. pelagicus*) in South Australian waters. Potter and de Lestang (2000) investigated the biology of the blue swimmer crab *P. pelagicus* in the Leschenault Estuary and Koombana Bay in south-western Australia.Brante *et al.* (2003) documented the reproductive investment in the crab *C. setosus* along latitudinal cline: egg production, embryo losses and embryo ventilation. Cobo and Fransozo (2003) described the external factors determining breeding season in the red mangrove crab *Goniopsis cruentata* in Sao Paulo State Nothern coast, Brazil. Lestang *et al.* (2003) explained the reproductive biology of the blue swimming crab (*P. pelagicus*) in five bodies of water on the west coast of Australia. Litulo (2004) reported the reproductive aspects of a tropical population of the fiddler crab *U. annulipes* at Costa do sol Mangrove, Maputo Bay, Southern Mozambique.Halawa and Efrizal (2006) investigated the reproductive biology and larval rearing of blue swimming crab, *P. pelagicus.* Stewart et *al.* (2000, 2007) observed the histology of the ovaries of two tropical portunid species *P. pelagicus* and *S. serrata.*Becker *et al.* (2011) reported the morphology of the female reproductive system of European pea crabs.

Haefner (1976) has described the maturity stages in the males of *C. irroratus.* Dhas *et al.* (1980) studied the germinal zone activity and oocyte differentiation in the marine crab *P.pelagicus.* Campbell and Eagles (1983) observed the stages of development size at maturity and fecundity of rock crab *C. irroratus* from the Bay of Fundy and southwestern Nova Scotia.Sukumaran *et al.* (1986) was reported the maturity stages in females of *P. sanguinolentus.* Developmental stages of deep sea golden crab *Geryon fenneri* was reported by Erdman and Blake (1988). Sukumaran and Neelakantan (1996) had documented the maturity stages and reproductive cycle in two marine crabs, *P.*

sanguinolentus and *P.pelagicus* along the Karnataka coast. Lestang *et al.* (2003) studied the stages of maturation in male *P.pelagicus* based on the development of vas deferens. Corgos and Freire (2006) explained the morphometric and gonad maturity in the spider crab *Maya branchydactyla*.Lawal-Are (2010) studied the reproductive biology of the blue crab, *C. amonicola* in the layos lagoon, Nigeria.

Brown and Powell (1972) reported size at maturity in male Alaskan Tanner crab, *Chionoecetes bairdii*, as determined by chela allometry, reproductive tract weights and size of precopulatory males.Somerton (1980) investigated a computer technique for estimating the size of sexual maturity in crabs. Somerton (1981) described the regional variation in the size of maturity of two species of tanner crab (*Chinoectes bairdi* and *c. opilio*) in the eastern Bering Sea, and its use in defining management subareas. Conan and Comeau (1986) explained the functional maturity and terminal moult of male snow crab, C. *opillio*. Campbell and Fielder (1986) studied the size at sexual maturity and occurrence of ovigerous females in three species of commercially exploited Portunid crabs in South East Queensland.Geographic variation in size at maturity in Brachyuran crabs was reported by Hines (1989).

Reeby *et al.* (1990) reported the size at maturity in the male crab of P. *pelagicus*. Relative growth, sexual maturity and gonadosomatic index in the marine crabs, *P. sanguinolentus* and *P. pelagicus* along the south-west coast of India was reported by Sukumaran and Neelakantan (1996). Lopez Greco and Rodriguez (1998) was observed the size at the onset of sexual maturity in *Chasmagnathus granulate.* Pinheiro and Fransozo (1998) recorded the sexual maturity of speckled swimming crab *Arenaeus cribrarius* in the Ubatuba litoral, Silo Paulo State, Brazil. Lopez Greco and Rodriguez (1998) studied size at onset of sexual maturity in *C. granulate*.Pincheiro and Fransozo (1998) investigated the sexual maturity of speckled swimming crab *Arenaeus cribrarius* in the ubatuka litoral, Silo pawlo state Brazil.Fisher (1999) observed that the effect of temperature and salinity on size at maturity of female blue crab.Sampedro *et al.* (1999) explained the morphometry and sexual maturity in the spider crab *Maja squinado* in Galicia, Spain. Muino *et al.* (1999) observed the size at maturity of *Liocarcinus depurator*. Flores and Paula (2002) studied the sexual maturity, larval release and reproductive output of two brachyuran crabs from a rocky intertidal area in central Portugal. Rasheed and Mustaquim (2010) studied the size at sexual maturity, breeding season and fecundity of three spot swimming crab *P. sanguinolentus* occurring in the coastal waters of Karachi.

Prager *et al.* (1990) studied the fecundity of blue crab *C. sapidus* in Chesapeake Bay. Reeby *et al.* (1990) reported the fecundity of *Portunus* species from Karwar waters.Somers (1991) studied the characterizing size-specific fecundity in crustaceans.Haddon (1994) has compared the size-fecundity relationships in New Zealand paddle crab, *Ovalipes catharus*. Mantelatto and Fransozo (1997) observed the fecundity of the crab *C. ornatus* from the Ubatuba region, Sao Paulo, Brazil.Mantelatto and Fransozo (1997) reported the fecundity of *C. ornatus* from the ubatuba region, sao Paulo, Brazil. Pinheiro and Terceiro (2000) studied the fecundity and reproductive output of the speckled swimming crab *Arenaeus cribrarius*. Muino (2002) recorded the fecudity of *Liocarcinus depurator* in the Ria de Arousa (Galicia, north-west Spain). Kumar *et al.* (2003) emphasized the fecundity of the blue swimming crab *P. pelagicus* in southern Australia.Harlioglu *et al.* (2004) have been reported the potential fecundity of freshwater cray fish *Astacus leptodactylus.* Nakata and Goshima (2004) studied the fecundity of the Japanese cray fish *Cambaroides japonicas.*Litulo (2004) studied the fecundity of the pantropical fiddler crab *U. annulipes* at costa do sol mangrove, Maputo bay, Southern Mazambique western Indian Ocean.

Fastan (1915) studied the male reproductive organs of decapoda. Fasten (1918) recorded the spermatogenesis of the Pacific coast edible crab,*C. magister.*Spalding (1942) documented the nature and formation of the spermatophore and sperm plug in *C. maenas.*Hinsch and Walker (1974) studied the vas deferens of the spider crab, *Libinia emarginata*. Gupta and Chatterjee (1976) reported the anatomical observations of the internal male reproductive organs of *S. serrata*. Uma (1978) compared the morphology of sperm and spermatophores of crustaceans. Uma and Subramoniam (1979) analysed the histochemical characteristics of the spermatophore layers of *S. serrata*. Sapelkin and Fedpseev (1981) reported the structure of male reproductive system of Tanner crabs.Dudenhausen and Talbot (1983) compared the ultrastucture of soft and hard spermatophores from the crayfish *Pacifastacus peninseula.* Ryan (1984) observed the spermatogenesis and male reproductive system in the Hawaiian crab *R. ranin*. Uma and Subramoniam (1984) compared the spermatophore in *S. serrata* and *Clibanarius longitarsus.* Hinsch (1986) compared the sperm morphologies, transfer, and sperm mass storage between two species of crab, *O. ocellatus* and *Libinia emarginata.* Hinsch (1988) observed ultrastructure of the sperm and spermatophores of the golden crab *Geryon fenneri* and a closely related species, the red crab *G. quinquedens*, from the eastern Gulf of Mexico.

Beninger *et al.* (1988) reported the functional anatomy of the male reproductive system and the female spermatheca in the snow crab *C.*

opilio and a hypothesis for fertilization. El-Sherief (1991) studied the fine structure of the sperm and spermatophores of *P. pelagicus*.Subramoniam (1991) reported the chemical composition of spermatophores in Decapod crustaceans. Chiba *et al.* (1992) studied the ultrastucture of the spermatozoa and spermatophores of the Zuwai crab, *C. opilio.* Subramoniam (1993) observed the spermatophore and sperm transfer in marine crustaceans. Minagawa *et al.* (1994) reported the male reproductive biology of the red frog crab *R. ranina*. Burton (1995) studied the spermatid pathway and associated reproductive structures of squat lobster *Thenus orientalis*. Taketomi *et al.* (1996) observed the testis and androgenic gland during the development of external sexual characteristic of the cray fish *P. clarkia*.Sainte-Marie and Sainte-Marie (1999) reported the reproductive products in the adult snow crab (*C. opilio*). Anilkumar *et al.* (1999) observed the spermatophore transfer and structure in the Brachyuran crab *Metopograpsus messor.* Benhalima and Moriyasu (2000) studied the structure and function of the posterior vas deferens of the snow crab*, C. opilio.* Morphological aspect of reproductive system of males of *Diagnosis Pagilator* was studied by Manjoncabeza and Rosa (2000). Moriyasu *et al.* (2002) investigated the reproductive biology of the male Jonah crab, *C. borealis* on the Scotain shelf, Northwest Atlantic. Vogt (2002) reported the functional anatomy of freshwater crayfish. Nagao and Munehara (2003) observed the annual cycle of testicular maturation in the helmet crab *Telmessus cheiragonus.* Garcia and Silva (2006) studied the morphology of the testis and vas deferens of red-clawed mangrove tree crab *Goniopsis cruentata.* Castilho *et al.* (2008) reported the morphology and histology of the male reproductive system of the mangrove land crab *Ucides cordatus*.Erkan *et al.* (2009) studied the male reproductive system of morphology and spermatophore formation in *Astacus leptodactylus*. Simeo e*t al.* (2009) reported the internal anatomy and ultrastructure of the male reproductive system of the spider crab *Maja brachydactyla*.Stewart *et al.* (2010) studied the spermatogenesis in the blue swimming crab, *P. pelagicus* and evidence for histones in mature sperm nuclei.Boopathi (2011) investigated the reproductive system of *P.sanguinolentus*. Recently Anand (2012) studied the male and female reproductive system of *P.pelagicus.*

Mating Behaviour

Childchester (1911) has reported the mating habits of four species of the Brachyura. Edwards (1966) studied the mating behaviour in the European edible crab *C. pagurus.* Hartnoll (1969) has documented mating in the brachyura. Teytaud (1971) observed the sex recognition in the blue crab, *C. sapidus.* Fielder and Eales (1972) investigated the courtship, mating and sexual maturity in *P.pelagicus.* Hartnoll and Smith (1979) observed the pair formation in the edible crab *C. pagurus.*

Glesson (1980) described the pheromone communication in the reproductive behaviour of the blue crab *C. sapidus*. Glesson (1982) reported morphological and behaviour identification of the sensory structures mediating, pheromone reception in the blue crab, *C. sapidus.* Campbell (1984) compared the adult sexual behaviour and larval ecology of three commercially important Portunid crabs from the Moreton Bay, Queenland. Paul and Adams (1984) reported breeding and fertile period of female *C. baridi.* Liplius (1985) studied size-dependent reproduction and moulting in spiny lobsters and other long lived decapods. Heasman *et al*. (1985) observed mating and spawning in the mud crab *S. serrata* in Moreton Bay, Queensland. Elner *et al.* (1985) studied the mating behaviour of the Jonah crab *C. borealis.*Christy (1987) demonstrated competitive mating, mate choice and mating associations of brachyuran crabs. Koga (1994) reported the alternative mating behaviours in the sand-bubbler crab *Scopimera globosa.* Haddon (1994) studied size-fecundity relationships, mating behaviour, and larval release in the New Zealand Paddle crab, *O.catharus.* Sainte-Marie and Lovrich (1994) studied the delivery and storage of sperm at first mating of female *Hionoecetes opilio* in relation to size and morphometric of male parent. Norman (1996) observed hard-female mating in the brachyuran crab *T. sima*. The advantage of large body size in sexual competition among males in the blue crab, *C. sapidus* was studied by Jivoff (1997). Jones and Hartnoll (1997) documented mate selection and mating behaviour in spider crabs. Jaroensatasinee and Jaroensatasinee (2003) reported male body size influence the female choice and male-male competition in the fiddler crab *U. paradussumies.* Eshky Ali (2003) reported the mating duration in *P.pelagicus.* Brockrohoff and McLay (2005) studied the mating behaviour, female receptivity and male-male competition in the intertidal crab *Hemigrapsus sexdantatus.*Dinakaran and Soundarapandian (2009) studied mating behaviour and broodstock development in commercially important three spotted crab *P. sanguinolentus.*Anand (2012) investigated the mating behaviour of *P.pelagicus.*

Embryonic Development

Classification of animal eggs was made by Needham (1950) and Pandian (1970). Both of them classified eggs based on the energy reserves (fat or protein).Later, Shakuntala and Reddy (1982) classified the crustacean embryogenesis into two groups on the basis of the egg size.

Studies on embryonic development of crustaceans display a remarkable underlying unity in all species and revealed remarkable contributions. Sundaramoorthy (1987) studied the embryonic development in the mangrove crab, *Neoepisesarma (Muradium)* *tetragonum*. Wu (1991) attempted on the embryonic development of the mud crab, *S. serrata*. Veera Ravi (1994) reported the embryonic development in *C. lucifera* and emphasized the utilization of yolk during embryogenesis.Parimalam (2001) studied the embryology in a hermit crab, *Clibanarius longitarsus*. Xue *et al*. (2001) investigated the embryonic development in *P. trituberculatus* and reported 5 stages. The other works on embryonic development of different crabs are Scylla spp (Quinitio and Parado-Estepa, 2003), *P. pelagicus* (Soundarapandian and Thamizhazhagan, 2009), *P.sanguinolentus* (John Samuel and Soundarapandian, 2009) and *S. serrata* (John Samuel and Soundarapandian, 2010).

Wear (1974) reported that crabs carry embryo for extended periods. Hartnoll and Paul (1982) opined that females exhibit complex behavioural patterns during brooding. Baeza and Fernandez (2002) also reported similar behavioural patterns in brooding female and emphasized that, these seemingly directed towards providing oxygen to the embryos. They also studied the relationship between female behaviour and oxygen consumption of the embryo.

Wear (1974) observed that, there is a gradual increase in the egg diameter as the development progresses. Oogenesis, embryogenesis and larval quality in crabs may be affected by temperature (Steele and

Steele, 1975), female's nutritional and reproductive condition (Harrison, 1990) and salinity (Bas and Spivak, 2000). Gimenez and Anger (2001) opined that prehatching salinity regulates the embryonic energetics and the biomass of freshly hatched zoea I. The quality of *S. serrata* eggs could be assessed by subjecting the newly hatched larvae to different stress tests (Mantellato and Garcia, 2001). Gimenez and Torres (2002) emphasized that initial variability in larval biomass has considerable influence on the survival and growth of later larval or juvenile stages.

The colour change is caused by absorption of the yellow yolk and development of dark pigment in the eyes (Sundaramoorthy, 1987; Krishnan, 1988; Vijayakumar, 1992; Lin *et al.*, 1994; Veera Ravi, 1994; Parimalam, 2001). Veera Ravi (1994) reported that as the progression of development occurs, the embryo decreases in dry weight stage by stage as it utilizes the yolk material.

Effect of Salinity on Larval Development

Several papers have been published in recent years on the relationship between salinity and the larval development of the brachyuran crabs. As the earliest study, Sandoz and Rogers (1944) examined the salinity tolerance of *C. sapidus* and found that 18 to 29‰ salinity were required for the metamorphosis of zoea II to zoea III.

Later on Costlow and Bookhout (1959) observed that the larval development of *C. sapidus* occurred in salinities ranging from 20.1 to 31.1‰.

Costlow and Bookhout (1960) reared the larvae of *Sesarma cinerium* under 12 different conditions of salinity and temperature and concluded that even though hatching of zoea I occurred in 12.5 and 31.1‰ salinities, first crab instar was reached only at 20.1 and 26.7‰. Costlow and Bookhout (1962, 1962a) while rearing the larvae of *Hepatus epheliticus* observed that the larva completed metamorphosis only in 30 and 35‰ salinities with higher survival at 35‰.

Costlow *et al.* (1962) observed that the larvae of *Panopeus herbstii* successfully completed its development at 20.1, 26.5 and 31.1‰ salinities. Subsequently, Costlow *et al.* (1966) studied the effect of 24 different combinations of salinities and temperatures on the rate of development and survival of the larvae of the mud crab *Rithropanopeus harrisii*. They found that the development time through four zoeal stages and megalopa was not significantly affected by salinities from 5 - 35‰. Costlow (1967) examined the effect of salinity, temperature and combined effects of salinity and temperature (23 combinations) on survival, developmental rate and metamorphosis of the megalopa of *C. sapidus*. His study indicated that the megalopa moulted in the salinities 5 to 40‰ with highest survival and development rate in 35‰.

Costlow and Bookhout (1968) investigated the effect of 24 different combinations of temperatures and salinities on length of larval life and survival through metamorphosis to the first crab in the land crab, *Cardisoma guanhumi*. They suggested that temperature played a major role in survival of the larvae of *C. guanhumi* than salinity and developmental duration was similar in salinities from 20 to 40‰. The effect of temperature and salinity on survival and growth of the larvae of dungness crab, *Cancer magister* was examined by Reed (1969). He concluded that the salinity range of 25 - 30‰ was the optimum range for the completion of the larval development. Ong and Costlow (1970) investigated the effect of 18 combinations of salinities and temperatures on the larvae of the stone crab, *Menippe mercenaria* and observed that 20 - 40‰ was the optimum salinity range required for better development.

Sastry and McCarthy (1973) reported that salinity tolerance of the larvae of two crabs, *C. irroratus* and *C. borealis*. The optimum salinity range required for metamorphosis of *C. irroratus* was found to be 20 - 35‰ and *C. borealis* was 25 - 30‰ for the zoea and 30‰ for the megalopa. Hill (1974) investigated the tolerance of the zoea I of *S. serrata* at 61 different temperatures – salinity combinations. He showed that the zoea I survived and moulted in the salinity above 17.5‰ and hence the zoeae were unsuited to estuarine conditions. The influence of salinity on the larvae of *P. spinicarpus* was studied by Bookhout and Costlow (1974). They suggested that 35‰ was the optimum salinity for successful metamorphosis.

Christiansen and Costlow (1975) reared the larvae of *R. harrisii* in 11 combinations of salinities and cyclic temperatures and concluded that the best survival to megalopa and first crab stage occurred in 20‰ at 20-25°C and the highest development rate to the first crab stage was noted in 20‰ at 30-35°C. They also suggested that the larval development of *R. harrisii* was strongly influenced by environmental factors and not completely related to genetic differences.

After examining the effect of temperature and salinity on survival and development rate of the larvae of the rock crab, *C. irroratus*, Johns (1981) suggested that larvae were eurythermal and stenohaline, complete development was occurred between 25 and 35‰. Subsequently, Johns (1981) examined the influence of temperature and salinity on respiration and excretion rates during the larval development of *C. irroratus*. He found that larvae at 25‰ salinity released greater amounts of ammonia than the larvae at 30 and 35‰. Later on Johns (1982) studied the effects of 6 combinations of temperature and salinity on the partitioning of energy resources during larval development of *C. irroratus*. He suggested that the larva's ability to acquire energy resources and effective partitioning of the energy between maintenance and growth depended on environmental factors.Anger (1985) conducted laboratory experiments to test the tolerance of larvae of *Hyas araneus* to salinity stress both at constant 12°C and at simulated ambient water temperatures and observed that the larvae tolerated 25 - 35‰ salinity. Finally he concluded that the optimum salinity for larval development was 30.0 – 32.5‰. Rabalais and Cameron (1985) studied the effects of environmental factors including salinity on the larvae of *Uca subcylindrica.* He observed that the range of tolerance of salinity was 0.08 – 50.0‰ and the optimum level was 5 - 20‰ salinities.

The above literature survey showed that almost all works on the salinity tolerance of brachyuran larvae until few years ago were confined to temperate species. Recently such studies have received attention from tropical waters. Balagurunathan (1987) reported that 25‰ was the optimum salinity for larval development of the mangrove crab *Metaplax elegans*. Rajendran (1987) studied the effect of salinity on the larval development of *Sesarma (Sesarma) quadrata* and reported that 15 - 25‰ salinity was the tolerance range for the production of megalopa.

The influence of salinity on the larvae of the terrestrial crab *Cardisoma carnifex* was observed by Rajendran *et al.* (1987). They noted that complete development occurred only in three salinities of 25, 30 and 35‰. Selvakumar *et al.* (1987) described the role of salinity on the metamorphosis of larvae and crab instars of the mangrove crab *Neoepisesarma (Neoepisesarma) mederi* and they reported that the salinity range of 10 - 30‰ was required for the zoeal development and 5 - 30‰ was essential for the metamorphosis to first crab instar. After rearing the larvae of mangrove crab, *S. andersonii* in eight different salinities, Vijayakumar and Kannupandi (1987) concluded that zoeal stages metamorphosed to megalopa was better in salinities 15 - 35‰. Whereas Krishnan and Kannupandi (1987) opined that 20‰ was the optimum salinity for metamorphosis of the larvae of the mangrove crab *M. distincta*. The *S. brockii* larvae successfully completed its development in the salinity ranged from 15 to 35 ppt and 25 ppt was considered as optimum salinity (Kannupandi *et al.*, 2000). The salinity range of 30 - 35‰ was the optimum value for the larval development of *Phylira corallicola* (Kannupandi *et al.*, 2005) and *P.sanguinolentus* (John Samuel and Soundarapandian, 2010, 2010a). The foregoing account clearly indicates that the salinity tolerance range and optimum salinity varies with species.

Seed Production

Studies on the life history of commercially important portunid crabs have been in progress for the past 125 years. The degree of tolerance to salinity for several species of crabs has also been studied (Costlow and Bookhout, 1968). These previous studies provide a clear view for further investigations on mass rearing of the larvae studied. Most of the mass rearing experiments were conducted to overcome constraints like brooder availability such as that by Ong (1966) and temperature by Du Plessis (1971). Du Plessis (1971) found that 24ºC is optimal for mass rearing of zoeae at reduced salinity. Motoh *et al.* (1977) established breeding techniques for mass seed production of *S. serrata* to meet the demand for farming of the crab. Millikin (1978) developed suitable methods and formulated a guide for suitable management practice to rear the larvae of *C. sapidus*. Nakanishi and Naryu (1981) reared the zoeae and postlarvae of *Paralithodes camatashatica* on large scale basis in 30 litre and 500 litre tanks. They obtained best survival, 38.8%, for the first crab stage in 30 litre tanks, whereas only 16.62 % in 500 litre tanks. Heasman and Fielder (1983) developed an inexpensive method for mass rearing of *S. serrata* larvae using a recirculatory system with continuous filtration. They found that survival and speed of development increased at 27°C. *P. trituberculatus* zoeae were reared with artificial diets, prepared with and without chitin, to study the effective feeding rate (Oda, 1983, 1983 a). Kasry (1986) cultured larvae of *S. serrata* using antibiotics, zooplankton and phytoplankton in a cooling system. Hartnoll and Mohamedeen (1987) studied the growth of the larvae of *C. pagurus, H. coarctatus, Inachus dorsettensis, I. leptochirus, Liocarcinus depurator* and *Pilumnus hirtellus* but not with the objective of industrial production of seeds. Liang (1987) artificially incubated larvae of the Chinese horse crab by induced breeding. Nakanishi (1987) studied the optimum temperature, salinity and light intensity for the larvae and post larvae of *P. camtschatica* with special reference to survival rate and growth. Sun *et al.* (1989) explored the possibility of producing *C. japonica* seeds by artificial rearing. Creswell *et al.* (1989) improved the rearing technique of *Mithrax spinosissimus* in land based hatcheries and floating cages at sea. Lim and Hirayama (1990) produced *P. trituberculatus* seeds in 100 and 70 tons rearing tanks. The bacterial flora infecting *P. trituberculatus* larval hatcheries was investigated by Suzuki *et al.* (1990). Lim and Hirayama (1991) mass reared *P. trituberculatus* in nine rearing trials at 23 and 28°C. The influence of temperature was found to have significant effects on survival and development of *S. serrata* larvae (Marichamy and Rajapackiam, 1992). Zainoddin (1992) reared the larvae of *S. serrata* in a hatchery at Malaysia, showed better survival when fed *Brachionus* sp. and frozen *Artemia* nauplii than when fed live *Artemia* nauplii alone.

In Indian perspective, mass seed production was carried out for commercially important crabs *viz.*, *T. crenata* (Godfred *et al.*, 1995), mud crabs (Marichamy and Rajapackiam, 1984, 1992; Srinivasagam *et al.*, 2000; Thirunavukkarasu, 2005), *P. pelagicus* (Josileen, 2002; Soundarapandian *et al.*, 2007), *P.sanguinolentus* (Nunnam John Samuel *et al.*, 2011) and *C.feriata* (Josileen, 2011).