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EXPERIMENTAL CULTURE OF THE SHORT-FINNED EEL *ANGUILLA BICOLOR BICOLOR* McCLELLAND

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ABSTRACT

In this paper the various techniques adopted in the culture of eels (*Anguilla* spp.) and the results obtained in the experimental culture of the short-finned eel, *Anguilla bicolor bicolor* McClell and in running water and in recirculating running water have been dealt with. Experimental culture of the eel, *A. bicolor bicolor* in running water was conducted during 1974-76 at the Regional Centre of Central Marine Fisheries Research Institute, Mandapam Camp. The average size of the elvers stocked at the beginning of the experiment was 13 cm in length and 3 g in weight. It has been found that the average size of the eels at the end of one year was 28 cm in length and 43 g in weight. The average length at the end of second and third years were 38 cm and 42 cm and weights 123 g and 177 g respectively. The overall increase in growth obtained in this experiment was found to be not rapid and the probable reasons for the same are pointed out. Studies on conversion efficiency of different eel foods have shown that silverbellies give high conversion ratio and sardines low conversion ratio. Clams, prawns and mixed foods have also been found to give better conversion ratio than sardines. From this experimental culture the net production potential has been estimated to be 2.2 kg/sq. m in one year and 4.11 kg/sq. m in two years.

In another experiment, the short-finned eel *A. bicolor bicolor* was cultured in re-circulating running water in an outdoor cement tank of 6 m length × 3 m width × 1 m height, with natural mud bottom. By suitable arrangements the water in the culture tank was automatically re-circulated after filtration and oxidation. About 1/3 of the water in the culture tank was drained out weekly and replenished with fresh water. In the beginning of the experiment 9 kg of eels, each eel, with an average weight of 43 g were stocked in the tank at a rate of 500 g per sq. m area.

An eel feed in the form of a paste made of minced silverbellies, broken rice and oil cake mixed in 2 : 1 : 1 proportion with 0.2% multivitamins was given to the eels at a daily ration ranging from 5 to 10% of their body weight. At the end of five months the total weight had increased to 47.7 kg which works out to a net increase of 430% of the initial stocking weight. The average weight of eel had increased from 43 g to 232.8 g in five months. The survival rate was 98.6%. The net production rate works out to 2.15 kg/sq. m in five months period.

INTRODUCTION

EEL CULTURE is a commercially profitable industry in several East Asian countries, particularly in Japan and Taiwan, where the Japanese eel *Anguilla japanica* Temminck and Schlegel is cultured on a large scale since several decades. Cultured eels are a delicacy and as there is great demand for the same, the production is increasing steadily. Throughout the world on an average about 25,000 tonnes of wild eels and 26,000 tonnes of cultured eels are harvested annually, of which Japan alone produces about 2,000 tonnes of wild eels and 24,000 tonnes of cultured eels (Usui, 1974). Faced with shortage of elvers for culture purpose Japan imported large quantities of elvers from countries like Taiwan, South Korea, China, Hong Kong, Philippines, New Zealand, France, Spain, Italy, Great Britain, Canada and United States of America (Folsom, 1973; Forrest, 1976). In India elvers of two species of *Anguilla, viz.*,

Anguilla bicolor bicolor McClelland and *Anguilla nebulosa nebulosa* McClelland are known to be available in the east coast rivers Tamraparni, Godavari and Hooghly (Rahimulla *et al.*, 1944 ; Pantulu, 1956 ; Ibrahim, 1961 ; Nair, 1973 ; Nair and Dorairaj, 1975). A recent survey has brought to light for the first time immigration of glass eels and elvers in many rivers in Tamil Nadu (Dorairaj and Soundararajan, 1980). Even though many fish species of both fresh and salt waters are being successfully cultured in India (Alikunhi, 1957 ; Tampi, 1960, 1969 ; Hickling, 1970), no attempt has been made to culture the Indian eels until 1971 when experimental culture of *Anguilla bicolor bicolor* was undertaken at the Central Marine Fisheries Research Institute at its Regional Centre at Mandapam Camp (Nair, 1973). In this paper the results obtained in the experimental eel culture in running and recirculated running water and food conversion studies are presented. The general techniques employed in eel culture at various stages are also briefly given.

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Eel Culture Techniques

Elvers are the starting point for eel culture. Seed elvers of 55-100 mm in length and 0.16-2.0 g in weight are collected during night time by using several types of nets like scoop nets, screen nets, bag nets and a special type of net known as 'Japanese Elver fishing net' when they ascend rivers immediately after a freshet. Very early stage elvers-glass eels-are completely transparent and thread like whereas last stage elvers are pigmented and slightly thicker in size. The elvers are transported in different types of containers like conventional fish tin carriers made of galvanised sheet metal, PVC containers, specially made wooden boxes, styroform containers etc. For conducting eel culture a good supply of fresh water or brackish water is very essential. In the initial phase of eel culture elvers are to be stocked and reared in small nursery ponds, the size of which may range from 150-600 sq. metres in area and 70 cm deep. After about three months elvers have to be stocked in bigger ponds known as fattening or adult ponds varying in size from 0.08 to 4 hectares and 1 to 1.5 metres deep. 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 eel locate food more easily in such ponds (Bardach *et al.*, 1972). The collected elvers have to be sorted accoring to size and stocked in densities which depend upon the quantity and quality of water supply. Stocking density is always higher in running water culture than in still water culture. The optimum stocking density is 30 elvers each weighing 0.16-0.2 g or 20 young eels of about 15 gm each per sq. metre.

In eel culture feeding is an important aspect. Elvers do not take food for the first few days after their capture and they have to be slowly acclimatised to a regular feeding habit. Crushed earthworms are to be given to the elvers when they begin feeding and later on a mixed food of earthworms and fish flesh. After a month the growing elvers may be supplied with fresh or cooked fish like sardines, silverbellies, trash fishes along with prawns and clam meat. Eels prefer to feed in a dark place. Therefore the feeding place should be provided with a shelter. Feeding should be done only in a particular place in the pond, preferably in a corner by placing the food in a wire basket or perforated tray and suspending it just above the water to prevent contamination of water. The elevers are given food at a ration of about 40% of their body weight and

the growing eels about 10% of their body weight. Growth rate in eels is observed to be very rapid during April-October period. Therefore eels should be given as much food as possible during the above period. Concentrated dry food in the form of pellets are also being widely used and has been found to give higher conversion ratio than the fish foods.

The success of eel culture also depends upon the proper maintenance of the farm. The ponds should have a minimum water depth of about 60 cm. Even under optimum conditions of good water supply, temperature, stocking density, adequate food and proper maintenance, cultured eels exhibit a wide range in growth rate, both in terms of length and weight. Therefore, at periodical intervals in all stages of culture culling should be done which will ensure uniform size of eels at the time of harvesting. Control and eradication of eel diseases is another important aspect in eel culture. Many types of diseases such as Fungus disease, Red disease, Gill disease, White spot disease, Myxidium disease etc. are known in eels. The diseases could be controlled by using suitable anti-bacterial drugs and flushing the pond with fresh water. The introduction of concentrated dry food has facilitated mixing of drugs in eel food which could be supplied to the eels to cure their diseases. The cultured eels are harvested when they reach marketable size. The principal nets used for harvesting are scoop nets, trap nets, cast nets, screen nets and seine nets. When a partial or selective harvest is done the water in the ponds is not drained but in the final harvest ponds are usually drained before fishing.

The production or yield per hectare varies with the type of culture method adopted. Eels are cultured by two methods *viz.*, running water culture and still water culture. The principal aim in these two methods is to achieve maximum production in a short period of time by culturing eels in a confined area and providing extra oxygen and more food. In running water culture a continuous supply of freshwater will be maintained to the pond and simultaneously an equal amount of water will be drained to keep the water level in the pond constant. In this method eels are supplied with a large amount of fresh oxygen through constant flow of fresh water. In still water culture the pond water will be more or less static and only about 5% of the volume of the pond water is changed daily. There is production of dense phytoplankton which in turn through photosynthesis increases the oxygen content of the pond water, thus providing extra oxygen for the eels. Depending upon the availability of water any one of the above two methods could be adopted in eel culture.

Results of Experimental Eel Culture

Culture in running water

A total of about 1200 elvers of *Anguilla bicolor bicolor* McClleland, collected from Srivaikundam Anicut near Tuticorin, during November 1973, were reared in eight fibre-glass tanks (122 cm × 76 cm × 76 cm) in densities ranging from 330 g per sq. m to 1,500 g per sq. m. Each fibre-glass 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. At periodical intervals the total weight of elvers and growing eels in each tank, were taken and the lengths and weights of about fifty numbers from each tank were masured to determine the growth rate. To measure live elvers an anaesthetic technique was followed. Out of the eight tanks growth studies were followed in four tanks for two years. At the end of two years culling was done and growth rate was followed for bigger size groups. The results obtained in the growth studies are given in Table 1.

TABLE 1. *The average sizes of eels* A. bicolor bicolor *in different tanks during different periods in experimental running water culture (Average weights are given in parentheses)*

Month	Tank 1	Tank 2	Tank 3	Tank 4	Average
November '73 ..	119 (2.1)	115 (1.9)	146 (4.2)	146 (4.0)	131 (3.0)
March '74 ..	149 (6.3)	150 (6.5)	189 (13.1)	175 (10.3)	166 (9.1)
May '74 ..	167 (8.5)	175 (9.6)	213 (16.9)	185 (11.2)	185 (11.6)
October '74 ...	280 (47.7)	289 (45.9)	288 (44.5)	256 (31.8)	278 (42.5)
February '75 ..	335 (92.6)	354 (96.6)	334 (80.1)	315 (68.7)	334 (84.5)
March '75 ..	364 (104.8)	366 (102.3)	345 (90.0)	327 (76.8)	350 (76.2)
July '75 ..	381 (115.4)	377 (106.4)	351 (86.7)	316 (60.7)	355 (92.3)
October '75 ..	430 (163.9)	384 (123.2)	348 (91.0)	358 (92.8)	380 (119.3)
November '76 ..	..	..	..	..	419 (177.0)

TABLE 2. *Total weights of eels in different periods and monthly rate of weight increase in percentage of previous total weight* (The density rates in g per sq. m are given in parentheses)

Tank	Total weight of eels (in g) and monthly weight increase in %			
	Initial	At the end of		
		1 month	2 months	4 months
I ..	581 (710)	957 (1153) 64.4%	1328 (1600) 38.8%	1901 (2290) 21.6%
II ..	702 (846)	1096 (1321) 56.1%	1657 (1996) 51.3%	2260 (2723) 18.2%
III ..	977 (1177)	1254 (1511) 28.4%	1557 (1876) 24.2%	1955 (2355) 12.8%
IV ..	1430 (1722)	1729 (2083) 21.0%	2062 (2484) 19.3%	2656 (3200) 14.4%

In the beginning of the experiment in November 1973 the sizes of elvers ranged from 71 mm to 191 mm in length weighing 0.3 g and 9.5 g respectively, with an average of 131 mm in length and 3 g in weight. At the end of six months the average size of elvers was 185 mm in length and 11.6 g in weight. 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 278 mm (43 g), showing an increase of 147 mm 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. During the second year an average growth increase of 102 mm and 76.3 g was observed with a monthly growth of 8.5 mm and 6.4 g. Thus in about two years the average size of growing eels had reached to 380 mm (119 g) and the increase was 249 mm (116 g). At the end of third year the average size of the eels was 419 mm in length and 177 g in weight. During the third year the monthly growth rate was 3 mm in length and 4.5 g in weight. It was observed that the length increase was faster in the first year and slower in the second and third years while the weight increase was more in the second year compared to first and third years. In the present experimental culture differential growth was observed among the eels reared in the tanks (Table 1). In the first year the average sizes attained by eels in different tanks were more or less similar except for one tank and were comparable with overall average size of about 28 cm and 43 g. But in the second year the differential growth of eels in different tanks was much marked which ranged from 60 mm (46.5 g) to 150 mm (122.2 g). It may be of interest to note here that the average size attained by the eels at the end of second year in one tank was higher than the overall average size of the eels at the end of third year.

There seems to be an inverse relationship between the rate of density and the rate of weight gain in eels in succeeding months. As the density increases, the rate of weight increase was found to decline progressively (Table 2).

Food conversion studies

Experiments were conducted to study the conversion efficiency of different animal feeds that were available locally so as to select an economically better feed for commercial culture of eels. The materials such as sardines, clam meat, silverbellies and prawns were given either separately or in mixed combinations. Seven types of feeds, namely (1) Sardines, (2) Clam meat (3) Silverbellies, (4) Prawns, (5) Sardines 50% and clam meat 50%, (6) Sardines 50% and prawn 50% and (7) Sardines 25%, clam

TABLE 3. *Results of conversion rates of various food items*

Type of feed	Daily food consumption in % of body weight		Increase in weight (g)	No. of days	Total amount of food consumed (g)	Gross conversion rate	
	Range	Average				Monthly range	Average
Sardines ..	1.9- 4.5	3.1	1,214	123	22,916	11.5-24.3	18.9
Sardines and clam meat ..	5.2- 9.6	7.0	2,700	218	19,933	5.22-8.3	7.38
Clam meat ..	5.5-10.3	7.7	3,060	218	25,128	6.4- 9.9	8.21
Sardines & prawns ..	3.2- 6.5	4.5	995	218	16,476	10.7-27.7	16.56
Sardines, clam, silverbellies & prawns ..	4.0- 8.1	5.0	2,678	218	22,364	7.9- 9.5	8.35
Silverbellies ..	3.1- 6.2	4.5	2,230	218	15,510	5.7- 8.2	6.96
Prawns ..	3.4- 6.0	4.6	1,660	218	11,619	6.0- 9.8	7.00

meat 25%, silverbellies 25% and prawn 25% were tested for gross conversion efficiency. The elvers and the growing eels were fed twice daily, morning and evening, to satiation. The feed was supplied in excess quantity at a ration of about 5 to 15% of the body weight. Usually the elvers and the growing eels were found to feed very actively when the feed was offered and within ten or fifteen minutes majority of them would have fed to satiation. However, the feed was kept for a longer time upto about one hour and then only the left over feed would be removed. The total weights of the feed supplied and the left over were taken to determine the actual consumption. The results obtained in the feeding experiments are given in Table 3.

It may be seen from the above table that the daily average consumption of eel feeds in percentage of body weight varied from 3.1 for sardines to 7.7 for clam meat. Silverbellies and prawns were found to give better conversion rate than the other feeds. The gross conversion rate of silverbellies was between 5.7 and 8.2 with an average of 6.96. Similarly for prawns the range was between 6.0 and 9.8 with an average of 7.0. The next best average conversion rate of 7.38 was for a mixed feed made of sardines and clam meat. Sardines had given the lowest gross conversion rate which ranged between 11.5 and 24.3 with an average of 18.9. Though the silverbellies and prawns were found to give more or less a similar conversion rate of 7.0, silverbelly feed is considered to be the best suitable feed for the eel culture at the locality because of its cheap price and easy availability. The nutritional values of silverbelly feed are as follows : crude protein 13.61%, fat 6.59%, ash content 7.18% and moisture 70.70%.

Production

For estimating the production rate the increase in total weight of elvers during the period from March 1974 to March 1976 has been taken into account. During March 1974, 7.28 kg of elvers were stocked in fibre glass tanks having a total surface area of 6.65 sq. m. At the end of one year the total weight of grown up 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 from initial weight in two years was 27.33 kg. The net production in one year works out to 2.247 kg/sq.m and in two years 4.112 kg/sq. m.

Eel Culture in Re-Circulating Water

In August 1978, another experiment was conducted to culture *A. bicolor bicolor* McClelland in re-circulating running water. For this purpose a separate cement tank of 6 m × 3 m × 1 m size with natural mud bottom was constructed. By sluice gate arrangement the bottom water was gravitationally drained out and passed through a filtering medium consisting of big and small granite stones and charcoal arranged in alternate layers and with a layer of sand at the top. The filtered water was allowed to settle in a settling tank. In the settling tank partitions using asbestos sheets, were erected in such a way that water travelled longer distance thereby allowing time for settlement. The clear water in the settling tank was then allowed to overflow to the oxidation tank. From the oxidation tank the water was pumped up into a small over-head tank and from it fed to the culture tank. Thus the water from the culture tank was reused again and again after filtration and oxidation. Weekly once about 1/3 of the water in the culture tank was drained out and replenished with fresh water. Water level was maintained at 70 cm in the culture tank.

An effective feeding method was adopted in this experiment. A sheltered feeding area was provided on one side of the culture tank in the form of a wooden platform with a small

door in the middle. The sides below the platform were covered with black cloth to cutdown direct light to the feeding area. The eel feed in the form of a paste made of minced silverbellies, broken rice and groundnut oil cake mixed in 2 : 1 : 1 ratio with 0.2% multivitamin was placed in a plastic tray and suspended through the door at the water level. Then the door would be closed. The eels in the tank would immediately congregate near the tray, climb over it, dart to the food, take a mouthful and slip back into the water. After gulping the food the eels would again climb the tray and take another mouthful of food. This is repeated and after satiation the eels would settle down at the bottom of the tank. The tray with leftover food would then be lifted out through the door. By this method contamination of water by food was effectively avoided. The eels were fed at a daily ration ranging from 5 to 10% of their body weight. The food values of the compound feed were : crude protein 23.20%, fat 7.63%, carbohydrate 21.51%, ash content 3.90% and moisture 43.76%.

In the beginning of the experiment on 1-8-1978, 9 kg of young eels, 208 in numbers, the size ranging from 20 g to 65 g with an average total weight of the eels was 47.8 kg. The net weight of 43 g, was stocked in the culture tank at a stocking rate of 500 g per sq. m. At the end of each month a sample of about 50 to 100 eels in the tank was scooped out and individual weights were recorded. Based on the average weight of the eel at the end of each month, the total weight of the eels in the tank was estimated. The results obtained in the experimental culture are given in Table 4. It may be seen from the table that the average weight of the eel has increased from 43 g to 84 g in one month, 132 g in two months, 203 g in four months and 232.8 in five months and ten days. At the time of harvest the increase in total weight works out to 430% of the initial stocking weight. The survival rate was 98.56%. The gross food conversion ratio for the four month period (from August to November '78) was 1 : 5.3. The stocking rate at the beginning of the experiment was 0.5 kg/sq. m. At the end of 5 months it had increased to 2.65 kg/sq. m. The net production rate works out to 2.15 kg/sq. m in five months.

TABLE 4. *Results of the experimental eel culture in re-circulated running water. The details of average weight, total weight, percentage increase, survival rate and gross food conversion during different months are given*

	1-8-78 (at stocking)	1-9-78	1-10-78	1-12-78	10-1-79 (at harvest)
Average weight of eel in g ..	43	84	132	203	232.8
Total weight of eel in the tank in kg ..	9	17.5	27.5	42.0	47.8
Percentage weight increase in initial stocking weight		94.58	206.0	366.7	430.0
Survival rate ..		100%	100%	99.5%	98.5%
Quantity of food consumed in kg. ..		34.57	37.82	102.98	
Gross food conversion ratio ..		1 : 4.0	1 : 3.8	1 : 7.1	
Average gross food conversion ratio ..			1 : 5.3		

DISCUSSION

Though the eel culture has been in vogue for the last ten decades in Japan, in India it was first done only in 1971 (Nair, 1973 ; Nair and Dorairaj, 1975). In their experimental eel

culture in running water, elvers with an average size of 10 cm and 2 g had reached an average size of 35 cm and 106 g at the end of about one year and 42 cm and 160 g at the end of second year with an average monthly increment of 8.6 g and 4.5 g during the first and second year respectively. In the present study, the size attained at the end of one year works out to about 29 cm in length and 49 g in weight and at the end of two years 38 cm and 119 g. As compared to the earlier results the present results are low. It may be mentioned here that in the present work elvers and growing eels were cultured in fibre glass tanks and they were subjected to constant handling and disturbance due to daily cleaning of the tank and periodical anaesthetisation for taking measurements of length and weight. Culture in fibre glass tanks and frequent disturbance could have inhibited the growth rates to a certain extent. The growth rate obtained in the re-circulated running water in the present study provides evidence to substantiate the above conclusion. When the eels of 43 g size were stocked in the outdoor tank with natural mud bottom, the average weight reached to 232.8 g in about 5 months, where as the same size eel cultured in fibre glass tank reached only to 76.2 g in the same duration (Table 2 and 4). Further, the result obtained in the re-circulated running water culture has been found to be very high as compared to results obtained in experimental eel culture in Europe. In Channel system 30 g European eel had reached to 160 g in 12 months and in river ponds 49 g European eel reached 109 g in six months (Tesch, 1977). In Japan, according to Usui (1974) 60 g Japanese eels reach marketable size of 150-200 gms in about twelve months.

The conversion rates of traditional foods and artificial feeds obtained in eel culture in Japan and Taiwan are given by Bardach *et al.* (1972). In Japan the sardines had been found to give conversion rates ranging from 5.4 to 7.2 and the mixed feed i.e. chopped fish, silk worm pupae etc. had given a conversion rate of 5.5. In Taiwan the conversion rates for trash fish ranged from 10-15. In the present work sardines had given poor conversion rates ranging from 11.5 to 24.3 with an average of 18.9. The conversion rate of the mixed feed, composed of silverbellies, broken rice and oil cake with 0.2% multivitamin given to the eels cultured in re-circulated running water, was more or less similar to those of chopped fish, silk worm pupae etc. Fresh fish feed, such as mackerel, atka fish, saury pike, miscellaneous types of brown fishes etc. used in Japanese eel farms, had given a conversion rate from 4.8 to 6.9 (Forrest, 1976). The conversion rate of silverbellies and prawn (7) obtained in the present feeding experiment is comparable to the above feed. Since silverbellies are available in this region in large quantities at cheap price it will be a best suited feed for commercial eel culture.

With regard to the production rate, what was obtained in one year (2.25 kg/sq. m.) in running water culture had been achieved in about five months in recirculated running water. In Japan the production potential in running water in one year is stated to be 26,360 kg/hectare which works out 2.6 kg/sq. m (Bardach, 1972).

Research work done so far to artificially spawn the *Anguilla* spp. has met with very little success only. By injecting three harmones and pituitary extract of rainbow trout, an adult female eel had been made to spawn about 5 million eggs (Anon, 1971) Artificial fertilisation and early development of larvae (5 days) in Japanese eel were successfully carried out by Yamamoto and Yamokuchi (1974).

There are good prospects for commercial eel culture in India as the Indian species had given encouraging results in the experimental culture. The recent survey undertaken to locate the elvers in Tamil Nadu had brought to light many promising centres for large scale elver collection. What is required now is to undertake the culture on pilot scale to work out the economics of culture operation.

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