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Biometric variables and relative growth of the date mussel *Lithophaga lithophaga* (L., 1758) (Bivalvia: Mytilidae) from the Eastern Mediterranean Sea, Egypt

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ABSTRACT
The present study was conducted to determine the biometric features of the Egyptian population of the date mussel *Lithophaga lithophaga* and the relationships between them. Over the study period, 746 samples were collected from the shallow area of Alexandria coastal line (3-6 m depth) by SCUBA diving from December, 2017 to November, 2018. The length frequency analysis of all the samples collected revealed that the most abundant shell length ranged from 45.0 to 50.0 mm amounting to19.71% of the population. The specimens ranged from 11.9 mm (minimum length) to 83.99 mm (the largest length) and 0.40 g to 40.1 g in weight. The current study is focusing on the relationships between length-width, height and length-weights (length-total wet weight, length-tissue dry weight and length-shell dry weight). All relations were of negative allometry growth pattern. The relationships between length and height/width were linear, while those between length-weights followed a non-linear pattern. Moreover, the results revealed high correlation coefficients between these shell morphological characters of the present studied population in the Egyptian waters. Moroever, peak values of meat yield (MY) and condition index (CI) were found in July, which is indicative of the nutritive status of *L. lithophaga* mussel. The mean values were from 23.91±5.61 to 47.32±5.14 and from 24.23±8.69 to 44.0±11.0 for meat yield and condition index, respectively. The results of the current investigation are valuable information about this species in the studied area, however, more research is required for a better understanding of the reproductive characteristics of *L. lithophaga* and the long term effects of its burrowing behavior on the ecosystem.

INTRODUCTION

Lithophaga lithophaga (Linnaeus, 1758) (Bivalvia: Mytilidae), the European date mussel, is one of the most common and well-known bivalve in the Mediterranean Sea, Red Sea and the Eastern Atlantic **(Fischer *et al.* 1987)**. It has an important ecological role because of its characteristic calcareous substrate penetrating life style as well as due to the concerns for its illegal harvesting that inevitably cause the destruction of the coastal habitats that it lives in **(Peharda *et al.*, 2015)**. The destroyed communities during the extraction of *L. lithophaga* has a very slow restoration rate and often impossible to be recovered due to the fact that this species has a long life span with one of the slowest growth rate known among bivalves **(Katsanevakis *et al*., 2008)**.

Nowadays, *L. lithophaga* is under a variety of pressures such as many sources of marine pollution, the invasions of many alien species, the continuous climate change, the destructive fishing techniques and the over exploitation of its population. Therefore, there is an urging need to assess its population status to be able to act accordingly towards its conservation.

Additionally, in Egypt, studies on *L. lithophaga* mussel have been scarce and essentially limited to the variations in the environmental conditions, in particular with reference to marine pollution **(El-Morshedy, 2015)**.

The aim of the present investigation is to study the biometric patterns and relative growth of the populations of *L. lithophaga* inhabiting the shallow coastal areas of Alexandria City, Egypt. These data are expected to provide a useful baseline for the future management and conservation measures for this valuable wild resource.

MATERIALS AND METHODS

Sampling:

Five sites were selected on the coast of Alexandria in shallow areas of depth ranging from 3 to 6 meters. These sites covered about 12 km of Alexandria coastal line and with different distances from the beach ranging between 300 to 700 meters as shown in Fig. (1). Monthly samples of date mussel were collected from December 2017 to November 2018 by SCUBA diving.

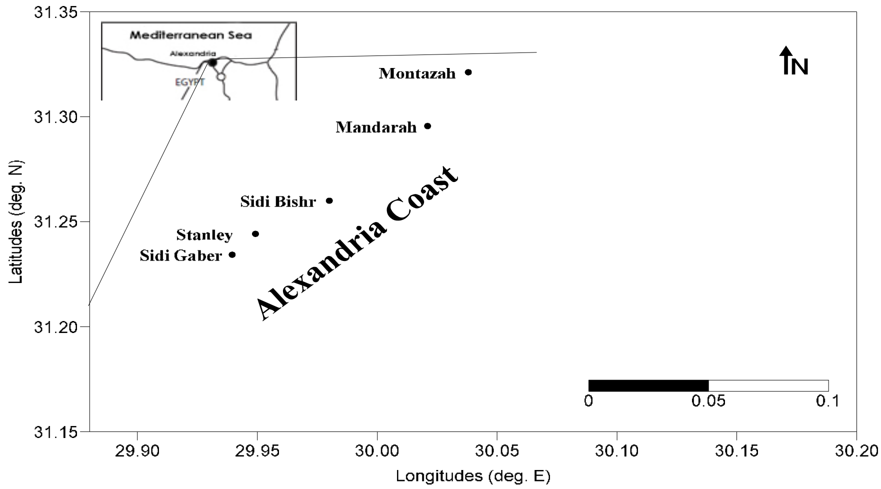

Fig. 1: Sampling locations on Alexandria Coast, Eastern Mediterranean Sea, during the study period (2017- 2018).

Rock structures of limestone were selected depending on their proximity to the beach in which the mussels' habitats are available. The rock blocks having the mussels were of different sizes and colors. During each collection, the work was done by pealing the surface of the crusting cover of the rocks (without breaking it apart from the rock) using a hammer sharpened like a knife to uncover the underlying holes that indicate the presence of the mussel in the stones. The animal is then drawn by means of a long nose plier to pull out the mussel and the hammer can be used to widen the hole if this is needed. All the date mussels in the holes are pulled out, to represent all available sizes. Afterwards, the incrusting cover is put back to allow new mussels to grow. This method of collection does not inflict major damage or degradation to the habitat structure by destruction of the rocks. The collected sample weighed no more than half kilogram monthly.

Morphometric measurements:

The harvested mussel sample was transferred to the laboratory alive, using polythene bags. The specimens were kept in an aquarium for 24 hours and washed for removing the mud and epifauna from their shells, then the measurements were taken as follows: shell length (L); the maximum anterior to the posterior ends of the shell, width (W); the maximum lateral axis, and height (H); the maximum distance from hinge to the ventral margin, all made to the nearest 0.01 mm using a Vernier Caliper. Shell wet weight was determined using a top loading digital balance with a precision of 0.01 g after drying the shell surface with filter paper. Then, the shell was opened, and the soft parts of the date mussels were carefully removed, and the shell dry weight (Sd.w.) and soft tissue dry weight (STd.w.) were determined by weighing to the nearest 0.01 g. The dry weights of shells and soft tissues were measured for each individual after drying at 60°C to constant weight.

The condition index was estimated using the formal CI= dry meat weight (g) / dry shell weight (g) x 100 according to **Crosby and Gale (1990)**. While, meat yield (MY) was calculated according to **Freeman (1974)** as MY= wet meat weight (g) / total weight (g) x 100. All the results of meat yield and condition index were the mean of twenty specimens collected monthly for analysis with ± S.D (N=20).

Seasonal water temperature and salinity averages that were recorded from the area of samples collection as:

Seasons	Water temperature (°C)	Water salinity S‰
Spring	17.3°C	38.7 ‰
Summer	27.4°C	38.8 ‰
Autumn	23.0°C	38.6 ‰
Winter	14.0°C	38.2 ‰

Relative growth:

The allometric relationships between the morphometric shell characters (shell length (x) and other biometric variables (W, H, Sd.w., STd.w. and Tw.w.) were established, through regression analysis, for all population combined and seasonally. Morphometric relationships were estimated using the linear equation y= a+bx, where a (intercept) and b (slope) are constants. The allometric length-weight relationship $w= aL^b$ was calculated, where a and b are constants **(Pauly, 1983)**.

To determine whether a was different from 1 (linear variables) and 3 (volume-related variables), respectively, t-tests were performed to determine the type of growth allometry. The association degree between variables was calculated by the determination of the coefficients (r^2). The values of b obtained in the linear regression were significantly different from the isometric value (b=1) or allometric range (negative allometry= b<1 or positive allometry= b>1).

Statistical analyses:

Monthly changes in the biophysiological indices were analyzed and compared between the sexes by a one-way ANOVA. The linear regression analysis was performed for the four seasons. Then, the resulted coefficients were tested by the t-test. The level of significance in all cases was considered at P ≤ 0.05. All statistical analyses were done using SPSS v. 15 and Excel 2013.

RESULTS

The description of *L. lithophaga* population:

The shell length frequency distribution of the collected *L. lithophaga* specimens (746), shown in Fig. (2) revealed wide variability. The smallest individuals recorded a shell length from 10 to 15 mm representing 0.13% of the population, and the largest shell length was from 80 to 85 mm representing 0.67% of the population. The most abundant individuals were of shell lengths from 45 to 50 mm amounting to 19.71% of the population.

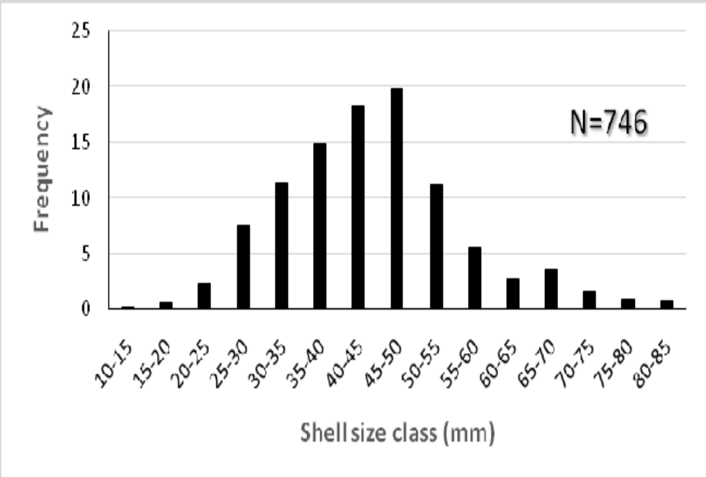

Fig. 2: The distribution of the size frequency of *L. lithophaga* (in 5 mm size class) collected from Alexandria Coast, Egypt.

The mean shell length of *L. lithophaga* as well as the mean total weight varied considerably among the population monthly as in Table (1), it ranged from 39.47±12.56 mm in July to 51.92±10.28 mm during September.

Table 1: *L. lithophaga* population from Alexandria Coast: sampling months, total number of individuals, mean shell length and total weight, with meat yield and condition index of (20 individuals per month).

Months	N.	Shell length		Total weight		Meat yield (N=20)	Condition index (N=20)
		min-max	Mean ± S.D	min-max	Mean ± S.D	Mean ± S.D	Mean ± S.D
Dec.2017	**89**	29.08-82.03	49.34±8.87	1.59-23.65	7.38±4.00	23.91±5.61	24.23±8.69
Jan.2018	**50**	34.76-83.99	49.89±10.14	2.90-40.10	8.62±6.59	28.70±7.50	25.75±9.68
Feb.	**69**	11.90-82.83	43.34±12.18	0.45-22.12	6.19±4.71	28.55±5.57	29.38±9.12
Mar.	**72**	24.29-78.69	44.42±11.29	1.00-27.91	6.45±5.07	31.27±11.50	27.12±12.59
Apr.	**80**	26.82-77.27	40.19±10.31	1.17-27.52	4.95±4.84	31.15±5.21	31.79±8.34
May	**65**	19.63-73.53	43.70±11.21	0.73-21.14	5.71±4.35	30.12±4.53	30.96±8.93
Jun.	**84**	18.67-69.83	40.34±11.14	0.40-19.04	4.71±3.72	36.26±6.27	36.11±8.43
Jul.	**62**	22.93-80.66	39.47±12.56	0.87-30.23	4.95±5.66	47.32±5.14	44.00±11.00
Aug.	**30**	26.95-77.66	49.47±13.29	1.39-27.99	8.56±6.47	33.68±7.63	36.18±12.21
Sep.	**20**	33.10-74.94	51.92±10.28	2.05-28.54	8.99±6.26	35.80±10.29	38.15±14.37
Oct.	**65**	25.34-83.30	44.89±11.55	1.24-28.65	5.22±5.14	33.66±7.41	34.41±8.63
Nov.	**60**	17.25-74.24	42.81±11.44	0.44-23.92	5.66±4.87	28.34±3.60	38.28±14.80
Total	**746**						

The largest shell length of *L. lithophaga* specimens recorded during this survey was 83.99 mm in January while the smallest one was found in February and measured 11.90 mm in shell length. While the specimen of maximum total weight recorded was 40.10 g collected in January and the smallest one was 0.40 g in June.

Relative shell growth analysis:

The studied biometric variables were significantly correlated with shell length as in Table (2). In order to investigate the variability of shell growth in *L. lithophaga* from the present study, five allometric relationships between morphometric shell dimensions were determined for all populations combined annually and seasonally. The annual populations are presented in Figs. (3 and 4). The results showed that for all allometric relationships, the types of allometric growth of *L. lithophaga* were negative allometry. As for the allometric growth of shell length-shell width relationship, the regression analysis showed a significant linear correlation for *L. lithophaga.*

Table 2: Relationships between the biometric variables of *Lithophaga lithophaga* from Alexandria Coast of Egypt; annually and seasonally. (S.L) shell length, (S.W) shell width, (S.H) shell height, (Sd.w.) shell dry weight, (STd.w.) soft tissue dry weight, (Tw.w.) total wet weight, (N) number of individuals, (GT) growth type, (-A) negative allometry. Bold values show high significance.

Biometric variables	period	N	Biometric equation	r	t	P	Type of growth (GT)
S.W / S.L	annual	**746**	**y=0.2783x+0.2592**	**0.8946**	54.60	< 0.05	-A
	winter	208	y=0.2583x+1.0059	0.8721	25.58	< 0.05	-A
	spring	217	y=0.2742x+0.3119	0.9291	36.83	< 0.05	-A
	summer	176	y=0.279x+0.0448	0.9442	37.83	< 0.05	-A
	autumn	145	y=0.3035x-0.1881	0.8367	18.26	< 0.05	-A
S.H / S.L	annual	**746**	**y=0.2877x+1.6945**	**0.9247**	66.23	< 0.05	-A
	winter	208	y=0.2689x+2.4684	0.9329	37.20	< 0.05	-A
	spring	217	y=0.2824x+1.8228	0.9541	46.75	< 0.05	-A
	summer	176	y=0.2864x+1.5478	0.9683	51.11	< 0.05	-A
	autumn	145	y=0.3141x+1.073	0.8523	19.49	< 0.05	-A
Tw.w. / S.L	annual	**746**	$\mathbf{y=0.0002x^{2.6671}}$	**0.9445**	55.93	< 0.05	-A
	winter	208	$y= 0.0006x^{2.3927}$	0.9031	24.56	< 0.05	-A
	spring	217	$y=0.0002x^{2.7481}$	0.9495	33.30	< 0.05	-A
	summer	176	$y=0.0001x^{2.8233}$	0.9788	32.20	< 0.05	-A
	autumn	145	$y=0.0002x^{2.6339}$	0.9320	23.66	< 0.05	-A
Sd.w. / S.L	annual	**239**	$\mathbf{y=0.0001x^{2.5389}}$	**0.9376**	28.17	< 0.05	-A
	winter	60	$y=0.00006x^{2.6729}$	0.9649	17.11	< 0.05	-A
	spring	59	$y=0.00009x^{2.5651}$	0.8871	11.35	< 0.05	-A
	summer	60	$y=0.0002x^{2.3313}$	0.9452	12.28	< 0.05	-A
	autumn	60	$y=0.00004x^{2.7861}$	0.9506	17.95	< 0.05	-A
ST d.w. / S.L	annual	**239**	$\mathbf{y=0.0002x^{2.0328}}$	**0.8099**	19.65	< 0.05	-A
	winter	60	$y=0.00007x^{2.2634}$	0.8455	8.50	< 0.05	-A
	spring	59	$y=0.0001x^{2.1576}$	0.7501	9.99	< 0.05	-A
	summer	60	$y=0.0004x^{1.916}$	0.8775	11.70	< 0.05	-A
	autumn	60	$y=0.0001x^{2.2523}$	0.9055	14.61	< 0.05	-A

The correlation coefficient was 0.8946 ($P < 0.05$) for the annual population as in Fig. (3) and Table (2), and it ranged among seasonal population from 0.8367 (autumn) to 0.9442 (summer). The (b) values fluctuated between 0.3035 (autumn) to 0.2583 (winter). While for the allometric growth of shell length-shell height in *L. lithophaga*, the regression analysis showed a significant linear correlation for the annual population as in Fig. (3), and the correlation coefficient was 0.9247 ($P < 0.05$). For seasonal population, it ranged from 0.8523 (autumn) to 0.9683 (summer). Meanwhile, for the total weight-shell length in *L. lithophaga,* the regression analysis showed a high correlation not only for the annual population (r= 0.9445 at $P < 0.05$) as in Fig. (4) and Table (2), but also that each seasonal population fluctuated between

0.9788 (summer) and 0.9495 (spring), while r= 0.9320 and 0.9031 in autumn and winter, respectively.

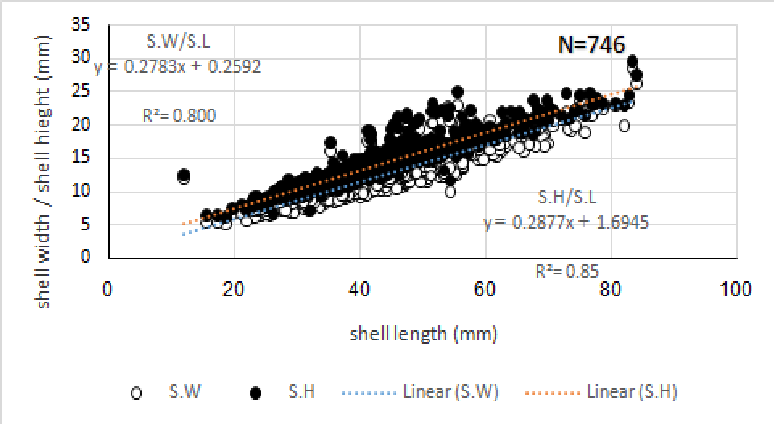

Fig. 3: Scatter plot of shell width against length and height against length with linear regression lines for date mussels *Lithophaga lithophaga*.

A negative relative growth was recorded for annual and seasonal populations in Sd.w./S.L and STd.w./S.L as in Table (2). Also, the shell length increased faster than the total wet and dry weight as in Table (2) and Fig. (4).

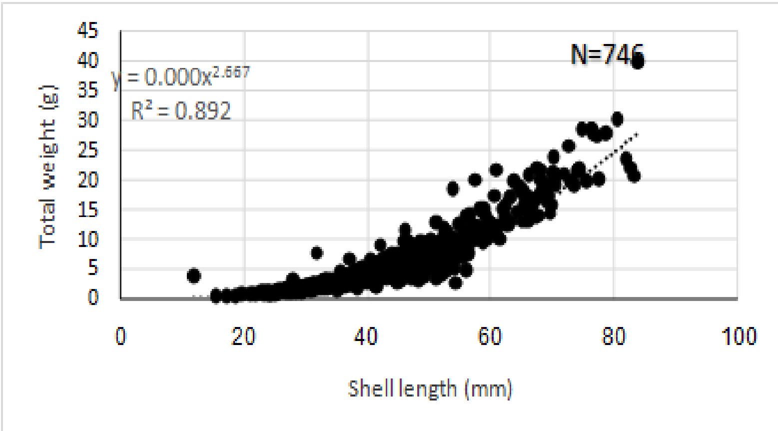

Fig. 4: Scatter plot of shell length against total weight with non-linear (allometric) regression line for date mussels *Lithophaga lithophaga*.

Variation of the condition index and meat yield:

In the present study, meat yield (MY) and condition index (CI) have been determined monthly as in Table (1). There were significant variations in (MY) from December, 2017 to June, 2018. The highest value of meat yield was recorded during July (47.32%). However, from August onwards the (MY) in date mussels started to decline and the lowest value (23.91%) was observed in December. The same trend of variations in condition index (CI) in *L. lithophaga* was observed with the highest value in July (44%) and the lowest value in December (24.23%).

DISCUSSION

The shell growth and shape of bivalves are influenced by several endogenous and physiological biotic factors, as well as abiotic factors of which are exogenous and environmental. **Gasper *et al.* (2002)** mentioned that a variety of environmental factors influence the morphology of shells and the relative proportions of many species of bivalves. The morphometric relationships are used for the comparison between the dimensional growth of related species or the same species in different habitats **(Hemachandra & Thippeswamy, 2008)**. The present study showed a linear relationship between length-height and width in the *L. lithophaga* population collected from Alexandria Coast, Eastern Mediterranean Sea, Egypt. Moreover, the results showed that the b value of length-height and length-width relationships was 0.2877 and 0.2783 for the annual population. In Bizerte Bay (Tunisia), **Kefi *et al.* (2014)** reported b values of 1.1148 for length-height and 0.9918 for length-width relationships for *L. lithophaga* mussel for the annual population.

Furthermore, the current results revealed that (Sd.w.) shell dry weight, soft tissue dry weight (STd.w.), total wet weight (Tw.w.), shell length-height and length-width relationships increased at a slower rate than the shell length (negative allometry). These results were achieved in Bizerte Bay for the same mussel, **Kefi *et al.* (2014)** reported a (positive allometry) for shell height (H) in both sexes, as well as the shell width (W) showed a negative allometry relationship that was recorded for females, while for males the relationship was isometric. **Peharda *et al.* (2015)** proved a high variation in growth rates between individuals of *L. lithophaga*, and the ontogenetic ages of the analyzed shells varied from 10 to 54 years (30.6-93.6 mm).

The fluctuation of b values in length-weight relationships is directly related to the weight affected by ecological factors and other factors such as sex, age, sampling time and sampling area **(Seed, 1968; Thippeswamy and Joseph, 1988; Boulding and Hay, 1993)**.

Additionally, in the present study, the estimated b values of length-total weight, length-tissue dry weight and length-shell dry weight relationships were 2.6671, 2.0328 and 2.5389, respectively, for *L. lithophaga*. In addition, **Kefi *et al.* (2014)** presented b values for the same previous length-weight relationships as 2.584, 2.611 and 2.613, respectively, for annual population in Bizerte Bay for *L. lithophaga* mussel.

In bivalve mollusk, the condition index technique has been considered as easy, inexpensive and a more validating method to identify the reproductive condition **(Lagade *et al*., 2014)**. The highest value of meat yield in the present study confirms that the date mussel is at maturity and this is a good indicator of physiological fitness.

The results proved that the largest values of meat yield and condition index were in July as shown in Table (1) and this may be due to the competently development of gonads.

The declining body condition index coincides with the onset of the spawning behavior from October to the following month of June and this may be an indication of the spawning behavior.

More detailed studies about the reproductive cycle of *L. lithophaga* in the area of study are necessary. Such knowledge will be useful in developing future management strategies for the non-destructive collection and conservation of the local wild stocks of *L. lithophaga.*

CONCLUSIONS OF INTEREST

The authors declare that there is no conflict of interest regarding the publication of this article.

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