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CENTRE OF ADVANCED STUDIES IN MARICULTURE
CENTRAL MARINE FISHERIES RESEARCH INSTITUTE
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SOME ASPECTS OF ENVIRONMENTAL PHYSIOLOGY OF RAFT GROWN MUSSELS

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ABSTRACT

Mussels (Perna viridis L) from marine intertidal region, when transplanted and grown under constant submergence in estuarine environment (on a floating raft) display a wide array of physiological adaptions in osmoregulation, growth and annual reproduction cycle.

By employing sequential multiregression technique, the interaction of environmental abiotic factors influencing growth, both linear and in mass, has been assessed, and the dominant role of salinity established. Importance of the abundance of food for growth progression has been evaluated. Allometric growth in relation to the interaction of abiotic and biotic parameters is estimated.

Development of a physiological mechanism for compensating the water balance in the body to counteract the wide temporal variations in salinity is reported. Synchronization of annual reproduction cycle in tune with exogenous and endogenous variables and under different environmental

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and metabolic stresses is discussed. Behavioural, physiological and biochemical adaptations of raft grown mussels are highlighted.

INTRODUCTION

Mussels which occur in intertidal to subtidal regions of marine and estuarine environments of northern as well as the southern hemisphere have been extensively studied for ecological, Physiological and economic aspects. (Bayne 1976; Korringa 1977). However, no information is available about the environmental physiology of raft grown mussels and therefore, it was felt desirable to investigate the changes due to the interaction between the exogenous and endogenous factors, which the green mussel (Perna viridis L.) from a marine intertidal habitat has to undergo when transplanted and grown under constant submergence in an estuarine environment.

The environmental characteristics, growth rate and cultivation aspects of mussels in marine and estuarine environments of Goa as reported earlier (Qasim, Parulekar, Harkantra, Ansari and Nair 1977; Parulekar, Ansari, Harkantra and Nair 1978) has clearly indicated the high magnitude of temporal variation in environmental factors. Of particular significance is the observed wide fluctuations in salinity; high productivity, fast growth and prolonged spawning. In the light of these observations attempts are made here to analyse how best the mussel from a marine intertidal niche, acclimatizes, grows and propagates in a dynamic and demanding estuarine environment.

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OBSERVATIONS AND DISCUSSION

Growth: Growth as a response to the integrated activity of an organism as a whole is a sensitive parameter, reflecting on the suitability of environment (Warren 1971). It depends on the metabolic state of the animal, the energy expended in maintenance and behaviour and the quality and quantity of food consumed, all these are the functions of the environment. Growth in mussels as defined by Seed (1976) is not simply an increase in linear dimensions or mass (weight or volume) but also includes tissue formation and related activities that precede and follow the actual change in linear dimensions or in body size and hence the progressive changes either in length, weight and/or volume may be the most appropriate parameter for interpreting the growth.

Data on the influence of environmental abiotic factors on the growth is shown in Figrure 1. Organisms in an open environment as in the present study are not exposed to a single environmental factor at a time and the interaction of two or more abiotic factors, nearing "tolerance limit" (Shelford 1913) and attainment of "Steady State" (Kinne 1964) or "biokenetic zone" (Vernberg and Vernberg 1978) generally produces a more drastic effect on animal than would any single factor. One of the most frequently used method for quantifying the growth in relation to the interaction of more than one abiotic factor is the sequential multiregression analysis.

The method involves the measure of relationship of a given morphometric character (dependent variable) in terms of regulating environmental parameter (independent

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variable). As in the simple linear regression equation, it is presumed that the dependent variable has normal distribution with constant variable while the independent variable may possibly have irregular or arbitrary distribution.

Date on monthly length measurement was examined as a function of temperature (T), salinity (S), dissolved oxygen (O) and suspended particulate matter (SL). In other words:

$$L = f\ (T, S, O, SL)$$

The sequential multiregression of the relation between the dependent variable was first examined in respect of each independent variable, separately by the regression line:

$$L = b_1T + b_2S + b_3O + b_4SL + C$$

Where L is the predicted value of the dependent variable, b_1, b_2, b_3 and b_4 are coefficients of independent variable and C is the intercept. The values of b_1, b_2, b_3 and b_4 depend on the unit in which the original variables were measured and accordingly for the sake of uniformity, all the values were standardized by expressing each one as the deviation from the mean, measured in units of 1 standard deviation. The regression line then appears, as

$$L = b_1T + b_2S + b_3O + b_4SL$$

Where b_1, b_2, b_3, and b_4 are standard partial regression coefficients which give a measure of the contribution of each independent variable to the predicted value of the dependent variable. For testing the effectiveness of the multiple regression analysis, R^2 which is

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an estimate of the proportion of total variance on the dependent variable was calculated. The significance of R^2 was confirmed through variance ratio test by making use of F test. All the statistical analysis was undertaken on a TDC-316 computer.

The interrelationship between morphometric variables (Table 1) as assessed from the values of correlation coefficient indicate that length varies linearly with width, depth (height) and total weight. When all three variable are taken together, the multiple correlation coefficient does not show any further improvement ($R^2 = 0.80$).

TABLE 1

Simple correlation coefficient (r) between morphometric characters in raft grown <u>Perna viridis</u> L.

	L	W	D	TW
L	1.00	0.91	0.86	0.93
W		1.00	0.60	0.83
D			1.00	0.80
TW				1.00

The relation between length and abiotic environmental factors is shown in Table 2 and the regression equations along with the multiple correlation coefficients and F values based on variance ratio is presented in Table 3. Salinity becomes the dominant abiotic parameter in view of its higher frequency of occurrence in combina-

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tion of two and three variables at a time.

TABLE - 2

Simple correlation coefficient (r) between length and abiotic factors in raft grown *Perna viridis* L.

	L	T	S	DO	SL
L	1.00	-0.06	-0.25	-0.43	-0.22
T		1.00	0.59	0.08	0.21
S			1.00	0.24	0.34
DO				1.00	0.42
SL					1.00

TABLE - 3

Multiple regression equations for predicting length from the abiotic factors and multiple correlation coefficient along with F values based on variance ratio in raft grown *Perna viridis*. L

Regression Equation	Multiple correlation Coefficient R^2	F values based on variance ratio
$L = -0.051\,T + 0.112\,S + 0.130\,\mathrm{DO} + 0.310\,\mathrm{SL}$	0.21	1.08
$L = -0.385\,T - 0.009\,S + 0.111\,\mathrm{DO}$	0.18	1.29
$L = -0.035\,S + 0.238\,\mathrm{DO} + 0.300\,\mathrm{SL}$	0.22	1.57
$L = -0.072\,T + 0.185\,\mathrm{DO} + 0.328\,\mathrm{SL}$	0.20	1.39
$L = -0.217\,T + 0.570\,S$	0.39	5.70*
$L = -0.376\,S + 0.141\,\mathrm{DO}$	0.19	2.12
$L = -0.079\,\mathrm{DO} + 0.339\,\mathrm{SL}$	0.16	1.75
$L = -0.206\,T + 0.203\,\mathrm{DO}$	0.09	0.88
$L = -0.148\,S + 0.281\,\mathrm{SL}$	0.12	1.30

* Significant at 5% level of significance

The relatively low magnitude of the variance ratio indicate any or all of the following:

a) The variability in abiotic factors is rather very large;

b) There is hardly any true relationship between length/weight and abiotic factors;

c) Observations are inadequate to find the true relationship, and

d) Additional important variable is lacking in the analysis.

The R^2 is a measure of mathematical association between variables and not necessarily the measure of physical relationship. Among the abiotic factors only temperature and salinity shows a significant relationship. In view of this when several abiotic factors are taken at a time, interrelationship may bring the reduction in the value of R^2 and confuse the interpretation of the variance ratio . The large amount of variations are probably due to wide variations in abiotic factors.

The role of biotic factors especially, the food availability, in the growth of mussels is indisputable (Seed 1976). In Figure 2 are shown the variations in the distribution of phytoplankton and particulate organic carbon in relation to cumulative growth progression in length and weight. Nannoplankton dominate the phytoplankton abundance in the area of study (Pant <u>et al</u> 1977). The curves (Fig.2) clearly indicate that the growth progression of both the linear (length) and exponential (weight) parameters is to a great extent dependent on the food availability and the seasonal variations are mainly due to the quantitative abundance of the phytoplankton. The present data being mainly field-oriented, the effect of quality of food on the growth of mussels could not be

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assessed.

By using the simple allometric equation $Y = ax^b$ (where Y is some measure of a part; X is a measure of the whole body or another part and a and b are constants to be estimated by least square regression technique, the dependence of morphometric parameters in respect of growth progression subjected to environmental variations are attempted. The relative increase in length, width, depth (height), total weight, shell weight, wet meat weight and dry meat weight indicates (Fig. 3) that in terms of temporal variations in abiotic and biotic environmental parameter, the growth continues, unabated, in one or the other morphometric dimension.

Accordingly, exponential growth was observed (Table 4) in total weight, wet meat weight and dry meat weight in relation to length with either cubic or square relationship. Lubinsky (1958) while discussing the possible adaptive advantages that mussels may encounter particularly in relation to adverse environmental conditions in relation to the growth of different morphometric characteristics has indicated that irrespective of variations in abiotic or biotic factors either jointly or independently, the growth as an indication of metabolic rate progresses.

COMPENSATORY MECHANISM

Of all the environmental variables, the salinity because of its wide fluctuations and its relevance to osmoregulation in organisms is a single important factor in an estuarine environment (Newell 1976). Animals often become excitable when the salinity of the medium is

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TABLE 4

Regression equations describing the allometric growth in raft grown *Perna viridis L.*

Relationship(Y/X)	Regression equation	r^2	SE
$\frac{\text{Total Weight}}{\text{Length}}$	Y = 0.000513 x 2.5001	0.9861	0.271
$\frac{\text{Total Weight}}{\text{Width}}$	Y = 0.000822 x 2.8756	0.9826	0.289
$\frac{\text{Total Weight}}{\text{Depth}}$	Y = 0.00563 x 2.6710	0.9964	0.247
$\frac{\text{Wet Meat Weight}}{\text{Length}}$	Y = 0.000001 x 3.6422	0.9653	0.321
$\frac{\text{Dry Meat Weight}}{\text{Length}}$	$Y = 0.000109\ x^{2.2609}$	0.9019	0.298
$\frac{\text{Shell Weight}}{\text{Length}}$	$Y = 0.000320\ x^{2.6810}$	0.9312	0.279
$\frac{\text{Wet Meat Weight}}{\text{Depth}}$	$Y = 0.00419\ x^{2.5081}$	0.9946	0.186
$\frac{\text{Dry Meat Weight}}{\text{Depth}}$	$Y = 0.000924\ x^{2.4324}$	0.9852	0.214
$\frac{\text{Wet Meat Weight}}{\text{Dry Meat Weight}}$	$Y = 0.3017\ x^{0.6524}$	0.6561	0.462
$\frac{\text{Dry Meat Weight}}{\text{Total Weight}}$	$Y = 0.1036\ x^{0.9135}$	0.9115	0.318
$\frac{\text{Dry Meat Weight}}{\text{Shell Weight}}$	$Y = 0.2129\ x^{0.8325}$	0.8616	0.338
$\frac{\text{Shell Weight}}{\text{Total Weight}}$	$Y = 0.4478\ x^{1.0696}$	0.8704	0.215
$\frac{\text{Wet Meat Weight}}{\text{Shell Weight}}$	$Y = 1.1268\ x^{0.8666}$	0.9612	0.238
$\frac{\text{Depth}}{\text{Length}}$	$Y = 0.4184\ x^{0.9298}$	0.9890	0.296

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changed and consequently expend increased energy on physical activity aswell as on basal metabolic processes (Gross 1957). Longterm response to given ionic condition results in enzymeic induction producing optimal conditions for energy supply (Lange 1968) whereas for short-term changes the animal reacts by developing a compensatory response (Lockwood 1976).

In the transplanted mussels growing on raft in an estuary, a compensatory mechanism in respect of osmoregulatory behaviour was observed. As shown in Figure 4, the mussels develop an isosmotic internal medium to compensate for considerable lowering of salinity during the monsoon season (June - September). The compensation is achieved by the dilution of the body fluids, resulting in higher water content in the tissues. In the postmonsoon, (October - January) and premonsoon (February-May) season, appropriate compensatory mechanism is exercised (Fig. 4) to counteract increasing salt content in the environment.

ANNUAL REPRODUCTION CYCLE

A complex of physical variables is thought to influence the sequence and timing of reproduction in mussels (Giese 1967). Besides the regulatory influence of exgenous factors like temperature, salinity, etc. the annual cycle of reproduction has dependence on the seasonal changes in the biochemical composition of the tissues (Dare 1973), and therefore, it was felt necessary to analyse the data on seasonal changes in temperature, salinity and biochemical constituents in relation to maturation and spawning in raft grown mussels.

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As shown in Figure 5, in the transplanted mussels of mean size 7 - 8 mm, the gametogenesis commences in the first month (December). In the second month i.e. January (Fig. 5) more than 70% of the animals were in maturing stage. The mature gonads in small proportion (10%) were first observed in the third month (February) after transplant. The occurrence of mature/ripe gonads increased from 38% to 85% in the succeeding months of March to May. Spawning, as evidenced from the occurrence of ripe as well as spent gonads, commences in the III month i.e. February and becomes intensive in March-April before attaining the peak spawning in May i.e. in the VI month since transplant. The "resting phase" coincides with the heralding of monsoon rains in June. It is followed by the recurrence of immature gonads, in July; maturing in August and the spawning commencing in September, intensifying in October and November. Thus, the species exhibit a prolonged breeding behaviour with spawning peaks in the favourable seasons, before and after the monsoon.

Annual cycle of reproduction is colsely associated (Fig. 5) with the temporal variations in temperature and salinity. While proliferation of germinal epithelium, maturation of gametes and spawning maxima coincides with favourable condition of temperature, salinity and abundance of food material (Fig. 2) the resting phase coincides with the lowering of temperature, salinity (Fig. 5) and scarcity of food.

Similarly, the seasonal change in some of the biochemical constituents, are associated with the different phases of annual cycle of reproduction. According-

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ly, the protein and lipid content (Fig. 5) shows a decline coinciding with the maturation, spawning and phase of recovery during the resting stage of gonads. Second maxima of protein content in September (Fig. 5) can be attributed to the abundance of food material (Fig. 2). Carbohydrate content exhibit an inverse relationship with the lipid content and thus serves as an index of high glycogen metabolism during the period of extreme environmental stress in the monsoon season (Fig. 5).

The foregoing account of some aspects of environmental physiology of raft grown mussels can be considered as a case history, for assessing the physiological adaptations, an organism from marine intertidal regime acquires when transferred and made to thrive in an estuarine subtidal biotope. Not only does the organism, Perna viridis L. thrives under the changed environmental conditions, but establishes, in the most successful way. It attains higher growth rate, propagates in tune with the environment and maintains a better metabolic condition than in the marine environment (Qasim, Parulekar, Harkantra, Ansari and Nair 1977). Thus it adapts bahaviourally, physiologically and biochemically, not only to wide ranging external conditions but also responds appropriately to rapid and irregular variations of these conditions. As discussed by Lockwood (1976), the breadth and flexibility of response is not based on the development of any fundamental new process but rather on the evolutionary adaptation and modification for different processes already present in marine species. However, it must be

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recorded, here that the present set of data has further to be substantiated by experimental work especially on oxygen uptake, rate of grazing, energy conversion efficiencies etc. for getting an insight into the physiological ecology of raft grown mussel and the work in this direction is in progress.

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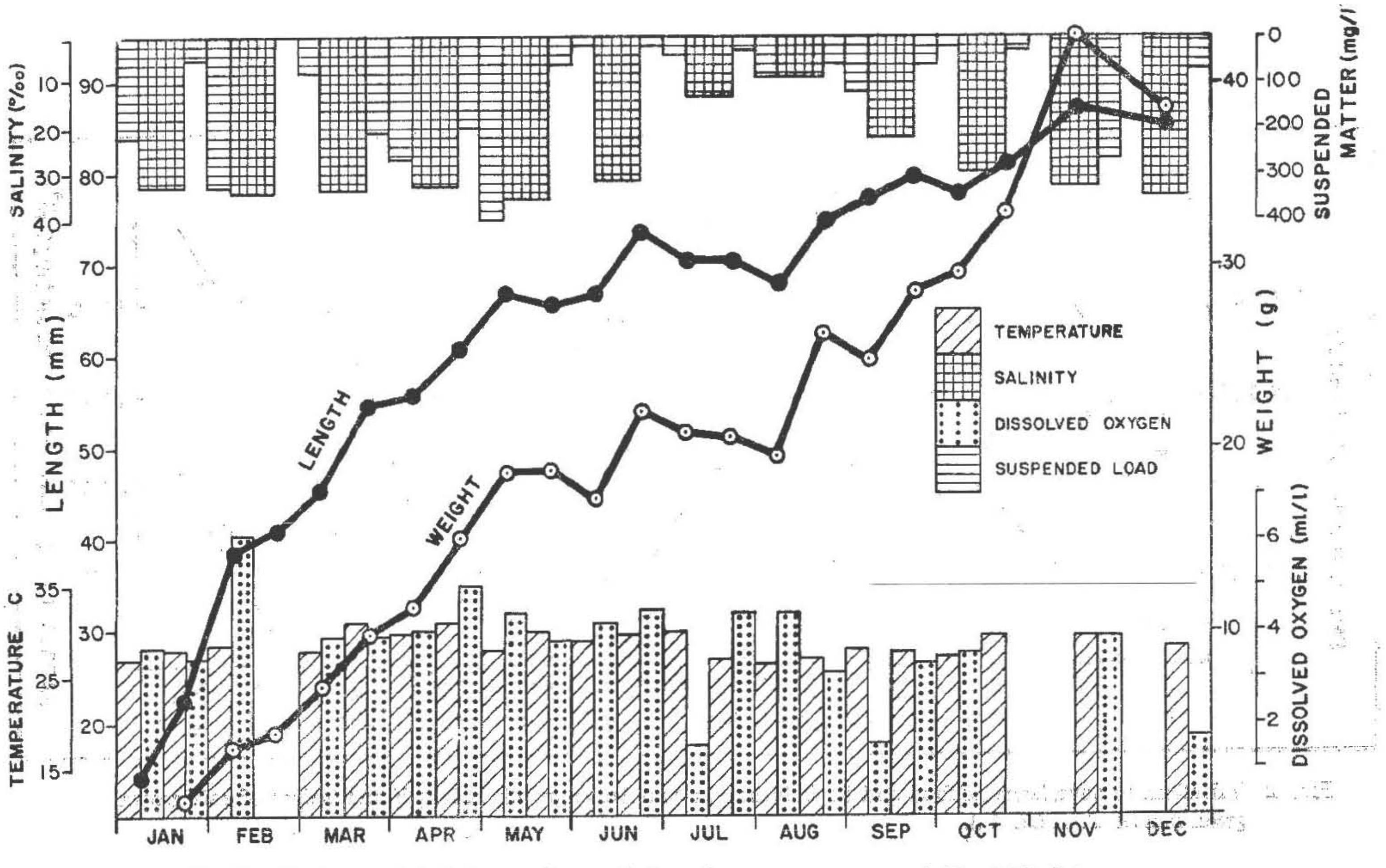

Fig. 1. Environmental factors and growth in raft grown green mussel (*P. viridis* L.).

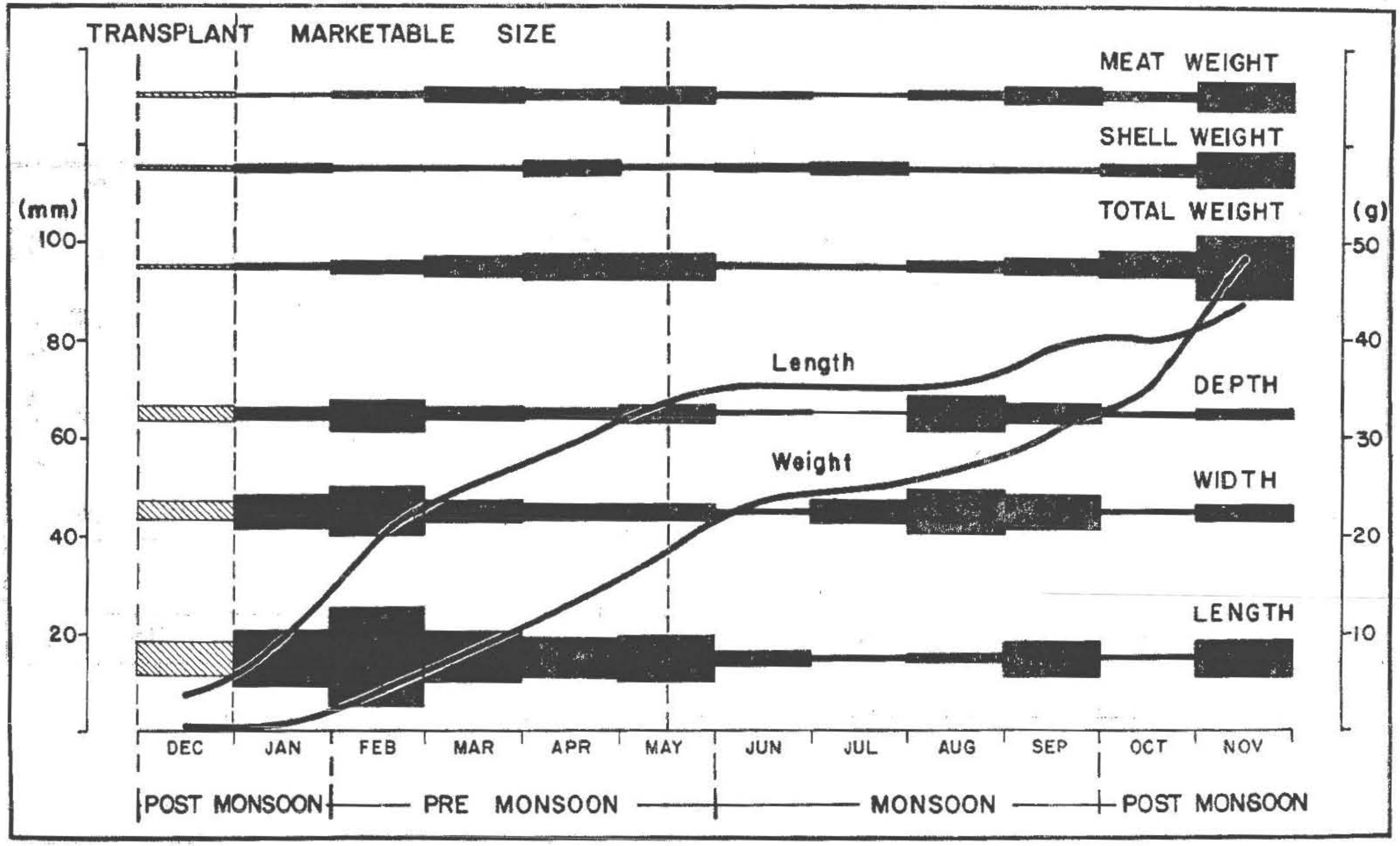

Fig. 3. Allometric growth in raft grown green mussel (*P. viridis* L.).

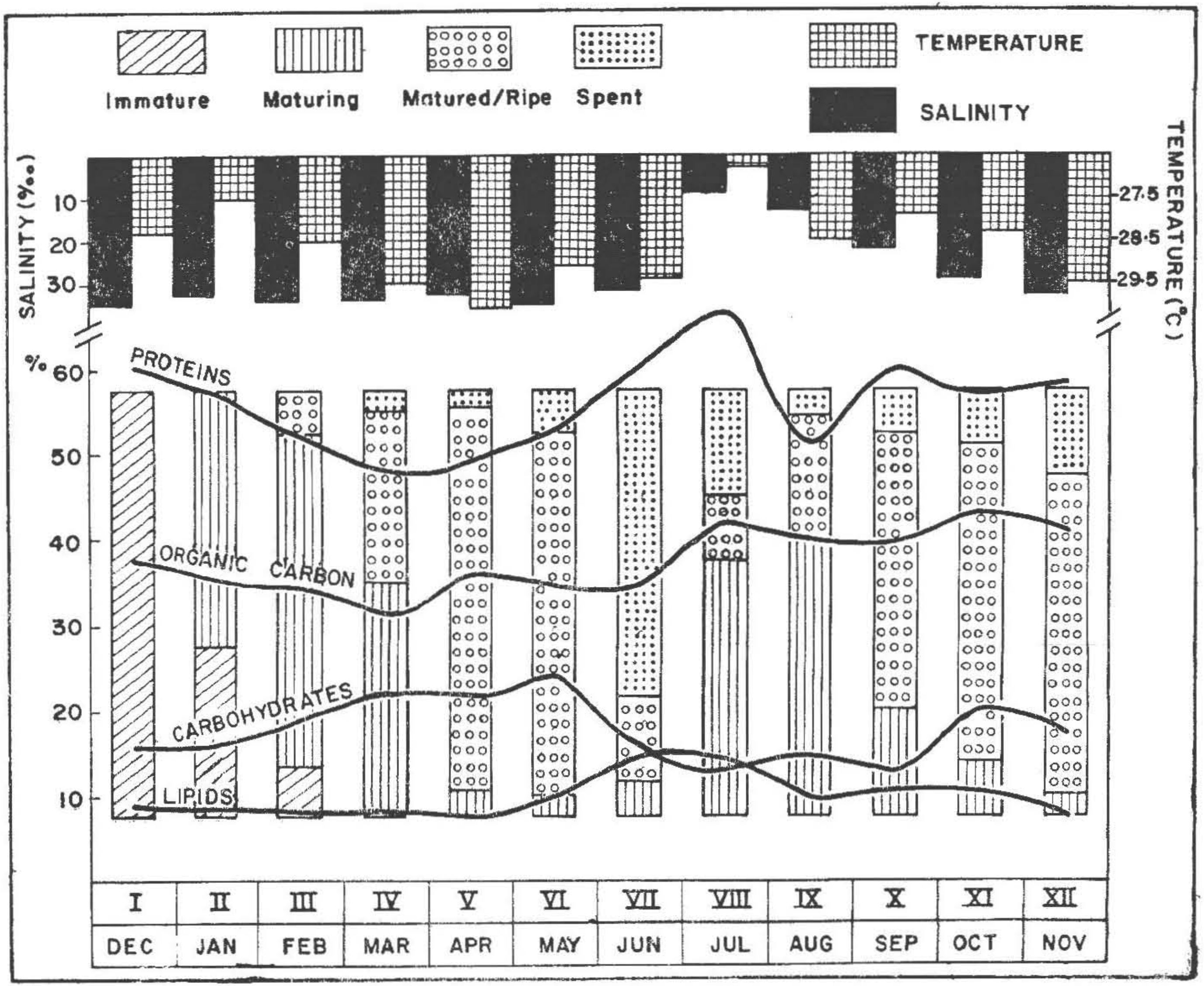

Fig. 5. Role of exogenous and endogenous factors in the growth of raft grown green mussel (*P. viridis* L.).