OXYGEN CONSUMPTION AND VIABILITY OF *CHANOS CHANOS* (FORSKÅL) IN RELATION TO SIZE*

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INTRODUCTION

THE importance of the size factor in metabolic studies on fish has been emphasised by Rubner (1924) who found that the oxygen consumption in the pike and in the tench was correlated exponentially with the body weight of the fish. More recently, Busnel, Drilhon and Raffy (1946) have investigated the oxygen consumption of the fry and alevins of the rainbow trout in waters of varying salinity; their results indicate that the salinity of the external medium is a second decisive factor influencing respiration.

It is obvious that the relationship between size and metabolic activity is highly significant in the transport of live fish. Estimates of the safe limits of numbers of fish that can be transported in limited volumes of water can be based on trial and error methods as has been done in *Chanos chanos* (Ganapathi, *et al.*, 1950). Alternatively, charts can be prepared, based on standard experimental data, from which it should be possible to read off information on the viability of the fish under different environmental conditions. The preparation of such charts would involve, among other things, a knowledge of the rate of variation of oxygen consumption with the size of the fish and a method for properly differentiating size effects from salinity effects. The present account describes an attempt along these lines to analyse the problems of transport of live fry and fingerlings of *Chanos*.

MATERIAL, METHODS AND RESULTS

I. Length, Weight and Oxygen Consumption in Chanos

(*a*) The gear employed in obtaining the different sizes of fish are known to influence the length-weight equation (*e.g.*, Le Cren, 1951). They will therefore be first described: (i) A mosquito-net cloth was used for collecting fry of length 16–40 mm. from the tidal creeks at Chinnapalam (Gulf of

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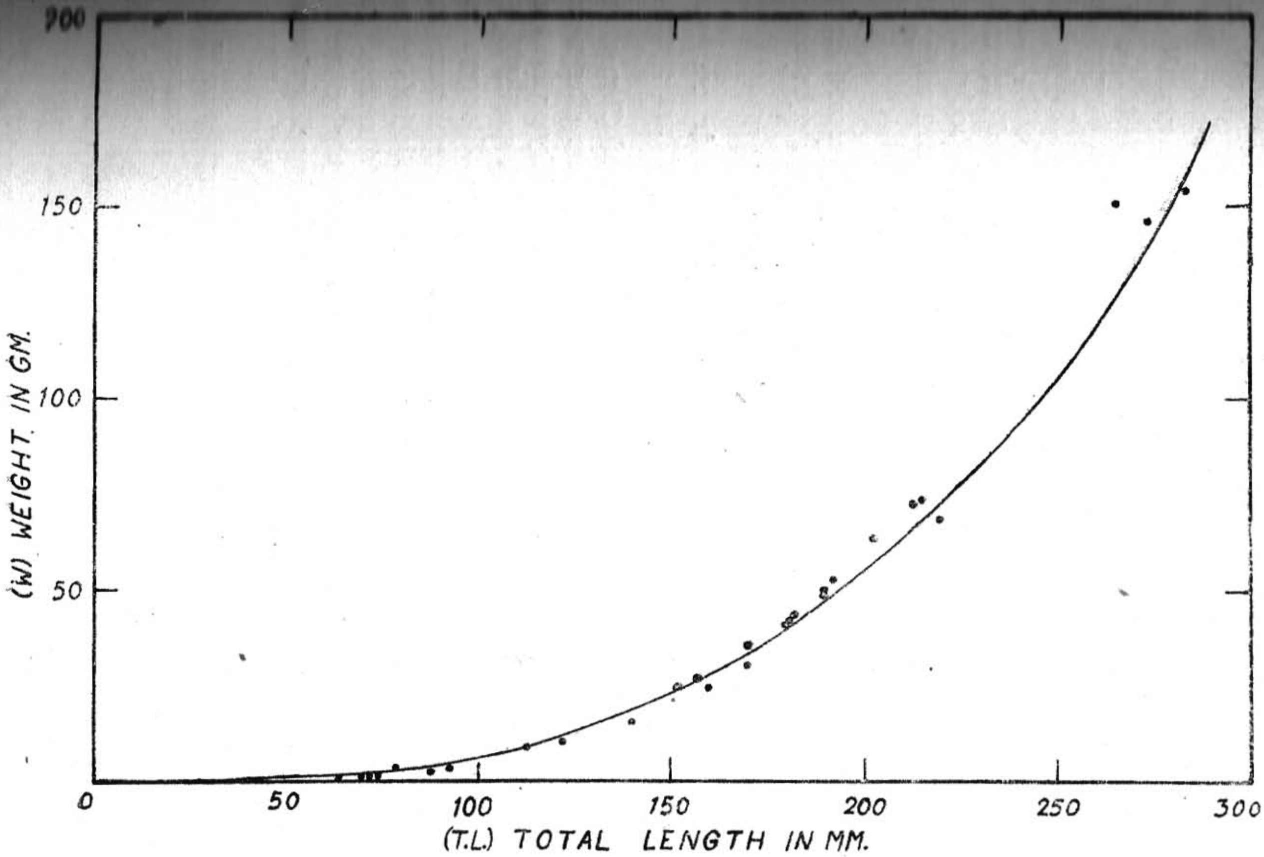

FIG. 1. Total length-weight relationship of ***Chanos chanos***. The curve is the graph of the equation $W = 0 \cdot 000004626\ (T.L.)^{3 \cdot 072}$. The dots represent the observational data.

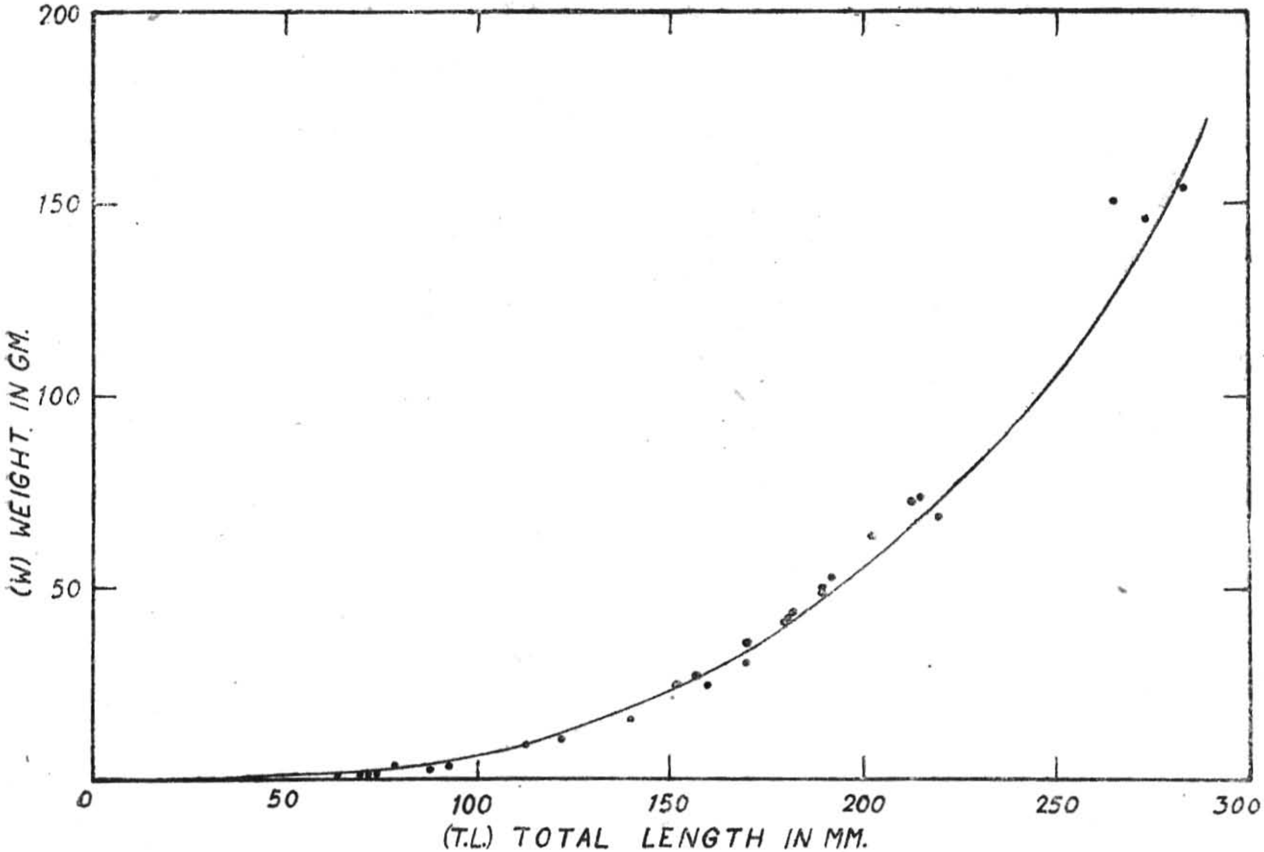

FIG. 1. Total length-weight relationship of *Chanos chanos*. The curve is the graph of the equation $W = 0{\cdot}000004626\ (T.L.)^{3{\cdot}072}$. The dots represent the observational data.

Mannar) where they swarm in large numbers; (ii) Fingerlings of about 100 mm. length were caught by dragging a scareline along the creeks and allowing the fish to jump into a piece of cloth held close to the scareline; (iii) Fish of larger size but below 200 mm. in length were obtained at Horseshoe Bay, Pamban, by the use of "Kalamkattivalai", a circular gill net, ½" sq. mesh, supported on stakes at high tide; and (iv) Fish longer than 200 mm. were caught in drift nets operated within the chain of islands in the Gulf of Mannar. The total length of the fish was measured (to the nearest mm.) from the tip of the snout to the end of the dorsal lobe of the caudal fin. The fish were weighed after removing the water on the body surface by the use of filter-paper. The fry were weighed to the nearest milligram and the larger fish to the nearest decigram.

Fig. 1 gives the total length-weight curve of *Chanos* up to a total length of 300 mm. of the fish. The curve (which is the graph of the equation

$$W = 0 \cdot 000004626\, L^{3 \cdot 0724}, \qquad (1)$$

where W = weight of the fish in gm. and L the total length in mm.) was fitted to the observational data by the regression method of least squares.

(*b*) For the determination of the oxygen consumption of *Chanos*, the fry or fingerling was starved overnight in the selected medium after which it was placed for 1–2 hours in a definite volume (290 ml. per fry or 1900 ml. per fingerling) of water contained in an Erlenmeyer flask. A seal of liquid paraffin above the surface of water prevented the diffusion of oxygen and carbon dioxide from and into the atmosphere. The temperature and dissolved oxygen content of the water were determined both before and after the introduction of the fish into the water. Winkler's method was used for the determination of dissolved oxygen. The weights of the fry were determined in a chemical balance and those of the fingerlings calculated from their lengths by the use of the length-weight equation (1).

Data on the oxygen consumption of *Chanos* are summarised in Fig. 2. For the fish in tap water (of salinity 1 part per 1,000 and temperature 28–31° C.), the weight-oxygen consumption relationship is satisfactorily described by the equation

$$Q = 1 \cdot 829\, w^{0 \cdot 8342}, \qquad (2)$$

where Q is c.mm. of oxygen consumed per hour by fish weighing w mgm.

From equations (1) and (2), we get

$$Q = 0 \cdot 02063\, L^{2 \cdot 563} \qquad (3)$$

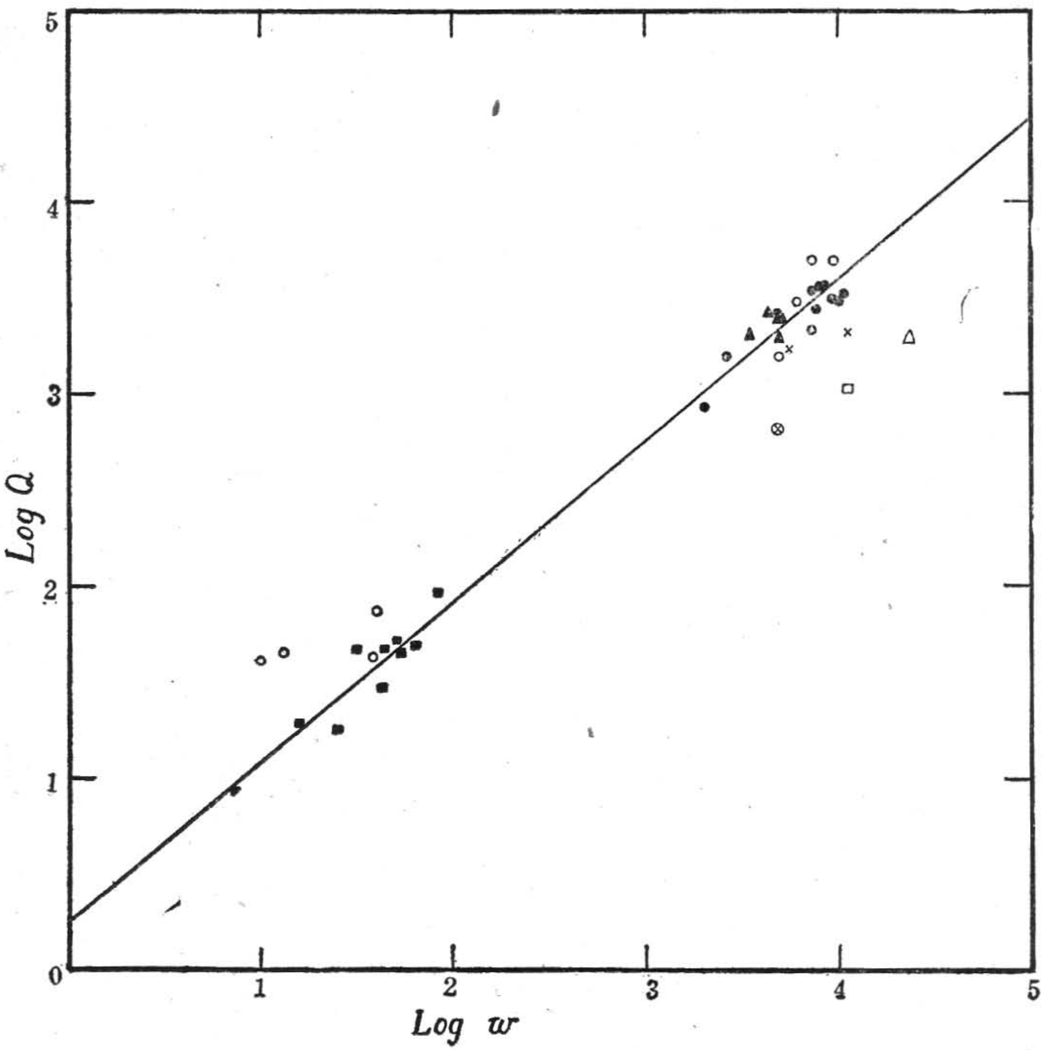

FIG. 2. Oxygen Consumption of *Chanos*. w = Weight of fish in mgm., Q = µl. oxygen consumed per hour. The straight line is the graph of the equation Log Q = 0·2622+0·8342 Log w. (1) Tap water, 28° – 31° C ●; 30° C ▲; 25° C ■; 25° C ×; (2) 25% sea water at 25° C ×; and (3) sea water, 30° C O; 27° C △; 25° C □.

II. Respiration of Chanos *Fry in a Noncirculating Volume of Water*

Chanos fry were preacclimatised to the experimental media for a day. 200 ml. of the test media (in thermal equilibrium with the atmosphere, temperature 30–31° C.) were taken in 500 ml. bottles and the fry were transferred to the bottles as quickly as possible by the use of a hand net. The bottles were then loosely stoppered, a little space being left for the entry

TABLE I

Survival of Chanos *fry in noncirculating volume of water in open containers*

Medium	Total number of fry	Length of fry: No. of fry in sample	Length of fry: Range mm.	Length of fry: Mean mm.	Length of fry: S.D.	Weight of fry g.	Ml. (initial) oxygen per g. fish (= X)	Time in hrs. 1·0	1·5	2·0	2·5	3·0	3·5	4·0	4·5	5·0	5·5	6·0	24	48	
Sea water Cl‰ = 17·9, Dissolv d Oxygen = 3·37 ml./l.)	5 20	15	23–28	24·8	1·2	0·446 1·795	1·511 0·375	80 100	80 85	80 85	80 85	80 85	80 85	80 85	80 85	80 85	80 85	80 85	80 20	.. ..	Per cent. survival of fry
	5 20	..	..	..	..	.. ..	.. ..	100 40	100 35	100 30	100 ..	100 ..	100 15	100 15	100 10	100 ..	100 5	100 5	100 0	100	
	5 20	8	22–41	29·8	7·6	0·780 3·347	0·864 0·201	100 75	100 70	100 ..	100 ..	100 60	100 55	100 45	100 ..	100 ..	100 40	100 ..	100 0	100	
Tap water (Cl‰ = 1·07, Dissolved Oxygen = 3·37 ml./l.)	5 21	21	15–32	23·1	3·5	0·358 1·614	1·883 0·418	100 100	100 100	100 95	100 95	100 95	100 95	100 95	100 95	100 95	100 95	100 95	100 95	100 ..	
	5 20	..	..	..	..	.. ..	.. ..	100 100	100 100	100 100	100 100	100 95	100 95	100 95	100 95	100 95	100 95	100 95	100 95	100 80	
Tap water	10 20	10 20	31–50 22–50	32·8 36·8	5·8 9·2	2·314 7·007	0·1845 0·0598	.. ..	.. ..	90 15	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	

of air into the bottle. The lengths of the fry were measured at the conclusion of the experiments. Where the lengths of all the fry couldn't be measured, the mean length of a suitable sample was taken to represent that of the population experimented upon. For the calculation of the weight of the fry, the length-weight equation (1) was used. The results are given in Table I.

III. Asphyxiation Experiments on Chanos *Fry*

The methods were similar to those used in the experiments described in Section II excepting that the bottles were completely filled with the medium and fully stoppered. Observations of mortality were made at intervals of 30 minutes. The per cent. survival of the fry was plotted against the time of experiment and the median survival time, *i.e.*, the time in which 50% of the fry die, was read off from the graphs. In Tables II and III are given the correlation coefficients and regression equations relating to the median survival time and the ml. (initial) oxygen per gm. fish.

TABLE II

Mortality of Chanos *fry under conditions of asphyxiation in sea water*

(Cl‰ = 18·46, D.O. = 2·93 ml./l.)

Volume of water ml.	Total no. of fry	Length of fry				Weight of fry g.	Ml. (initial) oxygen per g. fish (= X)	Median survival time (mts.) = Y
		No. of fry in sample	Range mm.	Mean mm.	S.D. mm.			
586	6	6	14–25	17·2	4·1	0·210	8·177	..
534	14	9	14–27	19·2	4·5	0·627	2·496	30
570	17	17	14–25	17·7	3·2	0·594	2·812	27
586	26	26	14–25	18·0	3·9	1·004	1·710	105
566	8	8	13–22	15·5	2·8	0·186	8·917	..
586	12	12	14–25	17·1	3·8	0·393	4·369	117
548	18	18	14–25	19·4	3·3	0·821	1·956	135
572	35	35	11–24	18·0	3·4	1·281	1·308	102
560	6	6	13–20	17·3	4·4	0·210	7·814	384
584	12	11	13–23	18·1	3·6	0·447	3·828	240
560	23	22	13–27	17·1	3·2	0·736	2·229	108
562	22	22	14–25	19·1	3·7	0·967	1·703	153

Correlation coefficient $r_{xy} = +0 \cdot 7778$

Regression equations:

$$X = 3 \cdot 023 + 0 \cdot 01155 (Y - 140 \cdot 1)$$

$$d_x = 0 \cdot 01155\, d_y$$

$$Y = 140 \cdot 1 + 42 \cdot 02 (X - 3 \cdot 023)$$

$$d_y = 42 \cdot 02\, d_x$$

TABLE III

Mortality of Chanos *fry under conditions of asphyxiation in hard tap water*

($Cl‰ = 0\cdot98$, D.O. = 3·37 ml./l., Ca = 5·6 mE./l.)

Volume of water ml.	Total no. of fry	Length of fry				Weight of fry g.	Ml. (initial) oxygen per g. fish (=X)	Median survival time (mts.) = Y
		No. of fry in sample	Range mm.	Mean mm.	S. D. mm.			
586	7	6	16–27	23·2	4·0	0·536	4·056	399
534	13	13	16–26	21·9	3·7	0·852	2·326	222
570	19	19	15–25	18·4	3·6	0·757	2·794	249
586	23	23	17–28	20·8	3·4	1·293	1·682	165
566	5	5	15–25	21·0	4·1	0·291	7·216	..
586	13	13	15–25	17·8	3·8	0·477	4·588	24
548	15	15	15–26	20·9	4·4	0·893	2·277	171
572	25	25	14–27	18·7	4·2	1·055	2·011	171
560	5	5	15–19	16·0	1·7	0·119	17·460	..
584	14	14	15–27	17·6	3·3	0·486	4·459	467
560	17	17	13–20	16·9	1·5	0·482	4·311	387
562	22	22	14–27	18·8	3·0	0·947	2·202	201

Correlation coefficient $r_{xy} = +\ 0\cdot3636$

Regression equations:

$$X = 3\cdot071 + 0\cdot0031\ (Y - 245\cdot6)$$
$$d_x = 0\cdot0031\ d_y$$
$$Y = 245\cdot6 + 42\cdot56\ (X - 3\cdot071)$$
$$d_y = 42\cdot56\ d_x$$

DISCUSSION

It may be seen from Figs. 1 and 2 that there is a close fit between the observed and calculated values over the entire range of total length studied (0–300 mm.). This indicates the absence in this range of sharp changes in the length-weight relationship and in the physiological behaviour such as would be caused, for instance, by the onset of maturity. The immaturity in 300 mm. long fish, suggested by this good fit, is in accord with independent observations on the gonadic condition of fish 500 mm. long which revealed that fish of even this size were immature. When applied to the only specimen of adult *Chanos* we could get, equation (1) showed a discrepancy of 2,420 gm. between the observed and calculated weights [total length of fish with spent ovaries, 1,240 mm.; standard length, 1,000 mm.; observed weight, 12,250 gm.; weight calculated from equation (1), 14,670 gm.].

In regard to the oxygen consumption of *Chanos*, it is seen from Fig. 2 that for the same salinity of the water, the oxygen consumption in the case of fish kept at 25–27° C. (during the colder months) is less than that of fish (at 28–31° C.) experimented on during the summer months. The differences between the means of oxygen consumption values in tap water and in sea water are, however, not highly significant [t (for fingerlings at 30° C.): calcd., 0·12; from Tables, 2·365 for $P = 0{\cdot}05$; t (for fry at 28° (tap water) and at 30° C. (sea water): calcd., 2·34; from Tables, 2·18 for $P = 0{\cdot}05$ and 2·68 for $P = 0{\cdot}02$]. A similar negligible influence of salinity has also been observed in the case of another metabolic characteristic, namely, the heat resistance of *Chanos* fry (Panikkar, Tampi and Viswanathan, unpublished).

The usefulness of the equations (1–3) in the study of the transport of live *Chanos* remains to be considered. Equations (4–7), derived from equations (1–3), deal with the relationship between the time of survival of the fish, the number and length of the fish and the volume of the external medium. Two simplifying assumptions have been made: (i) All the "first deaths" (Keys, 1931) are simultaneous at the critical oxygen tension. The classification of deaths of fish under conditions of asphyxiation into "first deaths" and "second deaths" was suggested by Keys. Since the mortality of fish during transport in a noncirculating volume of water is primarily due to lack of adequate oxygen and consequent asphyxiation, the use of Keys' concept of "first deaths" in the present case appears to be relevant. (ii) The net rate at which oxygen enters the water is negligible in comparison with the rate at which oxygen is consumed by the critical numerical limits of fish under transport.

Let the initial oxygen content of V ml. of the medium be X_1; let n_1 be the number of fish in V ml. of the medium; l_1, the average length in this batch of fish; r_1, the amount of oxygen consumed per hour per fish; and t_1, the time of survival, *i.e.*, the time in which there is a chosen level of mortality among the fish. If n_2, l_2, r_2 and t_2 are the corresponding characteristics of a second batch of fish and k the exponent in the length-weight equation, we have at the critical oxygen tension,

$$X_1 - n_1 t_1 l_1^{k} = X_1 - n_2 t_2 l_2^{k} \qquad (4\ \text{i})$$

$$X_1 - n_1 t_1 r_1 = X_1 - n_2 t_2 r_2 \qquad (5\ \text{i})$$

$$t_2 = t_1 \,(n_1/n_2)\,(l_1/l_2)^{k} \qquad (4)$$

and $$t_2 = t_1 \,(r_1/r_2)\,(n_1/n_2) \qquad (5)$$

Where the second batch of fish is kept in mV ml. of water, m being a dilution factor, we have, at the critical oxygen tension,

$$X_6 - n_1 t_1 l_1^{k} = (mX_1 - n_2 t_2 l_2^{k})/m \qquad (6\ \text{i})$$

$$X_1 - n_1 t_1 r_1 = (mX_1 - n_2 t_2 r_2)/m \qquad (7\ \text{i})$$

$$t_2 = mt_1 \,(n_1/n_2)\,(l_1/l_2)^{k} \qquad (6)$$

and $$t_2 = mt_1 \,(n_1/n_2)\,(r_1/r_2) \qquad (7)$$

Equations (4–7) could be used for the compilation of charts (see Appendix I) to indicate the number of fish which could be transported in known volumes of water. Adjustments of the volume of water and the frequency of change of water could be referred to experimental observations on the survival of fish combined with routine determinations on the lengths of the fish in random samples from the various batches of fish. It is proposed to test the utility of equations (4–7) as and when fish fry and fingerlings become available.

The data contained in Tables I–III clearly indicate the need for taking into consideration the weight of the respiring fish in its relation to the initial oxygen content of the medium. In Table I, the median survival time values are respectively 3·5 hours and 6–24 hours for values of X corresponding to 0·20 and 0·38 in sea-water. For higher values of X in sea-water (1·51 and 0·86), the survival in 24 hours is proportionately higher (80 and 100% respectively). Thus it is seen that a comparison of the viability of the fish under different environmental conditions is facilitated by the use of the factor x; while a mere grouping of the fish in terms of their length ranges or number in a given volume of water is not directly helpful in interpreting the experimental results. The advantages of using the factor X are, however, only to be expected in view of the very fundamental relationship between weight and oxygen consumption.

The difference between the correlation coefficients in Tables II and III is not significant at the probability level of 0·05 (Paterson, 1939), indicating thereby that salinity has no influence on the viability of the fry under conditions of asphyxiation. In a non-circulating volume of water in open containers, on the other hand, the mortality of the fry is significantly less in hard tap water than in sea water, for the same value of X (= 0·4) in both the salinities.

SUMMARY

Equations have been derived interrelating length, weight and oxygen consumption in *Chanos chanos*. The uses which these equations can be put to in the study of the transport of live fish have been discussed in detail.

The need has been pointed out for taking into account the size (especially the weight) effect in interpreting the data on the respiration of fish. While a mere grouping of fish in terms of their length-ranges or number in a given volume of water is not directly helpful in interpreting the experimental results, the factor, ml. (initial) oxygen per gm. fish, can be used with advantage to measure the influence of size on the respiration of the fish and to compare the viability of the fish under different environmental conditions.

On the basis of this factor, mortality of *Chanos* fry in hard tap water is seen to be relatively less than in sea-water; while, under conditions of asphyxiation, the median survival time of the fry does not appear to be affected to any significant extent by the salinity of the medium.

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APPENDIX I

(1) 100 *Chanos* fry, which had been in tap water for a day, were transferred to a limited volume, *viz.*, 3 l., of tap water (at 30° C.), kept in a tin fish carrier of effective capacity about 26 litres. The mortality of the fry 72 hours after the transfer was found to be nil. The mean length (l_1) of the fry was 20 mm. The dilutions and volumes for zero mortality in 72 hours for 100 fish have been calculated for various mean lengths of fish from equation (6) and are given below:

l_2 (mm.)	m	(mV/1000) l.
40	5·91	17·7
60	16·70	50·1
80	34·93	104·8
100	61·87	185·6

(2) 195 *Chanos* fry were transferred from a saline pond direct into 7·5 l. of well water at 29° C. 96 of the fry died within 4 hours of transfer. The mean length of the fry was 20·5 mm. The calculations given below correspond to a total volume of well water of (7·5 × 3) l.

(i) For 50% mortality in 4 hours ($t_2 = t_1$),

l_2 (mm.)	$n_2 \times 3$
41	98
62	35
82	16
103	9

(ii) For 50% mortality, where $l_1 = l_2 = 20 \cdot 5$ mm., and $n_1 = 195 \times 3$,

$n_2 \times 3$	t_2 (hrs.)
1170	2
2340	1

(iii) For 50% mortality where $n_1 = n_2$,

l_2 (mm.)	t_2 (hrs.)
41	0·7
62	0·2