REFERENCE ONLY

153
29/1/98

HANDBOOK OF AQUAFARMING 4

TROUT
EEL
FRESHWATER PRAWN
CRAY FISH

THE MARINE PRODUCTS EXPORT DEVELOPMENT AUTHORITY
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First Printed 1993
First Reprinted 1995

Price Rs. 40/-

Printed at Printers Castle, Kochi - 16

PREFACE

INDAQUA is India's prestigeous, international aquaculture show organised every two years with the intention of creating awareness about the vast unexplored potentials of Indian aquaculture and focussing on the latest developments in the field. It is also intended to serve as a medium for projecting the developments in Indian aquaculture scene to the global markets, thereby serving to attract more and more buyers for our aquaculture products.

On the occasion of the first INDAQUA in March 1993, MPEDA had brought out 15 handbooks on aquafarming highlighting the culture techniques of almost all the important candidate species for aquaculture in India. It was gratifying to note that the publications were well received by the farmers, entrepreneurs, students and others interested in aquaculture. Responding to the persistent demand for copies of these publications from different quarters, we are bringing out reprints of these handbooks.

I hope that these handbooks will be found very useful by all.

(K.B. Pillai)
Chairman, MPEDA

Cochin - 36
January, 1995.

FOREWORD

India's rich resources of freshwater are not properly tapped for export production of shell fishes and fin fishes. The demand for shell fishes and fin fishes is fast expanding. A few varieties of shell fishes such as freshwater prawn and cray fish and fin fishes such as eel and trout have good export potential. Therefore, it was decided by the Organising Committee of the *INDAQUA* - the first aquaculture show in India to bring out this handbook for the benefit of farmers. I express my very warm appreciation to Dr. M J Sebastian, Shri C Mohanakumaran Nair and Smt. Aneykutty Joseph, Fisheries College, Panangad for compiling the accounts on freshwater prawn and Cray Fish, Shri K Dorairaj, CARI, Andamans for preparation of the chapter on cultivation of eel and Dr. Kuldip Kumar, Chief Warden, Directorate of Fisheries, Himachal Pradesh for contributing the article on trout culture. The coordination work carried out by Dr. G Santhana Krishnan along with Shri M. Viswakumar, Shri D Vincent and Shri P Easwara Prasad to bring out this handbook at a very short notice is appreciated. The financial assistance rendered by the Ministry of Food Processing Industries - Fisheries Division, Government of India to print this handbook is deeply acknowledged. I have no doubt that this handbook will be of great help to all freshwater fish farmers in India.

(M SAKTHIVEL)
CHAIRMAN
MPEDA

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Part I

TROUT

Directorate of Fisheries
Government of Himachal Pradesh, Bilaspur

POTENTIAL AND PROSPECTS OF TROUT FARMING

The Directorate of Fisheries
Government of Himachal Pradesh

The trouts were introduced in the country mainly to encourage Sport Fisheries. Introduction of trouts has helped the fish to become established in most of the cold water bodies of the country. Now apart from sport fisheries, culture of trouts is increasingly being identified as a commercial venture for table fish production. Two major trouts available in our waters are brown trout (*Salmo trutta fario*) and rainbow trout (*Salmo gairdneri gairdneri*).

These two exotic game-fishes soon established in the streams and tributaries adapting to congenial water temperature and abundance of biotic life. The transplantations provided excellent game fishing to the anglers and started attracting large number of tourists to the country. In the last three to four decades, however, a sharp decline was observed in the catches on account of multiple factors such as large scale road construction in the valleys followed by destruction of breeding and feeding grounds of the fishes, emergence of river-valley projects, rapid urbanisation, fishing pressure and of course illegal and destructive means of fishing etc. The matter received serious attention of the various state governments and some states have taken steps to rehabilitate the exotic trouts in the streams as well as commercialisation of trout farming in the farms.

Norwegian Assistance for the State of Himachal Pradesh

During mid-eighties a scheme was formulated by the Himachal government which inter alia gave more stress on farming of rainbow trout. The Norwegian Government came forward to assist the State Government in this endeavour and an agreement was signed during

1988 and later the scheme was put into operation in May, 1989. The Project was split up into two phases viz. (1) transfer of technology, and (ii) production phase.

The transfer of technology (first phase) envisaged construction of a modern trout farm on Norwegian model with capacity to produce 10 tonnes of trout per year. Import of quick growing disease-resistant eggs, development of economical and viable pelletised feed with locally available ingredients, training of local staff and farmers & production of economically viable fingerlings with the aim to enable the local farmers to adopt trout farming were the other aspects included under this bilateral project. The Norwegian Government agreed for financial grant of 8.00 million NOK (Rs. 3.00 crore) mainly for meeting the expenditure under consultancies, cost of equipments and training of personnel. The State Government of Himachal Pradesh agreed to bear the cost of construction of the farm, payment of customs duty and salaries of the project personnel.

Impressive Results

After finalisation of the 'Conceptual Design Report' during August, 1989, the first phase of the project was put into operation. The infrastructure such as raceways, circular ponds, two lines of water supply were completed by April-1990 and first consignment of 'eyed ova' of rainbow trout were received at Patlikuhl farm during April-1991. A feed-mill was also installed and it started producing pelletised feed with a production capacity of 500 kg. per day. Four project personnel including two women candidates underwent training during the construction phase. The results on rearing achieved during the first year of the project far surpassed the expectations of the Norwegian as well as Indian counterparts. A record survival of 92% against expectation of 42% from 'eyed ova' to advanced fingerling was achieved which is an all time record in trout farming in the State.

Operations

The higher survival rate virtually created a problem of storage and in order to rationalise the possible carrying capacity, 38,000 fingerlings had to be taken out of the farm and stocked in various streams viz. Tirthan, Sainj, Parbati, Beas, Gadsa etc. between Manali and Mandi. In a period of less than one year the reared fish grew to marketable size of 300 g. The second instalment of eggs from Norway was received in

March, 1992 and were successfully hatched. It is heartening to note that open sale of trout at Patlikuhl farm was started from third week of March, 1992. The targeted production of 10 tonnes was achieved in the first year of the project. This is significant when viewed in the context of recurring land slides and prevailing not so clear water in one of the water line alignments.

Requisites of Trout Farming

Rainbow trout requires plenitude clear icy-cold-oxygenated water. The site should be adequate to accommodate future developments likely to be required in the foreseeable future. If a constant supply of water suitable for hatchery purposes in the required volume throughout the year is not available the hatchery is sure to be a failure. It should be borne in mind that water is to be used for incubating eggs and fish of all ages. Water that is satisfactory for growing trout may not be suitable for incubating eggs and holding brood stock. Factors influencing the suitability of water include temperature, oxygen content, pH, turbidity, mineral contents and pollution. The volume of flow including fluctuation and the elevation of the supply source above the hatchery are other important factors relative to the water supply. The source of water supply should be atleast ten feet above the hatchery site. If the water is from a spring, the temperature should be uniform throughout the year. However, under all circumstances the water temperature for incubation of eggs should not exceed 10-12°C.

Hatchery Practice

Fibre-glass hatchery troughs with Californian type of Incubators are installed. Each hatching tray should have the capacity to treat 1.5 litres of eggs i.e.. about 15 to 18 thousand in number and there can be 4-7 trays depending upon the length of the trough. On the perforated zinc-sheet bottom of the hatching tray is kept a same size piece of astroturf and over this is kept a plastic egg basket for laying the eggs. This plastic egg basket is removed after eggs hatch out and the alevins settle down into the astroturf. The advantage of astroturf is that it prevents the drifting of the alevins resulting into quicker absorption of the yolk sac. The eggs should be shielded from light by covers over the incubators to avoid damage by light. In the entire period, daily attention to the incubation process is needed so that (i) the dead eggs do not increase the spread of fungi (ii) malachite green bath is given to the eggs two days in a week depending upon the attack of fungus, (iii) dead eggs are removed after the embryonic eye has appeared, (iv) all egg shells are simultaneously removed, and (v) all dead yolk sac (alevins) fry are also picked up side by side. After about 75% of the yolk sac is consumed the fry is transferred to a 'Starter Unit' where it is fed with very small flakes of protein rich 'start feed'. This is the most critical stage in the life of fish because if there is slight delay in feeding or the feed is not of good quality the young fish will loose its interest in feeding and start dying. After the fry has commenced feeding it is transferred to purpose-built self cleaning type of early-rearing facility. Young rainbow trout should not be reared in earth ponds due to the danger of 'whirling disease'. With growth of this stock, to prevent imbalance in the unit weight of this biomass, grading atleast once in hatchery and later during on-growing whenever it doubles its weight should be done. A high class hygiene level is required to be maintained if good results are to be obtained. Complete cleanness of premises, removal of dead fry, excrement and uneaten food have to be ensured. Outlets of starter units generally tend to foul with accumulation of metabolites and therefore, all drain pipes and screen be kept clean by using a high pressure hoze.

Farming Cycle

Under the technology transfer phase of this Indo-Norwegian Trout Project a production plan has been followed covering the following aspects:-

i) 100,000 certified pathogen free eyed eggs of improved strain of rainbow trout have been imported from Denmark for three years. They were incubated here and a survival rate of 92% was obtained upto the swim-up fry stage.

ii) It took 195 degree days i.e. about 20 days at an average temperature of 10°C upto hatching.

iii) The fry upto 1 g was retained in the hatchery and later shifted to nursery ponds and retained there till it acquired the weight of 5 g.

iv) The stocking rate in start feeding was kept at 6 kg/M^3 and in nursery at 10 kg/M^3.

v) From 5-50g weight the fish was shifted to smaller raceways of 5M x 3M x 1M with a stocking rate of 10 Kg/M^3.

vi) From 50g to portion size of 250 g the fish was reared in bigger concrete raceways of size 15M x 2M x 1.5M at a stocking density of 30 Kg/M^3.

It took 10-12 months to attain the marketable size of 250 gms of imported stock of rainbow trout. To begin with trout feed imported from Norway was administered to the fish but during October, 1991 feed prepared in the plant set up at Patlikuhl farm was initiated.

About 1450 brooders of average weight 900 g have been raised and it is envisaged that egg taking from this stock will commence in January, 1994.

Technology Dissemination

Under this programme it is envisaged to provide about 4000 trout fingerlings each of 10 to 25 g weight for rearing on intensive basis upto the portion size of 250 g to the prospective farmers. About 20 sites initially for the setting up of about 35 to 40 raceways each of size 12M x 2M x 1.5M have been selected in Kullu district. Schematic drawings of rearing units in respect of all the sites have been prepared for the guidance of the beneficiaries and added into a study report on this subject which includes a manual for the selection of sites as well as analysis on the economics of trout farming in village raceways. It is proposed to provide major inputs of trout seed and dry compound pelletized feed to the farmer besides aqua-engineering guidance to build a suitable raceway with assured supply of sufficient good quality, pollution free water throughout the farming period. The selected farmers will be provided full technical support in the shape of 2 weeks training in rearing and harvesting techniques to achieve the targeted level of productivity and a unified extension approach through our trained staff to solve their day-to-day problems. With this end in view it is proposed to set up a 'Training Centre' with boarding facilities at the project farm in Patlikuhl.

A fair degree of success has been achieved in the development of an efficient and economic trout feed at the farm from raw material available within the country. Hopefully, its formulation will be soon standardized with per kilo production cost around Rs. 20. The objective feed conversion ratio has been kept at 1: 1.5 and a production plan has been designed to raise one tonne of 200 g portion size fish in one standard size village raceway in 10-12 months and is presented as Table I.

Economic Viability

In order to work out the economic viability of trout farming in village raceways by the target groups, the following parameters have been considered for analysis :

1. Two types of raceways for rearing of trout have been offered. One "semi-pucca" raceway of the capacity of 30 M^3 cost Rs. 15,000/-

Table I. Expected production plan of one tonne of portion size fish in 10-12 months

Month	April	May	June	July	August	Sept	Oct.	Nov.	Dec.	Jan.
Day No.	1	30	61	91	122	153	183	214	244	275
Temp (°C)	15.0	15.0	16.0	16.0	18.0	1.80	10.0	10.0	10.0	8.0
Individual seight (g)	20.0	29.0	42.0	59.0	84.0	114.0	154.0	193.0	232.0	268.0
Total bio-mass (kg)	80.0	116.0	169.9	237.8	336.0	457.0	616.0	775.0	930.0	1074.0
Sum harvest (ton)	0	0	0	0	0	0	0	0	0	1.074
Food required (kg)		54.0	80.9	101.9	147.4	182.3	239.0	238.0	232.0	216.0
% feeding	2.25	2.25	2	2	1.75	1.75	1.25	1	0.75	

and two such raceways of the same size will cost Rs. 27,000/-, second, two 'pucca type' of capacity of 60 M^3 will cost Rs. 57,000/ - under the local conditions.

2. Cost of 10-25 g average weight fingerling has been kept at Rs. 3 per fingerling, as fixed by Himachal Pradesh Government.

3. Optimum stocking density for ongrowing has been kept at 33.3 Kilos/M^3.

4. F.C.R. has been assumed as 1 : 1.5.

5. Though labour cost of 90 days @ Rs. 22/- per day has been considered in a year but this work, too, will be done by the beneficiary.

6. Watch and ward expenditure is estimated as Rs. 500/- per month, but the beneficiary will undertake this job, also.

7. Repair and maintenance of the raceways and water supply channel has been assumed at 10% of the capital cost in case of semi-pucca and 5% in case of pucca raceway.

8. Interest on 80% of the capital and running cost has been worked out at 12% rate of interest.

9. It has been assumed that with the implementation of complete package of rearing practices each raceway will give a production of one tonne of marketable trout fish.

On the basis of above parameters of economics of rearing in case of semi-pucca & pucca raceways is presented as Table-II & III respectively.

Areas of the State Declared as Trout Zones

i) Chamba Valley,
ii) Kinnanur Valley.
iii) Kullu Valley.
iv) Lahaul Spiti Area.
v) Pabbar Valley.
vi) Uhl Valley.

Table II

Economics of Trout fish farming in semi-pucca raceways

Capital Cost	Water Area 30 m^3	Water Area 60 m^3
1. Construction of Raceways	15000	27000
2. Cost of Hand Nets	500	800
3. Other equipment	1000	2000
TOTAL CAPITAL COST	**16500**	**29800**
Running Cost		
1. Cost of Fingerlings	12000	24000
2. Cost of Feed	30000	60000
3. Labour cost (for 90 days @ Rs. 22)	1980	1980
4. Watchman	0	6000
5. Fishing cost	0	0
6. Repair and maintenance @ 10% of Capital Costs	1650	2980
TOTAL RUNNING COST	45630	94960
Total Cost	**62130**	**124760**
1. Interest on the 80% of fixed and working capital @ 12% P.A.	5964	11977
2. Depreciation @ 10%	1650	2980
Total Annual Cost	**53244**	**109917**

TROUT

Sale of fish of 1000 kg @ Rs. 70 per kg.	70000	140000
Net profit	16756	30083
BEP	760 kg	1570 kg

Table III

Economics of Trout fish Farming in Pucca Raceways

Capital Cost	Water Area 30 m³	Water Area 60 m³
1. Construction of Raceways	30000	57000
2. Cost of Hand Nets	500	800
3. Other equipment	1000	2000
Total Capital Cost :-	**31500**	**59800**
Running Cost		
1. Cost of Fingerlings	12000	24000
2. Cost of Feed	30000	30000
3. Labour cost (for 90 days @ 22/-)	1980	1980
4. Watchman-cum-Fisherman	0	6000
5. Fishing cost	0	0
6. Repair and maintenance @ 10% of Capital Cost	1575	2990
Total Running Cost :-	45555	94970
Total Cost	**77055**	**154770**
1. Interest on the 80% of fixed and working capital @ 12% P.A.	7397	14858
2. Depreciation @ 10%	1575	2990
Total Annual Cost	**54527**	**112818**
Sale of fish of 1000 kg @ Rs. 70 per kg.	70000	140000
BEP	780 kg	1612 kg

Start Feed Tanks

Raceways

Circular Pools and Raceways

HISTORY OF EEL

Aristotle, the great master of thought was the first to make an observation on eels. According to him the eels were born from earth mount which in turn was produced spontaneously from mud and moist soil. He also observed the exodus of adult eels to the sea and the ascent of young eels into fresh water. In the first century the Roman scholar Pliny the Elder stated that the eels have no sex and they rub themselves against the rocks and the pieces scraped of from their bodies come to life. In the 16th century Rondelet put forward the hypothesis that young eels were produced from putrefied matter as well as from egg. Redi and Linnaeus believed that eels are viviparous.

Despite all research the genital organs of eels remained undiscovered till 1777 in which year Prof. Mondini announced their discovery in a female eel; he described the ovary as "frilled ribbons". These frilled ribbons were previously considered as adipose frings. Prof. Mondini observed ova in the frilled ribbons and compared them with those of the Conger and Roman eels and established their presence beyond any doubt. For this reason, the ovaries of eels are very often called "Organs of Mondini". The male organ, the testis was discovered in 1874 by a Polish naturalist, Syrski. The testes occupy the same position as the ovaries but instead of being like the frilled ribbons of the latter, they are looped or festooned.

While the mystery of the reproduction of the eel was being probed by naturalists, one of its secrets namely the larva was discovered in 1856 by a German naturalist, Kaup. From the collections made from the straits of Messina he described a peculiar transparent leaf-like fish without knowing that it is the larva of an eel. He considered it to represent a new genus and species of fish called *Leptocephalus brevirostris*. Forty years later two Indian scientists, Grassi and Calandruocio watched in an aquarium the metamorphosis of the transparent leaf-like fish into elvers and thus established that *Leptocephalus brevirostris* as larvae of the European eel, *Anguilla anguilla.*

The only point which remained undiscovered was the birth place of the eel. This problem was solved in the 20th century by the illustrations of a Danish oceanographer and biologist, Johannes Schmidt. In 1904, the Danish research vessel *Thor* was fishing for cod eggs and larvae in the Atlantic to the west of Faroes and among the larvae was found an eel larva, the Leptocephalus, the first one to be captured outside the Stratis of Messina. This discovery brought the eel question again to prominence and the Danish Commission for Fishery Investigations included this investigation in their programme and the work plan was to trace the smaller and smaller larvae with the expectation of ultimately reaching the spawning ground of the eel. This proved to be a very difficult task and involved several voyages of three research vessels *Thor, Margretha* and *Dana*, aided by several other Danish ships.

During the second expedition of *Thor* farther south of Faroes, hundreds of eel larvae were obtained, all of which were taken at depths of less than 1000 metres and none could be taken at shallow depths. It was thus concluded that the eels reproduce in open ocean. The third expedition of *Thor* in 1906 confirmed the above conclusion. During 1908 to 1910, *Thor* made many cruises in the Mediterranean which enabled Schmidt to come to the conclusion that the Italian, Greek, Egyptian, Turkian and Algerian eels do not reproduce in the Mediterranean but go to the Atlantic Ocean for spawning. The Italian naturalist, Grassi strongly protested and stated that if Schmidt had not found very young eel larvae in the Mediterranean it was because he had not searched properly or the number of his hauls were insufficient. Despite everything, proof continued to accumulate in favour of oceanic reproduction.

In 1910, a Norwegian ship captured around Azores smaller and younger eel larvae 40 to 60 mm in size. From 1911 to 1915, 23 ships of Danish nationality cast their nets more than 500 times along the merchant shipping routes between Europe and West Indies and captured smaller and smaller eel larvae. Finally, during the *Dana* cruise in 1920-22. Schmidt discovered the spawning ground in the Sargasso Sea, south east of Bermuda from where the tiny newly hatched larvae measuring 5 mm. in length were collected. He led his ship to the place of spawning itself and followed the larvae from year to year in the course of their trans-oceanic migration and thus solved the problem of the birth place of the European eel.

LIFE CYCLE

As the life cycle of the different species under the genus *Anguilla* are more or less similar, a general account of the same is given (Fig. 1). *Anguilla*

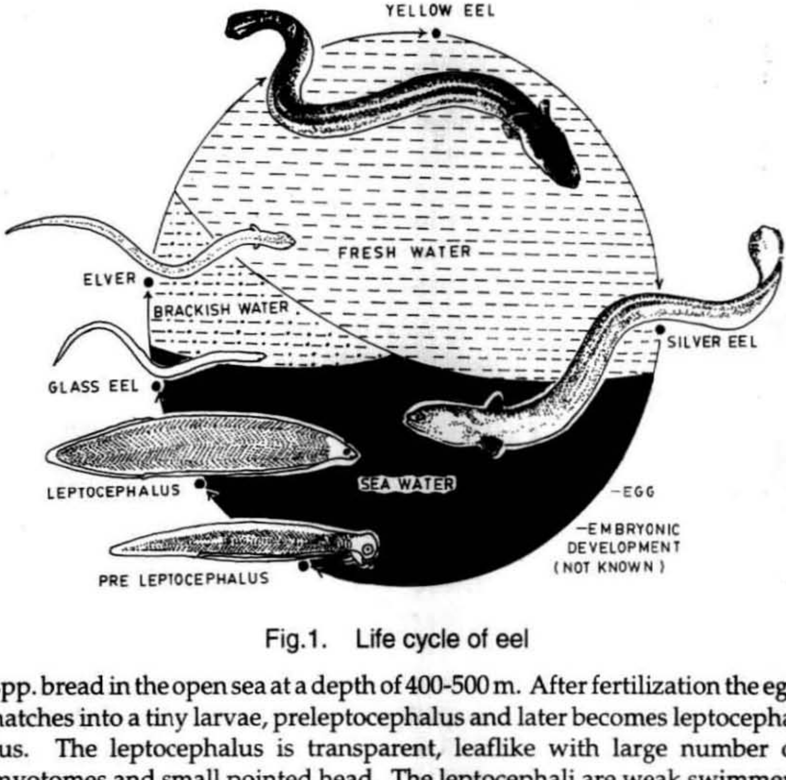

Fig.1. Life cycle of eel

spp. bread in the open sea at a depth of 400-500 m. After fertilization the egg hatches into a tiny larvae, preleptocephalus and later becomes leptocephalus. The leptocephalus is transparent, leaflike with large number of myotomes and small pointed head. The leptocephali are weak swimmers and their transport/drift from the open sea to the near shore regions is effected by oceanic and coastal currents. The duration of the larval life in different species varies from three months to two and a half years. The leptocephali metamorphose into glass eels which are thread like and transparent. On getting pigmentation the glass eels become elvers and approach the coasts. On entering brackish and freshwaters, the metamorphosis is completed and the elvers in a few months become young eels. They later grow in the brackish or freshwaters for some years and at this phase of life they are called yellow eels. On nearing sexual maturity the adult yellow eels cease to feed, acquire a silver colouration, leave the fresh and brackish waters and migrate to their spawning ground in the open sea where they breed. After spawning the silver eels are believed to die.

Thus, in the life history of the eel there are three phases viz., 1) marine larval phase (Leptocephalus, glass eels, elvers), (2) freshwater phase of growth (yellow eel) and (3) adult marine phase of reproduction (silver eel) (Table 1).

Life cycle of Indian short-finned eel

The life cycle of the Indian short-finned eel *Anguilla bicolor bicolor* is fairly well known. Leptocephalus is laterally compressed, leaf like in shape, with a small head and pointed teeth. The body is transparent with 106-114 W shaped myomers of which 68-67 are in preanal region. It has been reported that the development from the quite small larva to glass eel stage is carried through in the course of 2 or 3 months. (Jesperson, 1942).

The glass eels of *A. bicolor bicolor* measure 47 to 65 mm. The early stage glass eels are fully transparent while the late stage glass eels are pigmented. The glass eels and elvers were recorded in many estuaries and rivers along the Tamil Nadu coast during October-March months (Dorairaj and Soundararajan, 1980). By rearing the glass eels and elvers under controlled conditions in the laboratory for seven years the yellow eel and silver eel stages were well understood. A female migrating silver eel was caught alive in the inshore area of Karwar, which enabled to elucidate the reproductive and migratory phase of the eel. (Dorairaj and Nandakumar, 1982). The probable spawning grounds for *A. bicolor bicolor* are in the eastern Indian Ocean, near Sumatra in Mentavene deep between 4° S and 2° N latitudes and in the western Indian Ocean near the north east of Malagasy between 10° S and 20° S latitudes and 60° E and 65° E longitudes (Jesperson 1942, Tesch 1977). The interesting question is whether the Indian eels also undertake 3000-4000 km migration like the European eels for spawning, or whether there are yet unlocated spawning grounds close to the coasts of India. Detailed studies are necessary to throw more light on this aspect.

IDENTITY AND DISTRIBUTION

In Asia and Europe, during the last three decades, there has been a great impetus on research on anguillid eels, which enabled better understanding of the identity, distribution, biology and culture of several species of *Anguilla*. There are 17 valid species in the genus *Anguilla* of which two species are available in India; both are recognised at sub-species level *viz* - the short-finned eel, *Anguilla bicolor bicolor* McClelland and the long-finned eel, *Anguilla nebulosa nebulosa* McClelland (Fig. 2).

Table 1. Environmental and Morphological adaptation of the various stages of eel in their life cycle

Sl. No.	Characters	Egg	Leptocephalus	Glass eel	Elver	Yellow eel	Silver eel
1.	Nature of environment	Oceanic waters	Oceanic waters	Inshore/ esturine/ inland waters	Esturine and inland waters	Inand waters	Oceanic waters
2.	Activity	Passive drifting	Passive drifting	Active ascent	Active ascent	Active, domicile	Active, spawning migration
3.	Phase in life cycle	Embryonic development	Larval, growth phase	Metamor-phosing	Fingerling growth phase	Adult, growth phase	Adult, spawning phase
4.	Sex and stage of maturity	———— Indeterminate ————				Sexual differentiation	Definite males and females
5.	Food prefernce	Yolk utilisa-tion	Planktonic feeder	Selective carnivorous	Voracious carnivorous	Omnivorous	Ceases feeding
6.	Size	1.00 mm	22-54 mm	47-65 mm	52-120 mm	250-400 mm	Above 400 mm
7.	Shape	Round	Laterally compressed	oval	oval	oval	Body cylindrical tail oval
8.	Colour	Transparent	Transparent	Transparent	Pigmented	Ventral side dull white	Ventral side silvery

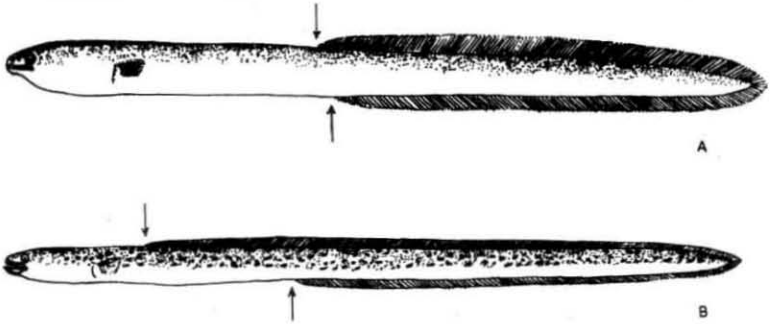

Fig.2. (a) The short fined eel *Anguilla bicolor bicolor* (b) The long fined eel, *Anguilla nebulosa nebulosa*

The following are diagnostic features of the family Anguillidae and those of the genus *Anguilla*:

Body elongate, snake-like, dorsal and anal fins confluent with the rudimentary caudal fin. Pectoral fins present, ventrals absent. Body covered with minute scales. Lateral line well developed. Vent remote from head. Mouth terminal; jaws not particularly elongate.

Description of Indian eels

***Anguilla bicolor bicolor* - McClelland**

Head slightly broader than the body. Extent of cleft of mouth equal to rather above 1/3 of the length of the head, and extending to atleast 1 diameter of the orbit behind the eye in the adult, to below it in the immature. Lips thick. Teeth bands nearly equal width, the vomerine reaching nearly as far backwards as those on the maxilla. Dorsal fin commences above the vent or slightly before or behind it. Body colours in adults a dark olive superiorly, becoming yellowish beneath.

***Anguilla nebulosa nebulosa* McClelland**

Head rather broader than the body: snout not broad. Lower jaw prominent. Length of the cleft of the mouth equals nearly or quite 1/3 in that of the head, while it extends behind the posterior edge of the orbit. Lips well-developed. Body colours in adult brownish superiorly, becoming yellowish on the sides and beneath; the whole of the upper surface of the body covered with black spots and blotches, some of which are continued on the dorsal fin which has a light edging; anal with a dark marginal band and a light outer edging.

Key to the identification of Indian eels

The following four characters are used to identify the different eel species.

1. The origin of dorsal fin - long-finned or short-finned.
2. Colouration of the body - plain or with variegated marking.
3. The pattern of dentition.
4. The number of vertebrae.

The first two characters alone may be sufficient to distinguish the Indian eels.

The following is the key for the identification of Indian eels.

1. The average breadth of the intermaxillary - vomerine band of teeth, measured in the middle, greater than or equal to the greatest breadth of the maxillary bands ....(2)
2. Skin with variegated markings ....(3)

   Skin without variegated markings ....(4)
3. The three rows of teeth forming, the main part of the maxillary bands are regular, longitudinal groove distinct without interruption; a projection on the inner side of the bands anteriorly. Number of prehaemal vertebrae 39-43. Average maximum value of distance between verticals through anus and origin of dorsal fin, in % of total length about 11.7 - 11.9; total number of vertebrae 106-112 ....*A. nebulosa nebulosa*
4. Constriction of the intermaxillary - vomerine band of teeth begins, on an average, before the middle of the band. Average maximum value of distance between verticals through anus and origin of dorsal fin, in % of total length, about 0.2 - 0.8; total number of vertebrae 106-115 *A. bi-color bicolor*

However, for the field identification the following key is suggested:

1. Origin of dorsal fin above vent 2

   Origin of dorsal fin midway in between snout and anus 3
2. Colouration of the body plain .... *A. bicolor bicolor*
3. Colouration of the body with variegated markings...*A. nebulosa nebulosa*

Standard common names, vernacular names

For *A. bicolor bicolor*

Country	Language	Name
India	English	Indian short-finned eel
	Tamil	Vilangu meen
	Andamanese	Jee-tah-deh
Ceylon	Sinhalese	Kakkuta arandha, Kalu arndha,Mada arandha
Malaya	Botavia	Mowa
Federation	Jarăn	Sidat

For *A. nebulosa nebulosa*

Country	Language	Name
India	English	Indian long-finned eel
	Tamil	Pulli Vilangu meen
Ceylon	Sinhalese	Gall arandaha, Ganja arandha, Kabara arandha, Pulli arandha,
		Kaha arandha, Pol arandha, Polan arandha, Vali arandha.

DISTRIBUTION

The subspecies *A. bicolor bicolor* occurs in the Indo-Pacific region, particularly in the northen to Equatorial region of the Indian Ocean and equatorial region of the Pacific Ocean; its range of distribution extends from the coast of Africa where it is found from Zanzibar to 28° S, with Madagascar and islands to the east, over the Seychelles to British India, where the distribution to the north-west reaches Bombay, to the north-east Calcutta and further, from the coasts of Burma, over the Andaman, Sumatra, Java, Lombok and Flores to North-West Australia. In the equatorial region of Pacific Ocean this subspecies is distributed in insular eastern part of Celebes and New guinea (Tesch, 1977). This species has been recorded by the author along the coast of Tamil Nadu from Madras to Pinnakayal and on the West coast at Cochin backwaters, and at Karwar.

The area of distribution of the subspecies *A. nebulosa nebulosa* embraces of the Indian continent from Bombay in the north-west to Calcutta in the north-east. The species is also distributed over Ceylon, Andamans and at Serdang, west coast of north Sumatra. The author has recorded this species along the Tamil Nadu Coast from Cuddalore to Pinnakayal.

EEL CULTURE TECHNIQUES

It is necessary to adopt suitable techniques based on scientific study at all stages of eel culture as it will not only enable smooth and efficient management of eel farms but also will ensure high production and profits. The different culture methods and the various techniques adapted in eel culture, commencing from the collection of seed elvers to harvesting of eels have been standardised (Dorairaj, 1980).

Culture methods

Eels are cultured in five different methods viz., 1) Still water method, 2) Running water method, 3) Recycled running water method, 4) Net preserve method and 5) Tunnel method. The first three methods only are commonly followed. In still water method the pond water will be more or less static and only about 5% of the total volume of the pond water is changed daily. The still water of the pond enables quick propagation and luxuriant production of phytoplankton which in turn will increase the oxygen content of the pond by photosynthesis and thus provide a suitable condition for the eels to strive well. In the running water method, there will be continuous flow of freshwater to the ponds and simultaneously an equal amount of water will be drained to keep the water level in the pond constant. In this method, the eels are supplied with more oxygen through the constant flow of freshwater. In the recycled running water method, the same water in the pond is re-used again and again after filtration, sedimentation and oxygenation. The carrying capacity of the filter bed should be determined and the water quality checked at periodic intervals. The basic principle in eel culture method is to rear eels in high densities in a confined area by providing extra oxygen and more suitable food to achieve maximum production in a short period of time. Depending on the facilities and quantity of water availability, any one of the three methods could be employed in eel farming in India.

Culture systems

Two types of culture systems are followed in eel culture *viz.*, monoculture and polyculture; the former system is adopted in Japan and the latter in Taiwan and Italy. Though a few numbers of common carp (*Cyprinus carpio*) and striped mullet (*Mugil cephalus*) are reared along with eels in some places in Japan, in order to keep the eel ponds free from the left over food, eel culture in Japan is essentially a monoculture system.

In the Taiwanese polyculture system, eels are the principal species stocked in the freshwater ponds. The species stocked are the silver carp (*Hypophthalmichthys molitrix*), big head (*Aristrichthys nobili*), common carp (*Cyprinus carpio*), mud carp (*Cirrhinus melitorella*) and striped mullet (*Mugil cephalus*).

Yields upto 15,000 kg/ha have been attained in some of the South East Asian countries in polyculture of eels and other fishes like carps and mullets (Iverson, 1968). In Italian eel farms at Comachio, eels constitute about 80% of the total production; the rest being mullets, Sparus, Chrysophrya, Atherines and Sea bass (Hickling, 1970).

In addition to the above two types of culture, eels are also farmed through monosex culture, as the females are known to grow faster than males (Bardach *et al.*, 1972). Through monosex culture it is possible to achieve high production.

Culture techniques

Collection of elvers

Elvers are the starting point for eel culture. Seed elvers measure 55-100 mm in length and about 0.16-2.0 g in weight. Elvers are generally collected at the lower reaches of the rivers when they ascend from the sea. In India, elvers of two species viz., *Anguilla bicolor bicolor* and *A. nebulosa nebulosa* are found to ascend along many of the rivers on the east coast. (Rahimullah, *et al.*, 1944; Pantulu, 1956; Ibrahim, 1961; Dorairaj and Soundararajan, 1980). They are collected from close to the banks of the rivers during night time with the help of suitable nets, when they ascend the rivers immediately after a freshet during October-March period.

Elvers are collected using different kinds of nets like scoop nets, bag net, dipnet, screen net, plankton net and a special type of net known as 'Elver net'. Elvers are also caught with some special gear viz., trotline and wire mesh sieve. In India elvers are collected mainly with scoop net, bag net, screen net, and elver net. The scoop net size and shape may very considerably and the net part consists of nylon fabric. This net is used to collect the elvers that would congregate near the closed sluice gates of the anicuts, in small streams and in pools close to the seashore which had a connection with sea during rainy months.

The drag net is in the form of a bag, stitched with two pieces of nylon mosquito nettings 5 metres in length and 1.5 metre in width, attach with lead sinkers on the foot rope and cloth loops on the four corners of the net. A minimum of three persons are required to operate the drag net; two persons will hold on the either side net. The cotton loop on the bottom side of the net will be inserted to their toes and the other end will be kept in the hand above the water level. The third person will hold the net in similar way in the middle. The net is dragged swiftly pressing the bottom edge firmly on the ground and taking all that are in the bottom into the net. Each drag may last for 5 to 10 minutes duration. After dragging the net to the shore, the contents in the net is accumulated in the middle and spread on the slopping ground. The elvers caught in the net would wriggle out, move downwards along the slope of the ground and by using small plastic containers, elvers caught in the net are collected from the net and put them into small plastic truffs/basins containing a little quantity of freshwater. After removing mud and other fish seeds in the basin, the live elvers alone are transferred into big polythene containers containing filtered freshwater. The drag net is the best gear to collect elvers from the pools, small streams as well as to capture the moving elvers near the closed sluice gates and the congregated elvers near the shutters.

`Elver net' is a special gear used exclusively for capturing immigrating elvers from the river and lakes. This is a modified fyke type net, made of nylon mosquito nettings of about 16 meshes per inch. It has two long wings and two conical bags, the short bag is about half the size of the longer bag and is attached within the inner cone. Cod end is attached with a small aluminium ring which extends upto half way inside the outer cone. The cod end of the outer cone can be opened or closed with a lace. These two bags are held together by a metal ring in the middle. The far end of the cod end is made of bolting silk to prevent escape of glass-eels through the mesh. The wings are large and vary in size. Lead sinkers are attached at the foot rope of the net and floats on the head rope. The net is operated during night time by fixing it on seven stakes in depths upto 1·5 metres across the river in `V' shape, covering any one bank of the river. The mouth of the net which is stretched and kept in position with the help of two stakes, faces downstream. One petromax lantern is fixed at the top of the stake at the cod end (Fig. 3). The elvers which actively migrate against the current are attracted towards the light source and are caught in the net. At periodical intervals the cod end of the net is examined and the trapped elvers are emptied into a bucket with a little quantity of water. Care is to be taken to fix the stakes firmly in the ground otherwise the force of the water-flow may uproot the stakes and wash away along with the net.

Another method of collecting elvers called 'primitive method' by the Japanese is trotline arrangement. In a trotline, at about every 3 metre interval, 1 metre droppers are attached and to these finely branched weighted brushes are tied. The gear is set close to the bank and kept overnight. On the next day early morning the droppers of the gear are lifted gently and the elvers present amidst them are emptied into a holding net (Topp and Raulerson, 1973).

By employing the most suitable net at right time and at appropriate place, it is possible to collect large quantities of elvers.

Transportation of elvers

At the collection centres the captured elvers have to be kept in temporary holdings like hapas or floating boxes till they are transported to shore facilities. The conventional method of transportation of elvers over short distances is by fish tin carriers or cans which are of different sizes and shapes. They are usually circular in shape with a flat bottom, the capacity of the cans varies from 20 to 40 litres. The cans are made of galvanized sheet metal or zinc and normally painted inside in light colours. The mouth of the can is closed with a perforated lid. Each can is provided with two handles at the sides. Due to inevitable bumping during transport, the elvers are likely to get injured by hitting against the sides of the cans. Therefore cans made of PVC or plastic are preferable to galvanized sheet metal cans.

For transporting large quantities of elvers over long distances and periods, special vehicles like motor lorries provided with a series of tanks are used. These tanks are insulated and have an inbuilt aeration system. Nets are suspended inside the tanks to protect elvers from injuring themselves by hitting on the sides of the tanks.

Elvers are also transported in some special containers as they are capable of remaining one or two days out of water either in moss or wet straw. Specially made wooden boxes are used to transport elvers over short as well as long distances by road and rail. The wooden box is designed to hold about 10 frames, each 80 x 40 x 5 cm in size, with linen at the bottom. Each frame can hold about 1000 to 5000 elvers depending on their size, the total duration of transport and temperature. Ten such frames are placed one above the other inside the wooden box and closed with the lid. The top frame will have crushed ice while below it are frames of elvers and bottom frame will have saw dust. The meltings of the ice will trickle down the frames, moistening the elvers and finally the ice water is absorbed by saw dust kept in the bottom frame.

For transporting elvers by air over long distances or to foreign countries, specially designed styrofoam containers are used. Each container can hold about 5 kg of elvers mixed with crushed ice and these containers are placed in 25 kg master cartons and transported by air.

One of the important precautions to be taken before transporting elvers is that they should be starved for a minimum period of 24 hours prior to transportation. When transporting elvers in water cans, care should be taken to see that density of elvers is not very high, as it will lead to shedding of mucus from the body which will make the water turbid and harmful to elvers. It is preferable to transport elvers in the evenings or during night time when the temperature will be slightly lower.

Selection of site and design of eel farm

For conducting eel culture, large quantity of fresh water or brackish water is very essential and therefore only those areas where copious supply of water is available are to be selected. Some other important aspects which must be carefully considered and planned while setting up an eel farm are the topographical characteristics of the site, design of eel farm, construction of dikes and arrangements for water supply and drainage system.

Eel farms are constructed in such a way so as to meet various requirements in different phases of culture. In the initial phase of eel culture, elvers are to be stocked and reared in smaller ponds. After about 3 months they have to be stocked and cultured in bigger ponds. The smaller ponds which are known as nursery ponds, should be about 150-600 sq.m. in area and 70 cm deep. The larger ponds which are known as fattening or adult ponds, vary in size from 0.1 to 4 ha. and are 1 to 1.5 m deep. The average size of the adult pond is about 0.3 to 1 ha. The bottom of the ponds could be muddy or clayey but the banks should be reinforced with stones and bricks or lined with concrete slabs. The running water ponds are relatively much smaller as compared to still water ponds. The former are normally less than 0.8 ha in area while the latter 1.5 ha or more in area. The adult ponds should be long, narrow and rectangular as it has been observed that the shape of the pond has an effect on growth and that eels locate food more easily in such pond (Bardach *et al.*, 1972).

An ideal eel farm should have a series of nursery and fattening or adult ponds in parallel rows, each with its own independent water supply and drainage system.

Stocking of elvers and eels in ponds

The stocking density of elvers and young eels in culture ponds depends mainly upon the quantity and quality of water supply. In running water ponds, stocking rate is always higher than those of still water ponds. Further, the stocking density also varies from country to country, in view of their different aquaculture traditions. In Japan, eel culture is essentially a monoculture system whereas in Taiwan it is an integral part of complex polyculture system. In Japan, in the nursery ponds elvers are stocked at a rate of 3 lakhs/ha or 30 per sq. metre (each seed elver weighs 0.16 to 0.2 g). In Taiwan, the stocking rate is very high; upto 3 million elvers per hectare are stocked and reared in nursery ponds (Bardach et al., 1972). In the fattening or adult ponds in Japan, the stocking rate of young eels ranges from 20 to 40 eels of 10 to 20 g weight per sq. metre. The normal stocking rate is 20 eels of 15g weight per sq. metre or 3,000 kg per ha (Huet, 1970).

While stocking the ponds care should be taken to stock elvers or young eels of more or less uniform size. The advantage for stocking the ponds with optimum density of young eels are that it ensures sufficient space for their living, reduces overcrowding which in turn prevents cannibalism and to a certain extent the outbreak and dispersal of diseases in culture ponds and gives higher production rate.

Feeding

Artificial feeding is an important aspect in eel culture which directly influences growth and thus production. Different kinds of food are used as eel feeds. The traditional items of eel food are sardines, mackerel, skipjack head, silver bellies, goatfishes, other miscellaneous fishes, trash fish, cuttlefishes, silkworm pupae, earthworms, minced clam meat and offal from slaughter houses. In the initial stages of culture, the young elvers are to be fed only with a particular kind of food. Elvers do not take food for the first few days after their capture and they have to be slowly

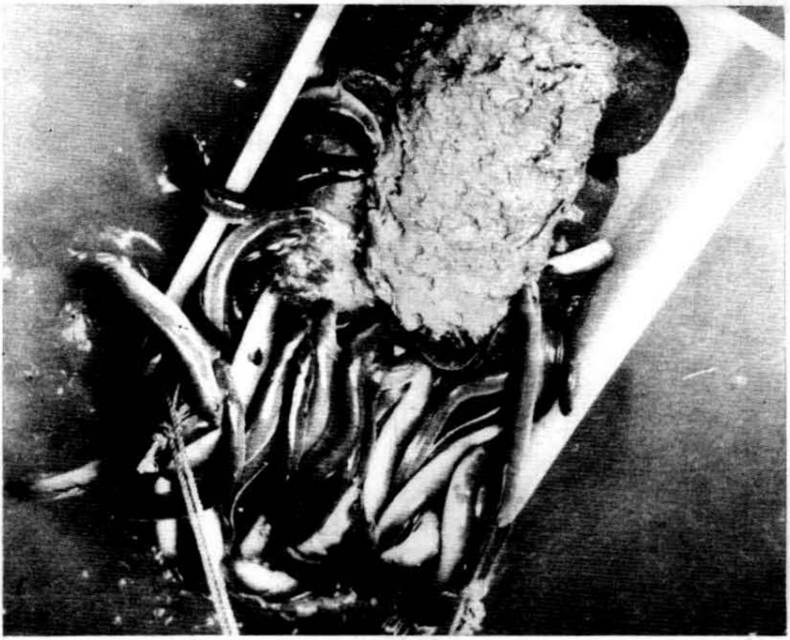

Fig. 3. Cultured eels feeding the artificial feed in suspended tray kept above the water level

acclimatised to a regular feeding habit. Crushed earthworms are to be given to the elvers when they begin to feed and after fifteen days, a mixed diet of earthworms and fish meat. After about a month the growing eels may be exclusively fed with fish meat. They may also be fed with artificial or concentrated dry food specially formulated for them.

Elvers and young eels prefer to feed in a dark place. Therefore, the feeding place should be provided with a shelter. The feed is placed in a wire basket or tray and suspended just above the water surface to prevent contamination of water. The elvers are given feed at a ration of about 30% of their body weight and the growing young eels about 10% of the body weight. Eels should not be fed when temperature drops to below 15°C as they become inactive, loss appetite and stop taking food. Growth rate in eels is observed to be very rapid during April-October period. Therefore, it is advisable to give as much food as possible during the above period. Crab flesh is believed to be more effective in accelerating growth of eels. In

Taiwan, silkworm pupae are supplied to the eels at the last stage of culture i.e., a few months before harvesting.

In intensive culture, eels are fed with artificial dry feeds. The conversion ratio of traditional eel feeds such as sardines, trash fish etc. has been reported to be low whereas the artificial dry feeds prepared in the form of pellets of various shapes have given remarkable results and the conversion ratio has been found to be very high (Table 2).

Table 2. Conversion ratio of eel feeds

Food	Conversion ratio	
Trash fish	10-15	:1
Chopped fish/Silkworm pupae	5.5	:1
Sardines	5.4-7.2	:1
Artificial feed (pellets)	3.0-4.4	:1
Artificial feed (granular)	2.1-2.6	:1
Artificial feed mixed with fish liver oil	1.9	:1

The main constituents of the artificial dry feed are fish meal 65%, fish concentrates 5%, multivitamins 1%, lysine 0.2%, antioxidant 0.2% and binding substance 0.2%. The chemical composition of the feed are crude protein 51.91%, crude fat 0.36%, crude carbohydrate 16.03%, ash 17.97% and moisture 8.73%.

Maintenance of eel farm

The success of eel culture also depends upon the proper maintenance of the farm. The quantity and quality of water in the eel ponds should be maintained satisfactorily. The ponds should have a minimum water depth of about 60 cm. The pH should not be allowed to fluctuate widely as it is not conducive to eel culture. The optimum pH for still water eel ponds is about 8.0 to 9.2 during day time and about 6.8 to 7.2 at night. In running water ponds, the flow of water should be maintained at a constant level. The sluice gates have to be periodically cleaned as it will ensure smooth flow of water both in the inlets and outlets.

It is very essential that the pond water should have high dissolved oxygen level. The minimum desirable value of oxygen for eels is 2.0 to 2.5 ml/l. Still water ponds are normally provided with water wheels to mix and oxygenate the water. The production of micro-organisms in eel ponds and their composition is of significant importance. A high percentage of phytoplankton in eel ponds is beneficial whereas abundance of zooplankton is not. A well managed eel pond is blue-green in colour with a composition of 97 to 99% phytoplankton and 1 to 3% zooplankton. Nutrients like calcium, nitrate and phosphate should be maintained in the pond at optimum level by the addition of fertilizers.

Through research it has come to light that even under optimum conditions of good water supply, temperature, stocking density, adequate food and proper maintenance, cultured eels exhibit wide range in growth rate both in terms of size and weight. Therefore, at periodical intervals, in all stages of culture, culling should be done, as it will ensure uniform size of eels at the time of harvest. If there are any cracks or holes in the banks of eel ponds they should be repaired immediately as otherwise eels will burrow into the mud in the crevices and escape.

Disease

Detection and eradication of diseases is another important aspect in eel culture. Eight types of diseases are found to attack the Indian short finned eel in culture ponds (Table 3) (Dorairaj, 1980). The 'Cauliflower' disease and cripple body disease affect the growth and survival of eels but no preventive method has yet been developed. Fungus, Fin rot and gas disease are the common diseases of elvers. A general method of eradication of diseases in eel farms is to disinfect the water by chemicals or by completely flushing the ponds with large quantities of water. The introduction of artificial dry feed facilitate mixing of drugs in eel food to control certain diseases. At the end of each harvest, the muddy bottom of the eel ponds should be dried, turned over by ploughing and sprinkled with lime to control the diseases.

Harvesting

When cultured eels attain marketable size, they are harvested and marketed. The principle nets used for harvest are scoop nets, trap nets, cast nets, screen nets and seine nets. The water in the ponds is not drained when a partial or selective harvest is done but in the final harvest, ponds are usually drained before fishing.

The size of cultured eels at harvest varies according to species in different countries. In Japan, the Japanese eel (*Anguilla japonica*) is harvested when it reaches a weight of about 100 to 200 g which is attained in about two years from elver stage. However, about 30% of the eels reach

Table 3. Disease of Indian Short finned eel

Sl. No.	Name of Disease	Causative factor	Symptoms	Cure
1.	Fungus diseases	Fungus	Whitish or greyish fungal growth on the body, especially on margins of fins.	Give bath in Malachite green or Methylene blue mixed water. Add anti-bacterial drug in the feed.
2.	Gas disease	Excess dissolved oxygen & nitrogen in water	Formation of air bubbles on the head in elvers or dorsal fin in adults.	Lower temperature of water by adding ice, cutt off aeration or remove the affected to other better ponds.
3.	Red pest and blotch disease	Bacteria	Rash like redding on the body and fins. In advanced condition oozing of blood from the affected portion.	Give bath in Malachite green Methylene mixed water. Add anti-bacterial drug in the feed.
4.	Gill disease	Bacteria	Damage to gill filament; gill raw and broken.	Give bath in Malachite green or Methylene blue mixed water. Add anti-bacterial drug in the feed.
5.	Cripple body disease	Protozoan parasite	Body mis-shapen in a Zig Zag manner due to the attack on the muscular system.	Not known
6.	Cauliflower disease	Virus	Skin tumor. Proliferous out growth, in the shape of cauliflower on any part of body.	Not known
7.	Tail fin rot disease	Bacteria	Damage to the skin and musculature of the tail region. In advanced condition severe haemorage and putrefacation.	Give bath in Malachite green or Methylene blue mixed water. Add anti-bacterial drug to feed.
8.	Swollen intestine disease	Bacteria	Swelling of the intestine leading to floating of eel in the water.	Add anti-bacterial drug to feed.

harvestable size by the end of one year itself and hence a partial harvest is done at the end of one year and the final harvest at the end of second year. The Taiwanese harvest when eels attain a weight of over 200 g. In Taiwan, harvesting is not confined to any particular period; depending upon the demand for cultured eels, each eel pond is fished selectively on a daily to monthly basis. In European countries also, larger sized eels are preferred. In Germany, the European eel (*Anguilla anguilla*) is harvested when the males attain 150 g and the females 500 to 600 g.

Production

The production of eels per hectare varies with the type of culture method. In running water culture, eel production is found to be about 4 times higher than that obtained in still water culture. The average yields from running water and still water eel farms in Japan are 26,360 kg/ha and 6,120 kg/ha respectively. The most productive running water ponds yield as high as 45,000 kg of eels per hectare. In Taiwan, the production of eels in still water ponds is about 10,000 kg/ha. The yield rate for the European eel in Germany varies from 50,000 kg/ha to 75,000 kg/ha. In the experimental culture of *A. bicolor bicolor* in running water at Mandapam, the estimated average eel production was 25,000 kg/ha/year, which is comparable to those obtained in other countries. The estimated cost of production arrived at by certain projections was about Rs. 22/- per kg of marketable size cultured eel. The actual cost of production remains to be worked out.

ELVER RESOURCES

Elvers, the young ones of eels, are the starting point for eel culture. In India, elvers of two species of *Anguilla*, viz., *Anguilla bicolor bicolor* McClelland and *Anguilla nebulosa nebulosa* McClelland are known to migrate in three major rivers of east coast. The upstream migration of elvers of *Anguilla nebulosa nebulosa* over the first anicut at Dowleshvaram on the river Godavari was recorded by Ibrahim (1961) and in the River Hooghly by Pantulu (1956) and that of elvers of *Anguilla bicolor bicolor* in the River Tambraparni at Srivaikundam Anicut by Nair (1973) and Nair and Dorairaj (1975).

In view of the great export potential for elvers, an investigation was undertaken during December 1975 to February 1980 and the entire Tamil Nadu Coast from Pulicat lake to Cape Comorin was surveyed. Out of the 102 centres surveyed, 57 centres were found suitable for elver collection

(Table 4) and in 32 centres either glass eels and/or elvers were collected during the survey. The details of the species composition and size range of elvers at selected centres are given in Table 5. The survey had brought to light for the first time the immigration of elvers of *Anguilla bicolor bicolor* and *A. nebulosa nebulosa* in rivers Vaigai, Vellar, Gadilam, Penniyar, Coleron, Vembar, Tambraparni, Korattalaiyar, Arniyar, Kaliveli canal, Ervadi and Pillaimadam creeks and in several seashore pools on the Gulf of Mannar at Mandapam, Vedalai, Seeniyappa Dharga and Kadharshaped backwaters near Pamban.

Table 4. Elver collection centres in Tamil Nadu

Name of rivers, lakes etc.	Centres	
Pulicat lake	1.	Near the South lock
Arniyar river	2.	Lakshmipuram Anicut
	3.	Puduvayal bridge
Korattaliyar river	4.	Vallur Anicut
	5.	Damarapakkam Anicut
Coovum river	6.	Near the estuary mouth
Adayar River	7.	At the estuary mouth
Buckingham canal	8.	North lock of Kovalam
Palar river	9.	South lock of Canal
Chinna aru	10.	At the bridge
Kaliveli canal	11.	At the bridge
	12.	Near Marakkanam
Kaliveli tank	13.	At the Regulator
Chunnambu river	14.	At the bridge
Penniyar river	15.	Near Manjakuppam bridge
	16.	Ellis anicut
	17.	Thirukoilure anicut
Gadilam river	18.	At Cuddalore
	19.	Tiruvendipuram anicut
	20.	Vanamadevi anicut
	21.	Thiruvadi anicut
Vellar river	22.	At porto Novo
	23.	Sthiyathope Anicut
Viranam yeri	24.	At north Regulator

Coleroon river	25.	Lower anicut
Cauvery river	26.	At estuary mouth
	27.	Melaiyur anicut
Vedavar	28.	At Trangqubar
Arasalaru	29.	Agalankani regulator
Thirumalairajannar	30.	Manamutti regulator
Puttar	31.	Near Nagore
Odampokaiyar	32.	Nariyangudi regulator
Vellayar	33.	Vellangani regulator
Harichandra nadi	34.	At Vettikaraniruppu
	35.	Brinjumollai regulator
Kanthaparisanaru	36.	At Alangudi
Korayar	37.	At Muthupet
	38.	At Alangudi
Pamaniyar	39.	Thoppadanavelli regulator
Vaigai river	40.	Athankarai estuary mouth
	41.	Athankarai ferry point
	42.	At Narippalam
Pillaimadam creek	43.	Near the bridge
Pamban	44.	At Kadarshapad
Seashore pools on Gulf of Mannar	45.	At Mandapam
	46.	At Vedalai
	47.	At Seeniyappa Dharga
Ramnad big tank	48.	North and South Regulator
Kanjarangudi river	49.	At the bridge
Ervadi creek	50.	Near the estuary mouth
Coonar	51.	At estuary mouth
Vembar river	52.	At the bridge
Tambraparni river	53.	At Pinnakayal
	54.	Eral causeway
	55.	Srivaikundam Anicut
	56.	Maruthur anicut
Korambalam tank	57.	Upparodai regulator

Table 5. Species composition and size ranges of elver at different centres

Sl. No.	Collection Centre	Month in which collection were made	Approximate species composition *A. b. bicolor* *A. n. nebulosa*	Size range (mm)
1.	Srivaikundam Anicut	Dec. 78, Jan. 79 October 79, Nov. 79 and Dec. 79	80 : 20	*A. b. biclor* : 102-185 *A. n. nebulosa* : 85-174
2.	Mandapam Seashore pools	Nov. 78, Jan & Nov. 79 Dec. 79 & Jan. 80	75 : 25	*A. b. bicolor* : 50-100 *A. n. nebulosa* : 50-100
3.	Vedalai and Senniyappa Dharga Seashore pools	Nov. 78, Dec. 78, Jan. 79 Feb. 79, March 79, Sept. 79 Oct. 79, Nov. 79. Dec. 79 & Jan 80.	75 : 25	*A. b. bicolor*: 49-98 *A. n. nebulosa* : 51-110
4.	Pillaimadam creek	Jan. 79, Feb. 79 and March 79	75 : 25	*A. b. bicolor* : 50-100 *A. n. nebulosa* : 45-110
5.	Kadharshapad backwaters	Nov. 78, Feb. 79 March 79, May 79 & Feb. 80	70 : 30	*A. b. bicolor* : 55-79 *A. n. nebulosa* : 55-115
6.	Lower Anicut	March 79, May 79 & Nov. 79	40 : 60	*A. b. bicolor* : 75-120 *A. n. nebulosa* : 63-112

Based on the results of the survey, the following centres are considered potentially rich for glass eels/elvers:

1. Srivaikundam anicut and Maruthur anicut on the River Tambraparni.
2. Lower anicut on the River Coleroon.
3. Melaiyar anicut on the River Cauvery.
4. Sethiyathope anicut on the River Vellar.
5. Thiruvendipuram anicut and Vanamadevi anicut on the River Gadilam.
6. Ellis anicut on the River Penniyar.
7. Vallur anicut on the River Korattaliyar.
8. Lakshmipuram anicut on the River Arniyar.
9. Several seashore pools on the Gulf of Mannar at Mandapam, Vedalai and Seeniyappa Dharga.
10. Pillaimadam creek near Pillaimadam bridge.
11. Kadharshapad backwater near Pamban.

For the successful elver collection it is essential to have some basic information about the behaviour of elvers. The very early stage elvers i.e. glass eels immigrate into the rivers from the sea immediately after the first flood and migrate upstreams. They bury themselves in the mud or hide in crevices during day time and become active during night time. After the sunset the elvers come out from their hidden places, re-group themselves and ascend the river along the banks and penetrate far interior places in the river and also in the side streams. If there are any barriers like anicuts or shutters across the river, the elver migration temporarily halted; they congregate near the closed gates of the anicut and may climb over the vertical wall by wriggling over the moistened surface with the help of the viscosity of their skin and cross the anicut.

The tail end shutter or the first anicut across the river from the seaward side is the most suitable place for collection of elvers. The scoop net and drag net are the most suitable nets for elver collection below the anicuts. Elver net is operated to capture elvers in such of those areas of the river where the banks of the river are fairly well defined with a uniform depth of about 1 to 1.5 metres from the one bank of the river upto about 10 metres width. The very early stage elvers (glass eels) can be collected by operating this net in the estuarine regions.

Another important aspect which requires precise information for the successful collection of elvers is the exact time of arrival of elvers at various localities. In Hooghly river, immigration of glass eels of long finned eel takes place during October-March period with a peak in January and February and Godavari river at Dowleshwaram (which is about 81 km from the sea) from August to February and again in June in the next season and Yanam, Kotipally and Kapileswaram in July month. In the Tambraparni river, the elver immigration at Srivaikundam Anicut is from October to January. At lower anicut congregation of elvers takes place from January to May. The immigration of glass eels of *Anguilla* spp. has been observed in December in Vaigai river at Athankarai, in January in rivers Vellar, Gadilam, Penniyar and Coleroon and in November in Vembar river. Around Mandapam region, the immigration of glass eels from the inshore waters into the seashore pools takes place during November-December.

In general it may be stated that the immigration of glass eels and elvers takes place in most of the rivers in Tamil Nadu in the months of October-November after the onset of the north east monsoon and continue upto March. The first anicut on the river from the seaward side is the most suitable place for large scale collection of elvers. The drag net and scoop nets are the effective gears for the collection of elvers below the anicuts. The elver collection during night, particularly between 10.00 p.m. to 01.00 a.m. yielded higher catch. Srivaikundam anicut on the River Tambraparni is the very rich collection centre for elvers, where in 32 days of survey, 57,220 live elvers weighing 72.1 kg was collected and transported to Mandapam Camp by the author. There are good possibilities for large scale collection of elvers from the other rivers on the east and west coasts of India.

EEL CULTURE IN INDIA - A REVIEW

Eel culture is a commercially profitable industry in several South-East Asian countries., particularly in Japan and Taiwan where the Japanese eel (*Anguilla japonica*) is cultured on a large scale since several decades. Cultured eels are considered as delicacy and as there is great demand for the same, the production is increasing steadily. Eventhough many fish species of both fresh and salt water are being successfully cultured in India (Alikunhi, 1957; Tampi, 1969; Hickling, 1970), no attempt was made to culture the Indian eels until 1971 when an experimental culture of *Anguilla bicolor bicolor* was undertaken at the Central Marine Fisheries Research Institute at Mandapam Camp, Tamil Nadu. Based on the encouraging results, a regular research project on 'Culture of eels' was undertaken by the author in November 1973 and continued till 1983. During the 10 years period various aspects on eel culture were studied, which included culture of short-finned eel in running and re-cycled running water, feeding and stocking density experiments, elver resources survey, transportation of live elvers and cultured eels, bio-chemical analysis of cultured eels and induced breeding with eels reared for 6.5 to 7 years under controlled laboratory condition.

Eel culture in running water

Elvers of *A. bicolor bicolor* collected from Srivaikundam anicut near Tuticorin during November 1973 were utilized for the culture experiment. A total of 1,200 elvers were stocked in eight fiberglass tanks (122x76x76 cm size) in densities ranging from 330 to 1500 g/sq.m. Each fibreglass tank was provided with independent running water facilities. The elvers and growing eels were fed twice daily to satiation with fish flesh and clam meat.

The size of elvers ranged from 7.1 to 19.1 cm in total length weighing 0.3 g and 9.5 g respectively with an average of 13.1 cm and 3 g respectively. At the end of six months, the elvers reached an average size of 18.5 cm and 11.6 g. The net increase in length and weight was 54 mm and 8.6 g respectively, with a monthly growth rate of 9 mm and 1.4 g. At the end of eleven months the elvers had reached an average size of 27.8 cm (43 g), showing an increase of 14.7 cm and 39.9 g from initial average size. The monthly growth rate works out to 13.4 mm in length and 3.6 g in weight. The maximum size at the end of eleven months was 38.9 cm and 115 g. The overall survival rate for the first year was 87%. The culture experiment was continued for another two years. At the end of second year the average size was 38 cm and 119 g, with monthly growth of 8.5 mm and 6.4 g. The maximum size eel measured 51.4 cm in length and 275.5 g in weight, while the average size was 41.9 cm and 177 g respectively. During the third year, the monthly growth rate was 3 mm in length and 4.5 g in weight. The maximum size eel at the end of third year measured 68 cm in length and 726 g in weight. It was observed that length increase was faster in the first year while the weight increase was more in the second year.

In this experiment 7.28 kg of elvers were stocked in fibreglass tanks having a total surface area of 6.65 sq.m. At the end of one year the total weight of eels was 22.22 kg with a net increase of 14.94 kg. At the end of second year the total weight of cultured eel was 34.61 kg. The net increase in two years from initial stocking weight was 27.33 kg. The net production in one year works out to 2.2 kg/sq.m. and in two years 4.1 kg/sq.m. or 22 t and 41 t per hectare respectively.

Another culture experiment was conducted from April 1980 to March 1981 in 12' dia polycraft tank. A total weight of 7.5 kg elvers was stocked at a density of 0.68 kg per sq.m. The average weight of elvers was 13.2 g. The elvers and the growing eels were fed with an artificial feed in the form of a paste. The average weight of elvers had increased from 13.2 g to 25.6 g in three months, 43.6 g in six months, 73 g in nine months and 88.2 g in one year. The net weight increase at the end of 3rd, 6th, 9th and 12th months were 4.3, 9.1, 12.5 and 18.5 kg respectively with percentage increase of 57.3, 121.3, 187.2 and 246.75% respectively. The survival rate at the end of one year was 75.96%. During the one year period 437.2 kg of feed was supplied to the eels of which they consumed 377.03 kg which works out to 84.87%. The gross conversion ratio for the feed was 20.06 : 1. The net production was 4.68 kg/sq.m./year.

Eel culture in re-cycled water

During 1978-1982, three experiments were conducted to culture the eel in re-cycled water. For this purpose an outdoor cement tank (6 x 3 x 1 m) with natural mud bottom was constructed. By three shutter sluice gate arrangements the bottom water was gravitationally drained out and passed through a filter bed consisting of big and small granite stones and charcoal arranged in alternate layers and a layer of sand at the top. The filtered water was allowed to flow into settling and oxidation tanks. In these tanks partitions were made by using asbestos sheets, in such a way that water travelled longer distance thereby allowing time for oxygenisation. Oxygen level in the oxidation tank varied between 2.26 l and 12.41 ml and in the culture tank between 2 and 9.32 ml/l. The clear water was allowed to overflow into a storage tank and then pumped to a small over-head tank and from there fed to the culture tank through pipeline. The water flow was regulated with the help of a wheel valve. Weekly once about 1/3 of the water in the culture tank was drained out and replenished with new fresh water. Water level in the culture tank was maintained at 70 cm.

An effective feeding method was adopted by providing a sheltered feeding area on one side of the culture tank. It was in the form of a wooden platform, with a small man hole with a lid in the middle. The sides below the platform was covered with planks to cut down direct sunlight to the feeding area. The eel feed in the form of a paste, made of minced sliver bellies, rice powder and ground nut oil cake powder mixed in 2:1:1 proportion with 0.2% multi-vitamin, was placed in a plastic tray and suspended through the man hole at water level. The eels in the culture tank would immediately congregate near the tray, climb over it, dart to the feed, take a mouthful and slip back into the water. After gulping the feed, the eel would again climb the tray and take another mouthful of food. This process is repeated until satiation when the eel would settle down at the bottom of the tank. The tray with left over food would then be lifted out through the door. By this method contamination of water by food was effectively reduced. The eels were fed at a daily ration 5 to 10 % of their body weight.

In the re-cycled running water culture tank, 9 kg of young eels (208 in numbers, ranging in size from 20 to 65 g with an average weight of 43 g) was stocked at a stocking density of 500 g/sq.m. in August 1978. The average weight of the eel had increased from 43 g to 84 g in 31 days, 132 g in 61 days, 203 g in 122 days and 232.8 g in 163 days. The eels were harvested after 163 days and the total production was 47.8 kg which shows a net increase of 430% of the initial stocking weight. The survival rate was 98.56%. The net production rate works out to 2.15 kg/sq.m in about 5 months.

The second experiment was carried out from 01.04.1980 to 31.03.1981 in the same outdoor cement tank. 520 numbers of young eels, with an average weight of 17.3 g, were stocked at a rate of 500 g/sq.m. The eels were daily fed with a mixed feed made of minced silverbelly, rice powder, oil cake powder and water mixed in 4:1:1:2 proportion in a paste form, at a ration of 7 to 12% of body weight.

The average weight of eel had increased from 17.3 g to 43.4 g in three months, 65 g in six months, 116.5 g in nine months and 182.6 g in twelve months. The net weight increase per eel in one year was 165.3 g which works out to a monthly growth rate of 13.8 g. The total weight of eels increased from 9 kg to 22.5 kg in three months, 34 kg in six months, 35.2 kg in nine months and 50.2 kg in twelve months. Excluding 9.8 kg of small sized eels culled during the experiments the new weight increase in one year was 51.03 kg, which works out to 567% of the initial stocking weight. The survival rate was 97.1%. Detailed analysis revealed that 201-700 g weight eels formed 23.35%, 101-200 g weight eels 60.95% and less than 100 g weight eels 15.70% in the total harvested eels. The marketable sized eel (over 100 g) was 84.3%.

In one year 417-5 kg of feed was given to the eel and the consumption was 87.3%. The feed had given a gross conversion ratio of 10.8:1. The net production works out to 2.8 kg/sq.m./year.

For the third experiment, the outdoor cement tank was prepared by allowing it to dry for three months. Then 3" of upper layer of dried up soil was removed and an equal thickness of new mud layer was laid. Just as in the previous experiments, arrangements were made for recycling the water, 208 young eels weighing a total of 9 kg were stocked into the culture tank. The eel size ranged from 25.2 to 34.6 cm (24-72 g) with an average of 29.9 cm. The stocking density was 500 g/sq.m. The proportion of compound feed and the feeding rates were same as given in the second experiment.

At the end of one year, the tank was harvested and total yield was 48.18 kg. The net weight increase was 39.18 kg which work out to 535.33% of initial stocking weight. At harvest, the size of eels ranged from 30.8 cm to 64.7 cm in length and 102 g to 650 g in weight with an average of 49 cm and 243.3 g. respectively. The survival rate was 95.2%. In one year 471 kg of feed was supplied to eels in 260 feeding days, they consumed 439 kg which works out to 93%. The gross conversion ratio of feed was 11.2:1. The net production was 2.18 kg/sq.m./year.

Of the three experiments conducted in the re-cycled running water tank, very high production was recorded in the first experiment. Enriched supply of compounded feed may be the probable factor for the accelerated growth. In the other two experiments more or less similar growth rate and production were obtained. Taking the average values for these two experiments as the standard growth and productional potential for the Indian short finned eel, it may be said that 17 g eel can attain weight of 55 g in six months, 160 g in one year and 243 g in seventeen months, with a production of 25 t/ha/year.

STATUS OF EEL CULTURE IN ASIA AND EUROPE

In Asia, Japan and Taiwan are the two leading nations in eel culture. Besides, many other countries like China, Republic of Korea, Hong Kong, Indonesia, Malaysia, Singapore and India are currently developing eel culture industry. In Europe also eel culture is given importance in countries like United Kingdom, France, Hungary, Netherlands etc. and cultured eels are produced in fairly large scale for consumption and for export. In Japan and Taiwan, intensive eel culture is practised whereas in Europe it is extensive. However, in recent years intensive eel culture are being attempted in some countries in Europe. In this chapter, the status of eel culture in different countries are briefly reviewed .

Japan

In eel culture, Japan is the leading nation in the World. For the last 150 years, the Japanese eel, *Anguilla japonica* is being cultured on a commercial scale. However, only in the last few decades, intensive eel farming is practised following still water culture system, utilising the under ground bore-hole water. The eel ponds in Japan are concentrated mainly in two areas viz. Hamanaka near Hamamatsu in Shizuoka Prefecture and Yoshida district by the Ohi river in Shizouka Prefecture extending to Yaizu district.

In the east central part of Japan in Ibaraki and Shizuoka Prefectures large quantities of elvers are fished with dip nets and Japanese elver nets. Elvers are kept for about 4 or 5 days in temporary holding like floating baskets or boxes before transferring to nursery ponds. The elvers measure 60-70 mm in length and weight 0.16 to 0.2 g.

Eel culture is done in two phases. The first phase is rearing the elvers to about 12 to 15 cm in length and about 20 gms in weight and the second phase is growing eels to marketable size of 45-60 cm in length weighing 100-200 gms. Since about 30% of the elvers stocked in the beginning reach marketable size within one year a partial harvest is done at the end of one year and equal number of young eels are restocked in the pond to maintain the density level. Final harvest is done at the end of second year. The survival rate over the two year period varies between 60 and 90%. The average production of eels in running water ponds is 26,360 kg/ha whereas the same for still water ponds is only 6,120 kg/ha. Yield upto 45,000 kg/ha has been obtained in running water eel culture. The domestic eel production in 1990 was about 40,000 tonnes.

Faced with short supply of elvers for culture purposes, Japan imports quantities of elvers from many countries like Taiwan, France, Republic of Korea, United Kingdom, Italy, China, Hong Kong, Philippines, New Zealand, United States of America, Canada, Morocco, Cuba etc. In addition to the local species i.e. *A. japonica* the European eel, *A. anguilla* is also cultured in Japan. Of the total cultured eel harvest, the former species farms about 95% and the latter species 5%.

With regard to profit and expenditure, it has been stated that the average costs of monitoring a running and still water eel culture ponds were 13,541 and 18,286 dollars, which includes an average profit of 2,113 and 2,142 dollars for the respective culture system (Tesch, 1977). Item-wise production costs for the two systems were as follow:

Item	Running water system %	Still water system %
1. Eel stock	24.9	16.1
2. Food stuffs	54.7	51.1
3. Management	2.5	3.6
4. Wages	4.8	11.0
5. Electricity, machinery and fuel	3.1	3.7
6. Maintenance including temperature control system	2.6	2.3
7. Interest	2.8	3.6
8. Insurance, rent and taxes	3.7	6.5
9. Miscellaneous	0.9	2.1

A sound business management and good biological techniques are stated to be the main reasons for the success of eel culture in Japan. In the organisation of the Japanese eel culture industry, eel farmers, co-operatives which are established in each district play a vital role. In addition to providing facilities like cold storages, supply of seed and artificial feed at wholesale prices and marketing of the harvest of the farmer members, the co-operatives also look into matters-like negotiating with the Government and assisting the members in their accounting and legal matters. Well organised and established Government research and experimental stations situated in each area also give guidance to the eel culturist.

The main developments that are taking place in eel culture industry of Japan are, the increasing use of "central heating" pipes to raise the temperature of the fingerling ponds during spring time, construction of more and more ponds of 100 sq.m. in size and rearing of eels in ponds in high density, with delicate control and management of water quality.

Taiwan

Taiwan is another South East Asian country where *Anguilla japonica* is cultured intensively following polyculture system. The methods of collection of elvers followed in Taiwan are more or less similar to those adopted in Japan but the culture methods are slightly different. The glass eels are collected in estuarine waters all around the coast. Nursery ponds with running water are heavily stocked with elvers, the density rate reaching as high as 3 million elvers per hectare. Stocking density of growing eels in adult ponds is also very high viz., 50,000 eels per hectare.

The most commonly used food in Taiwanese eel farms is trash fish. In addition to trash fish, silkworm pupae, earthworms, aquatic worms and offal from slaughter house are also fed. In recent years artificial dry feed in granular form has been widely in use. It has been found to give a conversion ratio of 2.1 - 2.6 : 1. The food is not scattered in the pond but is presented in bamboo mesh baskets, usually in double baskets, submerged in water. Eels are selectively harvested when they reach a weight of about 200 gms or more, on a daily to monthly basis. In Taiwan annually about 2 million kg of eels are produced in about 200 hectares of area, with an average production of about 10,000 kg/ha. (Chen, 1972). Significant portion of the cultured eels are exported.

In addition to culture of eel, collection and export of elvers has become a profitable business in Taiwan. Due to large profits derived from eel culture the number of eel ponds in Taiwan increased tremendously.

About 90% of the total eel production is exported to Japan which accounts for about 95% of the total eel imports by Japan. An analysis of the economic potential of the eel industry in Taiwan, revealed that the rate of return on initial investment was about 62% with a survival rate of 70%. This high profit rate is considered as a major factor for the tremendous expansion of eel culture in that country.

Italy

In Italy, the European eel *Anguilla anguilla* is cultured along with other groups of fishes in coastal brackish water ponds or lagoons which are known as *Valli*. The *valli* complex at Comacchio is about 300 sq. miles in area and has direct connection with sea. The *valli* are subdivided into ponds or lakes by erecting walls. Through canals and sluices sea water flows into *valli* from one side and fresh water from the other side from River Po. Hickling (1970) has described the management of the Italian brackishwater fish farms where eels are the major crop.

When elvers enter the ponds during spring they are impounded and reared. They feed on rich natural food available in the ponds and no supplementary food is given. In autumn or in the beginning of winter when sluice gates of *valli* are opened to let in sea water, the grown up silver eels escape through the inlets and large quantities of these (about 1000 tons) are caught with fixed fishing installations erected across the main sluice gates of *valli*. Eel production in *valli* farms is 30 to 40 kg/ha. The maximum production in *valli* cultivation is 90 kg/ha.

Denmark

In Denmark also *A. anguilla* is cultured on a large scale. The success of Danish brackish water eel farms is due to small outlays and low level of working expenditure. Lagoons along the coastlines of the Baltic Sea are converted into ponds by erecting a wall at the mouth. These large ponds are divided into smaller ones and are connected with each other by channels. The ponds are about 60 mm in depth and water level, salinity, and temperature are controlled by a steady supply of sea and freshwater by wind driven pumps. The eels feed mainly on natural plankton, molluscs and small unmarketable fishes. The production of eels in Denmark farms is reported to be much higher than that realized in Comaechio eels farms in Italy.

Germany

Even though many attempts were made to rear the European eel, *A. anguilla* by feeding them with supplementary animal feed as early as 1929, only in recent years controlled experiments were carried out which enabled for comparison with the results of similar experiments done elsewhere. In channel system in the district of Altenburg, young eels of 30 g in average weight were found to increase to 130 g in one year. The eels were fed with 50% fish and 50% dried food at a daily ration of 3-4% of body weight. The total weight at the end of one year showed five fold increase. Experimental culture of the European eel in warm water circulating system, carried out at the Max-Planclc Institute, near Hamburg, showed that the eels grow rapidly when the temperature of the water was kept constantly at 23° C. The largest eel weighed 320 g at the end of 19 months and the average being 50 g (Meske, 1970). Culture of eels in warm water effluents from the cooling systems of power stations seems to have yielded good results.

The production of eel from within the country is not sufficient to meet the demand and hence large quantities of eels both live and smoked, are imported from many European and Scandinavian countries. Smoked eels account for about 90%. The most popular eel size are 2-4 pieces per kg.

GENERAL REMARKS

Low temperature of the pond water is one of the main problems standing in the way of rapid development of eel culture industry in European countries. However, in recent years, Scientists have evolved several methods to tackle this problem. The important methods are 1) use of polyethylene multi-span covers over the culture ponds 2) artificial warming of the water with insulated bottom and sides under a green house and 3) Use of warm water effluent from the power stations. Experimental and commercial attempts to culture eels, research into new techniques of fish culture, especially the use of continuously circulated and purified water in heated, insulated, tanks and expansion of air-freight export of elvers to Japan are some of the major developmental effort that are taking place in the field of eel culture in many of the European countries.

MARKETS

Elvers and cultured eels have great export value. Japan, the leading country in eel culture, is importing large quantities of live elvers from many Asian and European countries like Taiwan, South Korea, China, Hong Kong, Philippines, New Zealand, France, Spain, Italy, Great Britain, Canada and United States of America, to meet the growing demands of eel culturist, since the supply of elvers for culture purpose from the sources within the country has decreased due to pollution of near coastal waters and rivers. Annually about 400 tonnes of live elvers, valued at about 4000 million Yen were imported by Japan during seventies. Beside, cultured eels were also imported either in live condition or in processed form ready for consumption. During 1990, the total quantity of live eel and eel products imported into Japan was about 49,000 tonnes at 525 million. The details of products and the country of origin are as follows:

			Qty. in tonnes
Country	Live eel	Processed eel	Frozen eel
Taiwan	16,038	25,186	7.9
China	4,027	3,635	184.7
Hong Kong	44	16	11.6
South Korea	3	-	-
France	-	-	0.6
Spain	-	-	0.5

In Japan, the imported processed eel is sold in two types viz. Kaьayaki (grilled with special sauce) and Shirayaki (semi processed product for Kabayaki without sauce) at major super markets. The domestic whole sale prices for live eel and eel products in July 1991 were as follows:

I. Live eel

Pieces/kg		Whole sale price Yen/kg
5 to 6	(Small size)	1650-1750
4	(Medium size)	1500-1650
3	(Big size)	1400-1600

II. Processed eel

A. Stick type (barbecue type)

Size of eel (g/stick)		Price (Yen)	
		Kabayaki	Shirayaki
50	(Small)	2650-2800	2350-2600
100	(Medium)	2600-2800	2350-2550
150	(Big)	2300-2500	2100-2300

B. Kabayaki type (split open and grilled with sance)

Size of eel (Nos/kg)	Price (Yen/kg) Headless		Head-on	
	Kabayaki	Shirayaki	Kabayaki	Shirayaki
9 and above	2950-3000	2050-2150	2900-2950	2750-2800
8	2800-2900	2050-2150	2800-2850	2650-2700
7	2750-2800	1950-2050	2700-2750	2550-2600
6	2650-2750	1900-2000	2500-2600	2350-2450
5	2550-2650	1850-1950	2450-2550	2300-2400

Eel known as 'Unagi' in Japan, is mostly consumed in Kabayaki type. During the last two decades, eel consumption in Japan had increased steadily and their demand is particularly very high during the summer months of June - August. Considering the food habits of the Japanese, the demand for the processed eel food is definitely going to increase. The nutritive value of the Indian short finned eel and the Japanese eel are more or less the same and hence there is a good scope for the export of Indian eel to Japanese market. What is urgently needed is a bold initiative by some Indian sea food processing company to enter into technical tie-up project with 100%, buy back arrangement, with some Japanese firm for the commercial scale culture of the Indian short finned eel in a few selected centres in Tamil Nadu coast. This new venture is bound to open up greater opportunities for the diversification of activities of sea food industry in India.

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Part III

GIANT FRESHWATER PRAWN

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THE GIANT FRESHWATER PRAWN

BIOLOGY, SEED PRODUCTION & FARMING

INTRODUCTION

Freshwater prawns of the genus, *Macrobrachium* are distributed througout the tropical and subtropical regions of the world and more than 25 species are listed under this genus from Indian waters. Among them the following ten species are considered commercially important since they support atleast a subsistence fishery in one part of the Country or the other. They are *Macrobrachium rosenbergii* (de Man), *M. malcomsonii* (H.M. Edwards), *M. choprai* (Tiwari), *M. idella* (Hilgendorf), *M. rude* (Heller), *M. equidens* (Dana), *M. idae* (Heller), *M. scabriculum* (Heller), *M. mirabile* (Kemp) and *M. lamarrei* (H. Milne Edwards). Of these, the first three species are considered candidate species for aquaculture in India. However, the most important species of them all from the point of commercial aquaculture is the giant, long-legged river prawn, *M. rosenbergii*. This species is by far the most extensively distributed one, indigenous to South and South East Asia, parts of Oceania and some Pacific Islands. *M. rosenbergii* is the best species for aquaculture since it can be grown in both fresh and low saline waters, is compatible for polyculture, omnivorous and hardy, has the maximum growth potential among the cultured prawns, has no serious problems of diseases and has good consumer preference and demand in the local as well as export markets. Possibly because of the above qualities and its aquaculture potential, the species was introduced from its native places to the other parts of the world. *M. rosenbergii* is now farmed in commercial quantities in many countries like USA, Honduras, Mauritius, Taiwan, Thailand, Brazil, Colombia, Ecuador, French Overseas Territories, Malaysia and Mexico, and farms are now being established in many other countries including India.

According to assessments made by New (1990), the global production of this species through culture is of the order of 27,065 mt in 1987/88.

Table 1. *M. rosenbergii* production through aquacuture from different countries (1984-1990)*

Sl. No.	Country	1984 mt	1985 mt	1986 mt	1987 mt	1988 mt	1989 mt	1990 mt
1.	Brazil	400	400	400	500	600	700	1000
2.	Colombia	5	1	1	1	3	50	60
3.	Costa Rica	2	4	4	6	7	7	7
4.	Dominican Rp	50	100	100	120	100	50	50
5.	Ecuador	—	—	—	745	764	806	849
6.	Fiji	0	0	0	0	0	1	2
7.	Fr. Guiana	2	15	36	71	63	89	83
8.	Fr. Polynesia	13	14	13	17	20	20	18
9.	France	—	—	187	192	195	280	280
10.	Guadeloupe	40	31	35	40	42	44	42
11.	Guam	2	0	0	0	0	0	0
12.	Guatemala	—	5	4	12	10	8	10
13.	Honduras	27	18	7	10	5	0	0
14.	India	—	—	—	—	—	150	198
15.	Israel	25	25	18	3	3	3	3
16.	Jamaica	15	15	19	20	30	30	30
17.	Japan	24	33	39	55	46	50	50
18.	Malawi	4	5	6	8	6	6	6
19.	Malaysia	67	84	79	5	68	128	137
20.	Martinique	47	35	50	53	52	57	49
21.	Mauritius	23	25	27	48	48	50	42
22.	Mexico	325	325	350	361	410	353	201
23.	Myanmar	7	10	8	6	5	4	3
24.	New Caledonia	—	—	—	1	1	1	0
25.	Panama	3	5	16	7	11	5	6
26.	Peru	3	—	—	18	18	10	10
27.	Puerto Rico	—	—	—	97	76	76	50
28.	Reunion	—	4	6	7	3	2	2
29.	Solomon Is	28	0	0	0	0	0	0
30.	Thailand	3103	2457	4507	11839	11837	7949	8000
31.	USA	144	131	81	91	130	159	184
32.	Venezuela	—	—	—	1	1	1	1
33.	Zimbabwe	6	9	10	12	13	13	15
34.	Others, not included elsewhere	1315	697	1382	1354	4355	6725	11607
	Species total	5657	4448	7385	15700	18922	17827	22995

*Source : FAO Fisheries Circular No. 815 Rev. 4. FAO, Rome, June 1992.

The major countries and their contribution of *M. rosenbergii* through auaculture during the years 1984 to 1990, as estimated by FAO, are furnished in Table 1. It can be seen that the world production of *M. rosenbergii* through culture is showing a somewhat steady increase from an estimated 5657 mt in 1984 to 22, 995 mt in 1990 (FAO, 1992).

Thailand is the major producer of *M. rosenbergii* through farming with an annual production of 11839 t in 1987. The development of *M. rosenbergii* farming has been rather quick and remarkable. In 1976 the production through aquaculture was only 3 mt/yr, which increased to 80 mt/yr in 1979, to more than 300 mt in 1984 and 4500 mt in 1986 and showed a sudden increase to about 12,000 mt in 1987. Unofficial estimates place production at 18,000 mt in 1987. The other country which showed a remarkable development is Taiwan which produced 65 mt in 1979 and increased the production to 3500 mt by 1986 and 4500 mt by 1988. Vietnam's farmed production is almost entirely from extensive, wild stocked ponds. In Hawaii, a production of 118 mt was achieved in 1981 but due to other constraints further growth was hampered. The development of *Macrobrachium* farming in the Latin American Countries and the French Overseas Territories with French know-how has been quite remarkable. These developments have taken place during the last one decade, and the major contributing factor has been the development of a technology for the hatchery production of seed. Farming of the species in countries like India and Bangladesh lagged behind since they relied more on collection of juveniles from the wild for stocking ponds rather than establishing hatcheries for seed production.

Following Ling's success with completing the larval cycle of *M. rosenbergii* in Malaysia, attempts at artificial seed production were made in India during 1963-65 by Rao (1965) at CIFRI, Barrackpore and by the Department of Fisheries of Kerala at its Edathua Research Station during 1966-69. Eventhough post-larval settlement were obtained at Edathua, the technology was not considered at that time to be sound enough for commercial application. The CIFRI at its Kakinada Research Station (now CIFA) completed the larval cycle first in1975 and evolved a technology for larval rearing using fine choppings of Tubifex worms as the main larval feed. Intesive cultivation of Tubifex worms was found to be cumbersome and the technology did not take off as a commercial proposition. Joseph (1978) undertook seed production and polyculture in outdoor tanks in Kerala and Dwivedi *et al.* (1983) set up a pilot hatchery mainly depending on Artemia, cultured zooplankton and egg custard, as the larval feed. Meanwhile, Alikunhi and Ali (1984) set up a pilot hatchery at Azhikode, Kerala, where cultured zooplankton was used as the main larval feed. The experiments conducted at the Fisheries College, Cochin since 1987 resulted in a cost-effective technology using suspended particles of shrimp/clam meat with egg as the major feed. Repeated success could be obtained and the technology was later upgraded for commercial production of seed of *M. rosenbergii*.

The development of a low-cost technology of *Macrobrachium* seed production and subsequent establishment of a few hatcheries in the public as well as private sectors, the increase in research on prawn cultue and nutrition, the production of extension literature, the conduct of a National Symposium on *Macrobrachium* spp., the training offered on seed production to farmers, entrepreneurs, officials and teachers, and the extension of subsidy by the Government for freshwater prawn farming as well as for establishment of hatcheries have given a real fillip to *Macrobrachium* culture and seed production in India. Requests are being received from farmers and entrepreneurs from coastal States, near and far, for the transfer of technology as well as for supply of seed. It is hoped that the information on the species, its culture and seed production contained herein will be useful to the farmers and entrepreneurs entering this new and emerging field of freshwater prawn aquaculture.

BIOLOGY

i. Distribution

In India, *Macrobrachium rosenbergii* is common in the lower reaches of Narmada and Tapti rivers, Thana creek and backwaters and adjoining rivers of Kerala along the west cosast and in nearly all the upper tidal zones and associated areas of rivers draining into the Bay of Bengal. Adults are found in rivers, lakes, swamps, canals and inundated fields. Ecological parameters limiting distribution are 15° to 34°C temperature range, and 0 to 25 ppt salinity for adults and 6 to 15 ppt for larvae and junveniles.

ii. Food & Feeding

The larvae feed on zooplankton. The juveniles and adults are omnivorous. A variety of food items of both plant and animal origin as well as detritus are ingested. Analysis of digestive enzymes have confirmed its omnivorous nature. Nutritional studies have further shown that the relatively low protein requirements can be met by vegetable protein. Lipid requirements are low, but Macrobrachium cannot synthesize enough sterols and poly unsaturated long-chain fatty acids to cover its needs and these should come from its diet. The first pair of chelipeds (claw-legs) is the chief organ for food capture, but the second pair also assists if the pieces are large or when live food is captured. Young one measuring 5 to 10 cm are voracious eaters. Older individuals are more cautious and slower in taking food. Females with mature ovaries seldom take food; however, berried individuals are found to take food normally.

iii. Growth

Rate of growth varies with temperature and other water quality parameters and with the nature and availablility of food. One estimate shows that at an age of 10-11 months, males may reach 60-80 g and females 35-40g. Panicker and Kadri (1981) reports a growth of upto 100 g in stagnant earthen ponds in 9 months and upto 120 g in 7 months in cement ponds supplied with running water.

iv. Breeding

With the onset of sexual maturity males become aggressive in the acquisition of territories, each large male attacking with its claws the smaller males coming into its territory. Such areas around a refuge are sought out by moulting females. Mature male prawns are considerably larger than females and the second pair of walking legs are much larger and thicker. In both sexes these legs are of equal length and clawed. In the male, the genital pores are between the bases of the fifth walking legs, while those of the female are at the base of the third walking legs.

The breeding season is found to vary in the different river systems. The spawning season in Kerala is reported to be from July-August to January-February with peak in October-November. It performs a spawning migration from its original freshwater habitat to estuarine regions and spawns in areas where salinity fluctuates from 5 to 20 ppt. Mating takes place a few hours after the female performs a premating moult. The hard-shelled male deposits the sperms in a gelatinous mass on the ventral median thoracic region of the soft-shelled female. Extrusion of eggs takes place generally within 24 hours after premating moult. Unmated females also release the eggs within 24 hours of premating moult but these eggs would drop off witin 2-3 days. It is believed that in nature the female may spawn 3 or 4 times a year producing about 1-2 lakhs eggs, but the fecundity may vary according to the size of the female and may be more in the wild stock. The females carry the eggs in the brood pouch beneath the abdomen formed by the long pleurae of the abdominal segments and the first four pairs of pleopods and are held in place by a thin membrane between the pleurae. Vigorous aeration is provided by the female prawn with movement of her pleopods throughout the incubation period. Incubation usually requires about 19-20 days at 25-32°C. From about the 12th day the colour of the bright orange eggs begins to fade to a pale grey, and further darkens to slate grey by the time of hatching. Dead eggs and extraneous materials are carefully removed by means of the first pair of chelate legs during incubation.

v. Embryonic Development

The eggs are slightly elliptical in shape. They measure 0.6 to 0.7 mm on the long axis. During the incubation period the fertilized eggs undergo cleavage. The first cleavage takes place at about four hours after fertilization. Subsequent divisions are at about 1 $^{1}/_{2}$ hours interval. However, the interval time for successive cleavages decreases. The body rudiments in the embryo are formed on the third day. On the fourth day the buds of appendages appear. The optic vesicles make their appearance on the 7th day, the eye pigmets on the following day and the heart beats by the 10th day. By the 12th day a well-developed embryo results in which the organogeny is almost completed. In the following days further development and elaboration of parts continue till hatching.

Hatching usually takes place at night hours. Hatching starts with slow but continuous vibrations of mouth part of the embryo. This is followed by the stretching of the body. As a result, the egg elongates. Thoracic appendages are also seen vibrating but only at an interval of about 10 minutes. As a consequence of egg elongaton, the telson, till now covering the eye and head, pushes outwards and breaks the shell. Telson comes out first followed by the head. With a forceful flexion and stretching, the entire larva springs out of the shell. Immediately the larva settles down and remains motionless for sometime. The larva at this state is known as 'prezoea'. After about 5-10 minutes the larva comes up and transforms into Zoea and is planktonic.

Hatching is normally completed within one or two nights. The larvae are dispersed by rapid movements of the abdominal appendages of the parent.

vi. Larval Development

Eleven larval stages have been recognized which last for about 16 to 45 days depending on the temperature, water quality and food. The first hatched larvae are about 2mm long and are planktonic, active tail-first swimmers. They pass through 10 more stages to reach the post-larval stage. The first stage is non-feeding and subsists on the reserved yolk material. On the second day, when metamorphosed to the II stage it starts feeding. Each subsequent stage is completed in 2 days. The optimum salinity is 14± 2 ppt and temperature 26-31°C. Temperature below 24°C and above 33°C cause retarded development and mortality. Sudden change in temperature more than 1°C is also not favoured by the larvae. Other desirable water quality parameters are pH 7.0-8.5, maximum nitrite (NO_2 - N) and nitrate (NO_3 - N) levels of 0.1 ppm and 20 ppm respectively, maximum total hardness of 100 ppm ($CaCO_3$), and low iron and manganese contents. Salient features of these larval stages are briefly given in Table 2.

Table 2. Salient features of larval stages of *M. resengergi*

Larval stages	Age (No. of days	Size (mm)	Prominent
I	9(0-2)	1.93	Eyes sessile; Telson triangular, fan shaped, 7 pairs of spines; uropods absent
II	2(2-3)	1.99	Eyes stalked; Telson triangular, carrying 8 pairs of spines; uropods absent
III	4(3-5)	2.14	Uropods present (exopodite with 6 spines, endopodite bare)
IV	7(5-9)	2.50	Telson oblong, almost rectangular, carrying 6 pairs of spines; uropods with spines on both exopodite and endopodite; Two dorsal teeth on rostrum.
V	10(9-12)	2.80	Telson with posterior margin narrower that the base; number of spines on uropods increased; red, blue and yellowish chromatophores on 2nd thoracic leg.
VI	14(12-18	3.75	Buds of pleopods appear; chromatophore mass on mid-ventral abdominal region present.
VII	17(15-20)	4.06	Pleopods biramous but bare; chromato - phore mass on mid-ventral abdominal region very prominent.
VIII	20(18-22)	4.68	Pleopods fully developed with setae.
IX	24(21-29)	6.07	Ist and 2nd thoracic legs chelate; Endopods of pleopods with appendix interna.
X	28(25-34)	7.05	Rostrum with 3-4 small teetch on its upper margin.
XI	31(28-37)	7.73	Rostrum teethed on half ot its upper margin.
XII	36(36-43)	7.69	Larvae fully grown at this stage and are ready to transform into juveniles.

Post-larva:

At this stage it resembles miniature juvenile except for the under-development of body parts. Rostrum with 11 teeth on the upperside and 5 ventral teeth. Exopod of 3rd maxilliped reduced but with setae. All exopods of the thoracic appendages become rudimentary. After a few moults they transform into juveniles and are transparent.

Larvae are active swimmers and planktonic in habit. They are phototactic but direct and strong light is avoided. It swims by tail up, head down and ventral side upward at an oblique angle. Upto 5th stage there is a schooling behaviour and swim in swarms. From 6th stage onwards, larvae tend to disperse. They spend most of their time at the surface and mid-column water, but settle down to bottom during moulting time.

Postlarvae and juveniles are crawlers and settle to the bottom or cling to the sides. There are 6 to 8 horizontal black bands, prominently present on the carapace at this stage. Juveniles migrate back to freshwaters and grow into adults.

SEED PRODUCTION

i. Site selection & facilities

The following requirements are seen identified by New & Singholka (1985) while selecting a site for the establishment of a *Macrobrachium* hatchery. Sufficient salt water and freshwater should be available so that the required quantity of 12 ppt brackishwater could be produced. On an average a hatchery of 50 m^3 larval rearing tank capacity may require 20-30 m^3 of 12 ppt water per day. However, the water requirement could be much reduced if biofilters are used. Artificial seawater could be prepared and used in sites remote from the sea. Electrical power supply should be ensured and a diesel generator set should be provided as a standby. The site should have good road access and the intended grow-out farms should be accessible within 16 hours. Optimum water temperature range should be around 28-30°C. Nearness to Governmental laboratories, access to food supplies for larvae and availability of skilled and trained staff would give additional advantage. A small water and soil testing laboratory, micro-scopes, feed mill unit, oil-free air-compressor/roots air blower with air supply channels, water supply and drainage systems, electrical and diesel pumps, hatchery tanks with biofilters, nursery tanks, shed with translucent roofing sheets to accommodate the tanks, breeder stock ponds etc. would be required.

ii. Selection & maintenance of breeders

In farms where *M. rosenbergii* farming is established, the berried females can be collected from farm ponds by cast netting or can be more easily obtained at the time of partial or total harvest. This is a more reliable source of berried females than from natural wild collections. Normally, a *M. rosenbergii* hatchery should have its own brood stock production ponds or should be in close liaison with the owners of the production ponds.

For hatchery purpose, the berried female should be selected carefully. Females which are obviously healthy and active, well pigmented and carrying large egg masses should be chosen. Larger the females, more are the number of eggs carried usually.

Depending on the volume of the larval tank and on the number of eggs carried by the females, the number of berried females required to be stocked in the larval tank can be estimated. A rough guide often used is to assume that 1000 larvae are produced from each 1 g of berried female weight. Berried females of 10-12 cm (rostrum to telson) normally carry about, 10,000 - 30,000 eggs each. There can be loss of eggs through physical damage and adult consumption during transportation of the female. At times, some of the eggs may fail to hatch. Taking into account all these possible losses of the eggs, it is recommended to introduce three berried females of the above size range in 1 m^3 larval tank. It is essential to select all the females in the same stage of ripeness. While doing this, females whose eggs are grey or black in colour, and not orange should be selected, because these eggs will hatch within 2-3 days. Thus it can be ensured that the larval tank contains larvae of more or less the same age (within 1-3 days), thereby reducing cannibalism and easing the feeding operations.

If the brood stock production ponds are adjacent to the hatchery, the berried females can be transported in buckets of water. Where long distance travel is involved, the berried females should be transported in oxygenated plastic bags filled with 1/3 water and 2/3 oxygen. Small bags containing only one animal and transported in darkness will reduce egg losses during transportation. Utmost care should be taken while catching, handling and transporting the berried female to minimise egg loss and damage.

On reaching the hatchery, the berried females should be disinfected by placing them in aerated freshwater containing 0.2 - 0.5 ppm copper sulphate or 15 - 20 ppm of formalin for about 30 minutes as a quarantine procedure. After this treatement, they are transferred to clean larval tank kept ready. Feeding should be done, according to the demand of the berried females. Care should be taken not to overfeed them, so that the water is not polluted. More often, berried females are not fed at all during the 2-3 days prior to egg hatching. Soon after the eggs hatch out, the spent females should be removed from the larval tank with a scoop net.

iii. Larval rearing system

The techniques of larval rearing of *M. rosenbergii* underwent considerable refinement and improvement since early 1960s and commercial level scaling up has been achieved in several countries. The systemes that are prevalent today can be basically divided into two categories, i.e. (1) the "green water" system and (2) the "clear water" system. It was Fujimura (1966) wo has standardized the method of production of postlarvae by using "green water" system. This method is still used in many hatcheries in Indonesia and Hawaii. The clear-water system which is an improvement over the green water system had undergone various modifications and include static or open clear water and closed or semi-closed recirculating water system. A modified static green water system is developed in Malayasia. Synthetic sea water is also used successfully by several hatcheries.

1. Green-water system:

This system is prevalent in Indonesia, Malaysia and Hawaii. The green-water is a mixed phytoplankton culture in which *Chlorella* sp. is the most dominant one. The tanks are fertilized with triple superphosphate and inoculated with *Chlorella* sp. The fertilizer is added to the tanks atleast once per week to maintain the culture. Male tilapia, *Oreochromis mossambicus* having 8-12 cm in total length (80 nos. in 5000 litre tank) are introduced to graze on and to control the filamentous algae. Copper sulphate at a rate of 0.6 ppm is added to the green water to control rotifers. The green water is prepared at 12 ppt salinity and used as replacement water instead of plain brackish water. The "green water" cultures of more than 3 days old are not used.

The production of PL in this system remains low, it being 19 PL/1 with an initial stocking density of 37 larvae/1 in Malaysia, where feeding is done with steamed egg custard (prepared by mixing hen's egg with milk powder and fortified with a vitamin premix) 3 times a day followed with a final feed of artemia nauplii. In Jepara, Indonesia where the green water system is used, when fed with formulated feed alone, at an average stocking density of 21.7 larvae/1, a survival of 19.1% was obtained whereas with formulated feed and artemia nauplii, the survival has gone upto 53.7% when stocked at a rate of 13.4 larvae/1.

2. Clearwater system

The clearwater system of larval rearing is now used in most of the hatcheries owing to the fact that the larvae can be reared in higher densities and that the necessity of maintaining phytoplankton cultures could be dispensed with. However, in this system atleast partial removal of the medium or recycling the water through biofilters and thorough cleaning of bottom of the tanks on a daily basis are required besides the use of antibiotics, to ensure high survival rate. This system has several modifications :

(a) Flow-through or'open' system

In areas where good quality water is available in sufficient quantities, static clearwater system is practised daily replacing the entire or major portion of water in the larval tanks.

Cylindronconical tanks used experimentally for the rearing of *Macrobrachium* larvae are found to be very efficient and convenient for the rearing of larvae. Cylindroconical tanks have the advantage that food particles together with the larvae could be circulated evenly over the whole water volume so that the larvae have more chance to catch the food. In an experiment done at Jakarta using this type of tanks of 50 and 500 litre capacity, it was found that the stocking density of the larvae could be substantially increased when the water is replaced daily. Using 50 litre tanks at a stocking density of 100 nos./1 an average production of 80 nos./1 was obtained within 42 days. At a higher stocking density of 200/1 the average production per litre worked out to 131 nos./1 within 39 days. Using 500 litre tanks with a density of 100 nos./1 an average of 61 PL per litre was obtained within 42 days, and with 200 nos./1, 111 nos. of PL were obtained within 42 days suggesting that for commercial scale production a stocking density of 200 nos./1 could be used, if such cylindroconical tanks are installed.

(b) Recirculation system or closed or semi-closed system

This technique reduces the water consumption of a hatchery considerably. In its simplest form it consists of recirculating the larval tank water through a graded sand gravel filter or biofilter. This system is adopted in many of the hatcheries in Thailand. The tanks used for the larval rearing as well as for setting the bioflters can be rectangular cement cisterns. In Malacca, this type of closed recirculating clearwater rearing system had been set up using twin concrete tanks, one funtioning as larval tank and the other as a biological filter. The substrate used for the filter there consisted of cockle shells. Water from the larval tank is transferred using theree air lift pumps to the filter, the rate of flow being regulated to approximately 2 litres/min/pump. This enabled the water to pass through the filter bed atleast 8 times a day. To prevent the larvae from being air-lifted to the filter bed, the suction ends are covered with a phytoplankton net screen. After passing through the filter bed, the water is airlifted back to the larval tank.

Using 300 litre capacity cylindrical fibre glass tanks with conical bottom and synthetic seawater a hatchery is being operated at South Carolina. M/s. Royal Hatchery, Thevara, Kerala use raw sea salt for the preparation of salt water for their hatcheries. The synthetic seawater prepared is continuously recirculated through the larval tanks and biofilter. Brackishwater of 12 ppt salinity required for larval culture could be prepared by dissolving commercial grade common salt (9.4 g), Magnesium chloride (1.9 g), Sodium sulphate (1.56 g), Calcium chloride (0.44 g), Potassium chloride (0.26 g), Sodium bicarbonate (0.908 g), Potassium bromide (0.04 g) and Boric acid (0.001 g) in one litre of ordinary water. On using this prepared salt water for larval culture, no significant difference in the percentage survival, production, moulting frequency, duration of rearing, growth etc. was noticed.

The advantage of "clear water" rearing over "green water" technique are (1) no phytoplankton culture is to be maintained (2) the larvae could be reared in higher densities (100-110/1 as against 25-40/1) (3) the rearing tanks need be smaller in size and can be easily handled, (4) the yield of postlarvae/unit volume of rearing medium is higher (50/1 against 10-15/1) and (4) observation of larval behaviour, feeding activity, extent of mortality, estimation of larval density and postlarval settlement etc. are possible at any time. However, "clear water" rearing required larger quantity of the medium because of the need for daily change of water, which however, could be minimised with the introduction of biofilters.

iv. Status of seed production

About two decades after the pioneering attempts of the State Department of Fisheries of Kerala at Edathua, the College of Fisheries under the Kerala Agricultural University took up this work at Panangad, Cochin.

An integrated approach was taken and the emphasis was on developing a low-cost technology. A technically feasible and economically viable technology for *Macrobrachium* seed production is developed which relies on the inclusion of an effective biofilter in a clear water recirculation system, the supply of particulate wet diets or tissue suspensions with one time a day of Artemia, the continuous aeration of the medium and the daily cleaning of the hatchery tanks. The technology has been widely accepted and six commercial hatcheries on the private sector and two in the Government sector have already started seed production and sales.

At the Fisheries College hatchery, Panangad, 1 tonne capacity oval and 1.5 tonne capacity cylindroconical fibre glass tanks are used for the larval rearing. Saline water of 12 ± 2 ppt and a larval density of 90 ± 15 per litre are maintained. Saline water is pumped from the nearby backwaters through an 'in situ' bed filter. According to the salinity regime this water is either diluted by adding filtered freshwater or concentrated by adding sea water. A concrete tank of 300 litre capacilty filled with pebbles and/or corals acts as a biofilter. The filterd water from the bottom chamber of the biofilter is taken to the larval rearing tank through air lifting. The rate of flow is regulated to enable the entire water to pass through the filter bed atleast 5 times a day. To prevent the larvae and food particles from being siphoned into the filter, the inlet of the siphon is kept inside a frame covered with 200 micron filter cloth. The tanks are kept inside a shed roofed partially with translucent FRP sheet to allow moderate light inside. Air from a 5 HP autostop pressure adjusted oil-free air-compressor is channelled through P.V.C. pipes and diffusion stones for continuous aeraton. Oil free roots air blowers are reported to be better than air compressors to supply air to the hatchery, for it gives high volume, low pressure, uncontaminated air which is required. The high pressure provided by an air compressor is not required. But in the College an air compressor with pressure switch and auto stop and start is used to get continuous supply of air without continuous working of the machine.

Feeding is done at 3 hourly intervals during day time ad libitum with prepared feed. Thelly meat (*Metapenaeus dobsoni*) and hen's egg (1 kg meat plus 5 eggs) are blended in a mixer grinder, coagulated by gentle cooking and particulated by passing through superimposed standard test sieves of appropriate size. For the first 4 stages particle size of 300-400 micron, V to VIII stages 400-600 micron, and IX to XI stages 600-1000 microns are used. Newly hatched brine shrimp nauplii are fed at 3 Nos./ml only once in the evening. The bottom of the tanks are cleaned daily in the evening before feeding with brine shrimp nauplii.

v. Culture of Live Feed

a. Culture of Brine Shrimp

The brine shrimp, *Artemia* is the best live feed due to its high protein content (65%) and the character of the cyst retaining its viability of hatchling for longer duration. It is a cosmopolitan inhabitant of coastal salt pans and inland salt lakes and in India it naturally occurs in Tuticorin, Bombay Sambhar lake and Gulf of Kutch. Artemia cysts are collected from the natural habitat and marketed at a cost of about Rs. 700/kg by M/s. Tata Chemicals, Gujarat and at Rs. 1250/kg by M/s. Ballarpur Industries, Gujarat. Imported cysts which give good hatchability are available for US $25-35 per kg. If quantities over 100 kg are purchased usually the prices will be around US $ 20/kg only.

Dried Artemia cysts are biconcave in shape and 300 microns in length. Upon immersion in seawater, the biconcave cyst hydrates, become spherical and within the shell the embryonic metabolism is resumed. After 15-24 hrs the cyst shell bursts (breaking stage) and the embryo appears, surrounded by the hatching membrane. Within a few hours the embryo leaves the cyst shell completely and hangs underneath the empty cyst shell to which it is still attached (umbrella stage). Within a few hours the hatching membrane ruptures and the free swimming nauplius is born. When hatched, the first instar will be brownish orange and 400-500 microns in size.

Before keeping the cysts for hatching, they have to be preferably incubated for 24 hrs in 40°C to remove the moisture content, if present; and then subjected to light which activates the triggering effect and increases the hatching rate. Transparent cylindroconical tanks (FRP tanks in original colour or perspex tanks) with efficient aeration are preferred for hatching. The tanks are filled with seawater of required salinity as specified in the packing container of the cyst. Bio-Marine brand supplied by M/s. Aquafauna, gives good hatching at 10 ppt salinity, Argentemia brand at 40 ppt, etc. As required, the seawater is diluted with freshwater or concentrated by adding common salt. Salt solution prepared by adding required salts to freshwater also gives good hatching as seawater. The water should be aerated vigorously by providing an aeration point (diffusion stone) at the bottom centre of the cylindro-conical tank. The cysts should remain in a floating condition. Temperature of 28-30°C and pH above 8.4 gives maximum hatching. Continuous illumination of light over the hatching media decreases the hatching period and increases the hatching rate. After 20 to 30 hrs, when hatching is completed the aeration is stopped and the nauplii are concentrated by focussing light at one corner. The nauplii are then siphoned out to another container, filtered in a bolting cloth, washed several times in clear fresh or salt water and introduced into the *Macrobrachium* larval rearing tank.

Decapsulation of Artemia cyst

If the separation process of nauplii from unhatched cysts and broken shells is not perfect, they may also be ingested by the *Macrobrachium* larvae, causing blockage of gut and indigestion problems. This may also increase the chances of bacterial infection in the culture.

Decapsulation is a technique of dissolving the outer chorion of the cyst without affecting the viability of the embryo inside it. Dry cysts are kept under the light of a 60 W bulb for 15 minutes and the triggering effect of light increases the hatching efficiency. The cysts are then hydrated in freshwater or seawater in a funnel shaped container with aeration. After one hour, the cysts are filtered and transferred to another container into which equal volume of commercial grade sodium hypochlorite and water (tap or sea water) are added and stirred continuously for 3-10 minutes. The chorion gets dissolved and the colour of the cyst changes to brownish orange. It is then filtered and washed thoroughly to remove the traces of hypochlorite present and then put for hatching. The decapsulated cyst hatch out within 12 hours. The decapsulated cyst as such is used in some cases as a direct feed.

b. Mass culture of Cladocera

Cladocerans of the genera *Daphnia* and *Moina* have been used as live feed in rearing *Macrobrachium* larvae. Their hardiness, filter feeding habit, high rate of reproduction through parthenogenesis and ready acceptance by a wide variety of fish and postlarval crustaceans, make these animals eminently suitable for culturing on a large scale as live feed organisms. A simple method of culturing Moina on a large scale has been evolved.

Moinā micrura Kurz, was isolated from the ponds of the Fisheries College when the salinity was less than 2 ppt. A stock culture is built up starting from a single parthenogenetic female kept in a 2 litre beaker containing *Chlorella* + *Scenedesmus* water. After 7 days, it has been possible to obtain 10,000 - 15,000 Nos./l of Moina.

Mass culture is obtained in plastic pools or concrete tanks kept outdoors. Freshwater from well or stored tap water is pumped into the pools or tanks and vigorously aerated. The water is fertilized with ground nut oil cake (100 ppm), urea (12 ppm), Super-phosphate (24 ppm) and rice-bran (100 ppm), and well-aerated. Freshly prepared stock culture of Chlorella + Scenedesmus is inoculated. On the second day, after the water becomes slightly greenish, the culture is inoculated with a pure stock culture of adult *Moina* at a stocking density of one animal per litre. Moina grows rapidly feeding on the algal bloom which develops utilizing the added fertilizers and natural sunlight and attains a concentration of 10,000 to 15,000 Nos/l in 7-9 days. At this stage $^1/_3$ volume can be harvested and replaced with freshwater containing proportionate amounts of the above fertilizers, or by Chlorella + Scenedesmus water cultured in a separate tank using the same fertilizers. If the latter method is followed $^1/_3$ of the culture volume can be harvested every day.

After obtaining a peak of production by 7-9th day, the population declines. Subsequently ephippium develops in majority of the brood females which in turn heralds the decline of the population. In the event of decline of Moina population half the volume of water is replaced by Chlorella + Scenedesmus water. The Moina culture revives in a few days and continuity of culture is maintained for over 3 months.

Harvesting is done in exponential growth phase by skimming the surface water with a plankton net during morning hours when they swarm at the surface. They are washed in freshwater, mixed with equal volume of 10% glycerol and frozen in a deep freezer into blocks.

Resting eggs can be collected from the bottom of the culture containers and stored in dry conditions at room temperature for 2-3 weeks without loss of viability. Fresh culture can be started by keeping the dry resting eggs in well aerated green water (Chlorella + Scenedesmus). Parthenogenetic females hatch out from the resting eggs within 48 hours. Moina grown on yeast or commercial single cell proteins, are deficient in PUFA and are therefore inferior as feed for the fish larvae. On the other hand, Moina fed with fresh algal cultures are nutritionally adequate.

vi. Prepared Larval Feed

In order to develop a successful compounded larval feed for *M. rosenbergii*, a clear and thorough knowledge of the larval nutrition is essential. In recent years some studies have been carried out to understand the nutritional requirements of *M. rosenbergii* with diets of different protein, carbohydrate, lipid, mineral and vitamin composition. Most of these studies relate to the nutritional requirements of juveniles and sub-adults, the information on nutritional requirements of larvae being very scarce.

Protein and amino acid requirements

Numerous studies have been reported on growth rates, feed efficiencies, etc. of various crustaceans fed different levels of dietary protein. It would appear that there is still considerable uncertainty as to the prawn's quantitative requirement of dietary protein. At one extreme there are those studies which suggest increased growth rates and efficiencies with increased protein even at levels in excess of 50% of the diet. At the other extreme are the studies suggesting that optimal dietary protein levels are more in the range of 29 to 30%. In this latter category, several of the reports show no additional growth response at the higher levels and in some instances indicate decreased growth rates/efficiencies when protein exceeds 40% of the diet. Possibly the combination of high dietary protein in the presence of low levels of non-protein energy may force the crustaceans to deaminate significant portions of the protein thus yielding the carbon fragments required for cellular energy metabolism. As a result of this altered metabolism, the animal could be expected to show reduced growth rates and efficiencies. For maximum growth and performance protein concentrations of 34-35% is required by the post larvae and 28-30% by the juveniles of *M. rosenbergii*. Best growth of the post-larvae was obtained when protein from animal and plant sources were included in the diet in 3:1 ratio. When evaluating the reliability of such recommendations, some caution should be exercised since there are numerous factors, which are not strictly of dietary nature which can interfere with or even cancel the free response of an organism to dietary protein. For instance, the experimental conditions under which a feeding study is conducted could have a significant bearing on final results, especially if one considers variables such as water temperature, salinity, D.O. levels, dissolved organics/harmful metabolites, biomass densities, potential space restrictions of the holding systems, length of the study and others. The growth stage of the prawn and its physical state are also highly influential on growth rates and efficiencies.

Beyond the actual levels of protein under investigation, we learn from studies with domestic animals that requirements are often affected by the quality (aminoacid composition) of the offered protein as well as its digestibility by the animal. The sparing action of one nutrient over another (i.e. protein versus energy) should also be considered. The effects of nutrient imbalance on protein utilization must be evaluated to ensure that excess or deficiencies of other dietary nutrients do not interfere with the animal's response to the dietary protein. The physical characteristics of experimental diets have a direct bearing on consumption rates and digestibility of ingested food. These characteristics include stability, form, texture, size, density and palatability.

Experiments in penaeid prawns have shown that they required 10 amino acids such as Arginine, Histidine, Leucine, Isoleucine, Lysine, Methionine, Phenylalanine, Threonine, Tryptophan and Valine. Experiments conducted in *M. rosenbergii* have revealed that it has qualitative requirements for the same amino acids except for lysine. However, in yet another experiment a tentative requirement was established for lysine (1.4% of the diet) in *M. rosenbergii*. Except these studies qualitative amino acid requirements for prawns remain undefined.

Energy :

Based on respiration data it has been shown that the calorific requirement of *M. rosenbergii* larvae is seven times higher than that of juvenile prawns. This higher energy requirement of the larval stages may reflect their perpetual swimming habit and activity associated with food gathering as well as their extremely rapid development.

Calorific comparisons were made to assess larval growth of *M. rosenbergii* fed different forms of various experimental diets. Six artificial feeds were prepared in three forms (freeze dried, flake and gep) and fed to stage 7-8 *M. rosenbergii* larvae under laboratory conditions. Results showed highest energy assimilations when diets in the freeze-dried form were fed.

Carbohydrates

Unlike fish, crustaceans show limited ability to tolerate monosaccharides like glucose in their diet. It is observed that disaccharides such as sucrose and maltose, and polysaccharides such as wheat starch, corn starch, potato starch, oyster glycogen and dextrin can be utilized more efficiently than simple sugars. Incorporation of polysaccharides at levels between 30 and 40% of the dry diet is most common in crustacean diets. However, extensive research is required to define the carbohydrate requirement of *M. rosenbergii* at various stages of growth and development.

Lipid

Unlike fish there is rather convincing evidence that crustaceans cannot tolerate high level of dietary fat. Essential fatty acids of linolenic series have greater value to marine crustaceans, while the freshwater crustaceans require more linoleic series or a mixture of both. A dietary requirement of 1 to 2% linolenic acids is indicated in the diet of prawns.

The quantitative and qualitative requirements for an exogenous source of sterols in artificial diets for marine crustaceans have been studied since the early 1970's. Reported levels required by larval and juvenile *P. japonicus* range from 0.1 to 0.2% and 0.5 to 1.2%. The absolute requirement of cholesterol by *M. rosenbergii* is still unconfirmed.

Lecithin at levels between 0 and 10% of the diet has, however, proved unnecessary in purified diets containing 1% supplemental cholesterol when fed to post larval *M. rosenbergii*. It was shown that there is no advantage conferred by supplementing cholesterol and/or lecithin to the basal diet (containing 0.12% endogenous cholesterol and 0.048% total phospholipids) formulated for *M. rosenbergii*. However, a trend towards the enhancement of growth rates was noticed when supplemented lecithin was increased from 0 to 5% at 0.5 and 1% levels of supplementary cholesterol. This trend was reversed when cholesterol was absent.

The qualitative and quantitative vitamin and mineral requirements of *M. rosenbergii* are yet to be assessed.

vii. Water quality management

Success in hatchery production of prawn seed largely depends on the water quality management. In hatchery, the quality of water is likely to be deteriorated mainly due to (i) accumulation of metabolic wastes of living biomass (ii) decomposition of unutilised feed and (iii) decay of biotic materials. Various methods have been developed to identify and quantify most of the undesirable chemical constituents in water; very often it is difficult to remove all of these substances efficiently from the hatchery system. Standardisation of water quality for achieving successful hatchery production would go a long way in commercial production of prawn seed.

Among the many parameters prescribed, some characteristics viz., pH, alkalinity, temperature, dissolved oxygen and salinity can be considered as gross and primary water quality parameters. These factors, if controlled within the safe range would result in the maintenance of many other parameters within the safe level.

Dissolved oxygen

Oxygen dissolved in water is an important factor not only for the respiraton of aquatic organisms, but also to maintain favourable chemical and hygienic environment of the waterbody. It controls many of the oxidation reactions and maintain aerobic condition in water.

A water quality problem seen in culture and hatchery system is oxygen deficiency. Insufficiency of dissolved oxygen may be due to several reasons like insufficient population of plankton causing diminished production of oxygen by way of photosynthesis, overgrowth of plankton followed by over utilisation of oxygen for respiration, decay of plankton and other organic matters like unutilized feed etc. Oxygen deficiency is managed in hatcheries usually by aeration. Accumulation of organic detritus should be avoided by cleaning bottom of the rearing tanks.

Ammonia may be formed by excretion of the organisms or by decay of organic matter. Its effect in water is pH linked. At pH below 8 ammonia may not cause much problem. If ammonia is excess it may be controlled by oxidation and by controlling the pH.

pH

pH is a measure of acid base status, or more precisely the hydrogen ion exponent that denotes the hydrogen ion concentration. Thus pH of an acidic substance will be less than the neutral value of 7 and similarly the value would be more than 7 for alkaline materials. pH of water body would influence the acid base condition of the body fluid of the organism. Extreme pH may cause external damage also. pH slightly greater than 7 is considered good for the prawns because certain salts like bicarbonate are to be present essentially for good growth, reproduction and other physiological activity. Low pH is corrected by adding calculated amount of well-mixed lime water and high pH by concentrated Hydrochloric acid.

Total alkalinity

Total alkalinity denotes the quantity of acid consuming constituents present in water. In natural waters carbonates and bicarbonates are the main alkaline source. These substances should be present in water to support the growth of plankton and also to buffer the pH of water body and body fluid of organism. A maximum total hardness of 100 ppm ($CaCO_3$) with low iron and manganese content are found to be desirable for the larval growth.

Temperature

A temperature of 26-31°C is considered as suitable for the larval growth. Temperatures above 33°C and below 24°C may cause retarded growth and mortality. Sudden fluctuations in temperature are also not considered as desirable for the larvae.

Salinity

Salts present in culture waters can be marine salts and/or salts of terrestrial origin. Marine salts are predominated by chlorides and sulphates while land based salts are usually carbonates and bicarbonates. The quantity of salts and type of salts would affect the survival and growth of organisms. Salinity of 12 to 15 ppt is considered optimum for the larval rearing. This is obtained by mixing freshwater and seawater in the appropriate proportions.

Water treatment

Some of the water quality parameters in the culture and hatchery system are often required to be maintained within the desirable range adopting management techniques.

Usually methods of water quality management practised in hatcheries are (i) exchange (ii) water recirculation with in-situ treatment systems (iii) treatment with certain material including chemicals.

The fresh and sea water collected are mixed in appropriate proportions to get 12‰ saline water. The mixed water if unfiltered and turbid, is allowed to settle in a settling tank for 3 days and the supernatant water is pumped into the treatment tank where it is treated with 5.25% sodium hypochlorite (NaClO) and allowed to precipitate for 5 days; to this 10 ppm Sodium thiosulphate ($Na_2S_2O_35H_2O$) is added and aerated vigorously for one day to remove the residual chlorine. The precipitate is then allowed to settle for one day and the supernatent solution is pumped to the larval rearing tanks. Instead of sodium hypochlorite 25 ppm formalin can also be used for the treatment. The formalin added water is aerated vigorously for 5 days for precipitation. The precipitate is then allowed to settle for one day and the supernatent water is pumped to the larval rearing tanks.

Water exchange is a good method of management of water quality. However, it may be costly and impracticable in certain situations.

Water recirculation system with inbuilt treatment facility is very often employed in modern hatcheries. Biological filters are used as treatment unit in such systems. It consists of an inert material like sand, splint, etc. filed in a container. Depending upon the requirement, the inert material is mixed with other materials like carbon, lime stone, bivalve shells etc.

When water is passed through such a prepared medium a film of micro organisms would develop over the surface of the inert material. If the effluent from hatchery or other system is passed through such active medium, vigorous microbial activity would take place and lead to bio-chemical changes in the dissolved constituents of the water. Thus, the decompossible matter is converted to simple and harmless materials.

In an effluent water sample coming from hatcheries, concentration of ammonia, nitrite and sometimes hydrogen sulphide would be considerable. Such water would not be suitable to use further unless the water is passed through an active biological filter. A prominent reaction taking place in biological filters is oxidation. Ammonia, nitrites and other oxides of nitrogen are oxidised to stable nitrates and sulphides are oxidised to sulphates. Organic compounds are also decomposed to simple products. Thus further consumption of oxygen from water is minimised. There is a chance for dropping of the pH of the effluent water coming from biological filters. In such cases alkaline calcareous substances like lime stone, bivalve shells, corals etc. are incorporated in the filter medium for the purpose of correcting pH. Different types of biological filters are used depending upon the quality requirement of water and design of hatcheries. High pH problem sometimes encountered in hatcheries can be corrected by mixing with calculated amount of hydrochloric acid applied in divided dose. Similarly, low pH and low alkalinity can be corrected by adding well-mixed lime-water. Aeration that is carried out continuously in most of the hatchery systems helps to maintain water quality apart from providing sufficient oxygen for respiration. Air passed through the water would drive away the foul gases such as carbondioxide, ammonia, hydrogen sulphide etc. formed as metabolic wastes.

On an average the PL settlement starts on the 24th day and ends within 10 days. When most of the larvae are settled the salinity is gradually lowered to freshwater over a period of 3 days. The remaining larvae also settle by that time. An average survival of 50% and production of 45 PL/l are obtained.

viii Commercial Seed Production

On a national level at present there are few commercial level public sector and private sector hatcheries working in India. Of these a few are only backyard hatcheries attached to the farmer's house and managed by the family members using artificial sea water. The others are medium sized commercial hatcheries using natural seawater or groundwater, vide Table, 3.

Table 3. Freshwater Prawn hatcheries in India

Name of hatchery	Capacity	Source of Water
I. Backyard		
1. Golden Freshwater Prawn Hatchery, Aiswarya, XLIV/2134, Asoka Road, Kaloor Kochi 682 017.	2 million	Artificial sea water
2. Royal Shrimp Hatchery, Perumbanoor, Thevara, Cochin.	2 million	Artificial sea water
II. Medium size		
(a) Private		
*(1) Aqua Plaza Hatcheries Pvt. Ltd. Beach Road Cherai (P.O.) Ernakulam Dist.	5 million	Sea water
(2) Kuttanad Hatchery, VII/319A, Kottapuram Mill Road, Kundannur, Maradu P.O. Ernakulam	10 million	Brackish water
(3) Rosen Fisheries, Marathakara, Thrissur, Kerala.	10 million	Transported seawater
(4) Ananda Prawn, Hatcherie,s Bhimavaram, Andhra Pradesh.	30 million	Bore water (ground water)
(b) Government Sector		
(1) ADAK Prawn Hatchery (Govt. of Kerala Undertaking) Neendakara, Kollam Kerala.	5 million	Brackishwater

(2)*	Regional Shrimp Hatchery (Govt. of Kerala) Azhikode Jetty P.O. Thrissur Dist., Kerala.	5 million	Brackishwater

* *Multispecies hatcheries (combination hatcheries) mainly concentrating on Penaeid prawn seed production and producing Macrobrachium seed only during the monsoon season (July to November) when the salinity drops in the water sources.*

In addition to these, there are a few number of research orgnisations (Central Institute of Fisheries Education, Bombay; Central Institute of Freshwater Aquaculture, Bhubaneswar; College of Fisheries, Cochin etc.) and training institutes producing Macrobrachium seed as a part of their research/training programmes. There is also a proposal for MPEDA to construct a big Macrobrachium hatchery in West Bengal (WESPARC) with DANIDA assistance.

The estimated total production of *M. rosenbergii* postlarvae in Malayasia amounted to 27.5 million in 1989 of which the public sector contributed 13.5 million and the private sector 14 million. There is a phenomenal growth in production by Govt. hatcheries from 1.5 million in 1983 to about 13.5 million in 1989. In Mauritius a commercial hatchery in the private sector with a capacity to produce 10-13 million postlarvae/yr. established in 1977 caters to the private sector and a Govt. hatchery established in 1982 takes care of the Govt. farms and the marginal farmers. In Brazil, the hatcheries are situated maily near the coast and range from Backyard enterprise to commercial hatcheries capable of producing more than 20 million PL/yr. The clearwater open system is predominant, with a few hatcheries resorting to water recirculation system. The average production is 30,000-40,000 PL/m^2/35 days. Postlarval production rates have been reported to be 10,000-20,000/m^3 in Thailand, 30,000/m^3 in Hawaii and upto 50,000/m^3 in French hatcheries.

FARMING

I. Pond Culture

Traditionally, freshwater prawn farming is practised by collecting juveniles from polders or flooded fields when they are dewatered for paddy cultivation, and stocking them in bheries or in rice field ponds. However, reliable data on this activity is wanting. The rearing of the prawns is carried out usually in earthen ponds of 0.1 to 2 ha in size, around 0.9 m in depth and preferably rectangular in shape for easy operation of nets. Larger ponds of 2 to 10 ha in extent are constructed in Hawaii and the whole farm may extend from 50 to 100 ha. Scientific prawn culture is better undertaken in small, shallow ponds with a little slope of 1: 300 towards one side to enable easy draining and harvest. Sandy-silt or clayey bottom soil is good. Bunds must have a free board of atleast 60 cm above the highest water level. The internal slope should be 3:1 in sandy areas and never less than 2:1. Top width could be 1-3 m.

A little marginal aquatic vegetation is desirable; it provides food and a habitat for the prawns in addition to protecting the pond bank. However, excessive growth might interfere with free movement of the prawns and harvesting. The growth of aquatic-rooted plants may be prevented. New ponds should be limed. In Thailand, application 1000 kg of agricultural limestone per hectare is recommended every time a freshwater prawn pond is drained. It is not recommended to build ponds on suspected acid sulphate soils as their recovery is expensive, requiring repeated flushing and drying.

Ponds are limed and fertilized as in carp culture. However, a higher oxygen content (above 75% saturation) is always necessary and hence fertilization should be done in slow doses. pH should be maintained within 7.0 - 8.5, temperature between 18° - 34°C (optimum 29 - 31°C) and total hardness below 150 ppm and above 40 ppm (as $CaCo_3$). The water should be free from pollution especially agricultural pesticides. A salinity upto 6 ppt is considered to be within the acceptable limit for freshwater prawns, eventhough it is reported that tildal water of salinity between 12 to 25 ppt has been utilized in Western Samoa.

Nursery Rearing

The post-larvae obtained from hatcheries are often reared in nursery tanks for about 1-2 months before they are stocked in grow-out ponds. One of the problems of stocking postlarvae directly in rearing ponds is that it is almost impossible to predict as to how many will survive until harvesting time. Both earthen and cement ponds can be used for nursery rearing. Experiments conducted at the Fisheries College, Cochin have indicated that various materials providd to increase surface area and shelter in tank help to reduce the problem of cannibalism. Survival and growth were found to be density dependent. It was found that a stocking density of upto $2000/m^2$ is not limiting survival provided sufficient food, aeration and additional substratum are provided. It was also found that rearing the postlarvae at 12 ppt salinity could be recommended in situations where suvival is the prime consideration. As a result of nursery rearing, better quality seed for stocking is obtained and greater accuracy in stocking density is ensured.

Stocking

Freshwater prawns are cultured alone or alongwith fishes in earthen ponds, rice fields, irrigation canals, in pens constructed along shallow lake margins, in cages and in concrete tanks. Post-larvae, 1-4 weeks after metamorphosis, may be stocked in earthen ponds after acclimatisation to the water temperature of the pond. pH difference is equally critical and the post-larvae should be gradually acclimatized to the new pH over a day in holding tanks. In Thailand, where the favoured size for marketing head-on prawns is about 70 g and the growing season is limited to 8 months, a stocking density of 50,000/ha is recommended. The post-larvae stocked are 1 month old after metamorphosis. Some farms in Thailand and Hawaii resort to stocking as high as 1,60,000 to 2,20,000/ha resulting in higher production by "continuous culture", but the size at harvest is reduced.

II. Culture techniques

Three methods could be adopted in farming:

(1) culturing after nursery rearing to a mean size of around 1 g.
(2) direct stocking of post-larvae without nursery rearing and
(3) continuous rearing with repeated harvesting and stocking extending over 3 to 4 years before the ponds are completely drained and dried.

"Continuous culture" consists of stocking the ponds, usually once a year or sometimes 4-6 times a year at high stocking densities and after about 5-7 months, culling off market-sized prawns at regular intervals. The ponds are not drained, but the larger prawns are fished by seining. This contiuous culture and repeated culling at regular intervals or "cull harvesting" is widely adopted in Hawaii and by larger farms in Thailand. Since there is wide disparity in the growth rate within a population of prawns, three major size-classes could be identified in a mature population. These are large 'bull' males, females and small 'Bachelor' males. Cull harvesting results in selective removal of the bull males, which is required for better stock management and achieving higher production. Following this system upto 276 kg/ha/month is reported to be produced in Hawaii, which works out to 3312 kg/ha/yr. The yield varied from 2500 to 4000 kg/ha/yr.

The other technique consists of "batch culture" and "batch harvesting" or "drain harvesting". It involves stocking the ponds at the optimum level for maximum rate of growth and harvesting the whole crop, possibly by draining the ponds. In Thailand, most farmers adopt a combination of these two techniques. About 5 months after the postlarvae are sotcked, cull harvesting commences to be repeated once every month until the 8th month when the pond is drained completely and the prawns harvested. The pond is prepared and restocked when the water supply is available again.

Other types of Culture

Experiments undertaken to increase prawn production form unit area have resulted in developing techniques of cage and pen culture, polyculture, tank culture, repeated grading, monosex culture and improved strategies of feeding. Cage culture of an all-male population yielded 473 $g/m^2/115$ days. In earthen ponds, all-male populations yielded nearly 8% more and all-female nearly 21% less than mixed populations. Pen culture is successfully conducted in Thailand in Songkhla Lake. Fishermen who capture prawns in natural water keep the small prawns in pens for further growth. The stocking rate is about $3/m^2$. The polyculture of freshwater prawn with fishes like carps, mullets, milkfish and Tilapia has been tried in several countries. The Indian experience is reported in this text under 'production'. Taiwanese farmers are reported to have returned from polyculture to monoculture because of predation problems and the high profitablity of intensive prawns monoculture. However, polyculture can result in satisfactory water quality and fewer problems of aquatic weed infestation and decomposition of organic matter. Attempts on intensive culture of *Macrobrachium* in cement tanks under controlled conditions were not quite encouraging. Semi-intensive culture in tanks provided with artificial habitats and aeration and stocked with 83 and 32 PL/m^2 gave estimated production of 3800-4700 kg/ha/yr. In 50 m^2 concrete tanks stocked at $5/m^2$, production of 465-820 kg/ha/119 days have been reported.

Freshwater prawns may also be stocked in reservoirs, lakes and rivers in order to replenish the depleted stocks or to start a new stock to support a fishery.

Feeds & Feeding

M. rosenbergii is omnivorous and its diet consits of aquatic insects and larvae, algae, grains, including rice, seeds, fruits, small molluscs, worms, crustaceans, fish, and offals of other animals. They accept compounded feeds, chopped butchery wastes, tapioca, oil cakes etc. and may turn cannibalistic occasionally. They relish live organisms and therefore manuring the pond to increase production of benthic fauna is advantageous. The nutritional requirements of *M. rosenbergii* have been reviewed and the preparation of balanced compounded feed has been discussed by New (1987). Compared to panaeid prawns, the freshwater prawns require only a lower protein level of 25-30%. Nutritional Studies undertaken at the Fisheries College, Cochin showed that the protein requirements of the postlarvae and juveniles of *M. rosenbergii* lie close to 30%; however, for maximum growth and performance protein concentrations of 34-35% and 28-30% maybe required for the postlarvae and juveniles respectively. A diet based on animal and plant protein in 1:1 and 1:3 are recommended for the manufacture of compounded diets for the postlarvae and juveniles respectively. Many farms use chicken feed, re-extruded after mixing with trash fish or prawn meal and carbohydrates. Mostly, the feed is prepared at the farm site itself. 7-8% lipid content and a 1:4 lipid : carbohydrate ratio have been recommended. Water soluble vitamins have been found to be more important in the diet, than the fat-soluble vitamins and trace minerals. Failure to moult has been shown to be one of the symptoms of Vitamin C deficiency. Some typical formulae for freshwater prawn diets are provided in the classical work by New and Singholka (1985).

Feed is usually spread around the periphery of the pond in the shallow or is presented in predetermined areas a few metres apart. The intention is to observe how much feed has been consumed. The feed ration will have to be increased or decreased according to the extent of consumption by the prawns. New and Singholka (1985) recommend that in a pond stocked at 5/m^2, a dry diet such as compounded chicken feed should be given initially at 6.25 kg/ha/day. This could be increased gradually to 37.5 kg/ha/day if a production of 1250 kg/ha/6-8 months is expected by batch harvesting, and to as high as 45 kg/ha/day if a production of 3000 kg/ha/yr. is anticipated through continuous rearing and cull harvesting. Food conversion ratios of 2:1 to 4:1 could be expected for commercial dry feeds, and 7:1 to 9:1 for wet feeds. Average growth rate would be around 1-2 cm/month.

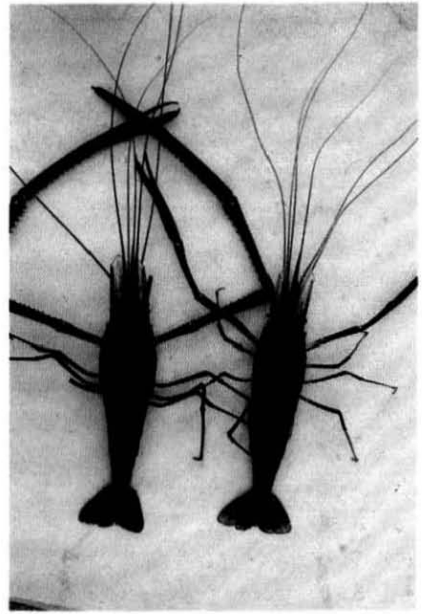
Harvesting

'Batch harvesting', 'cull harvesting' and a combination of both have been discussed elsewhere in relation to "pond culture". In all cases harvesting operations should take place in the early morning hours when it is cooler. In cull harvesting usually bottom seining is done and the first harvest takes place 5-7 months after initial stocking. In batch harvesting

2. Developmental Stages of Eggs

a) Early Stage - Berried Female with Bright Orange Colour Egg

b) Late Stage - Berried Female with Stale Gray Colour Egg



Male and Female of Giant Freshwater Prawn fishes such as the Common Carp and Mrigal are not recommended for polyculture. Subramanyan (1984) reported yields of 284-1640 kg of prawn/ ha/120-134 days in monoculture, and in polyculture, 85-709 kg of prawns with 1149-1574 kg of fish/ha/180 days. Trial culture in channels in coconut groves at Kumarakom in Kerala yielded 805 kg/ha/246 days. In another trial in a pokkali rice field at Fisheries College, Cochin, the field was manured and postlarvae at 30,000/- ha were stocked. Supplementary feed consisting of groundnut oil cake, raw polished rice and clam meat (80 kg) was given. The yield was 506 kg/ha/115 days. In an experiment on developing an intensive farming system with feeding and water management in a cement tank Sebastian *et al.*, (1992) achieved a production of 3,300 kg/ha/yr. These results indicate a good future for intensive farming of this species in India. With the supply of hatchery produced seed from Cochin, Kerala, entrepreneurs in Andhra Pradesh and Tamil Nadu have taken up freshwater prawn farming in these States.

DISEASES

In freshwater prawn several diseases have been identified both in the hatcheries and grow-out systems, but many of them have an unidentified aetiology. But most of the diseases appears to be due to poor hygienic conditions, inadequate water exchange, poor feeds or low oxygen levels. Protozoans, bacteria, fungi, coelentrates etc. appear to cause diseases to freshwater prawns. But most of them are considered as opportunistic rather than obligate pathogens.

Midcycle larval diseases

Epizootics of MCD have resulted in marked reduction of post larvae. In Hawaii where MCD have occurred in three hatcheries, these epizootics reduced PL production to 1 to 2 PLs per litre where the previous production was 10 to 25 PL per litre. The etiology of this disease has not been determined. The incubation period of this disease is about 5 days. This disease usually begins to rise on day 14 to 18 of the rearing cycle. The chemical signs associated with the disease are weak, spiraling movement, reduced feed consumption and the larvae remaining in moribund stage at the bottom of the larval rearing tank for 2 days before death. A variety of chemotherapeutics have been tested as treatments for MCD, but none have been beneficial in terms of showing an improvement in P.L. production.

Bacterial Necrosis

Bacterial necrosis cause high mortality in larval stage 4 to 5, but the older stages are more resistant. The affected larvae show reduced feed consumption and increased cannibalism. The moribund larvae turn greenish in colour and have empty intestinal tract. Though confirmatory experimental data are not available the etiology of this disease is suspected to be bacterial in origin.

Treatment with antibiotics to arrest the disease and prophylactic use to prevent it are suggested. Bipenicillin - streptomycin 2 ppm or erythromycin phosphate 0.65 to 1 ppm daily use for treatments and once in three days for prophylaxis are recommended.

Exuvia Entrapment Disease

This occurs to the final stages larvae and early PLs. The affected larvae are not in a position to free the pereiopods, anterior appendages, eyes, or rostrum from the exuvia. Some animals even shed the exuvia but die soon after moulting. The mortality from EED varies from 20 to 30%. The etiology of this disease is not determined.

Addition of lecithin to the diet decreased the incidence of moult associated mortalities. Use of algae in larval rearing tanks and feeding late stage larvae with lecithin rich feed are suggested to control the disease.

Microbial Epibiont disease

Epibiont fouling organisms include filamentous and nonfilamentous bacteria, algae, or protozoa common to the aquatic environment. The lesion which heralds this disease has been the attachment of microbial agents to epicuticular surfaces with no destruction of host tissue and little or no host inflammatory response at the site of attachment. In general, the occurrence of epibiotic fouling disease in culture systems has been considered as gross evidence of existing poor water quality conditions and it indicates an extended intermoult period. Antibiotic treatment has been reported to decrease mortality associated with nonfilamentous bacterial fouling.

Other protozoan epibionts like Zoothamnium, Epistylis, Vorticella etc. can be removed by treating the larvae with 150 ppm formalin for about one hour. In the culture system total exchange of water daily for a week is suggested as a remedial measure.

Brown Spot Disease

Brown spot disease can be recognised by the presence of brown to black ulcerative to raised lesions affecting any surface of the body or appendages and varying in size from tiny to large. The distribution of this lesion may be focal or multifocal. In brown spot disease the external surface of the article is always involved. A variety of causes have been suggested for brown spot disease. These include bacterial species which produce extracellular lipases, protoases and chitinases, fungi, mechanical trauma precipitating chemicals, nitrogenous waste products or nutritional abnormality.

The control measures include improved attention to husbandry and nutrition. Providing adequate hide out and space to minimize intraspecies aggression.

Hemocytic Enteritis

This disease which is associated with low chronic mortality in susceptible-sized prawn is characterised by the development necrosis of the mid and hind gut epithelium with moderate to marked accumulation of hemocytes in the gut lumen and a layer of the midgut wall in affected areas. This disease is reported to be caused by the ingestion of blue-green algae, primarily *Spirulina subsalsa* and possible other blue-green species.

Control methods include keeping adequate algae density in the ponds to preventing growth of filamentous blue-green forms.

Endocuticular Degeneration

Endocuticular degeneration in the form exoskeleton spotting in *M. rosenbergii* is of unknown etiology. This is reported from many places and no preventive or remedial measure is recommended.

White prawn disease

WPD has been found to be a chronic, progressive disease of adult prawns fed on artificial diet and maintained in a prawn culture system lacking exposure to direct sunlight. The prawn looses normal pigmentation due to atrophy of epidermal chromatophores and takes white colouration and cuticle becomes soft. The disease is of unknown etiology and addition of natural food items to the diet is recommended as a control measure.

In addition to these there are a large number of diseases caused by metazoan parasites like Trematodes, Turbellaria, Isopodes etc. A treatment with 100 ppm formalin has been found to be effective for all the metazoan parasities.

PROCESSING & MARKETING

Scampi has a very good international and internal market. The export mainly concentrate on the European countries and India's export of scampi in 1991-92 was of the order of 1281 tonnes Headless and 1 tonne Headon prawns (MPEDA Export Review 1992).

The present day market mainly depends on capture fisheries and a size range of U/3 to 61-70 or even smaller are being exported. It is usually packed as Headless (H/L) on 2 kg slabs and Headon 1 kg slabs. 'A' grade ranges from U/3 to 3/6 counts. For Headless packing the head including cephalothorax is removed and the egg cluster on the ventral side of the female during breeding season are scrapped out. The egg and the bigger legs are only removed for Headon packing. Very small size grades are packed and exported as PUD.

Scampi is also exported by air to Middle-east countries in freshly killed conditions in thermocole boxes of 200 kg capacity chilled with ice. The present day international market is US $ 6 to 16 with higher size grades getting better price.

Scampi has a comparatively low tail yield and high rate of hanging meat, than that of the Penaeid prawns, coming nearly to 45% and 5% respectively. The tissue mushiness which develop in 3 days under ice chilled condition and the white crust on the shell, soft shell, loosened shell and pink discolouration on the meat are the main problems which affect the quality of freshwater prawns in the market. These problems are still not resolved and satisfactory remedies are not available.

In the internal market scampi is a luxury item finding its place in star hotels and posh restaurants only. On an average whole scampi fetch Rs. 270/kg in the Calcutta market and Rs. 200/kg at Cochin. The live trade of scampi as practiced in Thailand and other countries is not followed in India.

ECONOMICS

The average initial investment required in 1989-90 for establishment of a commercial Backyard hatchery of 5-6 lakh annual production has been computed as around Rs. 2 lakh out of which about 68% is spent for generation of fixed assets such as equipments (52%), hatchery building/constructions (9%) and land (7%). Manpower and feed cost accounted for 20 and 8% respectively, and miscellaneous expenses like cost of glasswares, buckets, transportation etc. accounted for 4% of the total expenditure. The average total cost of hatchery per run showed that 47% of the total costs are fixed costs such as interest (19%), management (17%) and depreciation (11%), and 53 of the total costs are variable costs such as labour (24%), feed (19%), power (5%) and miscellaneous (5%). The average cost of production worked out to Rs. 90/1000 seed and sale price Rs. 300/1000. The average survival rate registered from the four hatcheries studied ranged from 36.93% to 67.31%. Each hatchery created 1202 man days of employment on an average.

The study further revealed that the average rate of return on total cost was 298.36%. The initial capital investment could be got back in the first year of operation itself by successful operation of 5 to 8 runs.

It is seen that in order to establish a hatchery in Kerala with a production capacity of about 5 million seed with all facilities an expenditure of about Rs. 15 lakhs would be required including the cost of land. The assessment is based on the information obtained from M/s. Aquabiotec, Kuttanad Hatchery, Kundannoor, Ernakulam. As in the case of a backyard hatchery, about 70% of the total expenses is spent on generating fixed assets. However, in the latter case much more amount (25%) is spent on buildings, and hatchery and nursery tanks make of R.C.C. The major reason for this difference is that in a Backyard hatchery the nursery tanks are make of F.R.P. and therefore movable and are classified under equipments & fittings. Cost of land and its improvement works out of 20% of the total cost. Construction cost of breeder ponds and storage tanks amounts to 5%. Cost of equipments and fittings (excluding hatchery and nursery tanks) amounts to 29% only of the total cost. The total recurring cost is 30% which consists of salary (10%), feed cost (15%) and Miscellaneous expenses (5%) of the total.

In a study made in Malaysia on the cost of production of *M. rosenbergii* when commercial feed was used, was found to range from M $ 10 to 15 per kg. Most of the prawns are sold alive in the local restaurant market. Live ones fetch prices ranging from M$ 18 to 25/kg while dead prawns sell at M$ 12 to 16/kg. The breakdown of cost in 1989 for culture at a stocking density of 20 PL/m^2 is Feed: 53.3%; cost of seed (PL) : 33.2%; Labour: 9.3%; Miscellaneous : 4.2%. According to a private firm producing its own postlarvae, the estimates are as follows: Feed : 50%; Postlarvae: 10%; Labour : 15% and Miscellaneous: 25%. Feed represents the major component of production cost exceeding half the total cost of production. Commercial grow-out feeds cost around M$ 1.60/kg in 1990.

In Brazil the production cost is worked out as US $ 5/kg; the most important items being cost of post-larvae, feed and labour. Prawns are sold on the internal market at US $ 7 to 12/kg.

Part IV

CRAY FISHES

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CRAYFISHES

INTRODUCTION

In many parts of the world, the freshwater Crayfishes (Crawfishes) are considered a delicacy. Eventhough, all the species of crayfishes are not suitable for commercial aquaculture, the culture of selected native or exotic species is gaining popularity all over the temperate regions of the world. Crayfish culture is more popular in North America, Europe and Australia. So far, there is no record of their introduction in India. According to a recent estimate the world production of crayfishes (possibly including the wild catches) is of the order of 70,000 to 100,000 tons per annum (Fish Farming International, Oct., 1989). USA (Louisiana) accounts for 80 to 90% of this total and atleast 80% of the Louisiana production is composed of Red Swamp Crayfish (*Procambarus clarkii*) and the rest, the white River Crayfish (*P. acutus acutus*). According to a more recent estimate by FAO (1992) the total world production of crayfish through aquaculture alone amounts to 34,842 tonnes in 1990 with the USA contributing 32,205 t, Spain 2500 t, Australia 109 t, U.K. 15 t, Sweden 8 t, and France 5 t. The contributions by Turkey, China, and some other traditional producers are not seen included. The most important species cultured is the Red Swamp Crawfish, *Procambarus clarkii* (34705 t), followed by the Yabby, *Cherax destructor* (63 t) and the Red claw, *C. quadricarinatus* (32 t), vide Table 1. An average production of nearly 1.5 per ha per year is usually obtained from culture systems, but reports of production as high as 4.5 t per ha per year are also available from Australia and France.

CRAY FISHES

Crayfishes are freshwater decapod Crustaceans belonging to Macrura-Reptantia. They have five pairs of walking legs, with the first pair enlarged and modified to form characteristic stout claws, and the second and third pairs bearing small claws or pincers. The body is elongated, abdomen extended, exoskeleton thick and the tail is large bearing a fan formed by an enlarged and flattened last pair of abdominal appendages. Their systematic position is as follows:

Suborder	:	Reptantia
Section	:	Astacura
Superfamily	:	Astacoidea
Family	:	Astacidae
Family	:	Cambaridae
Subfamily	:	Cambaroidinae
Subfamily	:	Cambarinae
Subfamily	:	Cambarellinae
Superfamily	:	Parastacoidea
Family	:	Parastacidae

In the central and southern parts of the Asiatic continent, including the Indian subcontinent, no representative of the crayfishes is known to exist. The largest of all the crayfishes, *Astacopsis gouldi* occurs in Tasmania which grows to a weight of 4 to 5 kg and is the largest invertebrate living in freshwaters.

The important species cultured are *Astacus astacus* (the Noble Crayfish), *A. leptodactylus* (the Slender Clawed or Turkish Crayfish), *A. pachypus*, *Austropotamobius pallipes* (the White Clawed Crayfish), *A. torrentium* (the Stone Crayfish), *Orconectes limosus* (the Striped or American Cray fish), *Pacifastacus leniusculus* (the Signal Crayfish), *Procambarus clarkii* (the Red Swamp Crayfish), *Cherax destructor* (the Yabby), *C. tenuimanus* (Marron) and *C. quadricarinatus* (Red Claw Crayfish). *Procambarus clarkii* (Red Swamp Crayfish) and *Cherax quadricarinatus* (Red Claw Crayfish) which prefer a tropical climate are candidate species for introduction to other parts of the world with a tropical climate. Exclusively temperate species can also be considered for introduction in high altitudes in the tropics. However, species with extensive burrowing habits are not generally considered for transplantation. The latter two species with better tolerance to temperature and salinity changes are widely transplanted in other regions and the studies made so far indicate that they have never been a destructive competitor to any of the native species. They are usually cultured alone, but farming in polyculture alongwith fishes and the freshwater prawn, *Macrobrachium rosenbergii* also have shown encouraging results. As such, the biology and farming of these two species are dealt with in greater detail.

MORPHOLOGY & GENERAL BIOLOGY

Crayfishes have a body plan typical of higher crustaceans. In dorsal view, the body is distinctly divided into two regions, an anterior unjointed cephalothorax and a posterior jointed abdomen or tail (Fig. 1).

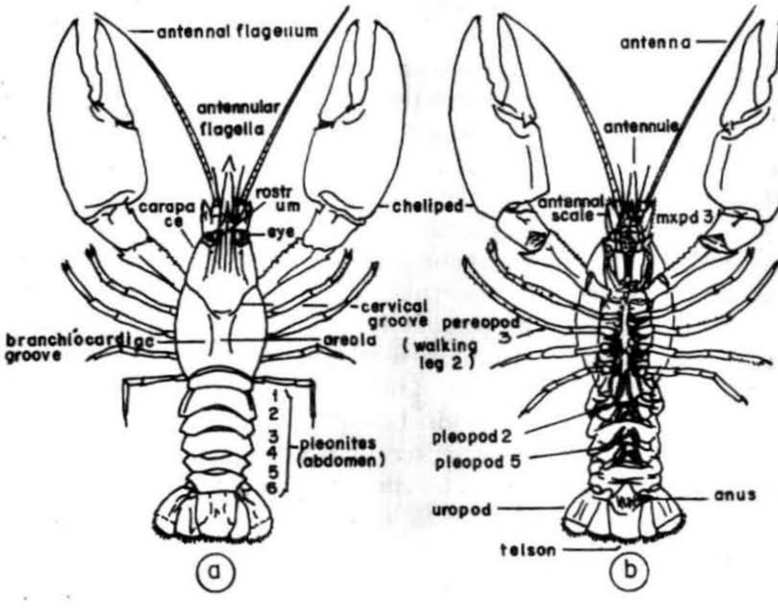

Fig. 1 Diagramatic sketch of a crayfish, a) Dorsal view b) Ventral view

The first three pairs of thoracic appendages are developed as maxillipeds and assist in food manipulation. The other five pairs constitute uniramous tube-like peraeopods, of which the anterior three pairs end in chelae or pincers. The first of these is characteristically stout ending in very large chelae. Abdominal segments 2-5 in females each bear a pair of feathery pleopods or swimmerets. In males, pleopods 1 and 2 are modified for copulatory purposes as gonopods.

Most of the species are purely freshwater inhabiting dams, swamps, creeks, rivers, lakes, irrigation canals, rice fields and farms. Almost all the crayfishes survive equally well in lotic and lentic waters but a few are essentially riverine in nature. Certain species like *Procambarus clarkii and Cherax quadricarinatus* tolerate salinity upto 10 or 12 ppt. All the species have a tendency to construct burrow systems except species like the Red claw. The burrows are usually 1 metre deep, but at times they may go as deep as 4.5 m. Most Crayfishes can live out of water for long periods as long as the air in the gill chambers is moist. If oxygen levels get critically low, the crayfish emerges to flush the gill chambers with fresh air.

Crayfishes are polytrophic and feed on a variety of food materials like detritus, aquatic vegetation, worms, insects, molluscs, tadpoles, small fishes and other aquatic animals and decaying vegetation. The mode of feeding is opportunistic and preference to the feed varies with season, age and the physiological condition of the animal. The optimum dietary protein requirement of *P. clarkii* has been estimated at 20-30 % with the optimum total animal protein in the range of 15-20%. Protein requirement as high as 50.5% has been reported for *P. acutus acutus*. There is not much information regarding the amino acid requirements, but arginine, histidine, isoleucine, leucine, lysine, methionine, phenylalanine, tryptophan, threonine, valin and asparagine have been identified as essential, eventhough the status of arginine as an essential aminoacid is disputed. As regards lipid requirements, linolenic series and linoleic series are reported as essential fatty acids. Like prawns it is also not capable of synthesizing sterols, and cholersterol has to be supplied through food. Sterol level of 0.4% is essential for survival while 0.5 - 1.0% is required for optimum growth.

The life cycle of a crayfish progresses through a series of moults during which the animal increases in size. During the first summer growth season they undergo 7 or 8 moults, the number governed by temperature. During subsequent summer growth seasons the cycle is repeated but each year the number of moults decreases as the animals increase in size, eventually declining to one moult per year.

CRAYFISH CULTURE IN NORTH AMERICA

Crayfish (crawfish) culture is the only commercially viable form of freshwater crustacean aquaculture in the temperate climate and 80-90 per cent of the crayfish grown in the world are produced in the State of

Louisiana, USA. There were over 53,000 hectares of crayfish ponds in Louisiana in 1988-89 with average production of around 600 kg/ha. It is reported that 80 per cent of the Louisiana production is contributed by Red Swamp Crayfish *Procambarus clarkii* with the remainder by White River Crayfish, *P. acutus acutus.*

1. *Procambarus clarkii* (The Red Swamp Crayfish)

Colour is red laterally and very dark, often black, dorsally. Some specimens may be purple, lavender, or burnt orange laterally. Blue, yellow and white mutants are rare colourmorphs.

Sexually active *P. clarkii* mate whenever they encounter receptive partners. Several weeks to several months after mating, prominent glair glands develop about the bases of the abdominal appendages and oviposition takes place. This is normally done in a burrow but can occur in open water also. Embryonic development is temperature dependent taking two to three weeks at 22°C and is effectively arrested below 10°C. Once hatched, the young crayfish undergo two moults in two to three weeks and are able to leave the female but will continue to stay with her for several weeks, being attracted by a maternal pheromone.

Atleast eleven moults are required before *P. clarkii* matures. The intermoult period varies according to temperature, but takes 6-30 days at 20-22°C with the period lengthening as size increases. At least two generations per year are possible at lower latitudes and can be easily attained in laboratory cultures. Under laboratory conditions, maximum life span is about 4 years, but it rarely exceeds 12-18 months in nature.

P. clarkii is active during the cool months at lower latitudes and dormant during hot months. During low water, dry periods, and/or reproductive periods, *P. clarkii* of all sizes retreat into burrows. The burrows rarely extend more than 1 m although depths of just over 2 m have been noted. A short, simple chimney of earthen pellets may or may not be present. Predators include most carnivorous aquatic vertebrates and invertebrates.

P. clarkii is found in waters ranging from 10 ppt brackish to almost freshwater. However, reproduction is said to be inhibited by salinities above 5 ppt. Moulting rate appears to be rapid at temperatures in the range of 22-30°C. This species is very sensitive to pesticides especially insecticides. Stress reactions, including climbing to the surface to obtain atmospheric oxygen, are observed when the dissolved oxygen level drops to less than 3 mg/l. pH should be in the range of 6.5 - 8.5 although the species can tolerate lower and higher pH. Detectable H_2S concentrations and dissolved iron concentrations above 3 mg/l should be avoided.

2. *Procambarus acutus acutus* (The White River Crayfish)

This species superficially resembles *P. clarkii*. However, Form I adult *P. a. acutus* have a colour pattern that is off-white to tan laterally becoming brownish with age, or dark to black dorsally becoming purplish with age. Juveniles and Form II crayfish are off-white to tan, with juveniles often exhibiting many black specks on the body surface. Those from dark, clear waters are very dark, overall. A narrow, but distinct aerola separates the two halves of the carapace. The chelae are dramatically elongated in Form I males and much narrower than those of comparable *P. clarkii* in all age groups.

Life history is similar to that of *P. clarkii* but *P. a. acutus* is much more abundant in flowing, riverine situations. The species also seems to be limited to one reproductive cycle per year.

There are no known disease problems that prevent the successful cultivation of *P. acutus*.

CULTURE : Extensive

The extensive culture of *P. a. acutus* and *P. clarkii* is best developed in the southern U.S.A. *P. acutus* and *P. clarkii* are cultured by establishing perpetuating populations in seasonally flooded earthen ponds. These are dry in summer months with crayfish surviving and reproducing in simple burrows. The ponds are filled during the cool months.

Pond types: Pond types include open ponds, swamp and/or marsh ponds, and rice field ponds. Open ponds are often constructed on low, marginal agricultural lands. Preferred depth is 0.5 m. Swamp ponds are built in low, swampy lands by constructing dikes around swamps that may or may not be partially cleared to provide access and water circulation. Marsh ponds are similar to swamp ponds but are built in marshes. Both swamp and marsh ponds are characterised by poor water quality from organic bottom sediments. Depths vary widely and can exceed 1 m in places but average 0.5 m would be desirable. Rice field ponds are rice fields with slightly elevated levees that increase water levels from the 0.1 m used in rice cultivation to about 0.3 m. Pond size varies greatly but open and rice field ponds average 8-20 ha, while swamp and marsh ponds are typically larger, upto 100 ha.

Production levels: Maximum production is achieved in open and rice field ponds and can reach 3,000 kg/ha but 1,000-2,000 kg/ha is more realistic. Production in swamp and marsh ponds ranges from 200 to 600 kg/ha.

Stocking: New ponds are usually stocked in the late spring when the crayfish are mostly mature and costs are lowest. *P. clarkii* is the recommended species. The sex ratio should be 1:1. Stocking rate ranges from 25 to 100 kg/ha. Lower rates are used in ponds where there are native populations of *P. a. acutus* and *P. clarkii*. Brood stock is transported in open mesh vegetable sacks under moist and cool (under 30°C) conditions. Normally, crayfish ponds do not have to be restocked after the initial stocking.

Feeding: Crayfish are opportunistic detritivores. Supplemental feeding is generally not practised in extensive culture. Vegetation that grows during the warm summer months serves as the basis for a detritus food chain for the crayfish. The crayfish consume microbially - enriched detritus, benthic and planktonic invertebrates and succulent green plant material when available. Rice is often planted at roughly 100 kg/ha as a detritus base in the open type ponds. Rice grain is seldom harvested in such ponds. Vegetative biomass of about 1 kg/m^2 dry weight, is average for most well-managed ponds and can sustain crayfish production in excess of 1500 kg/ha.

Crayfish readily accept grain-based, low protein livestock feeds and high protein fish feeds and grow well; however, it has generally been economically unfeasible to use such feeds in crayfish ponds. Supplemental feeding, where practised, involves addition of hay to pond. It takes 6-12 weeks, depending on water temperature for carbon, nitrogen ratios (indicative of an increase of microbial biomass) of hay to reach levels where it is attractive to crayfish as food; therefore, spoiled hay is preferable to cured, dry hay as a food.

Pond filling and draining

It is recommended that Louisiana crayfish ponds be filled in October when the weather begins to cool and that they be drained in late May or early June. Ponds filled in September, October and November, indicated that October filling permits best development of population structure with several distinct waves of young entering ponds.

Water quality

Total alkalinity and total hardness should exceed 50 mg/l. Desirable ranges for other water quality parameters include: pH, 6.5 - 8.5; Oxygen above 3.0 mg/l; carbondioxide, below 5.0 mg/l; hydrogen sulphide, not detectable and iron less than 3.0 mg/l. Well water should be used to fill ponds if feasible as it is normally free of contaminents such as predator/competitor fishes, pesticides and other pollutants. It may, however, have toxic levels of dissolved iron or hydrogen sulphide. It must be aerated to eliminate excess iron and hydrogen sulphide if present, and to oxygenate it. Some pesticides may be very toxic to crayfish and should be avoided. Toxicity of pesticides and other foreign substances is invariably a function of factors such as age, moult stage, temperature, water salinity etc. Thus, it is not unusual for a compound to be significantly more toxic in practice than reported in the literature.

The major water quality problem in crayfish aquaculture is low dissolved oxygen (DO). Crayfish show obvious signs of stress at DO levels 3.0 mg/l and begin to die at concentrations below 1.0 mg/l. Low levels are caused by high biological oxygen demands (BOD) arising from the rapid decomposition of vegetation in ponds especially during warm periods when biological activity is most rapid. To ensure maximum oxygenation, it is recommended that ponds have pumping capacity sufficient to exchange pond volume at least once every four days (9400 l/min./ha). Pumping should begin two weeks after ponds are filled. This should continue until night temperatures are around 15°C and day time temperatures rise in the spring. Pond filling should be delayed if pumping capacity is inadequate. Filling ponds initially to half of normal depth reduces pumping costs for water exchanges. In ponds, it is preferable to have low, inner levees situated 50-65 m apart to guide water to all parts of a pond to prevent the formation of deoxygenated areas in the pond. Cutting and removing some vegetation from a dry pond is practised by some culturists who return the material to the pond later. Emergent vegetation is a critical source of cover, substrate and access to the surface for crayfish during occasional, but inevitable periods of low levels of dissolved oxygen in crayfish ponds. Thus, some emergent vegetation should be maintained for as long as possible.

Crop rotations

Rice-crayfish and rice-crayfish-soybean rotations are becoming popular in Louisiana. In rice-crayfish rotations, rice is planted in March or April. Crayfish are stocked when the field is flooded for weed control after rice is established. The crayfish burrow in levees in the flooded field as the shallow water becomes too hot for them. The field is drained in August and rice is harvested. The pond is refilled in October for crayfish. Crayfish are harvested primarily in the spring. Rice may be replanted during the March-May period depending largely on the value of the crayfish crop. The rice-crayfish-soybean rotation is similar to the rice-crayfish rotation except that crayfish are harvested in May and soybeans are planted in June. Restocking of crayfish may be done the following spring when the new rice crop is established.

Polyculture

Crayfish can be cultivated with fish. This, for the most part, is largely unintentional with the crayfish appearing spontaneously in fish culture ponds. They thrive in situations with either non-predatory fish or the fry/fingerlings of predators which are too small to eat the crayfish. *Procambarus* spp. have been cultured in combination with finfish including hybrid buffalofish, *Ictiobus* spp., channel catfish, *Ictalurus punctatus* and paddlefish, *Polyodon spathula* - all of which are cultivated for food. Fish are stocked in the spring after most crayfish have reached a size invulnerable to the catfish. Fish yields exceed 3,000 kg/ha, mostly catfish, when harvested in the following autumn in October. Crayfish yields are about 1000 kg/ha.

Crayfish, fingerling channel catfish, and freshwater prawns, *Macrobrachium rosenbergii*, are found to be a compatible combination in experimental ponds. However, these are cultured simultaneously during warm months and crayfish yields are 400-500 kg/ha.

Current studies at Louisiana State University are exploring the feasibility of modifying crayfish ponds so that rice may be grown as a fodder over about 50% of the bottom in shallow water while channel catfish, tilapia (*Oreochromis* spp.), and freshwater prawns are cultured in deeper waters during warm months. Fish and prawns are stocked in late spring after ponds are drained and rice is established. Mature crayfish burrow at the waters edge and generally enter the water with young in October after ponds have been drained for fish and prawn harvest and refilled. Results are encouraging.

Harvesting

Crayfish are harvested now almost exclusively with baited traps. Most traps are cylindrical, 1 m long by 0.5 m in diameter, with one or more funnel entrances around the perimeter of the base. They are constructed from hexagonal steel poultry netting. This is usually coated with black plastic material to prevent deterioration. Traps with the coating also catch significantly more crayfish than uncoated traps. The most common mesh size is 1.9 cm and is mandated currently by law in Louisiana. This retains crayfish over 75 mm total length.

The conventional cylindrical trap is set vertically in the pond water column and extends above the water line. This facilitates checking of traps and provides crayfish with access to the surface during inevitable periods of low oxygen. At least part of the top of each trap is open. This permits the trap to be emptied and rebaited rapidly. Retainer rings prevent escape through the openings. A popular new trap has broad basket-like catching/holding area with a centrally located, narrow tube extending upwards to the surface. The open end of the simplest cylindrical traps may be closed for use in deepwaters common to natural crayfish fisheries. These are placed on the bottom with the funnels facing downstream. Crayfish traps are checked one to three times per day depending on catch rates. Trap density in ponds averages 50-75/ha. In fisheries for wild stock, fishermen use 100-500 traps.

Commercial crayfish operators generally use boats to harvest crayfish. Fishermen who catch wild crayfish use 5-7 m long flat-bottomed boats with high, pointed prows and large outboard motors. Such boats are necessary to move through forested, flooded swamps. Crayfish culturists use 5-6 m flat bottomed boats with square prows to harvest crayfish. Skilled operators can check 200-300 traps per hour in crayfish ponds.

Active capture devices, such as seines are usually ineffective in vegetation choked crayfish ponds. A unique crayfish harvesting system has been developed in Spain to capture *P. clarkii*. There, unbaited cylindrical eel nets are used. These are set -in irrigation channel and canals with the entrances pointed down-stream. Crayfish move upstream against currents and enter the nets. A net panel, or lead, at the entrance is set across the channel to increase efficiency.

Transportation

Crayfish are packed in open mesh vegetable sacks for transportation and cold storage. Capacity is 20 kg. In Louisiana, crayfish are normally placed in sacks when harvested and held in them until the final sales. The sacks must be kept cool and moist to prevent desiccation before reaching buyers.

CULTURE : - Intensive

Intensive culture of *P. a. acutus* and *P. clarkii* for all or part of the life cycle is biologically feasible but it is not economically feasible in most cases.

Hatcheries might be feasible for maximising production of high value, soft-shelled crayfish in small ponds or for ensuring satisfactory production in subsistence level ponds. However, those considering the use of hatcheries must thoroughly evaluate all costs involved before making any commitments despite the relative simplicity of hatchery methods.

Hatchery systems are very simple requiring space of about 80 cm^2/female in static containers with about 2.5 cm of water. No feeding is required if mature, presumably mated, females are stocked in late spring/early summer. Most will lay eggs and release young in the September-October period. Discarded 3.8 l plastic bottles are suitable hatching units. Ten by 10 cm pieces of plastic pipe held in shallow troughs work well, too, and are more compact than bottles.

Soft-shelled crayfish

Much interest has been shown in soft crayfish as their value is ten or more times that of hard-shelled crayfish. Crayfish captured in ponds are held in close confinement, 5-10 kg/m^2, in shallow troughs with high water flow and aeration. Those approaching the moult are then moved to a less crowded shedding container. Where, possible premoult crayfish should be captured for stocking troughs as they moult more rapidly and consume less food than intermoult crayfish. Feeding stops about four days before the moult. The pre-moult crayfish may be captured when feasible with seines having extra weights along the bottom edge. Identification of such premoult crayfish involves observation of changes in colour patterns (darkening) and in shell strength (becoming thin and brittle).

Water quality should be as described for extensive culture. Troughs, 0.91 m x 2.74 m and 0.15 m deep, should receive a steady flow of 100 ml/min. and water depth should be 5 cm (150 l of water). The flow provides an exchange every 4-5 hours. When properly adjusted, a sprayer head will maintain oxygen levels above 3 mg/l. Simple, rectangular troughs constructed from fibreglass or plywood are suitable. However, a special trough design has been patented and is claimed to be superior to conventional troughs in terms of segregating moulting from non-moulting crayfish.

High protein feeds such as trout pellets are suitable for moulting systems. These should be added at about 3% estimated body weight daily. Confined crayfish will eat high quality alfalfa, hay and fresh duckweed (*Lemna* spp. & *Spirodella* spp.) in addition to pelleted feeds. Crayfish can be induced to moult by injection of ecdysial hormones or bilateral ablation of eyestalks.

CRAYFISH CULTURE IN EUROPE

In Europe there are five native crayfish species viz., *Astacus astacus* (the noble crayfish), *A. leptodactylus* (the Slender-clawed or Turkish crayfish), *A. pachypus, A. pallipes* and *Austropotamobius torrentium* (the Stone crayfish). These native species have a widespread distribution and many have been severely affected by the plague fungus. In addition to disease, native crayfish population dwindled due to aquatic pollution and over-fishing.

Ever since crayfish plague started to eliminate crayfish stocks in Europe different methods have been tried to restore decimated crayfish populations. The first method was to introduce the same species from healthy populations to the infected water bodies. This method is still employed in some countries and appears successful for a short time but the plague has a tendency to reappear. Consequently Europe required a crayfish that was resistant to the plague. Resistance to crayfish plague has developed naturally in American crayfish species but resistant strains appear to be absent in European species. In 1890, *Orconectes limosus* from North America was introduced into the River Metzer in Germany. This species is now found in water systems in Germany, Austria, Poland, U.S.S.R. and France. It can live in quite polluted water unlike most other crayfish. Crayfish connoisseurs consider that it can never be a substitute for *Astacus astacus* as its taste is inferior. *Orconectes virilis* (Hagen) was introduced into France in 1897 and Sweden in 1960 but self-sustaining populations did not result. More recently, the signal crayfish, *Pacifastacus leniusculus*, has been imported into and distributed throughout western Europe in large numbers mainly via the Simontorps Akvatiska Avelslaboratorium hatchery in Sweden. Another species which has been introduced into Western Europe (e.g. Spain, France and Cyprus) and other parts of the world is the red swamp crayfish, *Procambarus clarkii*, a native of the southern United States, and Northern Mexico. Once introduced, this species spreads very rapidly and is virtually impossible to control or eliminate. In addition, there have been reports of marron, *Cherax tenuimanus*, from Australia being introduced for aquacultural purpose in a number of European countries.

Culture of Signal crayfish

Crayfish culture in Europe has been carried on for many years using the endemic species, usually in extensive or semi-wild situations.

The principal source of juveniles for stocking has been second stage newly independent animals supplied from the hatcheries. For juvenile production the males and females are brought in from grazing ponds in late summer and maintained in shallow concrete tanks supplied with running water and fed on parboiled vegetables such as potatoes. The excess food is removed daily in order to avoid contamination. The females are maintained in these tanks until just before hatching in spring and at that time they are transferred to smaller tanks with a grid to prevent access to the newly independent young when they reach stage two. As soon as the young leave the parent, or are removed from her just before natural independence, the females are removed and returned to the grazing ponds for summer. In this way the number of breeding stock is held conveniently during the moulting and feeding periods of the summer.

The newly independent stage two young are then despatched as quickly as possible to their prospective homes. This is done in specially designed holding tubes which may be introduced directly into the transplantation site so that the juveniles may crawl out at their will and to which they can retreat if necessary.

It is estimated that animals released in this way will reach a size of 40 mm total length by the end of the first growing season and will grow to the marketable size of 90-100 mm total length during their second summer. At this stage many individuals will be reproductively mature. This rate of growth may be exceeded in favourable circumstances.

The recommended water conditions for successful implantation are: a pH exceeding 6, dissolved calcium in excess of 5 ppm preferably greater than 7, a hard substrate with plenty of hides and temperatures that exceed 15°C for at least three months of the year.

Since crayfish live on the bottom and sides and utilise any refuge available the best ponds are those that offer a high ratio of hard creviced bank to deep open water. Crayfish are most easily caught in shallow water and so, long narrow ponds are to be recommended. A common practice is to dig V- shaped ponds 2 m wide and 1 m deep.

To get the best yields it has been recommended that stocking juveniles at 20-30/m^2 and then thinning these to 10/m^2 at the end of the summer, and again at the end of the second summer, so that an average of 3-4 crayfish/m^2 is present in the autumn. Another culture system recommended is that one adult crayfish should be stocked per meter and this is to be repeated with smaller numbers in subsequent years which will yield one kg of crayfish/annum/ square meter. This is equivalent to 10,000 kg/ha/yr. Yields of this magnitude are considered to be highly unlikely without careful management and supplemental feeding, although yields of 500-1000 kg/ha/year might be expected in British waters. It is considered unlikely that crayfish on their own would generate sufficient profit to cover the costs of setting up a crayfish farm; therefore polyculture exercises have been recommended.

CRAYFISH CULTURE IN AUSTRALIA

The Australian species *Astacopsis gouldi, Euastacus armatus* and *Cherax tenuimanus* are the largest freshwater crayfishes of the world, in that order. The genus *Astacopsis* comprises two species, *A. gouldi* and *A. franklinii* restricted to Tasmania. Eventhough *A. gouldi* is the largest crayfish growing to 4-5kg, its growth rate is particularly low making the species unsuitable for aquaculture. Likewise *Euastacus armatus*, the Murray Cray, eventhough attains a weight of almost 3kg and length of 45cm is a slow grower and is of little interest for aquaculture. However, three species of the genus *Cherax* are commercially important and they are: (1) *C. tenuimanus* (Marron) (2) *C. destructor* (Yabby) (3) *C. quadricarinatus* (the Red Claw).

1. *Cherax tenuimanus* (Marron)

Marron is a cold water species growing best at 16-24°C. They tolerate temperature near freezing but soon die on prolonged exposure to temperature above 28°C. It requires salinity of over 10 ppt for successful culture. It is detritivorous and will accept a variety of feed stuff including formulated crustacean rations, poultry feeds and pelleted plants such as alfalfa. Most 'feeds' appear to serve as food substrate for microorganisms rather than being eaten directly by the crayfish.

Marron had been cultured for more than 20 years in Western

Australia and some farms had been established in South Australia also. Estimate of Australian aquaculture production of marron for 1989-90 is 14 tons valued at Au $ 379,000. The species has been transplanted to several European and African countries, USA and East and South East Asian countries; however, only South Africa has reported any success in cultivation.

2. *Cherax destructor* (Yabby)

As indicated in the name, they are actually levee destructors, escavating deep burrows in the pond. As a result of this burrowing habit leading to difficulties in harvest, environmental problems and pond destruction, it is difficult to culture the species. Adults may grow to over 140g each. Females carry 300-400 eggs depending on size. Moulting and breeding are confined to the warmer months of the year. It cannot tolerate temperature above 30°C. The growth rate of Yabby compares favourably well with that of marron.

Semi-intensive pond culture of Yabby is undertaken in Victoria, W. Australia, New South Wales and S. Australia. The harvesting of Yabbys from extensively managed farm dams is undertaken with the majority of the production coming from W. Australia. Estimate of Australian aquaculture production of Yabbys for 1989-90 is 68 tons, valued at Au. $ 724,000.

3. *Cherax quadricarinatus* (Red Claw)

Red Claw is an ideal species for culture in tropical countries because of its wide temperature tolerance and other favourable characteristics. They grow best at temperature range of 24-30°C and growth is slow at 16-21°C. It grows to nearly 400g and the growth rate is about 80g in 6 months or 50-100g in 7-8 months. It is a multiple spawner. As there is no burrowing habit it is a desirable species for pond culture. It tolerates low oxygen range and a wide range of other water quality conditions. Adult Red Claw have been shown to tolerate dissolved oxygen levels as low as 1ppm, unionised ammonia concentration upto 1ppm and Nitrite as high as 1ppm without any noticeable adverse effect. They have been found to reproduce and thrive in water with hardness over 300ppm and less than 100ppm and pH in the range of 6.5-9.0. Though found in the freshwater river systems of Northern Australia they can withstand salinity in excess of 12ppt for extended periods. Red claw and freshwater prawn, *Macrobrachium resenbergii* occupy the same tropical zones in Australia but are not found to be destructively competitive. Polyculture of both the species undertaken in the USA also showed encouraging results. Initial trials of culture yielded 600kg/ha/6 months when the ponds were fertilised and supplied with hay, and 1200 kg/ha/6 months when supplied with commercial shrimp feed. Yields between 1000 and 2000 kg/ha in a 6-9 months period could be anticipated.

Eventhough differential growth is observed in the culture systems, it is not as pronounced as in the case of other crayfishes and the freshwater prawn. It is not as much territorial in behaviour as the other crayfishes with the result that it is possible to undertake high density culture. The brood stock requires no special maturation facility. They breed readily in captivity and throughout the year if the temperature is maintained above 21°C. There is no delicate larval stages which require elaborate hatchery system. Females carry the eggs in their brood till they hatch out. Incubation period is 4-6 weeks and the young hatchlings which go through two larval stages will cling to the abdominal appendages of the female for one or two weeks. The development is temperature dependent and high temperature will reduce the incubation period as well as the length of larval life. Cultured specimens attain sexual maturity in 7-8 months at an average weight of 40g. Fecundity is low ranging from 400-1000 eggs per individual, but this is compensated by its capability to breed several times in an year. Another favourable character is that they have a tendency to breed quickly when confined at high densities (10-15nos./m^2) in indoor hatchery recirculatory systems. The just hatched out young ones are reared in nurseries till they reach about 5cm in length and over 1g in weight. After nursery rearing the juvelines are stocked at 500-2500/m^2. Survival has ranged from 30 to 89% depending on stocking rate.

A variety of feeds like zooplankton, filamentous algae and soft-leafed aquatic plants have been used for feeding newly independent juveniles. Formulated feeds containing nearly 40% protein have been found to give promising results in nurseries.

Three types of culture are adopted: Farm dam or lake extensive culture, semi-intensive pond culture, and intensive or battery culture in tanks. Farm dam extensive culture involves only a low level of stock management, water quality management, predator control and supplementary feeding. A stocking density of 1/m^2 is used and production of less than 400kg/ha is expected.

In pond culture the water depth is usually 1-2 metres. Water depth greater than 2m and less than 0.2m are not preferred. Clay soil is the best as it promotes turbid water which will reduce predation and encourage longer feeding periods. Cut-off PVC pipes, car tyres, roof tiles etc. are provided for shelter as well as for growth of periphyton. A stocking density of 7-50 juveniles/m^2 is preferred and a production of 2000-3000kg/ha is expected. Crayfish will feed on naturally occurring food, but supplementary diets of grains, aerobically composted plant matter, earthworm and formulated feeds containing upto 40% protein are used.

Battery culture is in an experimental stage only and this operation is mainly undertaken in Western Australia and New South Wales. In this system, a flow-through or recirculatory system with biofilter is used depending on the availability of water. A stocking density of 50-100/m^2 is used and a production of 10,000kg/ha is expected.

In Queensland, the red claw is the major culture species. Pilot scale production of red claw is underway in the Northern Territory and some trials are undertaken in Western Australia under strict quarantine conditions. Estimates of Australian aquaculture production of Red claw for 1989-90 is 31 tons valued at Au.$ 496,000.

Some crayfish farms have diversified into the production of juveniles for stocking, tourism, equipment sales and consultancies. Some species have been cultured for more than 20 years in Western Australia. Cray fish are cultured for the restaurant trade both domestic and overseas and are usually harvested at approximately one year of age (50^+g).

DISEASES

Although viral, nutritional and environmental diseases have been increasingly recognised as major problems in intensive crustacean aquaculture, there are only a few reports of such conditions in the crayfish. However, crayfish plague, a fungal disease, is so lethal that one can only speak of control rather then treatment. Most bacterial diseases are susceptible to therapy, as are the ecto-commensal conditions.

Bacterial diseases

Three main categories of bacterial diseases have been found in crayfish: (a) bacteraemias involving the blood and /or the internal organs of the crayfish, (2) infections of the exoskeleton by chitinoclastic bacteria (3) gill infections by filamentous bacteria.

Fungal diseases

It has been found that *Saprolegnia spp.* such as *S. diclines* can be a significant problem to crayfish (*Astacus pallipes*) under conditions of intensive culture or stocking, where factors such as low dissolved oxygen and high levels of suspended solids may produce excessive stress and predispose the crayfish to infection by opportunist saprophytes. *Saprolegnia* may also infect crayfish eggs by invading dead eggs in the same egg-mass and then overgrowing and smothering nearby viable ones.

Crayfish plague: The causative organism of the epizootic disease, crayfish plague, is the fungus *Aphanomyces astaci.* Crayfish plague is essentially an European disease affecting European crayfish species, including *Astacus astacus, A. leptodactylus* and *A. pallipes.* In the late nineteenth and early twentieth centuries crayfish plague infection reached the waters of N. Italy, France, Germany, the Netherlands, Belgium, Romania, Russia, Finland and Sweden. Most populations of native European crayfish have been severely affected throughout their ranges in mainland Europe.

The efficacy of common fish farming disinfectants against *A. astaci* has been investigated and it was found that sodium hypochlorite at 100ppm chlorine was effective in killing hyphae in less than 15 seconds, whilst iodophores at 100 ppm iodine were almost equally effective although their performance was much inhibited by the presence of organic contamination. It has also been demonstrated that malachite green is very effective against *A.astaci.* This opens the possibility that appropriate disinfection of contaminated equipment and the animal could materially assist in control of spread of crayfish plague.

Protozoan diseases

Association of protozoans with crayfish cover the full range from simple epibionts to lethal parasites. Thelohaniasis falls into the latter category and may be considered to be the most serious disease of crayfish world-wide, after plague. Thelohaniasis, 'Porcelain' or 'white tail' owes its name to the characteristic and easily recognised, opaque white, china-like appearance of the muscles of crayfish infected with microsporidians of the genus *Thelohania.* Thelohania is known to spread only by the injestion of spores or infected tissue. No evidence of a secondary host has been found. No treatment is at present available; the only effective measure against spread of thelohaniasis is to remove any individual showing signs of infection.

HARVESTING, PROCESSING & MARKETING

Traditional baits are rough fish; but several artificial baits similar to fish feeds with 12-20% protein level and 12-24 hr. water stability have been developed. Crayfish culturists use 5-6m flat bottomed boats with square prows to harvest crayfish. These are propelled by transom-mounted air-cooled engines with long weedless propellors or by spoked wheels that push or pull the boat using air-cooled engines to pump hydraulic fluid or to provide direct drive. Skilled operators can check 200-300 traps per hour in ponds.

Active capture devices such as seines are usually ineffective in vegetation chocked crayfish ponds. Very few boats equipped with electrofishing system are in operation. In Spain, unbaited cylindrical eel nets are set in irrigation canals with entrances pointed downstream and crayfish which move upstream against currents are trapped. Harvesting accounts for 60-65% of the annual operating costs of crayfish production, with labour and bait costs accounting for most of the harvesting costs.

Processing

Some countries, especially France and Germany prefer to buy live crayfish whereas others like Sweden prefer the processed product. Purging or holding the crayfish in vats for 24-48 hours in order to evacuate the digestive tract is commonly practiced.

The main processing method in Turkey turns out cooked, vacuum-packed, pasteurised, frozen and ready-to-eat crayfish. On arrival at the plant, the crayfish are stocked in stocking ponds where dead and dying crayfish are sorted out. Live ones are thoroughly washed in tap water and placed in wire baskets which are then dipped into stainless steel tanks where they are boiled for 5-8 minutes. Boiled crayfish are cooked by air circulation in the storage room. They are then transferred to the processing room, and packed in 1kg plastic boxes. Special brine containing salt, spices, dill and water are applied to the boxed crayfish. They are then vacuum packed and after pasteurisation are cooled under tap water and frozen at -35°C to -40°C. They are stored at -18°C to -20°C. Under these conditions crayfish will keep for nine months. For export the packages are taken out of the storage room and packed into original cartons. They are transported by refrigerated trucks at 0°C. Package contains 1kg crayfish in brine weighing 2kg net. Crayfish are also exported in frozen form, when they are directly frozen in water while still alive.

In Europe crayfish are sold in shops where they are stored in basins with flowing water. Before transporting *Astacus astacus* are dried and placed on dry, moisture-absorbing material, and laid on the floor of an aired room or on the bottom of aired boxes. Drying of crayfish takes 4 to 6 hours. Wicker baskets or wood splint boxes are adequate to hold 60-80 crayfish in 2-3 layers put on packing sheets. Crayfish are packed with backs upwards and abdomens tucked, yet without squashing them. They are conveyed in refrigerator cars and the duration of transport is 5-6 days.

Edible Louisiana crayfish products are whole, live or frozen (cooked or uncooked) hard-shelled crayfish, similar soft shelled crayfish, and fresh or frozen abdominal muscle or tail meat with or without hepatopancreas material added. Roughly half of the harvest is sold whole and the remainder is peeled for meat. Peeling is done by hand generally and hand-peeled crayfish are boiled before being processed. Machine-peeled crayfish are fast frozen in a super - cooled brine solution, partially thawed, deheaded by hand and peeled with tongue-in-groove rollers. A number of trough moulting systems have been developed in Louisiana to produce soft-shelled crayfish which might fetch prices about 10 times those of hard-shelled ones. Approximately 85% of the live weight of crayfish constitutes waste in Louisiana peeling operations and this is a potential source of protein-rich meal and other by-products.

Marketing

Nearly 70% of the crayfish world market is in the live condition and the rest 30% is marketed as frozen blocks of tail, meat etc. In Louisiana 75-80% of the various crayfish products is consumed within the State. Efforts to develop markets outside the State have not been quite successful. There are basically three markets for the Louisiana crayfish, based largely on size. These are the peeler, restaurant and export markets. Peeler crayfish are generally smaller than 25 per pound and are peeled for tail meat by processors. Restaurant crayfish are usually in the 15-25 per pound range and are boiled or steamed by restaurants. Export grade crayfish are in the 10-15 per pound size range.

The collapse of the Turkish crayfish industry has led to an export market for the Louisiana crayfish that takes about 5-10% of the annual production. There is considerable emphasis on the development of value added products and promotion boards and marketing authorities are now in place working towards interstate markets. The European market remains a strong but competitive one for the boiled /frozen whole crayfish from the US since competition is being faced from Spain, the USSR, China and Australia.

ECONOMICS

In crayfish culture, operating costs depend largely on the size and intensity of operation; however, labour for harvesting represents the largest variable expense (30-60%), followed by feed (5-30%) and energy (0-15%). Crayfish farming in Britain is reported to be highly profitable with prices averaging around £ 5.50 per lb and operating costs relatively low. It is estimated that from a 3 acre professionally designed pond costing around £4000 to construct and £3000 to stock over 2 years, return of £26,000 - 30,000 a year could be expected of which well over 60% would be profit.

With reference to Louisiana crayfish production it is suggested that reduction in harvest effort to 3 days a week would cut production by about 30-40%, but savings on labour and bait cost would perhaps justify that strategy. Daily bait and labour costs are US$ 0.110 and 0.132 respectively per kg of harvested crayfish. The average price paid to the farmers was about $.077 per kg during 1988-89. In the past, farmers generally received the same price for their crayfish regardless of size; but a significant demand for large crayfish in the 30-40 g size range has developed to supply frozen, boiled crayfish for the Scandinavian market. Farmers receive $1.87 - 3.19 per kg for such large crayfish. Crayfish of 19-28g range fetched prices around $1.10 per kg and found ready markets in the live market for boiling. Crayfish in the 14-18 of range are peeled for tail meat and fetch $0.77 per kg or less. The bulk of the crayfish produced falls in the peeler grade. Those farmers who are able to produce larger crayfish are able to operate profitably. Those who produce largely peeler grade must produce well in excess of 1120 kg per hectare to be able to operate profitably. It is pointed out that reducing harvesting intensity has the beneficial effect of yielding larger and more valuable crayfish when finally harvested.

Processors justify low prices for peelers because they contend that they cannot market crayfish meat competitively otherwise. The principal competition comes from imported shrimp meat. Prices paid to the farmers for peeler grade are again affected when wild crayfish are abundant. Fishermen will accept prices much lower than those that the farmers will accept because their production costs are much lower. If it appears that there will be a large wild crop, processors hold prices down. However, the success of the wild crop depends on the high water level in the river and the flooding of the basins. Therefore, in order to be competitive with the wild fishery, the farmers must necessarily reduce the production costs as well as produce larger crayfish. Presently therefore much research is directed towards achieving these goals. Several automated crayfish harvesting devices are being fabricated and tested, aerators are introduced, increased levee area from inner guide levees is provided, compounded feeds are manufactured and stock management practices are undertaken.

Soft-shelled crayfish, a new product, became widely available in the 1987-88 season in Louisiana. The harvesting of soft-shell crayfish became commercially feasible with the development of electro-trawl. A system for shedding crayfish in tanks is also developed. Producer prices of over US $ 17.00 per kg resulted in considerable expansion of production capacity to over 230 tons.

Reviewing the prospects of expanding crayfish aquaculture on a global basis it is pointed out that unlike shrimp, crayfish do not have a widespread appeal in the world market. It will require major promotional and marketing efforts to expand the existing world markets. Competition will come from wild-caught crayfish and other crustaceans. This might expand the crayfish-eating population and in the long run might stimulate aquaculture of crayfish. The crayfish is reported to be an excellent candidate for aquaculture from a biological standpoint. Perhaps, the best species for consideration is the Australian Red claw, *Cherax quadricarinatus*. The red claw can tolerate temperature upto 34°C and salinity upto 12ppt, does not burrow, grows upto 80g in 6 months, has upto 30% tail meat, is a multiple spawner, reproduces readily in captivity, can tolerate harsh pond conditions and is compatible with the freshwater prawn and fishes in polyculture.