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A STUDY ON THE GROWTH RATE OF BROWN SHRIMP (*Penaeus aztecus aztecus* IVES, 1891) FROM THE COASTS OF VERACRUZ AND TAMAULIPAS, MEXICO

by

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EXTRACTO

Se hizo un estudio biométrico y del crecimiento individual promedio del camarón café (*Penaeus aztecus aztecus* Ives, 1891). Las muestras se tomaron en las empaca doras de Tampico, Mexico desde junio de 1967 hasta marzo de 1969, y una muestra complementaria hecha en julio de 1971. Los resultados del análisis consisten en regresiones logarítmicas que establecen las relaciones longitud abdominal–longitud total, y longitud–peso para cada sexo y para toda la muestra noblacional en conjunto. Con los datos mensuales de frecuencia de tamaños se determinaron las clases de edad mediante el uso del papel de probabilidad y posteriormente se hizo el adjuste de los datos resultantes, en longitud y peso, al modelo de crecimiento de von Bertalanffy.

INTRODUCTION

The present study was undertaken with the purpose of getting the proper basis for exploiting brown shrimp resources in a rational manner, by introducing control regulations of fishing activities. The growth rate models are necessary for the other parameters of population dynamics of the stocks of this species, whose annual catch, Osborn, Maghan and Drummond (1969), averages 54 million pounds of tail weight, representing 52% of the total shrimp caught in the Gulf of Mexico. This shows that *Penaeus aztecus aztecus* is the most important of shrimp species exploited in this region. Nevertheless, the brown shrimp is the least well known of the three most common species.

The growth rate was determined by fitting the von Bertalanffy growth curve to offshore populations, on which according to Cook and Lindner (1970), there are no published data, although an unsuccessful attempt was made by Klima (1964). Published data are only from inshore waters (Williams 1955, Loesch 1965, Joyce and St. Amant et al., from Cook and Lindner 1970).

Statistical calculations of length-weight and total length-tail

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length ratios were required before available raw data could be used in growth analyses. Tesch (1968), points out that age data, along with length and weight measurements represent the basis for information on growth, composition of stocks, maturity age, life span, mortality and production.

ACKNOWLEDGEMENTS

The writer feels deeply indebted to Miss Rocío González for her aid in the translation of this paper into English. I would like also to thank René Márquez, formerly jefe de la Estación de Biología Pesquera de Tampico, who provided access to the data studied here. The final revision of the manuscript was made by Dr. Gordon Gunter and Mr. J. Y. Christmas. I appreciate very much their time invested on the subject and the corrections made to this paper.

MATERIALS AND METHODS

The original information consists of samplings made in canneries, where offshore shrimp are landed in Tampico, Mexico. The samplings were made by biologist Jesús Macías and an assistant, Mr. Francisco Robles, both from the Estación de Biología Pesquera, in that port. The frequency of samplings was twice or thrice a week from June 1967 until March 1969 and consisted of abdominal length records, later grouped to give them monthly representation by means of size–frequency curves with 3 mm intervals for each sex.

The resultant length-frequency curves often show polymodal distributions, and by using probability paper and Cassie's method (1954), it was possible to locate the overlapping values of adjacent modal groups, such as in Fig. 1 where one analyzed month is shown as an example. The mean values gotten for each month were considered as age classes; in such a way a series of data was obtained, every one corresponding to the medium size of the respective generations presented in each monthly sample, averaged in order to fit von Bertalanffy's growth model.

To complete the von Bertalanffy growth model it was first necessary to know the corresponding total length of the original tail length data; consequently, a new sampling was made in July 1971, consisting of total length, tail length, and weight data of five hundred individuals of both sexes. Analyses of these data as logarithmic regressions of the form $Y=aX^b$ gave constants to establish the relationship between both variables and at the same time gave the necessary information on the growth constants not only in terms of length but also in weight.
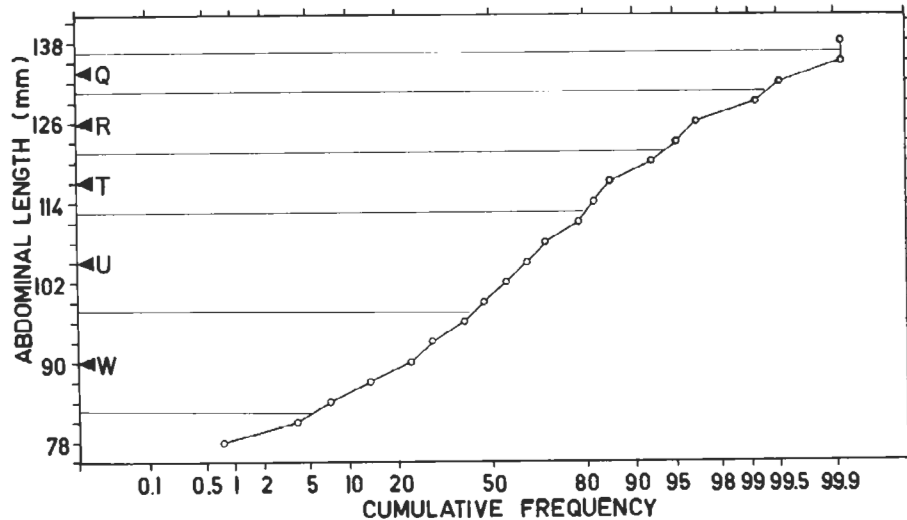
Figure 1. Size-frequency of tail length of brown shrimp plotted on probability paper. The data are from females sampled in January 1969.

RESULTS

Biometric analysis. The biometric study of samples was undertaken first for each sex separately, and later with both sexes together, in order to obtain the parameters of the analyzed population as a whole.

Figure 2 shows the scatter diagram of the total length–tail length data and the regression line describing the relationship between 251 pairs of values in males. The correlation coefficient was r $=0.999$ and the equation with the constants is $Y = 2.05 \times^{0.932}$; it corresponds to an almost straight line which is not rare in the relatively narrow range of sizes of the sampled shrimps.

In the case of females (Fig. 3), a straighter relationship than in males can be shown, getting the same value for the correlation factor, as in the former analysis, of r $= 0.999$. The values of constants found are as follows: a $= 1.531$ and b $= 1.001$. The number of females examined was 247.

After the data for each sex were studied, the regression constants for the whole population were calculated. The results are shown in Fig. 4. They indicate that the parameters found are values lying between those of the regressions formerly analyzed. They are as follows: r $= 0.998$; a $= 1.621$; and b $= 0.987$.

The length–weight ratios were determined in the way mentioned before, and for the same reason the results are analogous. The results
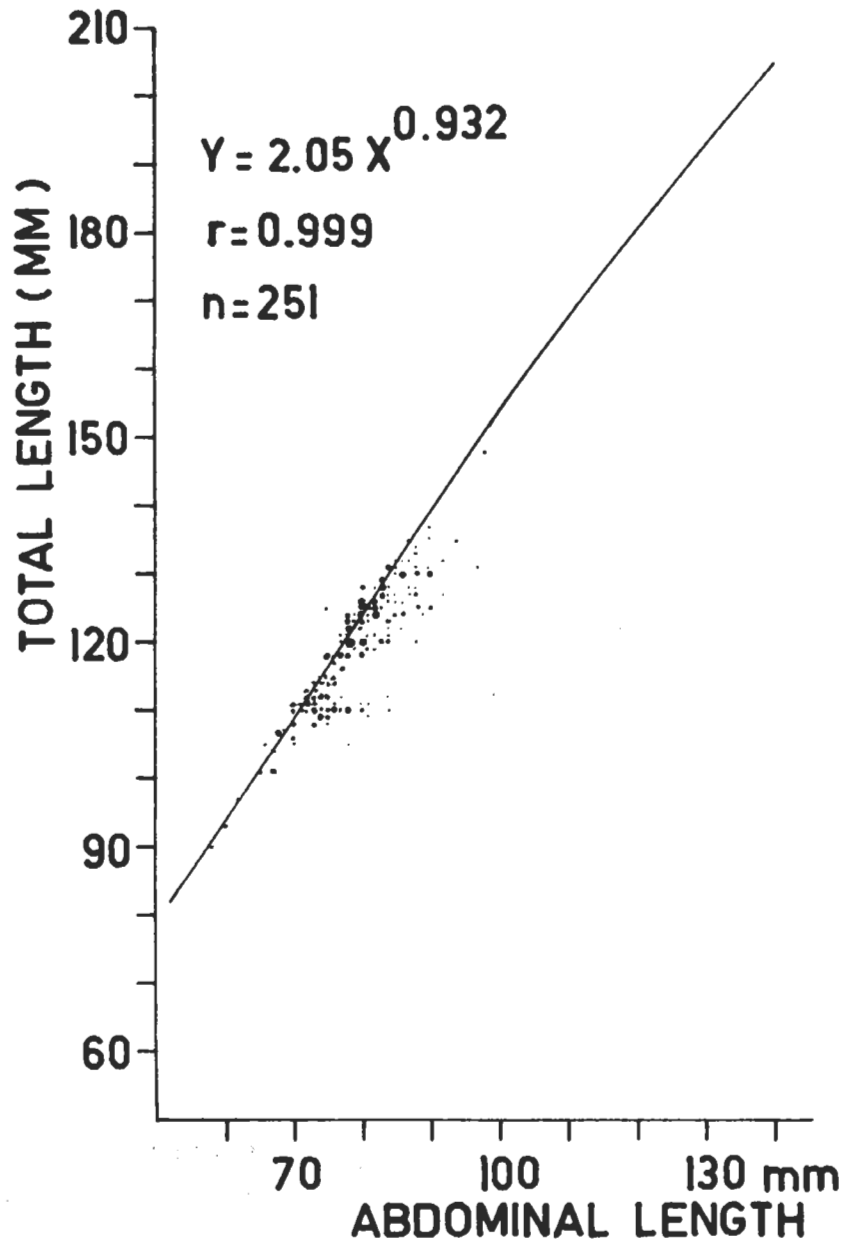
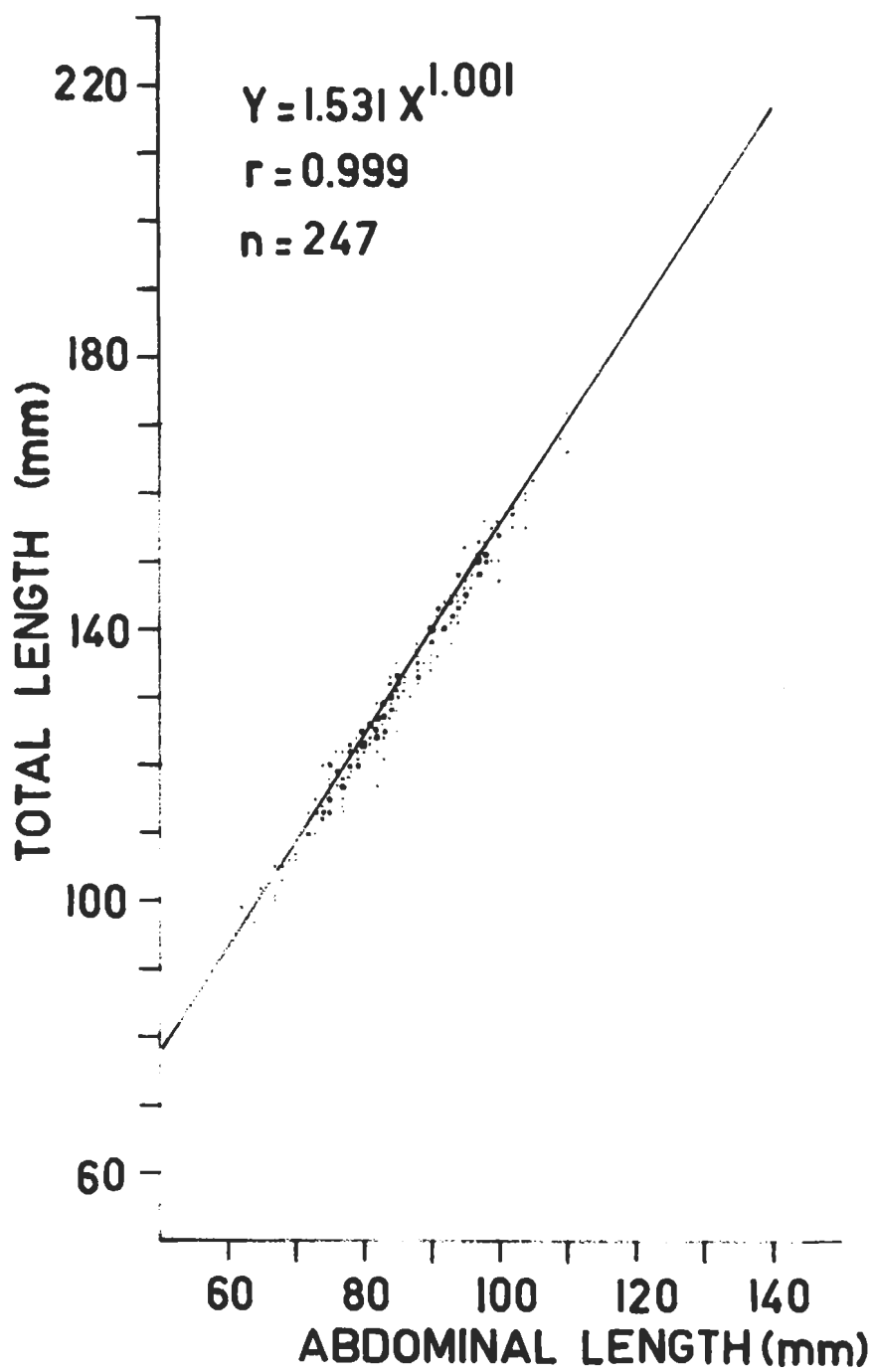Figure 2. Regression analysis of total length-abdominal length in males of brown shrimp.

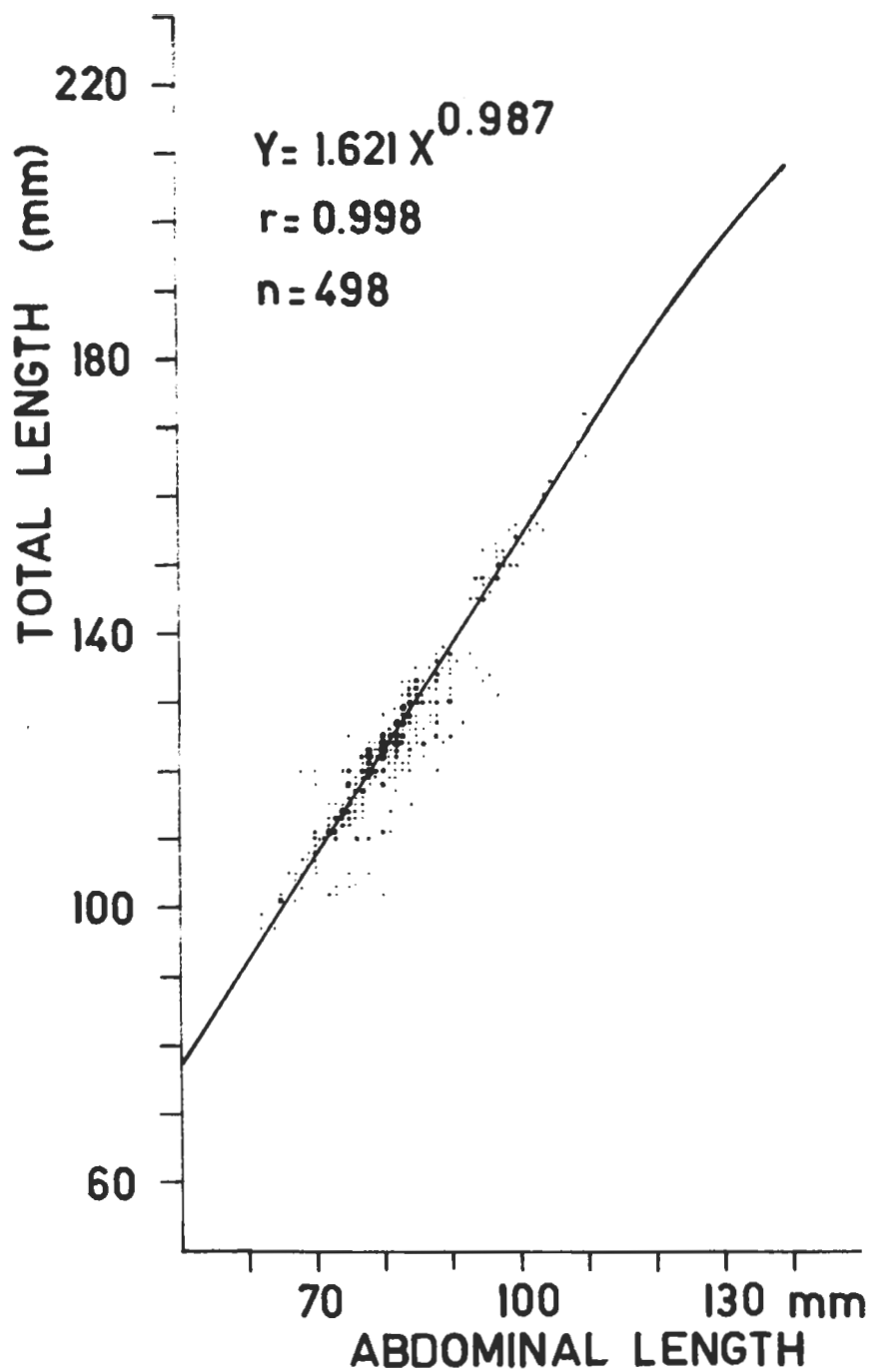Figure 3. Regression analysis of total length-abdominal length in females of brown shrimp.

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Figure 4. Regression analysis of total length-abdominal length of brown shrimp (both sexes combined).

gotten for each sex are slightly different, but the calculated constants
of the complete samples are intermediate, as follows:

$$\text{Males: } W = 0.000214 \; l^{2.325} \qquad r = 0.968$$
$$\text{Females: } W = 0.000010 \; l^{2.973} \qquad r = 0.997$$
$$\text{Both sexes: } W = 0.000023 \; l^{2.799} \qquad r = 0.986$$

It is pertinent to point out that in the first case (Fig. 5), the
value of the exponent seems to be underestimated. According to data
published by Chin (1960), values above three are expected. The ex-
ponent for female length (Fig. 6), and the one of both sexes together
(Fig. 7), are closer to those expected. Growth is supposed to be iso-
metric (at least in this group of crustaceans), and for this reason, the
theoretical expected value for that parameter is three.

One of the reasons the formerly obtained result is not satisfac-
tory is the narrow range of sizes of the male shrimp sampled for
biometric study (in spite of which, the total length-tail length ra-
tio found in this sex seems to be quite admissible). From the data
obtained, their narrow size range limited the range of conclusions, and
consequently the necessity of getting more sample increases, since at
present the probabilities of erroneous results are very large, due also
in part to the limited accuracy of measurement equipment. Also, Cook
and Lindner (1970) point out that old shrimp are proportionally
heavier than young. Nevertheless, the correlation coefficient was quite
high in all cases, particularly in females.

Growth. For growth studies, the 22 continuous monthly samp-
lings were used. The samples were taken in a cannery at Tampico.
The monthly data were grouped in 3–mm size classes and represented
by the Petersen method, that is by length–frequency curves. The cum-
ulative frequencies of each month were plotted on probability paper in
the same way as the example in Fig. 1. With this graphic method it
was possible to determine how many age classes were present in each
monthly sample, and at the same time to show some anomalies in these
data, because it was evident that in some months there were more age
classes than in others. Those anomalies are attributable, apparently,
to involuntary sampling errors, which were not completely random.
Nevertheless, they were very useful for inferences about growth of
individuals in the population.

The mean values of monthly age classes found were grouped in a
partially subjective way, for this was the only way possible to elimi-
nate some of the sources of error included, since the sampling time,
the intrinsic variations of population, and those due to ecological fac-
tors, such as temperature, that modify not only growth rate, but the
velocity of physiological processes in general and their effects are also
reflected among others in the growth.

The selection of age classes by this method has the convenience

Figure 5. Regression analysis of length-weight in males of brown shrimp.

$$W = 0.00010 \, l^{2.973}$$
$$r = 0.997$$
$$n = 250$$
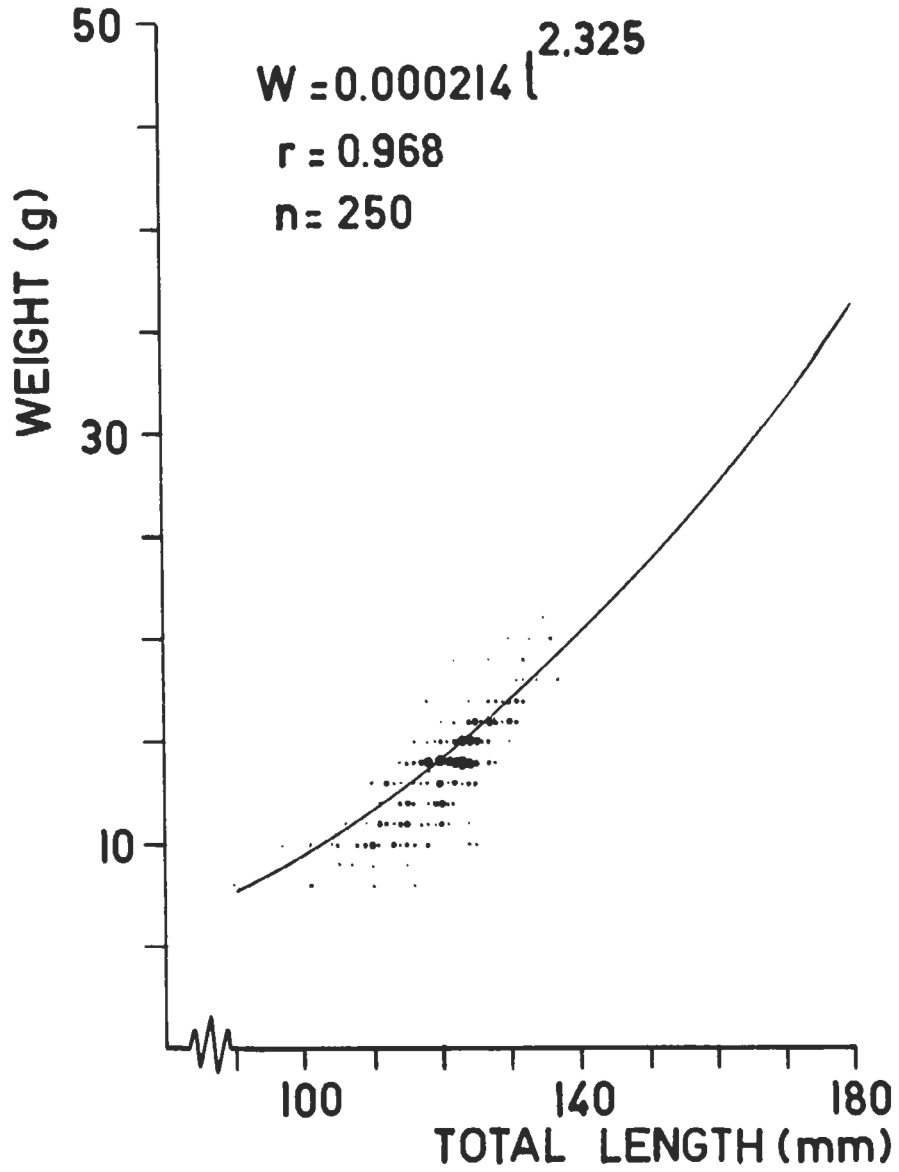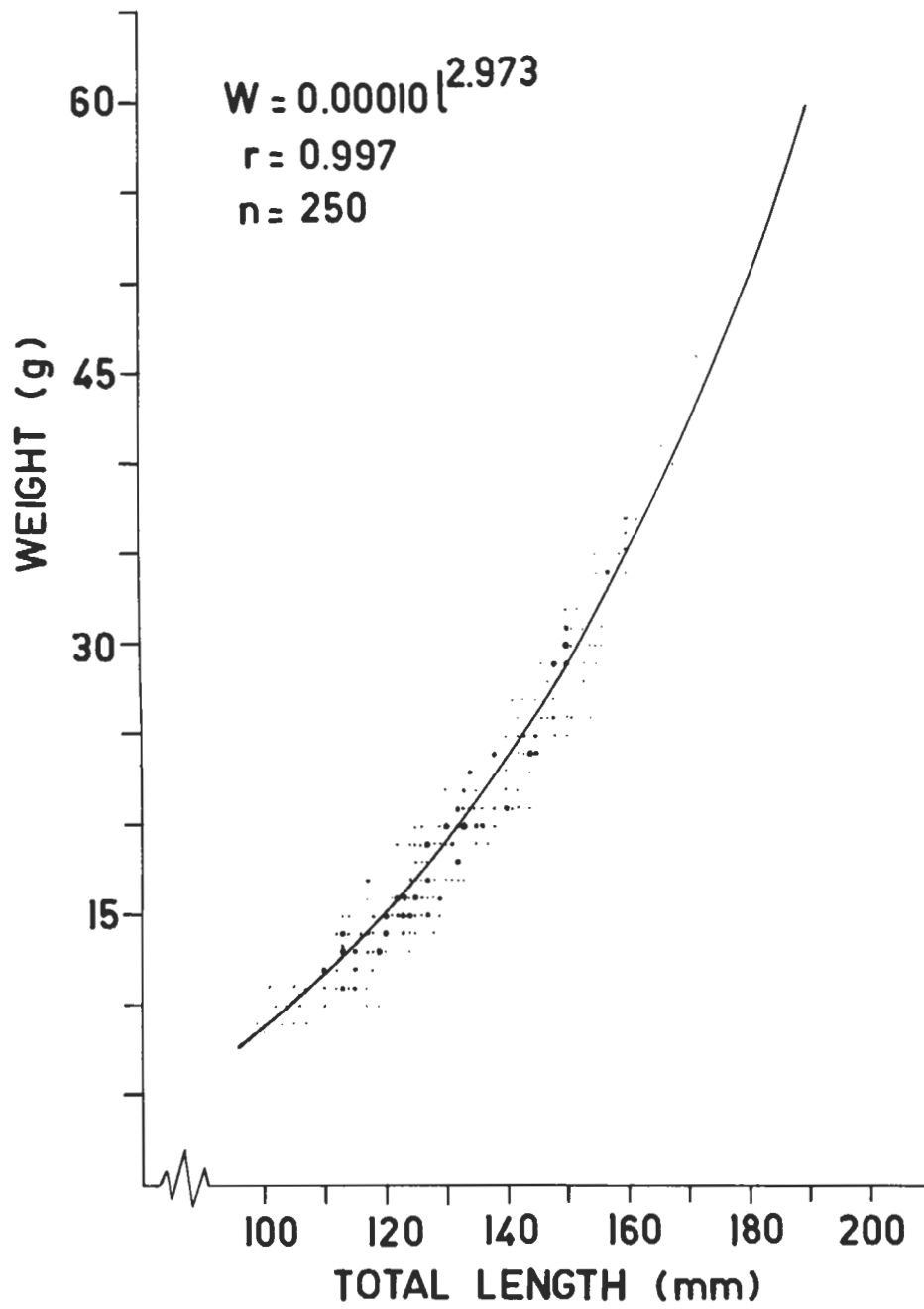
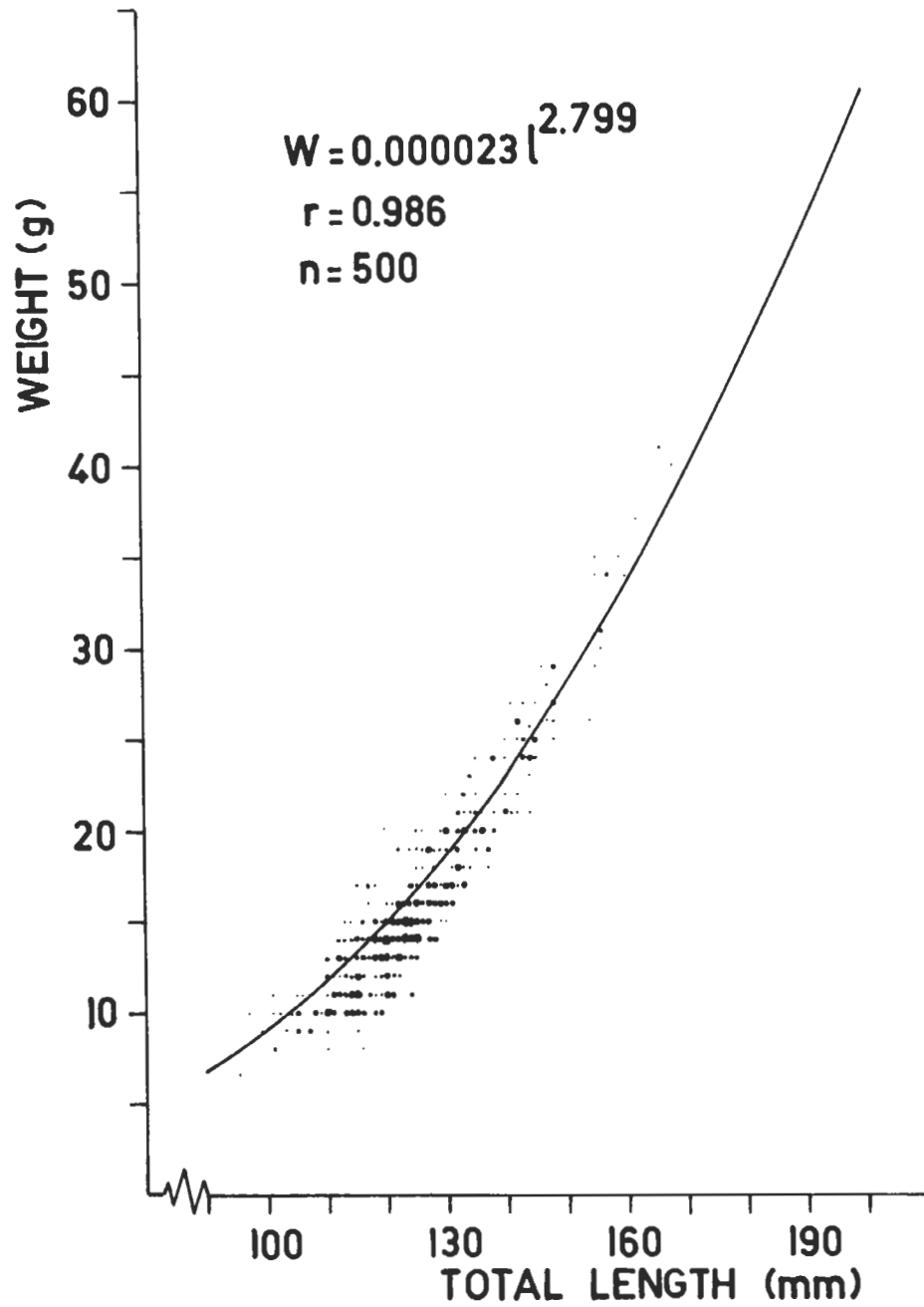Figure 6. Regression analysis of length-weight in females of brown shrimp.

Figure 7. Regression analysis of length-weight of brown shrimp (both sexes combined).

of reducing the variations in growth caused by the presence of intermediate age classes, by seasonal changes and by other ecological factors, from which a series of size classes result whose values represent the average growth rate of the analyzed population. For this reason in Fig. 8 by following the monthly growth of each age class, identified by letters, if some discrepancies are noticed, it is because it was necessary to make some adjustments to minimize extreme variations.

The mean values of selected age classes are indicated in Table 1. With respective averages obtained for each sex a Ford–Walford plot was done (Fig. 9), graphic method to estimate the average maximum length of individuals in the population studied, finding $L\infty = 117$ and 150 mm of abdominal length for males and females. With all these data, those of age classes and $L\infty$, transformations were made to determine their corresponding values in total length; this was done by using the regression formulas previously calculated, and with them the von Bertalanffy growth equation was fitted, as follows:

$$l = L\infty \ [1 - e^{-k(t-t_0)}]$$

where:

l = Length at age t in mm
$L\infty$ = Average maximum length
k = Constant, proportional to catabolic rate
t = Age, in months in this case
t_0 = Theoretical adjustment parameter, which expresses the age when the length is zero.

For additional details about this model, refer to Beverton and Holt (1957), Ricker (1958), Cushing (1968), Gulland (1969) and similar texts.

On following the curve as far as its origin, it was found to be reasonably well fitting in very small sizes, and it could be seen on the average, that the smallest age class fitted should be 4 months old, nine the elder in males, and ten in females.

The constants found in this case are shown in the following formulas, and the curves that they describe are also shown in Fig. 10.

$$\text{Males: } l = 178.1 \ [1 - e^{-0.2567(t+0.2388)}]$$
$$\text{Females: } l = 236 \ [1 - e^{-0.162(t+0.759)}]$$

With the growth model it is possible to express growth not only in terms of length but also in weight. This can be accomplished by transforming the values of $L\infty$ into its corresponding weight and raising the rest of the member to cube; the constants k and t_0 do not modify. The result is a sigmoid curve whose inflection point is found at the third part of the value of asymptotic weight or $W\infty$ of that population. The transformation of length into weight was done with
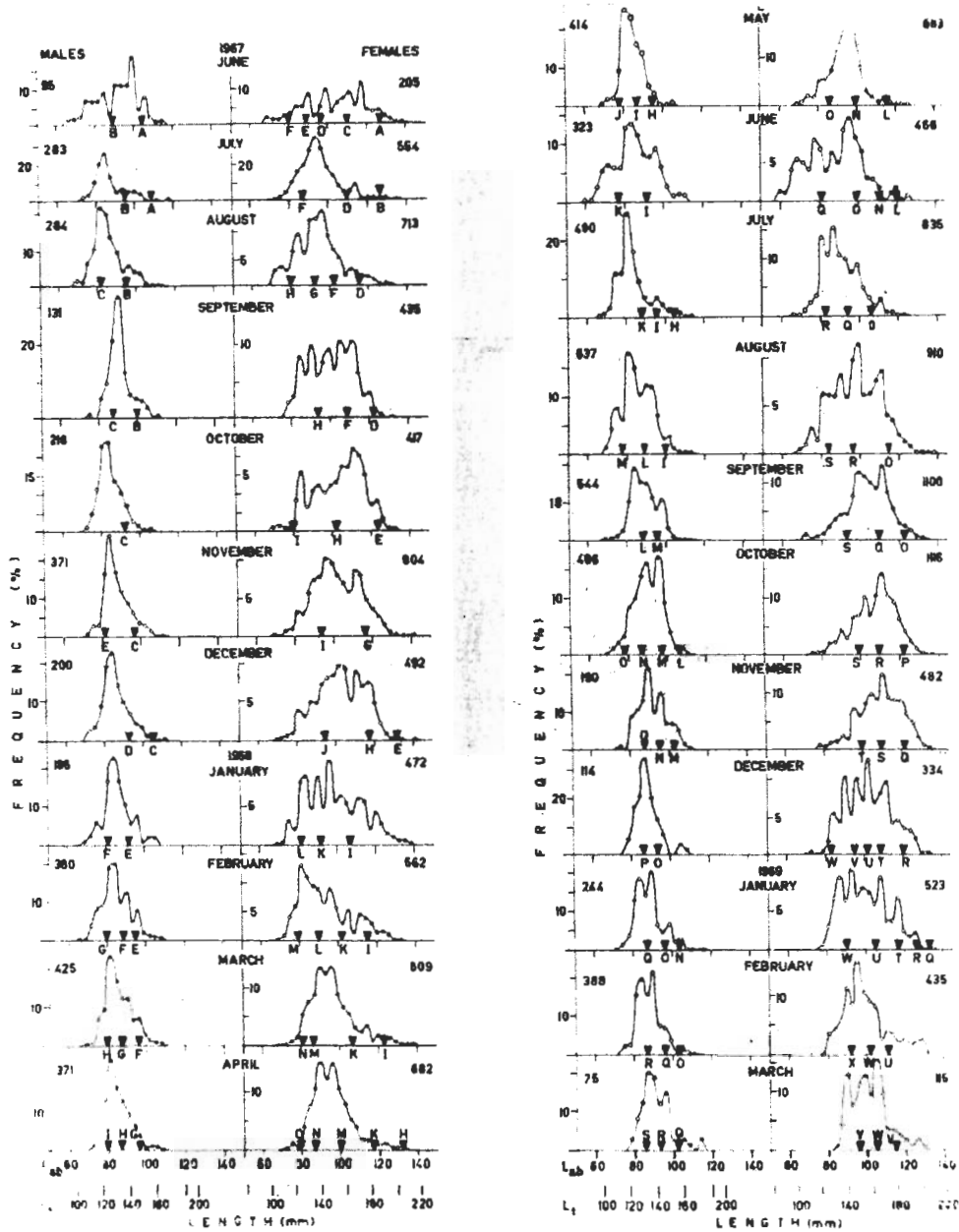
Figure 8. Monthly tail length-frequency curves of males and females of brown shrimp on which all the sampling period is represented. Mean length values of successive generations are identified by letters. The corresponding total length scale (L_t) is also shown below.

Table 1.

Monthly age classes determined from the analysis of frequencies made with probability paper. They are represented as abdominal length, in mm. Each generation is identified by letters. (These values are also shown in Figure 12)

Generation	Mean size values of monthly age classes					
	I	II	III	IV	V	VI
A					103.5	108.0
B		88.5	94.5	94.5	99.0	
C	82.0	87.0	91.5	96.0	105.0	
D			93.0			
E	81.0		91.5	94.5		
F	81.0	88.0	96.0			
G	79.0	87.0	96.0			
H	79.0	87.0	94.5		105.0	
I	79.0	87.0	91.5	96.0	100.0	
J	78.0					
K	77.0	88.0				
L		89.5	95.5	106.5		
M	78.0	88.5	97.5	102.0		
N		87.0	94.5		103.5	
O	78.0	87.0	93.0	96.0	103.5	
P		85.5				
Q		87.0	96.0	102.0		
R		87.0	93.0			
S		85.0				
Average	79.2	87.3	94.1	98.4	102.8	108.0

the regressions previously determined. But in the case of males and with the considerations formerly made, it seemed pertinent to take the results of males and females computed together instead of those of males only in order to reduce the risk of working with wrong data, mainly when there is the antecedent of no marked differences between the sexes (Chin 1960). Therefore, the results of growth in weight are shown in the following expressions:

$$\text{Males: } w = 46 \; [1 - e^{-0.2567(t+0.2388)}]^3$$
$$\text{Females: } w = 113 \; [1 - e^{-0.162(t+0.759)}]^3$$

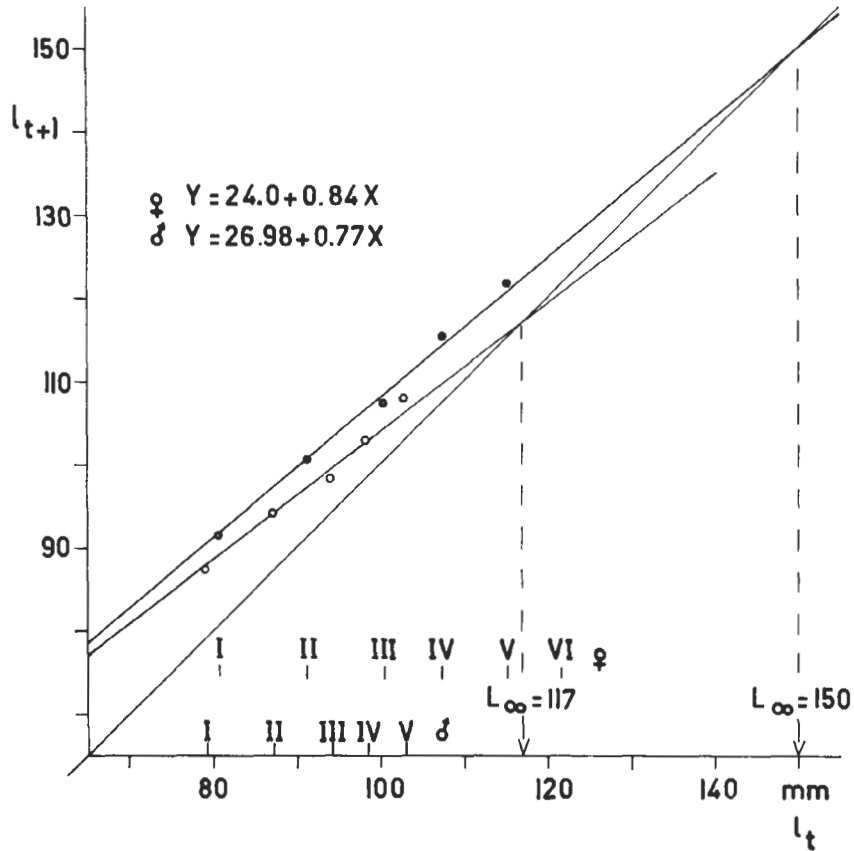The expressions seem to be similar to those of the length growth.

Figure 9. Ford-Walford graph of abdominal length in mm at age t
against length at age t+1 for males and females of brown shrimp.

Nevertheless, the differences existing between L∞ of each sex are
equivalent to quite distinct weights of specimens of the same age but
different sex, variations that increase with age. This can be seen in
Fig. 11 where the growth in weight is represented by sex.

The sizes and weights of each monthly age class calculated by
means of the von Bertalanffy growth model are shown in Table 2,
whose variations explain well the differences in growth found by
Williams (1955), Loesch (1965), and St. Amant et al. and Joyce
(both after Cook and Lindner 1970) upon juvenile brown shrimp
populations, somewhat larger growth rates than those found during
the present analysis for similar size ranges.

Finally, bearing in mind that only global data are frequently
available, for example, the Gulf Coast Shrimp Data, in which it is not
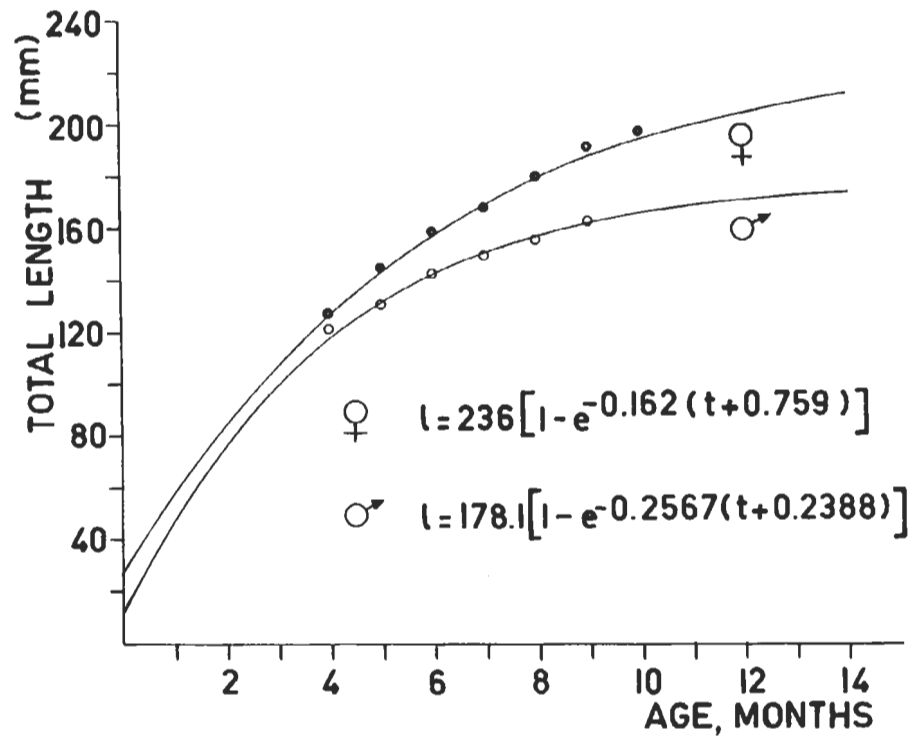
Figure 10. Von Bertalanffy growth curves, in length, found for each sex of brown shrimp. Observed values of age classes are shown by small circles.

possible to separate the differences due to sex, it was decided to calculate growth parameters of the population as a whole, which was done in the following way: with the values of L∞ and W∞ determined for each sex, new average values were obtained and were considered as L∞ and W∞ of the population, and the age classes were those determined by making an average of the resulting pairs of values formerly analyzed after the growth rate was considered for each sex separately. Therefore, the latest obtained results are as follows:

$$L\infty = 207 \text{ mm} \quad W\infty = 70 \text{ g}$$
$$k = 0.1904 \quad t_o = -0.872$$

The graphic representation of individual growth rate of the *Penaeus aztecus aztecus* population studied is shown in Fig. 12, and in Table 3 the length and weight values for each month of age are also indicated.

$$\female \quad W = 113 \left[1 - e^{-0.162(t + 0.759)} \right]^3$$

$$\male \quad W = 46 \left[1 - e^{-0.2567(t + 0.2388)} \right]^3$$

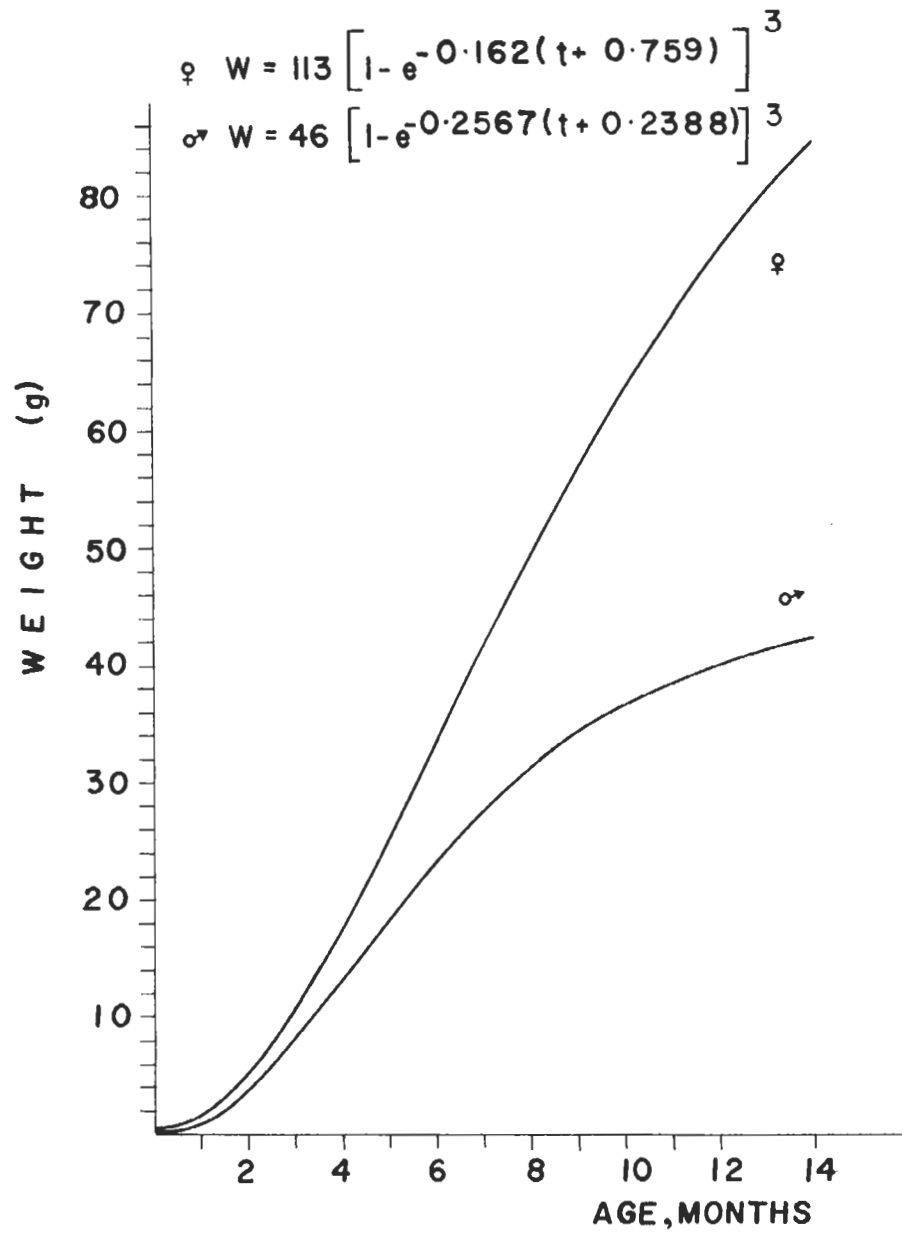Figure 11. Von Bertalanffy growth curves, in weight, for each sex of brown shrimp.

Table 2.

Growth rate in length and weight of *Penaeus aztecus aztecus* Ives
calculated for each sex and month during the first
fourteen months of age

MALES

Age (Months)	Length (mm)	Increase (mm)	Weight (g)	Increase (g)
1	48.5	37.9	0.9	0.9
2	75.7	27.2	3.7	2.8
3	100.6	24.9	8.3	4.6
4	118.3	17.7	13.4	5.1
5	131.8	13.5	18.6	5.2
6	142.0	10.2	23.4	4.8
7	150.4	8.4	27.7	4.3
8	156.6	6.2	31.3	3.6
9	161.4	4.8	34.3	3.0
10	165.3	3.9	36.7	2.4
11	168.2	2.9	38.7	2.0
12	170.4	2.2	40.3	1.6
13	172.1	1.7	41.5	1.2
14	173.5	1.4	42.5	1.0

FEMALES

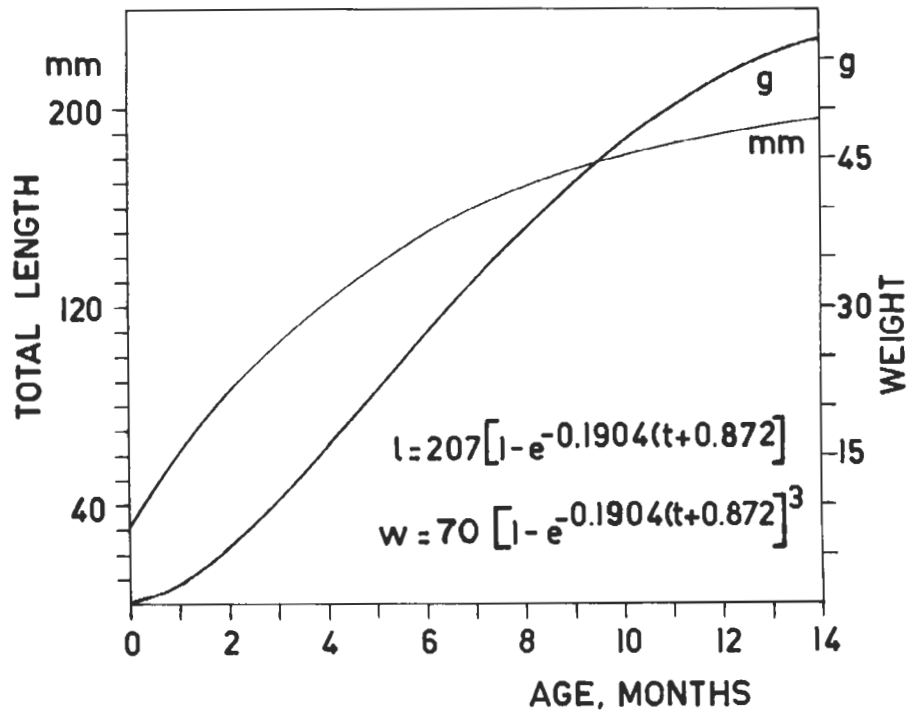| Age (Months)	Length (mm)	Increase (mm)	Weight (g)	Increase (g)
1	58.3	30.9	1.7	1.5
2	85.0	26.7	5.3	3.6
3	107.6	22.6	10.7	5.4
4	127.0	19.4	17.5	6.8
5	143.3	16.3	25.2	7.7
6	157.1	13.8	33.3	8.1
7	169.0	11.9	41.4	8.1
8	179.0	10.0	49.2	7.8
9	188.0	9.0	56.6	7.4
10	195.0	7.0	63.4	6.8
11	200.9	5.9	69.7	6.3
12	205.0	4.1	75.3	5.6
13	210.6	5.6	80.3	5.0
14	214.4	3.8	84.7	4.4

Figure 12. Von Bertalanffy growth curves found for all brown shrimp population sampled (both sexes combined). The curves show the longitudinal and ponderal average growth of individuals.

DISCUSSION OF RESULTS AND CONCLUSIONS

As a corollary of biometric study of the analyzed population, it is concluded that the total length–abdominal length ratio shows a mostly straight relationship in both sexes, and that the observed differences in each sex are very slight. For this reason, it is supposed that the calculated population formula is representative of such a transformation, a characteristic that on the other hand means that the shrimp growth is isometric respectively to these two factors. The calculated. relationship was made on a basis of the need of knowing the total length of specimens formerly sampled, and it was necessary to make a reference calculated in terms of total lengths of the shrimp.

Concerning the length–weight relationship, it is pertinent to point out that the exponent of length usually is a value which fluctuates about three, and in this case described an isometric growth, characterized from Ricker (1958), because the specific gravity and the body form remain constant, regardless of the size of the organism. Former experiences with shrimp (Hall 1962, Butler 1970, Chin 1960,

Table 3.

Monthly growth rate in length and weight of brown shrimp calculated for all population samples (both sexes combined)

Age (Months)	Length (mm)	Increase (mm)	Weight (g)	Increase (g)
1	61.8	30.1	1.9	1.7
2	87.0	25.2	5.3	3.4
3	105.5	18.5	9.9	4.6
4	121.1	15.6	15.5	5.6
5	139.6	18.5	21.3	5.8
6	151.1	11.5	27.2	5.9
7	160.8	9.7	32.8	5.6
8	168.5	7.7	37.9	5.1
9	175.2	6.7	42.6	4.7
10	181.0	5.8	46.7	4.1
11	185.4	4.4	50.3	3.6
12	189.1	3.7	53.4	3.1
13	192.2	3.1	56.1	2.7
14	195.0	2.8	58.3	2.2

Kutkuhn 1966, George 1970a and 1970b, Nikolic' and Garcia 1970, Cruz–Morejon and Cadima 1970, Angelescu and Boschi 1959, and Chávez and Rodríguez-de la Cruz (1971), suggest that at least in this group, the growth shows a remarkable tendency to isometry, where the calculated exponents fluctuate around three, ranging from 2.55 to 3.25. These variations are probably due to insufficient data, small number of samples, to variations in condition coefficient of shrimp, or to the influence of other physiologically responsible factors.

Gulland (1969) points out that there is a wide number of growth equations, but none is entirely satisfying in all possible situations. Dickie (from Tesch 1968), asserts that growth curves are valuable for descriptive purposes, but the biological interpretation of models and their parameters still present great difficulties. The von Bertalanffy growth model in the author's opinion, has been shown to be quite satisfactory; besides, it should be kept in mind that this model is the best known and the most widely used in production studies on species of economic value; it satisfies reasonably the two most important criteria: it fits most of the observed data on growth, and can be readily incorporated into stock assessment models.

The growth analysis developed in the present paper seems to offer

a good outlook for further application to the penaeid shrimp group. This group presents serious difficulties for the determination of age and growth of the species belonging to it, because of its variability due to environmental changes. There is also the impossibility of referring the age classes to growing marks to check the analytical inferences made from the information acquired with the samples.

With the comparative study of size–frequency curves, it is possible to figure out that in analyzed samples there is a small percentage of shrimp whose age ranges are from 2 to 13 months old in males, approximately, with lengths ranging from 93 to 172 mm in each case; in females, all seems to show that age classes ranging from 2 to 15 months old are present (the number of extreme size classes is also small), whose lengths lie between 91 and 216 mm. It is supposed that the presence of larger shrimp is a random occurrence rather than the result of an ecological factor. These large sizes were found from June through August in both sexes, from January until March in males, and from November to March in females. The smaller shrimp, approximately 2 months old, were observed quite well chronologically located. In spite of the fact that Gulf of Mexico shrimps virtually reproduce the year-round, the presence of the smallest shrimp is necessarily interpreted as a maximum of reproduction existing at least 2 months before their recruitment. If recruitment of such tiny shrimp occurs mainly from June through August, it is supposed that they belong to a generation born from March through May (it is necessary to add 15 days to the apparent age, because of the larval stage duration). In part, this confirms the opinion of Kutkuhn (1962) about the increased spawning activity during March–April and September–October.

The results obtained by the use of probability paper to determine the size classes suggests more objectivity than the use of the size–frequency curves only (Chávez and Rodríguez-de la Cruz 1971), especially when the number of samples is small. For instance, either one of these methods may be profitable, but the accuracy of the results is determined by the experience of the analyst.

It is necessary to keep in mind that the present study was undertaken with the idea of determining the average individual growth rate, regardless of the seasonal variations, due to the fluctuating changes of ecological factors determining the habitat of *P. aztecus aztecus* populations. The study was made in that way because on incorporating growth parameters into stock assessment models, extreme variations capable of modifying the results are discarded.

SUMMARY

A study of brown shrimp (*Penaeus aztecus aztecus* Ives, 1891) was undertaken. The data were obtained from samplings made twice

or thrice a week in Tampico (Mexico) canneries, during the period from June 1967 to March 1969. The data consist of abdominal length records of 20,003 specimens of both sexes, 6,879 males and 13,124 females. An additional sampling of 500 specimens was made in July 1971 in which total length, tail length and weight were recorded. These data were analyzed as logarithmical regressions establishing the corresponding relationships, of which the formulas are as follows:

Total length (Y) — abdominal length (X) ratio:

$$\text{Males:} \quad Y = 2.05 \; X^{0.932} \qquad r = 0.999$$
$$\text{Females:} \quad Y = 1.531 \; X^{1.001} \qquad r = 0.999$$
$$\text{Both sexes:} \quad Y = 1.621 \; X^{0.987} \qquad r = 0.998$$

Weight (W) — length (l) ratio:

$$\text{Males:} \quad W = 0.000214 \; l^{2.325} \qquad r = 0.968$$
$$\text{Females:} \quad W = 0.000010 \; l^{2.973} \qquad r = 0.997$$
$$\text{Both sexes:} \quad W = 0.000023 \; l^{2.799} \qquad r = 0.986$$

Tail length data were grouped and represented as monthly length–frequency curves, to which mean values of age classes found in each month were incorporated. These values were obtained after analyzing each monthly group of data on probability paper. Once the mean values of age classes were obtained, a Ford–Walford plot was made and a von Bertalanffy growth curve was fitted. The constants are as follows:

$$\text{Males:} \quad L\infty = 178.1 \text{ mm} \quad W\infty = 46 \text{ g}$$
$$\qquad k = 0.2567 \qquad t_o = -0.2388$$
$$\text{Females:} \quad L\infty = 236 \text{ mm} \quad W\infty = 113 \text{ g}$$
$$\qquad k = 0.162 \qquad t_o = -0.759$$
$$\text{Both sexes:} \quad L\infty = 207 \text{ mm} \quad W\infty = 70 \text{ g}$$
$$\qquad k = 0.1904 \qquad t_o = -0.872$$

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