EXPERIMENTS ON THE ACCLIMATISATION OF SALT WATER FISH SEED TO FRESHWATER*

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Introduction

It is now generally accepted that the freshwater fauna of the present day have been largely derived from ancient marine animals. Unlike the temperate regions, the number of marine animals that have migrated into brackish water and freshwater habitats is very large in the tropics. The meeting places of large volumes of freshwater and salt water, like the estuaries of large rivers, back-waters, etc., are the regions where this natural acclimatisation is daily taking place. Panikkar and Aiyar (1937) in a noteworthy contribution on the brackish water fauna of Madras observe: "We find in every tropical back-water, tidal creek or estuary, an active and aggressive attempt on the part of many marine species to secure a permanent foothold either in the semi-aquatic mudflats and mangroove swamps or in the salt marshes with peculiar environmental conditions of fluctuating salinity, temperature and hydrogen ion concentration." The above observation is no less true in the case of fishes, and in India, with the extensive coast line and numerous estuaries of

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rivers and streams, the number of species of marine fish that are capable of natural acclimatisation to lower concentrations of salinity and even to freshwater is large. The capacity to successfully adjust to the fluctuating conditions, however, varies with the species. While species like *Chanos chanos*, *Elops saurus*, *Megalops cyprinoides*, *Lates calcarifer*, etc., grow quickly in the freshwater environment, they have to migrate to the sea (salt water) for the normal ripening of their gonads and breeding. Several species of mullets (*Mugil* spp.) fatten quickly in freshwater and some have even been found to have the gonads in advanced stages of ripeness, even though they are not definitely known to breed in freshwater; *M. corsula* being the only known exception. *Hilsa* is a well-known example of a marine species migrating to freshwater for breeding purposes; but it is capable of thriving in freshwater also. Extreme adaptation is exhibited by the pearl-spot, *Etroplus suratensis*, the orange-chromide, *Etroplus maculatus* and the goby, *Glossogobius giuris*, all of which could live and propagate in both salt and fresh water. The relative, natural capacity of the different species to adjust to the fluctuating environmental conditions is bound to reflect in their resistance to sudden changes during experimental acclimatisation.

In Madras, the difficulties in securing enough seed of the economically important carps for stocking inland waters, and the availability of several valuable centres for collection of salt water fish seed, have naturally stimulated attempts at acclimatisation of selected species of the latter for enriching the inland water crop. Job and Chacko (1947) have given a brief account of the important species of saltwater fish that are capable of easy acclimatisation to freshwater and which are being employed for stocking inland waters in Madras. Devanesen and Chacko (1943) found the marine mullets *M. troschelii* and *M. waigiensis* capable of successful acclimatisation to freshwater in about 3 days. A protracted period of 12 days was found necessary for *M. seheli* for successful acclimatisation to freshwater (Venkataraman, 1944). Ranganathan and Ganapati (1949) have found that chanos fry (1″ to 6″) were hardy and capable of withstanding even direct transfer from seawater to freshwater.

The successful culture of salt water fish in freshwater depends mainly on the speed with which they could be acclimatised to the new environment, without any mortality being caused during the process. Since processes of osmoregulation are involved in the transition from salt water to freshwater and since the osmoregulatory powers of the different species of fish seem to vary during different stages of their life-history, it is of primary importance to ascertain, in respect of each species, the stage at which they could most

successfully withstand the variations in salinity and other environmental factors, without deleterious effects. Knowledge of the acclimatisable stage of the different species is of considerable economic significance as it would prevent wrong selection of stage or size and is likely to yield better results during experimentation and after.

Experiments on the acclimatisation of salt water fish seed to freshwater have been carried out, during the last five years, at the Freshwater Biological Research Station, Madras, with a view to evolving satisfactory methods for the different species and standardising the same, for field conditions and requirements. Details of these experiments are furnished in this report.

Experiment I

Fry and fingerlings of *Mugil* spp., *E. suratensis*, *M. cyprinoides*, *E. saurus*, *Gerres filamentosus*, *Scatophagus argus* and occasionally *L. calcarifer* are collected annually from the Adyar backwaters for stocking purposes. The season usually extends from October to February.

On 28–11–1945, a small experimental consignment of about 150 fry (0·6″ to 0·75″ long) of *Mugil* spp. was taken from Adyar to Chetput in an earthen pot. Salinity of the water was only 15·00‰. There was heavy mortality during transport and by about 3 P.M. even the remaining ones were weak. By setting up a siphon arrangement, fresh brackish water was allowed to drip slowly into the container, and this had beneficial effect on the fry. There was no mortality till 7 P.M., when some freshwater was added and the salinity was brought down to 12·69‰. By next morning 5 specimens had died and another 5 were weak and swimming near the surface. At 11 A.M. more freshwater was added and the salinity was lowered to 11·44‰. One specimen died at 2 P.M. At 5–55 P.M. salinity was stepped down to 5·11‰ and the fry were left overnight in this medium. There was no casualty during the night and by 9–45 A.M. the next morning, the salinity was further lowered to 2·64‰. The fry behaved quite normally, though appeared weak. More freshwater was added by 6 P.M. and the salinity dropped to 1·58‰. By next morning, the fry looked very weak and emaciated. Some live plankton collected from the pond was introduced into the aquarium and the fry immediately became noticeably active and were seen feeding on the plankton. More plankton was added and the fry were again left overnight in this sweet water and on the 4th day they were successfully transferred to freshwater. There was no mortality.

Remarks.—Only a limited number of fry were used in this experiment. The dilution of the medium was spread over a period of about 90 hours only.

The condition of fry during the third day was very poor and introduction of live plankton as food in the aquarium had definite, beneficial effect and mortality during the subsequent stages was negligible. This indicated the possibility that in a prolonged course of acclimatisation the young fry may be better equipped to adjust to hydrobiological changes provided they are fed suitably during the transitional phases.

EXPERIMENT II

A bigger consignment of about 600 fry, $\frac{1}{2}''$ to $1\frac{1}{2}''$ long, of *Mugil* spp., was taken from Adyar to Chetput on 3–12–1945. The bigger fry were provisionally identified as *M. cephalus* while the smaller ones, on rearing in the pond, were identified as *M. seheli*. The fry were collected from the shallow expanses, by means of miniature drag nets of fine mesh. In spite of the presence of shoals of fry, collection was comparatively difficult; the fry when frightened, generally take shelter in the small shallow depressions in the uneven muddy bottom. They remain quiet in these pits till the net is dragged over, when they escape. From the net the fry were transferred to a bucket of water by means of a small hand net. After about 10 minutes they were transferred to a second bucket of brackish water and thence to the tin carrier containing clean brackish water. They were transported to the Chetput Farm within 3 hours after collection. Mortality during transport was negligible. Salinity of water at the collection spot was 15·00‰. The following experiments were tried at the Farm:

(i) Direct transfer of fry and fingerlings from brackish water to freshwater was tried as follows:

TABLE I

Aquarium No.	No. of fry introduced	Average Size	Casualty		Remarks
			No.	Duration	
1	12	$1\frac{1}{2}''$	7	18 hrs.	Of the remaining, 2 weak; 3 normal
2	12	$1''$	7	18 hrs.	Remaining 5 normal
3	12	$\frac{1}{2}''-\frac{3}{4}''$	9	18 hrs.	Remaining 3 normal

While the mortality ranged from 58 to 75% it was evident that at least some of the fry could tolerate even direct transfer from brackish water to freshwater. Of the three sizes of fry taken, 1″ long fry gave the maximum percentage of survival (42%).

(ii) 550 specimens, ½″ to 1″ long, were released in a large shallow aquarium containing brackish water. A tin carrier of freshwater from the pond was placed at a higher level and by siphon arrangement, was made to drip in slowly into the aquarium. Some live plankton was also introduced into the aquarium.

During the first 24 hours, 168 specimens died and another 15 were extremely weak and were removed. The salinity had come down to 12·16‰. It was considered that the continuous though slow dripping in of freshwater will be continuously altering the salinity of water in the aquarium, and might have kept the fry in a very uncomfortable state throughout, without giving them time to adjust themselves to any fixed grade of salinity. This might have accounted for the high mortality and the above arrangement was therefore stopped.

Another 44 specimens died during the next 12 hours.

The salinity was then stepped down to 11·10‰. The general condition of the fry was very weak by this time, and feeding was therefore attempted. Small stones with algal encrustations were taken from a pond and placed in the aquarium. Immediately the fry were seen crowding round these stones and were actively feeding, nibbling at the algal growth. There was no mortality during the night.

On the third day the salinity was brought down to that of freshwater in three stages, *i.e.*, 6·51‰ in the morning, 4·58‰ at about 1 P.M. and freshwater at about 6 P.M. Feeding was continued. There was no mortality during the night. The fish were thus brought to freshwater in the course of about 74 hours. They were kept in freshwater in the aquarium for two more days with regular feeding, but there were no casualties. 323 Fry were successfully acclimatised and released into the pond.

Remarks.—Acclimatisation was completed in a shorter period than in the first experiment. Mortality during the experiment was about 43%. Continued dripping in of freshwater and the resulting slow but continuous change in salinity appear to be positively harmful to the young fry, and the mortality resulted only when this arrangement was working. When this was stopped and arrangements for feeding the fry were made, the mortality was reduced to nil. That feeding during acclimatisation is beneficial is again illustrated by this experiment.

EXPERIMENT III

A small consignment of about 250 fry of *M. seheli* and *Mugil* spp., 0·6″ to 1·5″ long, was transported from Adyar to Chetput on 18–12–1945,

The salinity of water at the collection spot was 27·27‰. The incoming high tide water was responsible for the increased salinity. 45 Specimens, mainly small ones, died during transport.

At the Chetput Farm an attempt was made to step down the salinity of water in different stages as follows:

Aquarium 1.—18 Litres of brackish water of salinity 27·27‰, were poured in and 100 fry were introduced. A few stones with algal encrustations were placed in the aquarium for the fry to feed. 3 hours later (4 P.M.) the salinity was stepped down to 21·35‰ by adding freshwater and the fry were left overnight in the aquarium. There was no mortality. At 8–30 A.M. ($16\frac{1}{2}$ hours after) the salinity was again lowered to 16·07‰; 6 hours later the salinity was again stepped down to 10·74‰ and was further lowered to 5·28‰ after a similar duration. By 2–30 A.M. the fry were successfully transferred to freshwater. Mortality during the experiment was only 11.

Aquarium 2.—18 litres of brackish water of salinity 27·27‰ were poured in and 100 fry were introduced. Stones with algal encrustations were placed for feeding. 3 Hours later (4 P.M.) the salinity was lowered to 17·84‰ by the addition of freshwater. By the next morning, 25 specimens had died. At 8–30 A.M. the salinity was again lowered to 8·96‰. By 2–30 P.M. 6 more specimens had died. The remaining fry were then transferred to freshwater and left overnight in the aquarium. 16 Specimens had died during the night making the total number of casualties 47.

Remarks.—In aquarium 1 the experiment was completed in about $34\frac{1}{2}$ hours; while in aquarium 2 the duration of the experiment was only $22\frac{1}{2}$ hours. The change in salinity in each step was about 5·28 parts in aquarium 1 and the mortality during the experiment was only 11%. In aquarium 2 the salinity was lowered more abruptly than in aquarium 1, the difference in salinity between the different steps being 8·96‰. The excessive mortality during this experiment is probably to be attributed to this factor. However, since two factors, *viz.*, duration of the experiment and change in salinity at each step were both variables in the two aquaria, exact comparisons cannot be made.

EXPERIMENT IV

Based on the trends indicated in the above experiments under laboratory conditions, a large-scale field experiment was planned and carried out in February 1947.

0·5″ to 1·0″ long mullet fry (*M. cephalus*, *M. seheli*, *M. speigleri*, etc.) were abundant in the shallow expansive Adyar backwaters, on 10–2–1947.

Tide was low at about 7·30 A.M. and owing to the low level of water the fry were largely confined (mainly in shoals) to the meandering course of the narrow 'Kalvai' (Channel) commencing from the nearby road bridge and extending eastwards to the backwaters. By fixing a small drag net of mosquito curtain cloth across the 'Kalvai', and driving in the shoals of fry, a good number of them could be easily collected. Fry from the net were transferred to a bucket of clean brackish water by means of a silk-hand-net, and later on to the tin carrier. A consignment of 4 tins containing fry and 2 tins with clean brackish water was transported in an open hand cart to Chetput. Water was poured on the tins *en route* so as to keep them cool in the hot sun. The consignment reached Chetput farm by 2 P.M. The physico-chemical conditions of the water at the collection spot and in the tin carriers at the time of commencement of transport and at the destination were determined and are tabulated in Table II.

TABLE II

Conditions of existence of mullet fry at the Adyar backwaters and in the tin carriers during transport to the Chetput Farm on 10-2-1947

(Results expressed in parts per 100,000 unless otherwise stated

No.	Location	Time	Weather	Temp. °C.	Free CO_2	CO_3	HCO_3	pH	D.O. c.c./l.	% Sat.	S. ‰
1	From the Kalvai ..	8-20 A.M.	Bright, sunny	26·6	nil	3·3	15·25	8·4	2·462	41·9	24·83
2	From tin carrier before transport	11 A.M.	,,	31·2	,,	3·6	20·44	8·3	2·111	..	24·83
3	Do. after transport, at Chetput	3 P.M.	,,	30·6	,,	2·7	19·93	8·2	2·99	54·2	24·83

The slight fall in the pH of the water recorded at the destination is attributable to the respiratory activities of the fishes. A slight rise in the dissolved oxygen content is also recorded at the destination, in spite of the presence of fishes in the tins. The continuous jolting during the three-hour period of transport is probably responsible for this increased oxygen content.

The consignment which consisted mainly of mullets with a few specimens of *Oryzias melastigma* and *Acentrogobius* sp. was sorted out at the Chetput Farm and was found in Table III.

Out of 1,369 mullets transported 157 died during transport, representing 11·4%. It is interesting to note that mortality was nil in the miscellaneous species like *Oryzias melastigma* and *Acentrogobius* sp,

TABLE III

Tin No.	Mullets		*Oryzias*		*Acentrogobius*		Total	
	Alive	Dead	Alive	Dead	Alive	Dead	Alive	Dead
1	313	88	4	Nil	Nil	Nil	317	88
2	322	35	26	,,	9	,,	357	35
3	361	29	43	,,	36	,,	442	29
4	216	5	1	,,	3	,,	220	5

At the Chetput Farm, the live fry were sorted out from the dead ones and three experiments were arranged, each for different periods of acclimatisation. In all the experiments the salinity during the different stages of dilution was stepped down to the extent of 8·96. Details of the experiments are as follows:

(i) *Tub No.* 1.—40 litres of brackish water (24·83‰) were measured out into a large wide-mouthed earthenware tub and 404 mullet fry were introduced. After noting the physico-chemical conditions of the water, the salinity was stepped down by 8·96 by removing the calculated volume of brackish water from the tub and adding requisite volume of freshwater from a pond. The physico-chemical conditions after dilution were noted. Six hours later

TABLE IV

S. No.	Date	Time	Before (A) or after (B) dilution	Temp. (°C)	S. ‰	*Free CO_2	*CO_3	*HCO_3	pH	D.O. c.c./l.	% Sat.	No. of Fry	No. died	% Mortality	Dilution interval Hrs.
1	10-2-47	5-15 P.M.	A	26·3	24·83	Nil	0·45	22·26	8·0	1·527	36·9	404	1	..	..
2	,,	,,	B	27·0	16·07	,,	0·90	22·56	8·0	2·267	55·4	403	..	..	..
3	,,	11·15 P.M.	A	23·9	16·07	,,	0·90	24·40	7·9	1·133	26·3	403	12	3	6
4	,,	,,	B	..	7·04	,	0·60	24·23	8·0	2·759	..	,,	..	..	..
5	11-2-47	5-15 P.M.	A	23·0	7·04	,,	0·60	26·23	8·0	1·823	41·7	391	12	3	6
6	,,	,,	B	..	0·14	,,	0·90	26·23	8·0	2·759	..	379	.	..	..
7	12-2-47	8 A.M.		..	0·14							,,	18	..	..
											Total		42	10·4	12

* Results expressed in parts per 100,000.

the salinity was again lowered by 8·96, bringing it to 7·04. In the third step, 12 hours after commencement of the experiment the fish were brought to freshwater. Only 24 specimens died during the experiment. In freshwater 18 more specimens died within the first 24 hours; bringing the total percentage of mortality to 10·5.

The physico-chemical conditions of the water during the experiment are given in Table IV.

(ii) *Tub No.* 2.—The total period for acclimatisation of the fry to freshwater was longer, being 16 hours; while, all other conditions were identical to those in Tub No. 1. The salinity was also stepped down by 8·96 at a time, but the duration in each grade was longer than in the first experiment. The data gathered are tabulated below:

TABLE V

S. No.	Date	Time	Before (A) or after (B) dilution	Temp. °C	S‰	*Free CO_2	*CO_3	*HCO_3	pH	D.O c.c./l.	% Sat.	No. of fry	No. died	% Mortality	Dilution interval Hrs
1	10-2-47	5-15 P.M.	A	26·3	24·83	Nil	0·45	22·26	8·0	1·527	36·9	404	12	..	..
2	,,	,,	B	27·0	16·07	,,	..	..	..	2·267	..	392	..	..	..
3	11-2-47	1-15 A.M.	A	23·6	16·07	0·184	..	26·23	7·8	1·108	25·6	392	78	..	8
4	,,	,,	B	..	7·04	0·164	..	24·40	7·9	2·462	..	314	..	..	..
5	,,	9-15 A.M.	A	23·9	7·04	0·228	..	27·76	7·8	0·990	22·9	314	41	..	8
6	,,	,,	B	26·1	0·14	Nil	0·30	26·23	8·0	2·659	64·1	273	..	..	..
											Total		137	34	16

* Results expressed in parts per 100,000.

(iii) *Tub No.* 3.—The experiment was carried out under identical conditions as in the two previous ones, but the total period of acclimatisation was 20 hours, the duration in each grade of salinity being 10 hours. The results are given in Table VI.

Remarks.—The three experiments were carried out under identical conditions like volume, depth and surface area of water, number of fish, etc. The hydrological conditions to start with were also more or less identical. The only variable factor was the duration in each grade of salinity (6 hours, 8 hours and 10 hours in tubs 1, 2 and 3 respectively). In tub 1 the fish were brought to freshwater in 12 hours. Mortality during the experiment was low, being only just over 10%. In tubs 2 and 3 the acclimatisation was

TABLE VI

S. No.	Date	Time	Before (A) or after (B) dilution	Temp. °C	S ‰	*Free CO_2	*CO_3	*HCO_3	pH	D.O. c.c./l.	% Sat.	No. of fry.	No. died	% Mortality	Dilution interval Hrs.
1	10-2-47	5-15 P.M.	A	26·3	24·83	Nil	0·45	22·26	8·0	1·527	36·9	404	18	..	..
2	,,	,,	B	..	16·07	,,	..	..	..	2·369	..	386	..	..	..
3	11-2-47	3-15 A.M.	A	23·0	16·07	0·204	..	22·535	7·7	0·523	0·84	,,	43	..	10
4	,,	,,	B	..	7·04	0·196	..	25·315	7·8	2·512	..	343	..	..	..
5	,,	1-15 P.M.	A	26·9	7·04	0·232	..	28·010	7·6	0·486	8·27	,,	34	..	10
6	,,	,,	B	27·5	0·14	..	0·80	24·095	8·1	3·300	81·4	309	..	..	..
7	12-2-47	..	..	..	0·14	..	..	..	..	..	..	..	13	..	..
											Total		90	22·2	20

* Results expressed in parts per 100,000.

completed in 16 and 20 hours, respectively. The mortality was high, being 34 and 22·2% respectively.

There is no doubt that a considerable proportion of the casualties was due to shock sustained and injuries received during collection and transport. The fact that fish were dying in the experimental tubs even before actual commencement of the acclimatisation experiments, *i.e.*, before salinity was lowered, clearly supports this. However, since no control tub with fish in brackish water was maintained the extent of the mortality due to injuries cannot be ascertained. In any case, it is obvious that mortality due to strain during acclimatisation would be appreciably less than what is now recorded.

Since the extent of mortality due to injuries should be considered as equal in all the three tubs, the reason or reasons for the excessive mortality in tubs 2 and 3 has to be sought for elsewhere. A perusal of the physico-chemical data in Tables V and VI will show that in tubs 2 and 3 since the duration in each grade of water was long, the depletion of dissolved oxygen has been very marked, much more than in tub 1 (Table IV) and this might probably account to weaken the general condition of fry. Low oxygen tension, coupled with free carbon-dioxide in the water is inimical to their existence.

EXPERIMENT V

Another consignment of fry and fingerlings of mullets, *Elops saurus*, *Gerres filamentosus*, etc., was transported from Adyar to Chetput on

17-2-1947. The consignment was analysed at the Chetput Fish Farm as follows:

TABLE VII

Tin No.	Mullets				*E. saurus*		*G. filamentosus*		Total fry in each tin		Total
	Alive * (Small)	Dead	Alive * (Large)	Dead	Alive	Dead	Alive	Dead	Alive	Dead	
1	32	nil	10	4	42	31	16	2	100	37	137
2	99	17	76	nil	4	nil	nil	nil	179	17	196
3	59	14	17	6	6	,,	1	11	83	31	114
4	115	32	63	4	4	,,	1	4	183	40	223
Total	305	63	166	14	56	31	18	17	545	125	670

* Small size, less than 1 inch; Large size, above 1 inch.

Mortality during transport has been heavier in the case of smaller mullets than in the larger specimens. In *Elops* and *Gerres* also the mortality has been very high. The physico-chemical conditions of water at the collection spot and during transport were as follows:

TABLE VIII

Serial No.	Location of sample	Time	Temp. °C.	S. °/₀₀	Free CO_2	CO_3	HCO_3	pH	D.O. c.c./l.	% Sat.	Remarks
1	From the 'Kalvai'	8-30 A.M.	26·6	28·32	nil	3·3	15·25	8·4	2·462	41·9	
2	From the tin carrier before transport	11-45 A.M.	31·2	28·32	,,	3·6	20·44	8·3	2·111	..	
3	From the tin carrier at Chetput	4 P.M.	30·6	,,	,,	2·7	19·98	8·2	2·990	54·2	

The live specimens were then segregated into species in separate tubs in Table IX.

The volume of water in all the tubs was equal; and the salinity was also reduced by 8·96 at a time, as in Experiment IV and the fry were brought to freshwater in 3 stages in the course of 12 hours. The hydrological condi-

TABLE IX

Tub No.	Species	Size	Number	Remarks
1	*Mugil* spp.	0·5″ to 0·75″	305	..
2	*Mugil* spp.	1·0″ to 1·5″	166	..
3	*E. indicus*	2·0″ to 2·5″	56	..
4	*G. filamentosus*	0·75″ to 1·25″	18	..

tions and the reaction of the fry were noted as in the previous experiment and are tabulated below:

TABLE X

Experiment V: Tub No. 1. Small mullets—Total Period—12 hours

Serial No.	Date	Time	Before (A) or after (B) dilution	Dilution Interval	Temp. °C.	S. ‰	*Free CO_2	*CO_3	*HCO_3	pH	D.O c.c./l.	% Sat.	No. of Fry	No. died	% Mortality	Remarks
1	17-2-47	7 P.M.	A	..	26·5	28·32	nil	2·10	28·37	8·6	0·070	1·19	303	..	..	
2	,,	,,	B	..	26·4	19·59	,,	2·40	22·06	8·5	2·005	33·99		10		
3	18-2-47	1 A.M.	A	6 hrs.	23·1	,,	,,	1·65	25·32	8·3	1·126	18·07		18		
4	,,	,,	B	..	26·0	10·74	,,	1·50	25·16	8·5	3·659	61·60		..		
5	,,	7 A.M.	A	6 hrs.	28·2	,,	,,	1·20	25·11	8·1	2·111	36·82		10		
6	,,	,,	B	..	25·6	0·14	,,	2·10	23·18	8·4	3·589	62·03				
7	,,	12·20 P.M.				0·14								57		
														95	31·3	

Experiment V: Tub No. 2. Larger mullets—Total Period 12 hours

1	17-2-47	7 P.M.	A	..	26·5	28·32	nil	2·10	23·49	8·5	0·352	5·97	166	..	..	
2	,,	,,	B	..	26·6	19·59	,,	1·50	24·86	8·5	2·111	35·90		9		
3	18-2-47	1 A.M.	A	6 hrs.	22·0	,,	,,	1·05	25·93	8·3	0·926	14·24		2		
4	,,	,,	B	..	26·8	10·74	,,	1·50	25·32	8·5	4·784	81·70		..		
5	,,	7 A.M.	A	6 hrs.	28·3	,,	,,	0·75	26·84	8·0	1·055	18·45		15		
6	,,	,,	B	..	26·0	0·14	,,	1·05	25·93	8·2	3·440	58·06		8		
7	,,	12 noon														
														34	20·5	

Table X—(*Contd.*)

Experiment V: Tub No. 3. *Elops saurus*—Total Period 12 hours

Serial No.	Date	Time	Before (A) or after (B) dilution	Dilution Interval	Temp. °C.	S. ‰	*Free CO_2	*CO_3	*HCO_3	pH	D.O c.c./l.	% Sat.	No. of fry	No. died	% Mortality	Remarks
1	17-2-47	7 P.M.	A	..	27·2	28·32	nil	3·60	19·52	8·7	2·814	48·34	56	..	..	
2	,,	,,	B	..	26·8	19·59	,,	2·70	21·81	8·6	3·238	55·27		5	..	
3	18-2-47	1 A.M.	A	6 hrs.	23·0	19·59	,,	,,	22·42	8·5	1·809	28·97		3		
4	,,	,,	B	..	26·4	10·74	,,	2·10	24·10	8·6	4·643	78·70		..		
5	,,	7 A.M.	A	6 hrs.	28·3	,,	,,	,,	23·18	8·2	2·990	52·25		4		
6	,,	,,	B	..	26·6	0·14	,,	1·80	24·10	8·3	3·941	68·11		..		
7	,,	12·30 P.M.												13		
														25	44	

Experiment V: Tub No. 4. *Gerres filamentosus*—Total Period 12 hours

1	17-2-47	7 P.M.	A	..	26·6	28·32	nil	2·40	19·54	8·6	1·548	26·32	18	..	..	
2	,,	,,	B	..	26·7	19·59	,,	2·40	20·44	8·6	3·377	57·53		4		
3	18-2-47	1 A.M.	A	6 hrs.	23·1	19·59	,,	2·85	20·43	8·5	2·321	37·27		2		
4	,,	,,	B	..	26·4	10·74	,,	2·70	22·88	8·6	4·504	76·33		..		
5	,,	7 A.M.	A	6 hrs.	28·4	10·74	,,	2·25	23·25	8·3	3·709	64·91		7		
6	,,	,,	B	..	28·4	0·14	,,	2·10	,,	8·4	4·222	71·93		..		
7	,,	9 A.M.												4		
														17	94	

* Results expressed in parts per 100,000.

Remarks.—Even though the duration of the experiment and the change in salinity during the different stages were common in all the experimental tubs, heavy mortality (31·3%) is recorded in the case of the smaller mullets. In the larger specimens also the mortality is high (20·5%) though relatively less than in the former. Comparing with the conditions in Experiment IV two factors are seen to be slightly variable. In the present case the salinity of water at the collection spot was higher than in the previous collection; and the final step of dilution in this case was from 10·74 to 0·14 of salinity. It is likely that these factors might have contributed to cause the heavy mortality. In the case of *E. saurus* and *G. filamentosus* the heavy mortality

(44% and 94% respectively) is only attributable to the inherent incapacity of the species to withstand the sudden hydrological changes. The very heavy mortality in *E. saurus* even during the short duration of transport is significant in this connection.

Since no actual 'Control' was kept in this experiment also the extent of the mortality due to mechanical shock and injuries that would have resulted even in pure brackish water, cannot be correctly estimated. As in the previous experiment, mortality due to rigours of acclimatisation would therefore be really much less than what is now recorded.

EXPERIMENT VI

During the first week of October 1947, the river Adyar established connection with the sea by the opening of the sand bar across its mouth. Millions of post-larval leptocephalus like specimens of *Megalops cyprinoides* and *Elops saurus* and post-larval specimens of mullets, *Gerres*, *Scatophagus*, *Sillago*, *Ambassis* and *Hemirhamphus* were then found entering the back-

TABLE XI

Stages of reduction in the salinity of water during acclimatisation of Leptocephalus-*like post-larvæ of* E. saurus *and* M. cyprinoides

Jar No.	Salinity													
	Brackish water	1st dilution			2nd dilution			3rd dilution			No. of fish	Reaction	% Mortality	Remarks
		Vol. of water c.c.	S°/₀₀	Duration (hours)	Vol. of water c.c.	S°/₀₀	Duration (hours)	Vol. of water c.c.	S°/₀₀	Duration (hours)				
1	18·54	Control		–	48	hours	..	2000	c.c. of	water	10	Normal	nil	
2	,,	2000	13·93	21·0	3500	8·00	2·0	2000	0·14	..	10	,,	,,	Third dilution to fresh-water
3	,	2500	11·17	21·5	2250	3·67	1·5	2000	0·14	..	10	,,	,,	do
4	,,	3000	9·32	23·0	2500	1·84	1·15	2000	0·14	..	10	,,	,,	do
5	,,	3500	8·00	20·5	2000	3·93	3·0	2000	0·14	..	10	,,	,,	do
6	,,	2000	13·93	2·5	2000	0·14	..	..	..	..	10	,,	,,	Second dilution to fresh-water
7	,,	2900	3·67	4·0	2000	0·14	..	..	..	..	10	,,	,,	do
8	,,	2500	1·48	5·25	2000	0·14	..	..	..	..	10	,,	,,	do
9	,,	2000	0·14	..	..	..	..	..	..	..	10	,,	,,	Sudden transfer to fresh-water
10	,,	10,000	0·14	..	..	..	..	..	..	..	10	,,	,,	do

waters from the sea through the open bar. A series of experiments on their acclimatisation to freshwater was carried out by stepping down the salinity in different stages and duration. The details of these experiments are incorporated in Table XI.

It was found that besides *E. saurus* and *M. cyprinoides* post-larval stages of *Scatophagus argus* and *Ambassis* sp. could also be successfully transferred direct from brackish water to fresh water. It is remarkable that even direct transfer from brackish water to freshwater involving extreme fluctuations in environmental factors is manifested only in visibly mild reaction for a short duration.

Discussion

The salinity of water in the estuaries and backwaters is daily subject to wide fluctuation. It is seen that the chloride content of water at low tide in the shallow expanses at Adyar is only about half the chloride content of the incoming high tide water. It is therefore clear that the estuarine and brackish water species are being daily subjected to a certain degree of acclimatisation to conditions of changing salinity. The success of experimental acclimatisation of saltwater fish seed will therefore depend on the care with which the young fry are handled and the gradual stepping down of salinity. In the experiments reported in this paper, the fry were collected from Adyar and transported in carts for a distance of about 8 miles in the open sun, the duration being about 3 to 4 hours. In all the experiments the mortality of fry during this stage of transport was appreciable. Mechanical injury and shock during collection and transport will certainly weaken the resistance of the fry and this is bound to reflect adversely during acclimatisation. This could possibly be avoided if field facilities are provided at Adyar for carrying out the experiments so that the transport stage could be avoided.

Prolonged course of acclimatisation is bound to tell on the condition of the fry, particularly if they are not fed, since they have to cope up with the increased metabolic activity during acclimatisation, starving. Experiments have indicated that feeding during acclimatisation is beneficial to the fry.

Dilution of water and stepping down of salinity should always be by gradual steps. In our experiments a difference of 8·96 of salinity at each dilution gave encouraging results. Longer duration in each grade of water is also harmful since the increased metabolic activity will soon deplete the oxygen content of water, reduce the pH and result in accumulation of carbon dioxide, all of which are deleterious to the young fry. For post-larval mullets, 0·5 to 1·5″ long, stepping down the salinity by 5·28 at every 4-hour period would appear to give very encouraging results.

The experiments on post-larval leptocephalus like stages of *E. saurus* and *M. cyprinoides* have clearly demonstrated that at this particular stage they are capable of withstanding extremely wide and sudden fluctuations in the salinity of water. This is in sharp contrast to the reaction of the same species in the fingerlings stage. In the fingerling stage these two species are very sensitive to the strain of transport and acclimatisation and as shown in Experiment V heavy mortality results. Even after acclimatisation to freshwater *E. saurus* is appreciably susceptible to strain during transport, as is generally experienced when they are occasionally collected from the freshwater sections of the river Cooum for stocking purposes. The fact that either during transport or during the different laboratory experiments not a single leptocephalus died is proof that they are best acclimatisable at this particular stage. Similar acclimatisable stages for the other species have to be experimentally ascertained for the proper exploitation of the salt water fish seed resources and further detailed field experiments, preferably at the collection spot itself are urgently necessary.

SUMMARY

1. Laboratory and field experiments, carried out during 1945–48 on the acclimatisation of fry and early fingerlings of mullets (*Mugil cephalus*, *M. sehelii*, etc.), *Megalops cyprinoides* and *Elops saurus* (leptocephalus and later stages), *Gerres filamentosus*, *Scatophagus argus*, *Sillago sihama*, *Hemirhampus gaimardi* and *Ambassis* sp. are described.

2. An attempt has been made to elucidate the physico-chemical variables in the medium during the several stages of transition of the young fish from salt water to freshwater.

3. In the early post-larval stage, most of the above fishes possess the capacity for quick adaptation to wide and sudden fluctuations in salinity and other environmental conditions; but advanced stages (2 to 3 inches long) of atleast *Megalops* and *Elops* are found to be more susceptible to such changes, resulting in considerable mortality.

4. The knowledge that these common food fishes, at this early stage, can withstand even direct transfer from brackish water to freshwater has a bearing on the possibilities of their successful culture in freshwater. Their small size and low mortality during acclimatisation would enable transport of large numbers at relatively low cost.

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