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

BY R. VISWANATHAN AND P. R. S. TAMPI 
(Central Marine Fisheries Research Station, Mandapam) 

Received July 29, 1952 
(Communicated by Dr. N. K. Panikkar, F.A.Sc.) 

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 
alalyse the problems of transport of live fry and fingerlings of Chanos. 

MATERIAL, METHODS AND RESULTS 

1. 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 

* Published with the permission of the Chief Research Officer, Central Marine Fisheries 
Station, Mandapam.

148
Fig. 1. Total length-weight relationship of *Chanos chanos*. The curve is the graph of the equation $W = 0.00004626 \times (T.L.)^{3.072}$. The dots represent the observational data.
Fig. 1. Total length-weight relationship of *Chanos chanos*. The curve is the graph of the equation \( W = 0.00004626 \times (T.L.)^{3.672} \). 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 Horse-shoe Bay, Pamban, by the use of “Kalamkattivalai”, a circular gill net, \( \frac{1}{4} \) 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

\[ W = 0.000004626 L^{3.0724}, \]  

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

\[ Q = 1.829 w^{0.842}, \]  

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

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

\[ Q = 0.02063 L^{2.563} \]  

(3)
Oxygen Consumption and Viability of Chanos chanos (Forskål) 151

Oxygen Consumption of Chanos. \( Q = \mu \) mgm. 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**

<table>
<thead>
<tr>
<th>Medium</th>
<th>Total number of fry</th>
<th>Length of fry</th>
<th>Weight of fry (g)</th>
<th>Ml. (initial) oxygen per g. fish (= X)</th>
<th>Time in hrs.</th>
<th>Per cent survival of fry</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No. of fry in sample</td>
<td>Range mm.</td>
<td>Mean mm.</td>
<td>S.D.</td>
<td>1.0</td>
<td>1.5</td>
</tr>
<tr>
<td>Sea water</td>
<td>5</td>
<td>15</td>
<td>23-28</td>
<td>24-8</td>
<td>1-2</td>
<td>0.446</td>
</tr>
<tr>
<td>Cl%\textsubscript{o} = 17.9, Dissolvd Oxygen = 3.37 ml/l.</td>
<td>20</td>
<td>..</td>
<td>..</td>
<td>..</td>
<td>..</td>
<td>..</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>8</td>
<td>22-41</td>
<td>29-8</td>
<td>7-6</td>
<td>0.780</td>
</tr>
<tr>
<td>Tap water</td>
<td>20</td>
<td>..</td>
<td>..</td>
<td>..</td>
<td>..</td>
<td>..</td>
</tr>
<tr>
<td>(Cl%\textsubscript{o} = 1.07, Dissolved Oxygen = 3.37 ml/l.)</td>
<td>5</td>
<td>21</td>
<td>15-32</td>
<td>23-1</td>
<td>3-5</td>
<td>0.358</td>
</tr>
<tr>
<td></td>
<td>20</td>
<td>..</td>
<td>..</td>
<td>..</td>
<td>..</td>
<td>..</td>
</tr>
<tr>
<td>Tap water</td>
<td>10</td>
<td>10</td>
<td>31-50</td>
<td>32-8</td>
<td>5-8</td>
<td>2.314</td>
</tr>
<tr>
<td></td>
<td>20</td>
<td>20</td>
<td>22-50</td>
<td>36-8</td>
<td>9-2</td>
<td>7.007</td>
</tr>
</tbody>
</table>
Oxygen Consumption and Viability of Chanos chanos (Forskål) 153

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 mortality 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%o = 18·46, D.O. = 2·93 ml./l.)

<table>
<thead>
<tr>
<th>Volume of water ml.</th>
<th>Total no. of fry</th>
<th>Length of fry</th>
<th>Weight of fry g.</th>
<th>Ml. (initial) oxygen per gm. fish (= X)</th>
<th>Median survival time (mts.) = Y</th>
</tr>
</thead>
<tbody>
<tr>
<td>586</td>
<td>6</td>
<td>6</td>
<td>14-25</td>
<td>17·2</td>
<td>0·210</td>
</tr>
<tr>
<td>534</td>
<td>14</td>
<td>9</td>
<td>14-27</td>
<td>19·2</td>
<td>0·627</td>
</tr>
<tr>
<td>570</td>
<td>17</td>
<td>17</td>
<td>14-25</td>
<td>17·9</td>
<td>0·594</td>
</tr>
<tr>
<td>586</td>
<td>26</td>
<td>26</td>
<td>14-25</td>
<td>18·0</td>
<td>1·004</td>
</tr>
<tr>
<td>566</td>
<td>8</td>
<td>8</td>
<td>13-22</td>
<td>15·5</td>
<td>0·186</td>
</tr>
<tr>
<td>586</td>
<td>12</td>
<td>12</td>
<td>14-25</td>
<td>17·1</td>
<td>0·393</td>
</tr>
<tr>
<td>548</td>
<td>18</td>
<td>18</td>
<td>14-25</td>
<td>19·4</td>
<td>0·821</td>
</tr>
<tr>
<td>572</td>
<td>35</td>
<td>35</td>
<td>11-24</td>
<td>18·0</td>
<td>1·281</td>
</tr>
<tr>
<td>560</td>
<td>6</td>
<td>6</td>
<td>13-20</td>
<td>17·3</td>
<td>0·210</td>
</tr>
<tr>
<td>584</td>
<td>12</td>
<td>11</td>
<td>13-23</td>
<td>18·1</td>
<td>0·447</td>
</tr>
<tr>
<td>560</td>
<td>23</td>
<td>22</td>
<td>13-27</td>
<td>17·1</td>
<td>0·736</td>
</tr>
<tr>
<td>562</td>
<td>22</td>
<td>22</td>
<td>14-25</td>
<td>19·1</td>
<td>0·987</td>
</tr>
</tbody>
</table>

Correlation coefficient \( r_{xy} = +0·7778 \)

Regression equations:

\[ X = 3·023 + 0·01155 (Y - 140·1) \]

\[ d_x = 0·01155 \ d_y \]

\[ Y = 140·1 + 42·02 (X - 3·023) \]

\[ d_y = 42·02 d_x \]
TABLE III

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

\[ \text{Cl}_\text{ppm} = 0.98, \ D.O. = 3.37 \text{ ml/l., Ca} = 5.6 \text{ mEq/l.} \]

<table>
<thead>
<tr>
<th>Volume of water ml.</th>
<th>Total no. of fry</th>
<th>Length of fry</th>
<th>Weight of fry g.</th>
<th>Ml. (initial) oxygen per g. 6 h (= X)</th>
<th>Median survival time (mts.) = Y</th>
</tr>
</thead>
<tbody>
<tr>
<td>586</td>
<td>7</td>
<td>16-27</td>
<td>4.0</td>
<td>0.536</td>
<td>4.056</td>
</tr>
<tr>
<td>534</td>
<td>13</td>
<td>16-28</td>
<td>3.7</td>
<td>0.852</td>
<td>2.326</td>
</tr>
<tr>
<td>710</td>
<td>19</td>
<td>15-23</td>
<td>3.6</td>
<td>0.737</td>
<td>2.794</td>
</tr>
<tr>
<td>586</td>
<td>23</td>
<td>17-23</td>
<td>3.4</td>
<td>1.293</td>
<td>1.682</td>
</tr>
<tr>
<td>566</td>
<td>5</td>
<td>15-25</td>
<td>4.1</td>
<td>0.281</td>
<td>7.216</td>
</tr>
<tr>
<td>586</td>
<td>5</td>
<td>15-25</td>
<td>5.8</td>
<td>0.477</td>
<td>4.388</td>
</tr>
<tr>
<td>548</td>
<td>5</td>
<td>16-26</td>
<td>4.4</td>
<td>0.893</td>
<td>2.277</td>
</tr>
<tr>
<td>572</td>
<td>25</td>
<td>14-27</td>
<td>4.2</td>
<td>1.055</td>
<td>2.011</td>
</tr>
<tr>
<td>560</td>
<td>5</td>
<td>15-19</td>
<td>1.7</td>
<td>0.119</td>
<td>17.460</td>
</tr>
<tr>
<td>584</td>
<td>14</td>
<td>15-27</td>
<td>3.3</td>
<td>0.482</td>
<td>4.419</td>
</tr>
<tr>
<td>560</td>
<td>17</td>
<td>13-20</td>
<td>1.5</td>
<td>0.047</td>
<td>4.311</td>
</tr>
<tr>
<td>562</td>
<td>22</td>
<td>14-27</td>
<td>3.0</td>
<td>0.047</td>
<td>2.202</td>
</tr>
</tbody>
</table>

Correlation coefficient \( r_{xy} = + 0.3636 \)
Regression equations:
\[
X = 3.071 + 0.0031 (Y - 245.6)
\]
\[
d_x = 0.0031 \ d_y
\]
\[
Y = 245.6 + 42.56 (X - 3.071)
\]
\[
d_y = 42.56 \ d_x
\]

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 m.m. 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 m.m.; 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 differ-
Oxygen Consumption and Viability of Chanos chanos (Forskål) 155

ences 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 = 0·05; t (for fry at 23° (tap water) and at 30° C. (sea water): calcd., 2·34; from Tables, 2·18 for P = 0·05 and 2·68 for P = 0·02]. 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, Tampl 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,

\[
X_1 - n_1 l_1^k = X_1 - n_2 l_2^k \tag{4 i}
\]

\[
X_1 - n_1 r_1 = X_1 - n_2 r_2 \tag{5 i}
\]

\[
t_2 = t_1 \left( \frac{n_1}{n_2} \right) \left( \frac{l_1}{l_2} \right)^k \tag{4}
\]

and

\[
t_2 = t_1 \left( \frac{r_1}{r_2} \right) \left( \frac{n_1}{n_2} \right) \tag{5}
\]

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,

\[
X_1 - n_1 l_1^k = (mX_1 - n_2 l_2^k)/m \tag{6 i}
\]

\[
X_1 - n_1 r_1 = (mX_1 - n_2 r_2)/m \tag{7 i}
\]

\[
t_2 = mt_1 \left( \frac{n_1}{n_2} \right) \left( \frac{l_1}{l_2} \right)^k \tag{6}
\]

and

\[
t_2 = mt_1 \left( \frac{n_1}{n_2} \right) \left( \frac{r_1}{r_2} \right) \tag{7}
\]
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.
Oxygen Consumption and Viability of Chanos chanos (Forskål)

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.

ACKNOWLEDGMENTS

Our grateful thanks are due to Dr. N. K. Panikkar for his interest in the work and to Sri. S. K. Banerji for his suggestions and advice in regard to the mathematical aspects of the paper. The collections of fish fry and fingerlings were made with the kind co-operation of Sri. D. A. S. Gnanadoss, Inspector of Fisheries (Madras), Pamban.

REFERENCES


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:

<table>
<thead>
<tr>
<th>( l_1 ) (mm.)</th>
<th>( m )</th>
<th>(mV/1000) l.</th>
</tr>
</thead>
<tbody>
<tr>
<td>40</td>
<td>5.91</td>
<td>17.7</td>
</tr>
<tr>
<td>60</td>
<td>16.70</td>
<td>50.1</td>
</tr>
<tr>
<td>80</td>
<td>34.93</td>
<td>104.8</td>
</tr>
<tr>
<td>100</td>
<td>61.87</td>
<td>185.6</td>
</tr>
</tbody>
</table>

(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 \((7.5 \times 3)\) l.

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

<table>
<thead>
<tr>
<th>( l_2 ) (mm.)</th>
<th>( n_2 \times 3 )</th>
</tr>
</thead>
<tbody>
<tr>
<td>41</td>
<td>98</td>
</tr>
<tr>
<td>62</td>
<td>35</td>
</tr>
<tr>
<td>82</td>
<td>16</td>
</tr>
<tr>
<td>103</td>
<td>9</td>
</tr>
</tbody>
</table>
Oxygen Consumption and Viability of Chanos chanos (Forskål) 159

(ii) For 50% mortality, where $l_1 = l_2 = 20.5\text{ mm.}$, and $n_1 = 195 \times 3$,

<table>
<thead>
<tr>
<th>$n_2 \times 3$</th>
<th>$t_2$ (hrs.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1170</td>
<td>2</td>
</tr>
<tr>
<td>2340</td>
<td>1</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>$l_2$ (mm.)</th>
<th>$t_2$ (hrs.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>41</td>
<td>0.7</td>
</tr>
<tr>
<td>62</td>
<td>0.2</td>
</tr>
</tbody>
</table>