6. STUDIES ON POPULATION
6.1. ON LENGTH AND WEIGHT
6.1.1 LENGTH-WEIGHT RELATIONSHIP

Individual total length and weight of a number of fish were utilized each season to calculate the length-weight relationship

$$\log W = a + b \log L$$

where

$$b = \frac{\sum XY - \sum X \sum Y}{\sum X^2 - (\sum X)^2} \frac{N}{N}$$

and

$$a = \frac{\sum Y}{N} - b(\frac{\sum X}{N})$$

The X and Y in the equation are log values of the total length in mm and the log values of the weight in grams respectively.

Data on 18,141 mackerel; collected at Manassery from the boat seine landings for 15 seasons during 1965-'66 to 1979-'80 and the purse seine landings at Fisheries Harbour for another season in 1980-'81, were treated in the above manner for finding out the relationship. The length-weight relationships thus calculated for 16 seasons are given in Table I, and illustrated in Fig. 30, 31, 32, and 33.

A simple arithmetic mean of the 'a' values and 'b'
Table I

Logarithmic value of the length-weight relationship from season to season.

<table>
<thead>
<tr>
<th>Year</th>
<th>Log W</th>
<th>Log L</th>
</tr>
</thead>
<tbody>
<tr>
<td>1965-'66</td>
<td>-6.6417570</td>
<td>3.7351015</td>
</tr>
<tr>
<td>1966-'67</td>
<td>-6.5382332</td>
<td>3.6715624</td>
</tr>
<tr>
<td>1967-'68</td>
<td>-5.7415300</td>
<td>3.3295900</td>
</tr>
<tr>
<td>1968-'69</td>
<td>-5.2560758</td>
<td>3.1187024</td>
</tr>
<tr>
<td>1969-'70</td>
<td>-6.1530601</td>
<td>3.5182661</td>
</tr>
<tr>
<td>1970-'71</td>
<td>-5.1772416</td>
<td>3.0732987</td>
</tr>
<tr>
<td>1971-'72</td>
<td>-5.0165294</td>
<td>3.0046418</td>
</tr>
<tr>
<td>1972-'73</td>
<td>-5.4994377</td>
<td>3.2320052</td>
</tr>
<tr>
<td>1973-'74</td>
<td>-5.1756602</td>
<td>3.0865672</td>
</tr>
<tr>
<td>1974-'75</td>
<td>-5.5035330</td>
<td>3.2296853</td>
</tr>
<tr>
<td>1975-'76</td>
<td>-5.8901863</td>
<td>3.3959418</td>
</tr>
<tr>
<td>1976-'77</td>
<td>-5.7806300</td>
<td>3.3503130</td>
</tr>
<tr>
<td>1977-'78</td>
<td>-4.8357030</td>
<td>2.9336154</td>
</tr>
<tr>
<td>1978-'79</td>
<td>-5.5500726</td>
<td>3.2491487</td>
</tr>
<tr>
<td>1979-'80</td>
<td>-5.3598009</td>
<td>3.1675454</td>
</tr>
<tr>
<td>1980-'81</td>
<td>-5.0999085</td>
<td>3.0570810</td>
</tr>
</tbody>
</table>
Fig. 30: Logarithmic length-weight relationship, calculated (continuous line) and cubical (broken line) against observed average values (dots) from 1965-'66 to 1968-'69.
Fig. 30

Log values of total length in mm.

1955-56
\[ \log W = 0.6410L + 0.3730 \log L \]

1966-67
\[ \log W = 0.4362/10 + 0.3715 \log L \]

1967-68
\[ \log W = 0.4102 + 0.3291 \log L \]

1968-69
\[ \log W = 0.2560768 + 0.3187524 \log L \]
Fig. 31: Logarithmic length-weight relationship, calculated (continuous line) and cubical (broken line) against observed average values (dots) from 1969-'70 to 1972-'73.
Fig. 32: Logarithmic length-weight relationship, calculated (continuous line) and cubical (broken line) against observed average values (dots) from 1973-'74 to 1976-'77.
Fig. 32

Log values of total length in mm.
Fig. 33: Logarithmic length-weight relationship, calculated (continuous line) and cubical (broken line) against observed average values (dots) from 1977-'78 to 1980-'81.
values of the seasons was found out, according to which the average length-weight relationship of the mackerel was

\[ \log W = -5.5762101 + 3.2595716 \log L. \]

From the pooled value of X and Y of 16 seasons, the 'a' and 'b' were calculated afresh and the length-weight relationship accordingly is

\[ \log W = -5.6738829 + 3.2995842 \log L. \]

The values on exponential equation

\[ W = aL^b \]

of the length-weight relationships for 16 seasons are given in Table II and in Fig. 34, 35, 36, and 37.

An arithmetic mean of these is

\[ W = 0.000002653322 L^{3.2595716}. \]

Exponential value of the pooled length-weight relationship of the 16-season period is

\[ W = 0.000002118932 L^{3.2995842}. \]

These calculations as already mentioned are based on length in mm. With reference to length in cm, the relation on pooled value would be
Table II

Exponential equations on the logarithmic values of length-weight relationship

<table>
<thead>
<tr>
<th>Year</th>
<th>Equation</th>
<th>Logarithmic Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1965-'66</td>
<td>$w = 0.000000228162 \ L$</td>
<td>3.7351815</td>
</tr>
<tr>
<td>1966-'67</td>
<td>$w = 0.000000289579 \ L$</td>
<td>3.6715624</td>
</tr>
<tr>
<td>1967-'68</td>
<td>$w = 0.000001813301 \ L$</td>
<td>3.3295900</td>
</tr>
<tr>
<td>1968-'69</td>
<td>$w = 0.000005545289 \ L$</td>
<td>3.1167024</td>
</tr>
<tr>
<td>1969-'70</td>
<td>$w = 0.000000702975 \ L$</td>
<td>3.5182661</td>
</tr>
<tr>
<td>1970-'71</td>
<td>$w = 0.00000649032 \ L$</td>
<td>3.0732987</td>
</tr>
<tr>
<td>1971-'72</td>
<td>$w = 0.000009626548 \ L$</td>
<td>3.0046418</td>
</tr>
<tr>
<td>1972-'73</td>
<td>$w = 0.000003166375 \ L$</td>
<td>3.2320052</td>
</tr>
<tr>
<td>1973-'74</td>
<td>$w = 0.000006673287 \ L$</td>
<td>3.0865672</td>
</tr>
<tr>
<td>1974-'75</td>
<td>$w = 0.000003136657 \ L$</td>
<td>3.2256853</td>
</tr>
<tr>
<td>1975-'76</td>
<td>$w = 0.000001287691 \ L$</td>
<td>3.3959418</td>
</tr>
<tr>
<td>1976-'77</td>
<td>$w = 0.000001657181 \ L$</td>
<td>3.3503130</td>
</tr>
<tr>
<td>1977-'78</td>
<td>$w = 0.000014598122 \ L$</td>
<td>2.9336154</td>
</tr>
<tr>
<td>1978-'79</td>
<td>$w = 0.000002817912 \ L$</td>
<td>3.2491487</td>
</tr>
<tr>
<td>1979-'80</td>
<td>$w = 0.000004367160 \ L$</td>
<td>3.1675454</td>
</tr>
<tr>
<td>1980-'81</td>
<td>$w = 0.000007944956 \ L$</td>
<td>3.0570810</td>
</tr>
</tbody>
</table>
Fig. 34: Exponential relation of length and weight, calculated (continuous line) and cubical (broken line) against average observed values (dots) from 1965-'66 to 1968-'69.
Fig. 35: Exponential relation of length and weight, calculated (continuous line) and cubical (broken line) against average observed values (dots) from 1969-'70 to 1972-'73.
Fig. 36: Exponential relation of length and weight, calculated (continuous line) and cubical (broken line) against average observed values (dots) from 1973-'74 to 1976-77.
Fig. 37: Exponential relation of length and weight, calculated (continuous line) and cubical (broken line) against average observed values (dots) from 1977-'78 to 1980-'81.
\[ \log W = -2.3742987 + 3.2995842 \log L \]

logarithmically and

\[ W = 0.004223780 L^{3.2995842} \]

exponentially. Against arithmetic mean the relationship for length in cm is

\[ \log W = -2.3166385 + 3.2595716 \log L \]

logarithmically and

\[ W = 0.004823491 L^{3.2595716} \]

exponentially.

These values against measurements in cm are necessary for comparison with the findings of some earlier workers in discussion.

6.1.2. TEST OF SIGNIFICANCE

The 'b' values during the study differed from season to season within a range of 2.933614 of 1977-’78 and 3.7351815 of 1965-’66, and the average value was different from the pooled one. The number of fish utilized for calculating the length-weight relationship (Table III) each season was not equal. The test of significance between 'b' values
Table III

Test of 't' on seasonal 'b' values against pooled and isometric values

<table>
<thead>
<tr>
<th>Year</th>
<th>No. of fish studied</th>
<th>'b' value</th>
<th>$H_0: B_1 - B_2 = 0$</th>
<th>$H_0: -0=0$ weighted</th>
</tr>
</thead>
<tbody>
<tr>
<td>1965-’66</td>
<td>931</td>
<td>3.7351815</td>
<td>4.0196</td>
<td>6.3133</td>
</tr>
<tr>
<td>1966-’67</td>
<td>1247</td>
<td>3.6715624</td>
<td>3.9408</td>
<td>7.0979</td>
</tr>
<tr>
<td>1967-’68</td>
<td>657</td>
<td>3.3295900</td>
<td>0.2342*</td>
<td>2.3253**</td>
</tr>
<tr>
<td>1968-’69</td>
<td>554</td>
<td>3.1187024</td>
<td>1.3048*</td>
<td>0.8335+</td>
</tr>
<tr>
<td>1969-’70</td>
<td>1058</td>
<td>3.5182661</td>
<td>2.1537**</td>
<td>5.2394</td>
</tr>
<tr>
<td>1970-’71</td>
<td>2135</td>
<td>3.0732987</td>
<td>3.0902</td>
<td>1.0857+</td>
</tr>
<tr>
<td>1971-’72</td>
<td>1184</td>
<td>3.0046418</td>
<td>3.1068</td>
<td>0.0674+</td>
</tr>
<tr>
<td>1972-’73</td>
<td>414</td>
<td>3.2320052</td>
<td>0.4255*</td>
<td>1.9098+</td>
</tr>
<tr>
<td>1973-’74</td>
<td>484</td>
<td>3.0865672</td>
<td>1.4530*</td>
<td>0.9937+</td>
</tr>
<tr>
<td>1974-’75</td>
<td>1097</td>
<td>3.2296853</td>
<td>0.9646+</td>
<td>2.3323**</td>
</tr>
<tr>
<td>1975-’76</td>
<td>842</td>
<td>3.3959418</td>
<td>0.8491+</td>
<td>3.4685</td>
</tr>
<tr>
<td>1976-’77</td>
<td>1641</td>
<td>3.3503130</td>
<td>0.6102*</td>
<td>4.1874</td>
</tr>
<tr>
<td>1977-’78</td>
<td>1879</td>
<td>2.9336154</td>
<td>4.7284</td>
<td>0.9436+</td>
</tr>
<tr>
<td>1978-’79</td>
<td>1307</td>
<td>3.2491487</td>
<td>0.5472*</td>
<td>2.7045**</td>
</tr>
<tr>
<td>1979-’80</td>
<td>886</td>
<td>3.1675454</td>
<td>1.1960*</td>
<td>1.5653+</td>
</tr>
<tr>
<td>1980-’81</td>
<td>1825</td>
<td>3.0570810</td>
<td>3.0864</td>
<td>0.7882+</td>
</tr>
</tbody>
</table>

*Not significant at 5% level and **not significant at 1% level. The table values of 't' at 5% and 1% level are 1.96 and 2.5758 respectively.
from season to season against the pooled one was hence conducted with the help of following formula (Dixon and Massey 1969) giving weightage also to the number of fish each time, and the results given in Table III.

\[
t = \frac{b_1 - b_2}{s^2 \left( \frac{1}{N_1} + \frac{1}{N_2} \right)}
\]

where

\[
s^2 = \frac{(N_1 - 2) \frac{S_y^2}{Sx_1^2} + (N_2 - 2) \frac{S_y^2}{Sx_2^2}}{N_1 + N_2 - 4}
\]

According to the results obtained, the values on 1965-'66, 1966-'67, 1970-'71, 1971-'72, 1977-'78, and 1980-'81 were significantly varying. The values on 1967-'68, 1968-'69, 1972-'73 to 1976-'77, 1978-'79, and 1979-'80 were not significant at 5% level. The 'b' values within the range of 3.0865672 and 3.3959418 were the ones not significant at 5% level. The values of 'b' beginning at 3.6715624 on 1966-'67 and more on the higher side, and 3.0732987 of 1970-'71 and
below which are on the lower side of the pooled one were significantly varying. The difference in 'b' value of 1970-'71 from the pooled one is 0.2262855, and it amounts to 6.9% in the pooled value. In 1969-'70, the 'b' value was only 3.5182661 and it was only 6.6% in the pooled value and the 't' was not significant at 1% level. The lowest value 3.0865672 falling in the 5% confidence limit was 0.2130170 less from the pooled one and it forms only 6.45% in the pooled value. Probably variations around 6.5% of the pooled value are within the tolerance limits, beyond which it becomes significant in 't' test.

The values of 'b' in each season were similarly tested individually against isometric growth by using the formula (Snedecor 1959)

\[ t = \frac{b_1 - 3}{\sqrt{\frac{S_y^2}{S_x^2}} \cdot \frac{1}{n-2}} \]

and results given in Table III. Against isometric growth the 'b' values of 3.1187024 in 1968-'69 and below were found not
significant at 1% level and between 3.2491487 of 1978-'79 and
3.3295900 of 1967-'68 not significant at 5% level (Table III).
The values showed significant variations when they went
3.3503130 of 1976-'77 and above. The differences of the
values in 1967-'68 and 1976-'77 from 3.0 were respectively
0.3295900 and 0.3503130 forming 11.0 and 11.7% in the isometric
value and the tolerance limit of 'b' values against isometric
growth falls somewhere between 3.33 and 3.35.

6.1.3. RELATION BETWEEN 'b' AND 'a' VALUES OF LENGTH-WEIGHT
RELATIONSHIP

The 'a' and 'b' in Le Cren's (1951) formula are con-
stants computed by least squares method from 2 variables.
The 'a' is independent of 'b' in different species of
fishes. Within a species, they may be related to each other
in their fluctuations from season to season. Otherwise, there
cannot be a set pattern of growth in the species concerned.
For a species the growth can either be isometric or allometric
but cannot be both occurring at different times. As the
length-weight relationship of mackerel at Cochin is available
for 16 seasons, and as the 'b' value during this period was
ranging between 2.9336164 and 3.7351815 and the 'a' value
between -4.8357030 and -6.6417570, a regression of 'a' on 'b' was found out by the formula

\[ a = A + Bb \]

where

\[ B = \frac{\bar{xy} - \bar{x}\bar{y}}{\bar{x^2} - (\bar{x})^2} \]

and

\[ A = \frac{\bar{y}}{n} - B(\bar{x}) \]

to be

\[ a = -1.8209470 + 2.2693648b \]

depicting a perfect straight line as shown in Fig. 38. On a 'b' value of 3.0 of the Cube Law, the value of 'a' accordingly would be -5.0 and the length-weight relationship on isometric growth condition emerges as

\[ \log W = -5.0 + 3.0 \log L \]

or

\[ W = 0.00001 L^{3.0} \]

for length measurements in mm, and

\[ \log W = -2.0 + 3.0 \log L \]
Fig. 38: Relation between 'a' and 'b' values of logarithmic length-weight relationship of mackerel, calculated (continuous line) against observed values (dots).
\[ a = 1.8209470 + 2.2693648 \times b \]
or \[ w = 0.01 L^{3.0} \]

for lengths in cm.

A test of significance was done on the relation between 'b' and 'a' values by applying the following formula (Snedecor 1959)

\[
t = \frac{\hat{b}}{\sqrt{\frac{\hat{a} - \hat{a}^2}{n-2}}}
\]

where \( \hat{a} \) is calculated by using the regression equation on 'a' and 'b' found above, the value of 't' works out to be 132.344. As this value is very much higher than the table value of 2.977 at 1% level for df 14, it is highly significant showing good regression relationship between the 'a' and 'b' values of the length-weight equations. The value of \( \hat{B} \) being positive, it indicates an increase in the 'a' value with every unit increase in 'b' value of the relationship. In other words, one can expect that with an increase or decrease of every unit of 'b' value there will be a corresponding increase or decrease of 2.2693648 units in the value of 'a'.
6.1.4. LENGTH-WEIGHT RELATIONSHIP BETWEEN SEXES

Morphometrically, male and female mackerel look externally alike. With no indication of sexual dimorphism even in their size and weight at any time of the life-span, there would normally be no difference in length-weight relationships between them. However, to be sure about it, the length-weight relationships of the male and female mackerel were separately found out for some seasons as given in Table IV.

Data for the 4 seasons were pooled together and the following logarithmic equations were found out for 1977-’81 as

\[
\begin{align*}
\text{Male} & \quad \log W = -5.3256977 + 3.1511524 \log L \\
\text{Female} & \quad \log W = -5.1637076 + 3.0820961 \log L \\
\text{Combined} & \quad \log W = -5.2462069 + 3.1172780 \log L
\end{align*}
\]

Exponential equivalents of the above equations for male and female are respectively

\[
\begin{align*}
W & = 0.000004723917 \ L^{3.1511524} \\
\text{and} & \\
W & = 0.000006859499 \ L^{3.0820961}
\end{align*}
\]

The relationship of the sexes in lengths in cm are for
<table>
<thead>
<tr>
<th>Year</th>
<th>Male</th>
<th>Female</th>
<th>Combined</th>
</tr>
</thead>
<tbody>
<tr>
<td>1977-'78</td>
<td>( \log W = -4.9518299 + 2.9829876 \log L )</td>
<td>( \log W = -4.6868760 + 2.8700984 \log L )</td>
<td>( \log W = -4.8230999 + 2.9281299 \log L )</td>
</tr>
<tr>
<td>1978-'79</td>
<td>( \log W = -5.4888035 + 3.2224718 \log L )</td>
<td>( \log W = -5.4616184 + 3.2114887 \log L )</td>
<td>( \log W = -5.4760252 + 3.2173248 \log L )</td>
</tr>
<tr>
<td>1979-'80</td>
<td>( \log W = -5.3960609 + 3.1828652 \log L )</td>
<td>( \log W = -5.3151701 + 3.1486472 \log L )</td>
<td>( \log W = -5.3598009 + 3.1675454 \log L )</td>
</tr>
<tr>
<td>1980-'81</td>
<td>( \log W = -5.1329277 + 3.0717023 \log L )</td>
<td>( \log W = -5.0671463 + 3.0425456 \log L )</td>
<td>( \log W = -5.0999085 + 3.0570810 \log L )</td>
</tr>
</tbody>
</table>
\[ \log W = -2.1745452 + 3.1511524 \log L \]

**Male:**

\[ W = 0.006690442 \times 3.1511524 \]

and

\[ \log W = -2.0816115 + 3.0820961 \log L \]

**Female:**

\[ W = 0.0082868313 \times 3.0820961 \]

The 'a' and 'b' values as seen in this analyses for all the 4 seasons (Table IV) for females were slightly lower than those with the males.

A test of significance was done on the relationship between males and females with the equation (Bailey 1959)

\[ t = \frac{|b_m - b_f|}{\sqrt{s_m^2 + s_f^2}} \]

where \( b_m \) and \( s_m^2 \) stand for males, and \( b_f \) and \( s_f^2 \) stand for females, and the equations for \( s_m^2 \) and \( s_f^2 \) were as follows:
The values of 't' obtained on these computations were

\[
1877-'78 = 0.026 \\
1978-'79 = 0.002 \\
1979-'80 = 0.008 \quad \text{and} \\
1980-'81 = 0.007
\]

The combined value for the 4 seasons of 1977-'81 of the 't' was 0.015. All these values being much lower to the Table value of 1.645 of t df α at 1% level shows the regression coefficients of males and females not to differ significantly, and a combined equation composed on both sexes together will suffice.
6.1.5. LENGTH-WEIGHT RELATIONSHIP BETWEEN INDETERMINATE AND DETERMINATE FISH

As there is no difference between males and females, there appears to be no significant difference between the fish in which sexes are distinguishable (i.e. above 119 mm size) and the fish in which sexes are not discernible (below 120 mm size). Indeterminate fish of size 67-119 mm numbering 302 that occurred during the seasons from 1975-'76 to 1980-'81 were pooled together and their length-weight relationship worked out separately from that of the rest. The relationship for these 2 groups of fishes were as follows:

Indeterminate

\[
\log W = -5.6652489 + 3.3064783 \log L
\]

Others

\[
\log W = -5.2462069 + 3.1172780 \log L
\]

Exponential equivalent on the above relations respectively are

\[
W = 0.000002161479 L^{3.3064783}
\]

and

\[
W = 0.000005672743 L^{3.1172780}
\]
The relationship of them in length in cm are Indeterminate

\[
\log W = -2.3587706 + 3.3064783 \log L \\
W = 0.004377533 L^{3.3064783}.
\]

and Determinate

\[
\log W = -2.1289289 + 3.1172780 \\
W = 0.007431408 L^{3.1172780}.
\]

6.2. GROWTH AND AGE

The growth of fish is generally depicted in the progression of modal sizes in catches from month to month. But the mode at times, whatever may be the reason, especially among older fish seems to remain static (Fig.28). The monthly average size provides more or less good positive progression (Fig.29), and through this the growth rate of mackerel up to December as displayed in Table V is calculated. The mean growth derived from this Table is 15.07 mm a month, and at this rate the fish in one year could attain a length of 180.86 mm.

The monthly average growth as given in Table V ranges
Table V

Growth of mackerel during season time up to December in mm

<table>
<thead>
<tr>
<th>Year</th>
<th>Months</th>
<th>Mean length range</th>
<th>Length gained</th>
<th>Period months</th>
<th>Mean growth</th>
</tr>
</thead>
<tbody>
<tr>
<td>1965</td>
<td>Sep-Dec</td>
<td>169.2 - 204.6</td>
<td>35.4</td>
<td>3</td>
<td>11.80</td>
</tr>
<tr>
<td>1966</td>
<td>Jun-Aug</td>
<td>147.1 - 172.8</td>
<td>25.7</td>
<td>2</td>
<td>12.85</td>
</tr>
<tr>
<td>1967</td>
<td>May-Oct</td>
<td>130.2 - 191.4</td>
<td>61.2</td>
<td>4</td>
<td>15.30</td>
</tr>
<tr>
<td>1968</td>
<td>Jun-Dec</td>
<td>140.4 - 210.6</td>
<td>70.2</td>
<td>6</td>
<td>11.70</td>
</tr>
<tr>
<td>1969</td>
<td>Jul-Dec</td>
<td>137.4 - 214.2</td>
<td>76.8</td>
<td>5</td>
<td>15.36</td>
</tr>
<tr>
<td>1970</td>
<td>Jul-Dec</td>
<td>116.3 - 205.0</td>
<td>88.7</td>
<td>5</td>
<td>17.74</td>
</tr>
<tr>
<td>1971</td>
<td>Aug-Dec</td>
<td>138.7 - 202.1</td>
<td>63.4</td>
<td>4</td>
<td>15.85</td>
</tr>
<tr>
<td>1972</td>
<td>Jul-Aug</td>
<td>118.1 - 136.6</td>
<td>18.5</td>
<td>1</td>
<td>18.50</td>
</tr>
<tr>
<td>1973</td>
<td>Aug-Sep</td>
<td>145.2 - 162.1</td>
<td>16.9</td>
<td>1</td>
<td>16.90</td>
</tr>
<tr>
<td>1974</td>
<td>June-Dec</td>
<td>132.4 - 224.5</td>
<td>92.1</td>
<td>6</td>
<td>15.35</td>
</tr>
<tr>
<td>1975</td>
<td>Aug-Dec</td>
<td>122.0 - 185.4</td>
<td>63.4</td>
<td>4</td>
<td>15.85</td>
</tr>
<tr>
<td>1976</td>
<td>Aug-Dec</td>
<td>131.3 - 202.1</td>
<td>70.8</td>
<td>4</td>
<td>17.70</td>
</tr>
<tr>
<td>1977</td>
<td>Jul-Nov</td>
<td>146.5 - 205.7</td>
<td>59.2</td>
<td>4</td>
<td>14.80</td>
</tr>
<tr>
<td>1978</td>
<td>Jun-Oct</td>
<td>146.4 - 206.6</td>
<td>60.2</td>
<td>4</td>
<td>15.05</td>
</tr>
<tr>
<td>1979</td>
<td>Jul-Nov</td>
<td>123.8 - 190.4</td>
<td>56.6</td>
<td>4</td>
<td>14.15</td>
</tr>
</tbody>
</table>

Total 859.1 57 15.07
mostly between 11.70 mm of 1968 to 15.85 mm of 1971 and 1975. At this minimum, the annual attainable length is only 140.40 mm. But with 15.85 mm, the length attained in a year can be 190.20 mm. An average of the 2 works out the length reached in 12 months to be 165.30 mm. Fish below 160 mm, hence are treated in the study as 0-year old.

The period considered for growth in Table V ends in December. The length by then is mostly around 200 to 205 mm. Fish in subsequent months being bigger and older grow slower. This, in fact, is the time when stagnation in monthly modal sizes mostly occurs. Nevertheless, the monthly average length of the fish caught (Table VI) shows without doubt growth then also.

Growth of mackerel in the months immediately following December as treated in Table VI is 5.26 mm. Tagging mackerel at Cochin, a fish of 189 mm was found to grow to 191 mm in 7 days registering 2.0 mm increment. This observation was made in December 1967 (Noble 1974 a) and at this rate the mackerel of given size and time gains 8.57 mm in one month. Another mackerel of 195 mm size tagged and released on 29th of January 1968, during 25 days at liberty gained 5.0 mm in length. The monthly growth in February thus calculates to be
Table VI

Growth of mackerel in months following December in mm

<table>
<thead>
<tr>
<th>Year</th>
<th>Months</th>
<th>Mean length range</th>
<th>Length gained</th>
<th>Period months</th>
<th>Mean growth</th>
</tr>
</thead>
<tbody>
<tr>
<td>1967</td>
<td>Mar-Apr</td>
<td>213.0 - 219.7</td>
<td>6.7</td>
<td>1</td>
<td>6.70</td>
</tr>
<tr>
<td>1969</td>
<td>Jan-Feb</td>
<td>209.4 - 216.6</td>
<td>7.2</td>
<td>1</td>
<td>7.20</td>
</tr>
<tr>
<td>1970</td>
<td>Feb-May</td>
<td>205.0 - 221.1</td>
<td>12.1</td>
<td>3</td>
<td>4.03</td>
</tr>
<tr>
<td>1971</td>
<td>Feb-Mar</td>
<td>204.8 - 211.3</td>
<td>6.5</td>
<td>1</td>
<td>6.50</td>
</tr>
<tr>
<td>1972</td>
<td>Jan-Apr</td>
<td>204.8 - 219.1</td>
<td>14.3</td>
<td>3</td>
<td>4.77</td>
</tr>
<tr>
<td>1974</td>
<td>Nov-Jan</td>
<td>217.7 - 228.7</td>
<td>11.0</td>
<td>2</td>
<td>5.50</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td></td>
<td>57.8</td>
<td>11</td>
<td>5.26</td>
</tr>
</tbody>
</table>
At the rate of 5.26 mm per month derived from Table VI which agrees closely with tag recoveries, the fish in a year attains an additional 63.12 mm to the 165.30 mm already reached in previous year. The fish at the end of second year accordingly gets 228.42 mm length and those that are between 160 mm and 229 mm are therefore treated as 1-year old. As the fish becomes older, the rate of growth reduces still further. Enough data, however, is not available at Cochin to substantiate this. The fish between 230 and 269 mm lengths in consonance with the findings of earlier workers (Ramamohana Rao et al. 1962 and Seshappa 1969) are kept in the study as 2-year old. Those fish from 270 mm and above are considered hence as 3-year old.

6.3. AGE COMPOSITION OF CATCHES

Based on the above growth structure, the fish landed at Manassery by Thangu vala from season to season during July 1965 to June 1980 were compartmentalized into different age years and given in Table VII. As already dealt with in seasonal break up, care was taken in this excercise to ensure all the
Table VII

Age composition of mackerel landed at Manassery by boat seine

<table>
<thead>
<tr>
<th>Season</th>
<th>0-year</th>
<th>1-year</th>
<th>2-year</th>
<th>3-year</th>
<th>Total</th>
<th>Effort</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>&lt;159 mm</td>
<td>160-229 mm</td>
<td>230-269 mm</td>
<td>&gt;270 mm</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1965-'66</td>
<td>92.93</td>
<td>24.34</td>
<td>.</td>
<td>.</td>
<td>117.27</td>
<td>10251</td>
</tr>
<tr>
<td>1966-'67</td>
<td>51.67</td>
<td>38.48</td>
<td>0.09</td>
<td>.</td>
<td>90.24</td>
<td>10632</td>
</tr>
<tr>
<td>1967-'68</td>
<td>54.50</td>
<td>71.97</td>
<td>.</td>
<td>.</td>
<td>126.47</td>
<td>10580</td>
</tr>
<tr>
<td>1968-'69</td>
<td>6.50</td>
<td>24.73</td>
<td>.</td>
<td>.</td>
<td>33.23</td>
<td>8614</td>
</tr>
<tr>
<td>1969-'70</td>
<td>36.79</td>
<td>120.00</td>
<td>0.46</td>
<td>.</td>
<td>157.25</td>
<td>6708</td>
</tr>
<tr>
<td>1970-'71</td>
<td>204.16</td>
<td>1055.17</td>
<td>5.03</td>
<td>.</td>
<td>1264.36</td>
<td>14279</td>
</tr>
<tr>
<td>1971-'72</td>
<td>1.07</td>
<td>449.82</td>
<td>33.79</td>
<td>.</td>
<td>484.68</td>
<td>14128</td>
</tr>
<tr>
<td>1972-'73</td>
<td>19.54</td>
<td>206.38</td>
<td>5.61</td>
<td>.</td>
<td>231.53</td>
<td>9589</td>
</tr>
<tr>
<td>1973-'74</td>
<td>253.05</td>
<td>25.23</td>
<td>0.12</td>
<td>.</td>
<td>278.40</td>
<td>9196</td>
</tr>
<tr>
<td>1974-'75</td>
<td>3.19</td>
<td>8.83</td>
<td>90.46</td>
<td>.</td>
<td>102.48</td>
<td>7819</td>
</tr>
<tr>
<td>1975-'76</td>
<td>582.16</td>
<td>26.69</td>
<td>21.85</td>
<td>0.14</td>
<td>630.84</td>
<td>5812</td>
</tr>
<tr>
<td>1976-'77</td>
<td>104.43</td>
<td>127.03</td>
<td>2.29</td>
<td>.</td>
<td>233.75</td>
<td>4847</td>
</tr>
<tr>
<td>1977-'78</td>
<td>35.19</td>
<td>698.59</td>
<td>.</td>
<td>.</td>
<td>733.78</td>
<td>7248</td>
</tr>
<tr>
<td>1978-'79</td>
<td>1.00</td>
<td>443.80</td>
<td>20.02</td>
<td>.</td>
<td>464.82</td>
<td>9188</td>
</tr>
<tr>
<td>1979-'80</td>
<td>0.72</td>
<td>8.19</td>
<td>0.53</td>
<td>.</td>
<td>9.44</td>
<td>4228</td>
</tr>
</tbody>
</table>

Thangya vale - cpue in numbers
fish of a season included in it, even if they occur outside July-June period.

6.4. COMPUTATION OF K, L∞ AND W∞

In the chapter on growth and age, mackerel of 159 mm and below were considered as 0-year olds. Sizes between 160 and 229 mm were likewise found to be 1-year old and those between 230 and 269 mm as 2-year old. Taking the 3-year olds to attain a length up to 289 mm in the year, the parameters of K and L∞ were worked out through least squares method, using the lengths at the end of successive year classes as X and Y. From its 'a' and 'b' values the K (e^{-1/b}), and L∞ (\frac{a}{1-b}) were found out to be 0.600774 and 314.8785713 mm respectively.

Looking through monthly progression of modal sizes (Fig. 28) the fish at 120 mm reaches a length of 182 mm in 6 months time. Assuming the 120 mm fish to be 6 months old the 182 mm size would be 1-year old, and at the end of the 2nd year this attains a length of 254 mm.

Following the straightline method of Alagaraja (1984), the L∞ and K from the above growth structure were found to be 316.7 mm and 0.7643 respectively. Majority of the modal
progression in Fig. 28 conform to this growth pattern. Moreover these parameters are close to the \( L_\infty \) 314.8785713 mm and \( K \) 0.600774 calculated from average monthly sizes using least squares method. As most of the sizes fall on this and as there is no risk of assuming age at any stage involved, the pair of \( L_\infty \) and \( K \) calculated from monthly average sizes are considered the best fitting in this study.

A fish of 314.8785713 mm size according to the pooled value of length-weight relationship

\[
\log W = -5.6738829 + 3.2995842 \log L
\]

would weigh 370.64 g. The cube value of the above length, however, is only 312.20 g. The weight got from \( L_\infty \) through length-weight relationship was higher than the cube value of \( L_\infty \). An independent calculation of \( W_\infty \) was therefore made through least squares method from the following weights got converted from lengths with the help of length-weight relationship,

\[
\begin{align*}
159 \text{ mm} &= 38.89 \text{ g} \\
229 \text{ mm} &= 129.60 \text{ g} \\
269 \text{ mm} &= 330.44 \text{ g} \\
289 \text{ mm} &= 279.29 \text{ g}
\end{align*}
\]
and found it out to be 586.02 g. The largest recorded size of mackerel is 360 mm (Dhulkhed and Annigeri 1983). According to length-weight relationship the above fish would weigh 576.57 g and it is nearer to the actual observed weight of 560 g and the above calculated value of 586.02 g. The cube value of 360 mm, however, is only 466.56 g, and all the weights calculated as well as observed are higher than this. These being isolated cases of individual fish, the \( \omega = 370.64 \) g got converted from the \( L_\infty = 314.8785713 \) mm through length-weight relationship is taken as the best for the population.

6.5. CALCULATION OF \( t_0 \)

The \( L_\infty \) as calculated in the previous section was 314.8785713 mm and \( t_0 \) is found out through least squares method on the relation between: \( X \) and \( Y \) where

\[
X = \text{age in years (t)}
\]

\[
Y = \log_{e} \frac{L_\infty - L_t}{L_\infty}
\]

\( L_t = \text{length at time t.} \)

Taking the lengths from which 1, 2, and 3 years of age
Fig. 39: Growth in length of mackerel fitted through von Bertalanffy's Growth Function.
commence as 159, 229, and 269 mm respectively 'a' and 'b' values were computed and the \( t_0 = \left( \frac{a}{K} \right) \) found out to be \( 0.1413431664 \). Assuming the 120 mm fish to be 6 months old, according to Alagaraja's (1984) method the \( t_0 \) is found to be \( 0.1232 \) and it being very near to the above value supports it.

Length at age back calculated by using von Bertalanffy's Growth Formula

\[
L_t = L_{\infty} e^{-K (t - t_0)}
\]

is plotted in Fig. 39, and the calculated values tally well with the observed ones.

**6.6. MORTALITY**

**6.6.1. INSTANTANEOUS TOTAL MORTALITY**

Based on the survival and progression of a year class in one season to the next higher one in the succeeding season, the instantaneous total mortality of the fish is computed by using the formula
of Gulland (1969) where \( \tilde{N}_0 \) and \( \tilde{N}_1 \) are the seasonal catch per unit of effort of an year class during 2 consecutive seasons.

In mackerel, the 0-year old fish generally does not support the commercial catches, and it so happen that they are recruited only for a short time before the commercial exploitation commences. The 1-year olds constitute the bulk of the landings with 2-year olds also fished along with them (Table VII). Occurrence of 3-year olds in the coastal fishery is only negligible if not absent. The mortality in mackerel, hence can better be computed between the 1-year and 2-year old fishes occurring in the fishery.

In 1965-'66, for instance, 24.34 numbers of fish caught per unit of effort represented the 1-year old population. This seems to have reduced and represented as 0.09 fish in numbers of cpue next season as 2-year olds. In other words, a death of 99.63% of the fish and survival of only 0.37% is indicated in the season. The instantaneous total mortality (Z) here is 5.601. The Z calculated likewise for other seasons at
Manassery are given in Table VIII along with the one that of 1965-'66. The Z during the period under study varied between 2.4557 of 1975-'76 and 7.4500 of 1972-'73.

6.6.2. INSTANTANEOUS NATURAL AND FISHING MORTALITY

The instantaneous total mortality of an underexploited species of fish exploited by a specific non-selective gear in principle should linearly be related to the effort expended in a season for its exploitation. Higher the effort, greater the Z becomes, and a lowering of the former causes a reduction of the latter. The values of Z for different seasons in this study were plotted against respective effort (f) of Thangu vala each season and given in Fig. 40. The Thangu vala being a multispecies gear exploiting other fishes as well, as and when they become available in the grounds, shows no apparent relation between its effort and the Z of mackerel (Fig. 40 A). The regression equation

\[ Z = a + bf \]

where 'b' is the catchability coefficient (q) and 'a' is the instantaneous natural mortality (M) was fitted to the
Table VIII

Instantaneous total mortality (Z) and total effort (f) during different seasons

<table>
<thead>
<tr>
<th>Seasons</th>
<th>Z</th>
<th>f</th>
</tr>
</thead>
<tbody>
<tr>
<td>1965-'66</td>
<td>5.6001</td>
<td>10251</td>
</tr>
<tr>
<td>1968-'69</td>
<td>3.9845</td>
<td>8514</td>
</tr>
<tr>
<td>1969-'70</td>
<td>3.1721</td>
<td>6708</td>
</tr>
<tr>
<td>1970-'71</td>
<td>3.4413</td>
<td>14279</td>
</tr>
<tr>
<td>1971-'72</td>
<td>4.3843</td>
<td>14128</td>
</tr>
<tr>
<td>1972-'73</td>
<td>7.4500</td>
<td>9589</td>
</tr>
<tr>
<td>1973-'74</td>
<td>3.3554</td>
<td>9196</td>
</tr>
<tr>
<td>1974-'75</td>
<td>6.4710</td>
<td>7819</td>
</tr>
<tr>
<td>1975-'76</td>
<td>2.4557</td>
<td>5812</td>
</tr>
<tr>
<td>1977-'78</td>
<td>3.5523</td>
<td>7248</td>
</tr>
<tr>
<td>1978-'79</td>
<td>6.7303</td>
<td>9188</td>
</tr>
</tbody>
</table>
Fig. 40: Relation between effort _Thaungu vala_ and instantaneous total mortality (Z).

A. All seasons included.

B. Seasons of high Z omitted.

C. Seasons of high Z and F excluded.
Fig. 40

[Graph showing data points and trend lines with annotations for A, B, and C.]
data. The 'q' for the available data in Table VIII in the equation was found to be 0.0000779849 and 'a' 3.8707.

Where

\[ q = \frac{\bar{Z} - M}{\bar{F}} \]

the instantaneous fishing mortality (F) is the product of 'q' and 'f' as in the equation

\[ F = q \bar{F} = \bar{Z} - M. \]

The \( \bar{F} \) for the 11 seasons in Table VIII being 9348.36, the \( \bar{F} \) is calculated to be 0.7290 and the \( \bar{Z} \) is 4.5997. The value of 'r' in this being only 0.127 indicates absence of any linear relationship between fishing intensity by Thangu vala and \( Z \) and hence separation of \( M \) from \( Z \) by this method is not valid.

Invalidity of this calculation is comprehensible in yet another angle. The \( M \) 3.8707 as calculated above first of all is higher than the \( Z \) values of 1969-'70, 1970-'71, 1973-'74, 1975-'76 and 1977-'78 (Table VIII). Even in its simple arithmetic mean of 4.5997 for the period under study, death due to natural causes (3.8707) seems to be very high leaving only 0.7290 for mortality on account of fishing. In
such a situation where exploitation is only 15.8% of the fishable stock, plenty of fish must be available in the grounds for further tapping at some time or other. Attempts to exploit mackerel with additional mechanized effort in recent years are with no positive results.

A regression of the data in Table VIII excluding 1972-'73, 1974-'75 and 1978-'79 seasons when $Z$ was too high was attempted and the resultant equation is

$$Z = 2.4672 + 0.0001330 f.$$ 

The values of $Z$, $F$, and $M$ were 3.7432, 1.2760 and 2.4672 respectively. Here too, the $M$ is on the higher side (Fig.40 B). The exploitation accordingly is only one-third of the fishable stock. Moreover, the 'r' value at present being only 0.4544, it does not support a good linear relationship between fishing intensity and mortality.

A regression of $Z$ and effort for 1968-'69, 1969-'70, 1973-'74, 1975-'76, and 1977-'78 avoiding years of very high $Z$ and $f$ values in Table VIII was tried and the equation was

$$Z = 1.0275 + 0.003029 f.$$
According to this the $Z, F, M,$ and $r$ are respectively $3.3040, 2.2765, 1.0275,$ and $0.7454$. The $r$ value in this shows a linear relationship. The value of $M$ being lower than that of $F$ (Fig.40 C), it indicates an exploitation of $69\%$.

Separation of $Z$ into $F$ and $M$ was tried again on the lines followed by Sekharan (1974) where the rate at which the population reduces to $1\%$ level in unfished state during its effective life-span can be taken as its $M$. In the present study, the mackerel appears to enter into 4th year of life and its effective life-span ($L_{max}$) hence is 5 years. According to the equation of Cushing (1968) which Sekharan seems to have followed

\[
M = \frac{1}{L_{max} - 1} \log_{e} \frac{N_t}{N_{T\ max}}
\]

when $L_{max} = 5$ years, $N_t = 100$ and $N_{T\ max} = 1$, the value of $M$ emerges as $1.1513$.

Natural mortality in fishes can also be demonstrated as correlated to mean environmental temperature expressed for length - growth data by the multiple regression
\begin{align*}
\log_{10} M &= -0.0066 - 0.279 \log_{10} L_\infty + 0.6543 \log_{10} K + 0.4634 \log_{10} T \\
of \text{ Pauly (1983).}
\end{align*}

The \( L_\infty \) and \( K \) as detailed elsewhere in the present study are 31.487857 cm, and 0.600774 respectively. The \( T \) according to an earlier study along the North Kanara Coast by Noble (1968) can be calculated as 28.28\(^\circ\)C. Substituting the \( \log_{10} \) values of these in the model, the \( M \) is calculated to be 1.2684.

Correlating the temperature data with weight-growth through Pauly's multiple regression equation

\begin{align*}
\log_{10} M &= -0.2107 - 0.0824 \log_{10} W_\infty + 0.6757 \log_{10} K + 0.4687 \log_{10} T \\
the M turns out to be 1.2835 when \( W_\infty = 370.6385795 \ g \) (found from \( L_\infty \) using length-weight relationship), \( K = 0.600774 \), and \( T = 28.28\(^\circ\)C \) (Noble 1968). But with \( W_\infty = 586.0178 \) calculated independently from the weights of the fish at different age classes the \( M \) becomes 1.2360 only.

An average of the values derived from the linear regression of 5 seasons, and through Cushing's (1968) and Pauly's (1983) methods gives the \( M \) in Indian mackerel to be 1.1708.
6.7. ESTIMATION OF MAXIMUM SUSTAINABLE YIELD

Based on the data on catch in kg (y), effort in numbers of Thangu vela (f), and cpue in kg (y/f) of the mackerel caught at Cochin given in Table IX, the value of 'b' and 'a' are found to be 0.00474017 and -20.21787573 respectively. The observed effort and cpue are plotted in Fig. 41 with the above regression equation fitted to it. As the 'b' value is positive and the 'a' value negative, the Schaefer's (1954) model

\[ \frac{y}{f} = a - bf \]

or

\[ y = af - bf^2 \]

\[ MSY = \frac{a^2}{4b} \quad \text{and} \]

\[ F_{\text{max}} = \frac{a}{2b} \]

are not useful here and the fishing as such does not seem to affect the stock.

The estimation of yield per recruit (\(Y_w/R\)) using the
Table IX

Estimated catch in kg, effort of *Thangul vala* in numbers, and catch per unit of effort in kg of the mackerel caught at Manassery (Cochin)

<table>
<thead>
<tr>
<th>Season</th>
<th>Catch</th>
<th>Effort</th>
<th>cpue</th>
</tr>
</thead>
<tbody>
<tr>
<td>1965-'56</td>
<td>28712</td>
<td>10251</td>
<td>2.801</td>
</tr>
<tr>
<td>1966-'57</td>
<td>50671</td>
<td>10632</td>
<td>4.766</td>
</tr>
<tr>
<td>1967-'58</td>
<td>48969</td>
<td>10580</td>
<td>4.628</td>
</tr>
<tr>
<td>1968-'59</td>
<td>15418</td>
<td>8614</td>
<td>1.790</td>
</tr>
<tr>
<td>1969-'70</td>
<td>61482</td>
<td>6708</td>
<td>9.165</td>
</tr>
<tr>
<td>1970-'71</td>
<td>1332468</td>
<td>14279</td>
<td>93.317</td>
</tr>
<tr>
<td>1971-'72</td>
<td>612422</td>
<td>14128</td>
<td>43.348</td>
</tr>
<tr>
<td>1972-'73</td>
<td>222030</td>
<td>9589</td>
<td>23.155</td>
</tr>
<tr>
<td>1973-'74</td>
<td>87591</td>
<td>9196</td>
<td>9.525</td>
</tr>
<tr>
<td>1974-'75</td>
<td>117693</td>
<td>7919</td>
<td>15.052</td>
</tr>
<tr>
<td>1975-'76</td>
<td>46233</td>
<td>5812</td>
<td>7.955</td>
</tr>
<tr>
<td>1976-'77</td>
<td>59131</td>
<td>4847</td>
<td>12.200</td>
</tr>
<tr>
<td>1977-'78</td>
<td>432406</td>
<td>7248</td>
<td>59.659</td>
</tr>
<tr>
<td>1978-'79</td>
<td>364451</td>
<td>9188</td>
<td>39.666</td>
</tr>
<tr>
<td>1979-'80</td>
<td>3013</td>
<td>4228</td>
<td>0.713</td>
</tr>
</tbody>
</table>
Fig. 41: Relation between effort (*Thangu vela*) and its catch per unit of effort in mackerel fishery.
formula of Beverton and Holt (1957) simplified by Ricker (1958) where $Y_w/R$ is equal to

$$F e^{-M(tc-tr)\omega_0} \left[ \frac{1}{F+M} - \frac{3e^{-K(tc-to)}}{F+M+K} + \frac{3e^{-2K(tc-to)}}{F+M+2K} - \frac{e^{-3K(tc-to)}}{F+M+3K} \right]$$

was done by feeding the values of

- $\omega_0 = 370.6385795$
- $K = 0.600774$
- $t_o = -0.1413431664$
- $tr = \text{age at recruitment}$
- $tc = \text{age at capture}$ and
- $M = 1.1708$

into a computer programme and the resultant $Y_w/R$ at various values of $F$ against changing ages are found out and plotted in Fig. 42. The mackerel gets caught as and when they are recruited and hence its $tr$ and $tc$ are considered to be equal to one another. The fishing as already sensed while applying Schaefer's (1954) model, is not adversely affecting the stock in this computation also. Nevertheless enhancement of fishing intensity ($F$) does not seem to have any concurrent appreciable increase in the yield per recruit.
Fig. 42: Eumetric fishing curve of mackerel.
Yield per recruit of the fish in each age at various F values was then computed separately and the maximum got against different fishing intensities are plotted for Eumetric Yield Curve in Fig. 43. The curve according to this takes a right turn after F 2 and more or less stabilizes at 4 though it drags beyond and continues to ascend with almost insignificant additions to succeeding values on the preceding ones. The Eumetric Fishing Curve as plotted in Fig. 42 also shows stagnation between F 4 and 8. This stabilization attained at F beginning with 4 is exhibited right at the commencement of commercial exploitation itself when the fish is 1-year old (Fig. 42). However, the best age for large-scale exploitation of commercial importance is derived by plotting the increment in Yw/R between fishes at consecutive ages at changing F values in Fig. 44. The best results according to this are obtained when the fish is 1.55 years of age. The length at age, back calculated by using VBGF and plotted in Fig. 39 indicates the length at age 1.55 years to be about 200 mm, and as per the pooled value of the length-weight relationship worked out in this study, it may weigh about 83 g.
Fig. 43: Eumetric yield curve in mackerel fishery.
Fig. 44: Yield per recruit of the mackerel fishery at different ages and varying values of $F$. 
Fig. 44

Increment in yield per recruit in grams between $t_c$.

Instantaneous fishing mortality ($F$).

Age at capture in years ($t_c$).
6.8. RATE OF EXPLOITATION

The mackerel fishery in 1970-'71 season was the best (Fig.24) with highest catches in the history of the species. The fishery was widely spread out in all the months of the season and chances of representation of different year classes in the catches thereby were very good. In 1971-'72 also the season was a protracted one. The 1-year old population in 1969-'70 represented as 120.00 numbers of fish caught per unit of effort reduced to 5.03 numbers of 2-year old fish caught per unit of effort in 1970-'71. The 1055.17 numbers of 1-year old fish caught per unit of effort in 1970-'71 likewise reduced to 33.79 numbers of 2-year old fish caught per unit of effort in 1971-'72 (Table VII). The instantaneous total mortality in 1969-'70 and 1970-'71 accordingly were 3.1721 and 3.4413 respectively (Table VIII). Pooled data for the 15 seasons from 1965-'66 to 1979-'80 on the age composition of the catch was computed to be 90.33 fish caught per unit of effort in 0-year olds, 271.08 fish in numbers of cpue in 1-year olds, 12.32 fish caught per unit of effort in 2-year olds and 0.01 numbers of fish in cpue in 3-year olds. Between 1 and 2-year olds which form the bulk of the catch the instantaneous total mortality is 3.0913 and it closely approximates the values for the seasons.
of abundance with well spread out catches already dealt with above. An arithmetic mean of the above 3 values along with 3.3040 computed for 5 seasons excluding seasons of very high z and effort, calculates the z to be 3.2522. The average value of M derived early in this study being 1.1708, the F value emerges as 2.0814.

The rate of exploitation according to the formula

\[ U = \frac{F}{M+F} \left[ 1-e^{-(F+M)} \right] \]

of Ricker (1958) based on above values of M and F is 0.6152. According to Gulland (1971), the maximum sustainable yield is optimized when F = M and the exploitation rate is about 0.5.

6.9. ESTIMATION OF STOCK

The average all-India yield (Y) of mackerel during 1969-‘80 period was 87,257 tonnes. The standing stock (Y/F) accordingly is 41,922 tonnes, and the annual stock (Y/U) is 141,835 tonnes.
The \( F \) as already found in the Eumetric Fishing Curve stays almost stabilized between the values 4 and 8. Increase in yield after \( F \) 4 is very nominal and worth not bothering for. However, on account of the existence of a tendency for increase, it is felt safer to clamp the \( F_{\text{max}} \) as 5.0, and at a value of 1.1708 M, the \( Z \) becomes 6.1708. The values of \( Z \) in most of the seasons as seen in Table VIII are within this limit only.

Where the \( F_{\text{max}} \) is 5.0, and \( Y/F \) is 41,922 tonnes, from the relation

\[
Y_{\text{max}} = F_{\text{max}} \times (Y/F)
\]

the potential mackerel yield in India is 209,610 tonnes, and the highest annual estimated landing of 204,575 tonnes (Fig.2) as it occurred in 1971 approximates to it.

At \( F \) 2 where the yield curve turns to the right, the yield could be 83,844 tonnes and at \( F \) 4 where stabilization begins it would be 167,688 tonnes. The average yield of 87,257 tonnes during 1969-'80 is within this range.