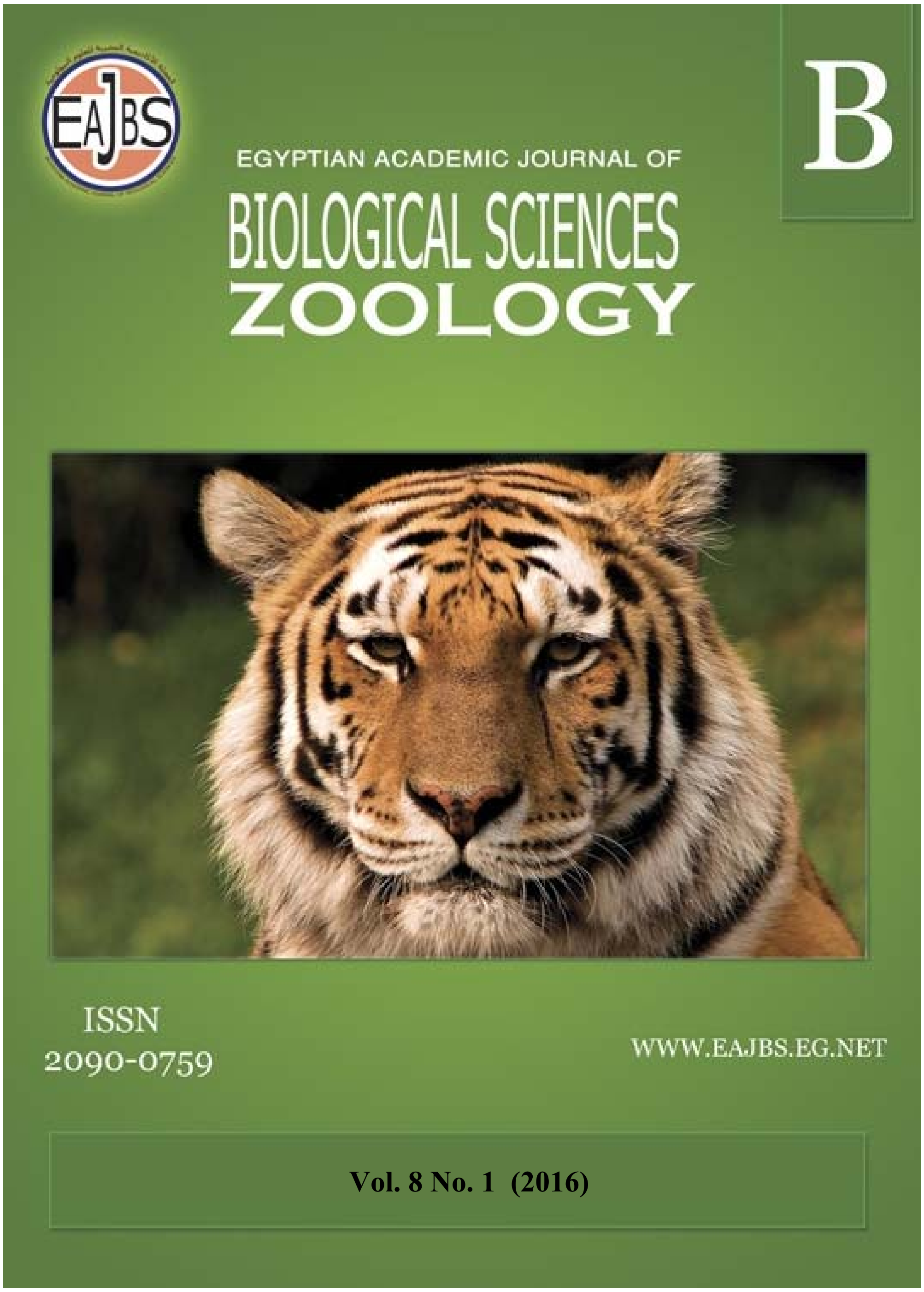

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Biometric Relationships for the Bivalve Mussel, *Brachidontes pharaonis* Populations from the North-Western Coast of Suez Gulf, Egypt.

Awaad, A. El-Sayed [1]; Najat, El-Mabrouk O. Ibrahim[2]; Amr, M. Nassef[1]; Montaser, A. El-Hammady[3] and Hosam, A. El-Mekawy[1]

1- Faculty of Science, Al-Azhar University, Cairo, Egypt.
2- Faculty of Science, Zawia University, Sabratha, Libya.
3- National Institute of Oceanography and Fisheries, Red Sea, Hurghada, Egypt.

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ABSTRACT

The biometric relationships for two populations of the bivalve mussel *Brachidontes pharaonis* collected monthly during the period from January 2014 to December 2014 from the intertidal zones of Adabia and Ain Sokhna coasts at the north-western portion of Suez Gulf were studied. The obtained results showed that there is a good relation between length and total body weight represented by allometric regression coefficients (b) being 2.112 and 2.376 for Adabia and Ain Sokhna populations, respectively. The overall value for relative condition factor "kn" varied from 0.83 to 1.22 and from 0.67 to 1.41 and averaged 1.01±0.13 and 1.02±0.22 for the two populations at Adabia and Ain Sokhna, respectively. These values denote to good well-being or fitness, but were not stable between different size classes; being higher in smaller individuals at size class 2.5 mm but decreased in the following size classes between 5 and 12.5 mm, and increased slightly again in the medium sized and larger individuals. The present results also showed that, the relations between both length and breadth as well as between length against width were allometric with regression coefficients "b "values less than "1" and were represented by 0.66 and 0.74 for the two variables respectively, at Adabia, but increased slightly to 0.74 and 0.85 at Ain Sokhna. These data show that, available habitats and favorable conditions being better at Ain Sokhna than Adabia. The length frequency distribution for the whole populations at the two sites were represented by 5 size classes, denotes to population stability controlled by continuous nearly equal adding for juveniles and removal by different mortality rates.

INTRODUCTION

Bivalves play an important role in the ecosystem equilibrium and constitute an important member of the nearshore biota, contributing significant part in the food chain and in the modification of sea bottom nature at their occurrence (Desouky, 2009). *Brachidontes pharaonis* (Fischer, 1870) is a small intertidal bivalve, belongs to family Mytilidae, Order Mytilida, within class Bivalvia, Phylum Mollusca (Vine, 1986; Rusmore-Villaume, 2008). This species is a euryhaline, eurythermal, diet generalist, anchors itself to hard substrates in the mid-littoral zone with abyssal threads, forming mytilid beds, which may reach high densities and completely cover rocky shores when wave exposure and sedimentation conditions are optimal (Safriel *et al*., 1980).

This species has high fecundity, early maturity, with planktonic larvae, and its tolerance of high salinity and high temperature enable it to occupy diverse habitats across a wide geographic range. It has been reported in high-salinity lagoons, on open coasts, and in polluted waters (Radwan (2014).

It was widely reported that the geographical range of *Brachidontes pharaonis* includes the western Pacific Ocean, the Indian Ocean, the Red Sea (Taylor 1971; Sasekumar 1974; Barash and Danin 1986; Morton 1988), and had migrated to the Mediterranean Sea after opening Suez Canal (Sara *et al.,* 2000, 2008; Zenetos, *et al*., 2005; Radwan, 2014), but the occurrence of this species in some areas is controversial (Sara *et al.,* 2008). According to Barash and Danin (1986), *Brachidontes pharaonis* occurs along eastern African coasts, from the Red Sea to southern Africa, in the Indian Ocean except for the Persian subregion and Malaysia, and in the western Pacific Ocean.

Sasekumar (1974) reported *Brachidontes pharaonis*, in Malaysia, while Arcidiacono and Di Geronimo (1976) supported the occurrence of *Brachidontes pharaonis*, along the western African coasts. It was reported from the Red Sea including Gulfs of Suez and Aqaba by several authors particularly Sharabati (1984), Vine (1986), Head (1987), Mastaller (1987), Mohamed (1992), Rusmore-Villaume, (2008), and Radwan (2014).

Scattered studies on distributions, ecology, interaction between adults and recruitments, age structure, as well as reproduction in addition to length weight relationships for *Brachidontes pharaonis* under its specific name or for its synonyms were treated in few articles in the Red Sea, Gulf of Suez as well as at Suez Canal and at eastern Mediterranean Egyptian coasts by Mohamed (1992, 1997) and Radwan (2014). But no intensive studies were done on the biometric relationships for those populations of this species at the north-western coasts of the Gulf of Suez. Therefore, this study aims to investigate the biometric relationships of *Brachidontes pharaonis* collected from the intertidal and shallow subtidal zone at the north-western portion of Suez Gulf.

MATERIALS AND METHODS

Study area and sample collection:

Samples of *Brachidontes pharaonis* were collected monthly during the period from January 2014 to December 2014 from the intertidal and shallow subtidal rocky zones from Adabia (32°30'3.84"E- 29°50'46.41"N), and Ain Sokhna (32°21'39.30"E- 29°33'29.40"N). These sites lie at 18 km and 65 km south Suez City (Fig. 1), and along the north-western portion of Suez Gulf.

The habitats at these sites were characterized by rocky, sandy, sand-rock and coral reefs at Ain Sokhna, but has sandy bottom with scattered rock boulders at Adabia. The individuals of this species were collected by hand and detached from its substrates using forcipes of different sizes. Other two sites comprised Km 78 and 85 South Suez City were surveyed three times but no specimens *B. pharaonis* were collected.

Sampling and identification:

A total of 1103 individuals of *Brachidontes pharaonis* were collected from Adabia (532) and Ain Sokhna (571), at the northern-west portion of the Suez Gulf. These specimens were fixed in 10 % formalin solution and kept in plastic containers provided with information on date and site of collection and transferred for laboratory.

At the laboratory, each individual of the collected mussel was firstly cleaned from the extraneous bio-fouling organisms by scraping shell, then sorted, and examined morphologically and identified according to Sharabati (1984), and Rusmore-Villaume (2008) to its specific level, depending on form, external sculpture and color of the shell.

Fig. 1: Study sites at the north- western coast of Suez Gulf.

Morphometric measurement had been recorded for each of the collected sample. Each mussel was measured with caliper veriner to the nearest 0.1mm and weighed to the nearest 0.01 mg using an electric balance (Centaurus Scale, JM, 1002). All terminology and measurements were recorded for each individual as illustrated in Fig. (2) and taken according to Rusmore-Villaume (2008), and comprised mainly the following:

a) Shell length (L): It taken as the maximum distance between the anterior and posterior margins of the shell.
b) Shell breadth (B): It represents the maximum distance from hinge to ventral margin.
c) Shell width (W): It represents by the maximum distance between outer edges of the two valves.

Biometric relationships:

Length- weight relationship:

The relationship between shell lengths and total body weight was calculated and represent by the following equation:

$$\mathbf{Y = a \pm bX}$$ (Hile, 1936, Bagenal and Tesch, 1978).

Where Y= body weight in mg, X = shell length in mm, a = constant and equal to the intercept of the straight line with Y axis; b = the coefficient of allometry.

The method of least squares was used and the coefficients “a” and “b” were calculated by plotting log Y (body weight) against log X (shell length) according to the following formula:

$$\mathbf{Log\ Y = Log\ a \pm b\ log\ X}$$ (Hile, 1936 and Bagenal & Tesch, 1978)

Condition factor:

The well-being or the relative condition factor "Kn'" was calculated for the collected individuals according the following formula:

$$\mathbf{Kn = W/W`}$$ (Hile, 1936, Bagenal and Tesch, 1978)

Where W = observed weight, and W`= calculated weight from the length-weight relationship.

Size-frequency distribution:

The size frequency distribution for the monthly sampled individuals of *B. pharaonis* was estimated. The individuals of this species were measured and allocated to 2.5 mm size classes. The frequency of each size class was determined and plotted histographically according to Hartnoll and Bryant (1990).

Fig. 2: Morphological measurements of *Brachidontes pharaonis*, L = length, B = Breadth and W = Width.

RESULTS

A- General morphology:

The collected specimens of *B. pharaonis* were varied from 2.8 to 37.3 mm in shell length, 1.6 to 22.3 mm in shell breadth, and from 1.2 to 15.9 mm in shell width. Shell is equivalent, in equilateral, attached to substrate by stout byssus. Sculptures are numerous, with fine radial bifurcating ribs, which become coarser posteriorly. Margin is crenulated. The hinge has dysodont teeth. Shell has dark brown-black color and internally tinged violet-black.

B- Length-weight relationship:

A total of 1103 individuals of *Brachidontes pharaonis* were used for studying the length-weight relationships at the two sites. For Adabia, 532 specimens were varied from 3.6- 33.2mm in total length, and 0.01- 3.25 g in body total weight. While at Ain Sokhna, 571 specimens were collected and varied from 2.8-37.3mm in total length and 0.01-4.75gm in total body weight.

The relationships between shell length (L) and total body wet weight (W) for the whole population is considered (Table 1 and Fig. 3) and represented by the following equation:

Log W= 0.273+2.112 Log L (r = 0.997) (Adabia)

Log W= 0.037+2.376 Log L (r = 0.993) (Ain Sokhna)

Where W= total weight (mg), L = shell length (mm).

The regression coefficient (b) of these relations have an allometric values, beings 2.112 and an intercept with Y axis, “a’ = 0.273 for the whole populations of *B. pharaonis* at Adabia and 2.376 with an intercept with Y axis a= 0.037 for those collected from Ain Sokhna. However, the two relations have high correlation coefficient ‘r’ being 0.997 and 0.993 for the two stations, respectively. These results exhibit that “b” values being clearly lower than an isometric value (b=3.0).

Seasonal variation in length weight relationships:

The length-weight relationship was also treated for the two populations in Adabia and Ain Sokhna during different seasons. All seasons have negative allometric coefficients, being slightly higher in summer at Adabia and reached the highest value during winter at Ain Sokhna. These relations are represented by the following equations:

Adabia:

Log W= 0.209 + 2.175 Log L (spring, r = 0.997)
Log W= 0.189 + 2.218 Log L (summer, r = 0.998)
Log W=0.385 + 2.004 Log L (autumn, r = 0.991)
Log W= 0.291 + 2.092 Log L (winter, r = 0.992)

Ain Sokhna:

Log W=- 0.035 + 2.448 Log L (spring, r = 0.988)
Log W= 0.041 + 2.424 Log L (summer, r = 0.996)
Log W=0.092 + 2.303 Log L (autumn, r = 0.991)
Log W= -0.165 + 2.598 Log L (winter, r = 0.994)

Table 1: The length–weight relationship and condition factor for *B. pharaonis* from Adabia and Ain Sokhna.

	Adabia			Ain Sokhna		
Length (mm)	**Observed weight (mg)**	**Calculated weight (mg)**	**Kn**	**Observed weight (mg)**	**Calculated weight (mg)**	**Kn**
2.5	15.88	13.00	**1.22**	11.88	9.61	**1.24**
5.0	47.10	56.23	**0.84**	42.57	49.87	**0.85**
7.5	114.19	132.42	**0.86**	106.77	130.69	**0.82**
10.0	241.07	243.15	**0.99**	224.37	258.88	**0.87**
12.5	363.55	389.58	**0.93**	408.00	439.92	**0.93**
15.0	594.19	572.61	**1.04**	669.23	678.45	**0.99**
17.5	787.62	793.02	**0.99**	963.00	978.57	**0.98**
20.0	1114.00	1051.44	**1.06**	1625.00	1343.97	**1.21**
22.5	1478.50	1348.48	**1.10**	2510.77	1778.01	**1.41**
25.0	1802.73	1684.63	**1.07**	3146.67	2283.81	**1.38**
27.5	1984.00	2060.36	**0.96**	2885.00	2864.27	**1.01**
30.0	2967.50	2476.11	**1.20**	3545.00	3522.12	**1.01**
32.5	2430.00	2932.26	**0.83**	2840.00	4259.94	**0.67**
35.0				4750.00	5080.18	**0.94**
Total			**1.01 ± 0.13**			**1.02 ±0.22**

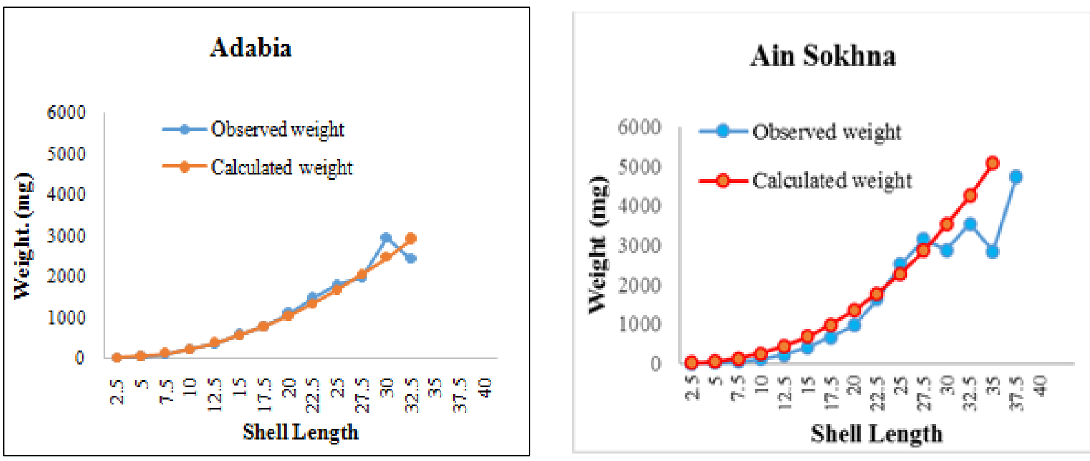

Fig. 3: Observed and calculated weight for the whole population of *B. pharaonis* from Adabia and Ain Sokhna.

C- Length breadth relationship:

The present results show that, shell breadth varied from 2.3 to 17.6 mm in Adabia and between 1.6 and 22.3 mm at Ain Sokhna .

The relation between shell length (L) and shell breadth for the two populations is considered, and represented in Fig. (4) and by the following equation:

Log Breadth = 0.170 + 0.663 Log L (r = 0.997) Adabia

Log Breadth = 0.082 + 0.740 Log L (r = 0.997) Ain Sokhna

This relation is linear and shows an allometric negative regression coefficient b= 0. 663 and 0.740 with an intercept of Y-axis ‘a’= 0. 0.170 and 0.082 for Adabia and Ain Sokhna respectively, with high correlation coefficient ‘r’= 0.997 for both stations.

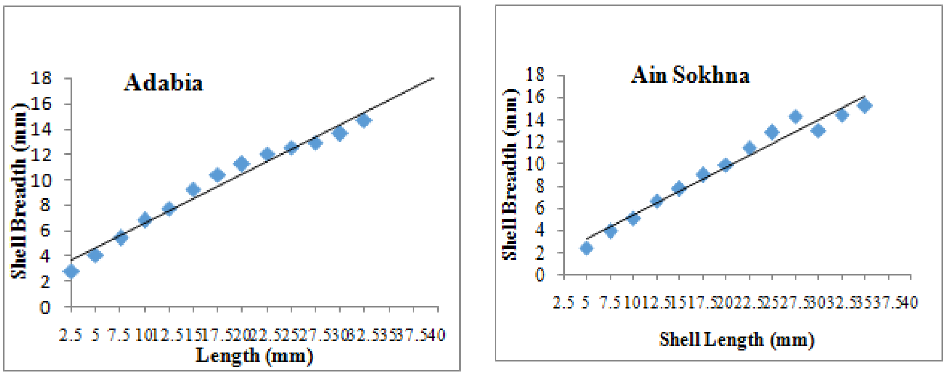

Fig. 4: Length- breadth relationship for the whole population of *B. pharaonis* from Adabia and Ain Sokhna.

D- Length- width relationship:

The individuals of *B. pharaonis* were varied from 1.2 to 15.9 mm in shell width at Ain Sokhna and between 1.4 and 13.4 mm at Adabia. The length- width relationships (Fig. 5) for the two populations were calculated and represented by the following equations:

Log width = -0.025 + 0.746 Log L (r = 0.998) for Adabia

Log width = -0.105 + 0.853 Log L (r = 0.994) for Ain Sokhna

These relations are linear and show an allometric negative regression coefficients b= 0.746 and 0.853, with an intercept of Y-axis ‘a’= -0.0.025 and 0.105, with correlation coefficients ‘r’=0.998 and 0.994 for Adabia and Ain Sokhna, respectively.

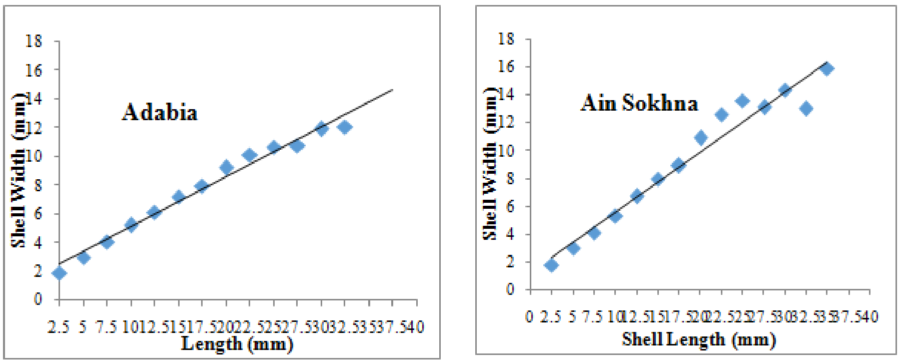

Fig. 5: Length- width relationship for the whole population of *B. pharaonis* from Adabia and Ain Sokhna.

E-Condition factor:

Results of relative condition factor ‘Kn’ for the two populations of *B. pharaonis* from Adabia and Ain Sokhna are given in Tables (1&2) and represented in

Fig. (6). The overall value for "kn" varied from 0.83 to 1.22 and from 0.67 to 1.41 with an average of 1.01±0.13 and 1.02±0.22 for the two populations, respectively. These values denote to good well-being or fitness. However, these values were not stable between different size classes; being very high, 1.22 and 1.24 for the two stations respectively, in smaller individuals at size class 2.5 mm but decreased in the following larger size classes between 5-12.5 mm, and increased again slightly in medium-sized and larger individuals (Table 1). The values of condition factor were very close in the two stations within all seasons (Table 2).

Table 2: Seasonal variation of condition factor for *B. pharaonis* in Adabia and Ain Sokhna.

Stations / **Seasons**	**Adabia** Kn	**Aain Sokhna** Kn
winter	1.02±0.21	1.02±0.21
spring	1.01±0.13	1.04±0.32
summer	1.00±0.08	1.01±0.16
autumn	1.02±0.20	1.01±0.16
Average ± SD	**1.01±0.13**	**1.02±0.21**

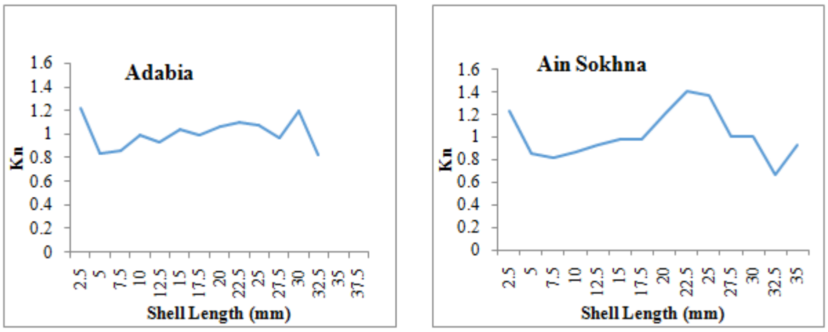

Fig. 6: Relative condition factor (Kn) for the whole population of *B. pharaonis* from Adabia and Ain Sokhna.

F - Size-frequency distribution:

The size frequency distribution for the populations of *B. pharaonis* is represented in Fig. (7). These data show that, population of this species is stable during the period of study. The population at both sites composes of at least five size classes. It was represented by early juveniles (from 2.5 to <5.0 mm), small size (between 5.0 and <12.50 mm), medium size (from 12.50 to <17.50 mm), larger individuals (from 17.50 to <25.0 mm), and oldest individuals (>25.0 mm).

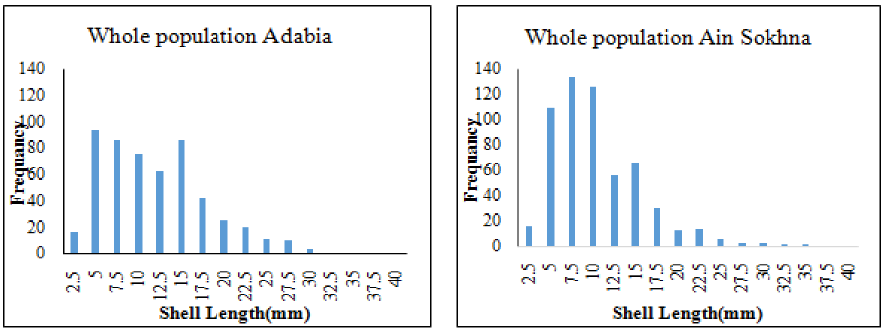

Fig. 7: Size frequency distribution for the whole populations of *B. pharaonis* from Adabia and Ain Sokhna.

The monthly fluctuations were clearly observed. The onset of juveniles was detected in most months of the year (Figs. 8 & 9). With exception only February, April, June and September at Adabia, the recruitment of juveniles was reported in all months. This leads to increasing modes of size classes from three modes during these months to at least 4 or five modes in the next month.

At Ain Sokhna (Fig. 9), the recruitments disappeared during February, March, May, June, and October, in addition to disappearance of old and adult individuals in other months particularly September and November, which may be attributed to an increasing in sea level, compared with January and May at Adabia (Fig. 8).

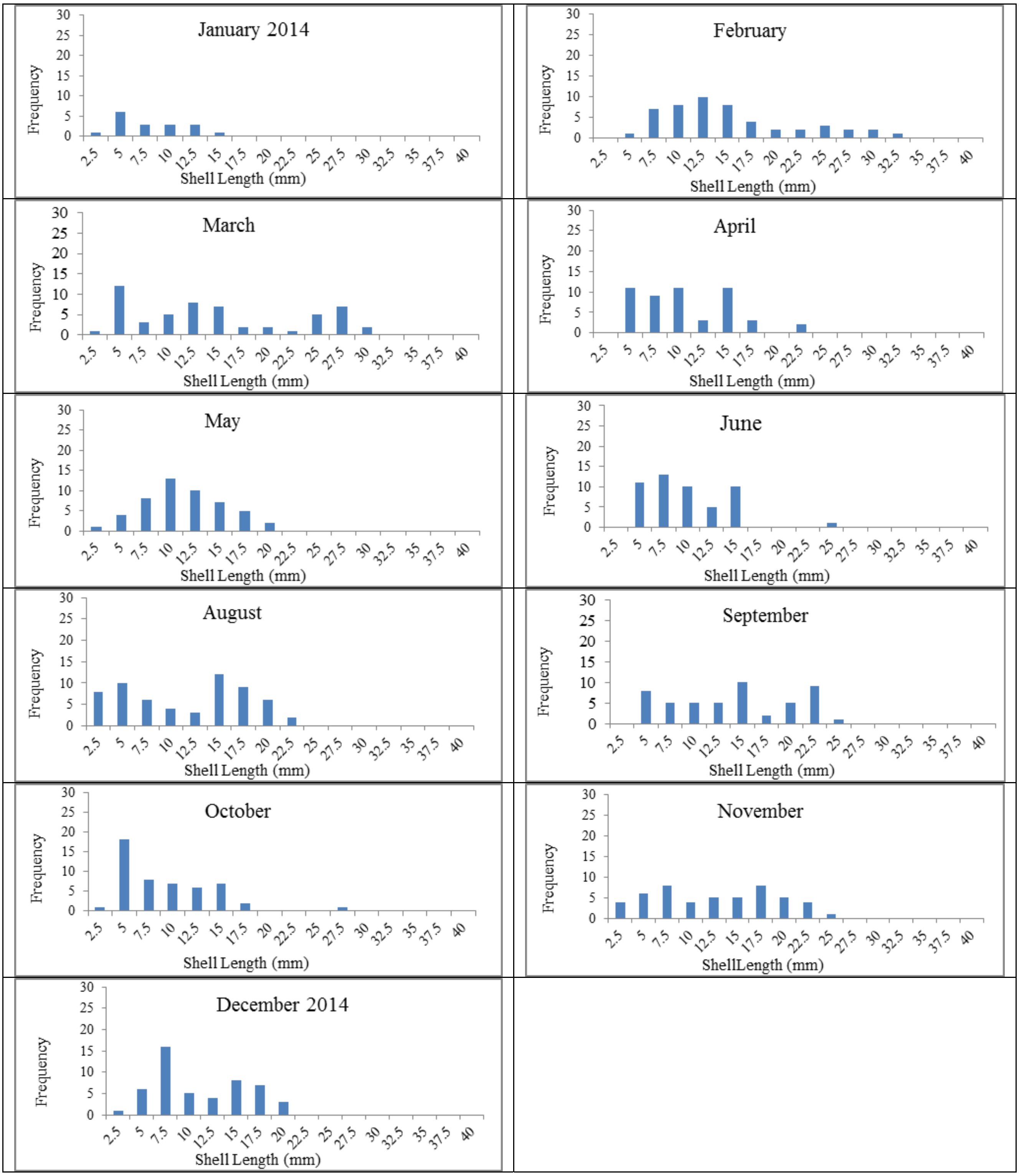

Fig. 8: Monthly variations in size frequency distribution for *B. pharaonis* from Adabia.

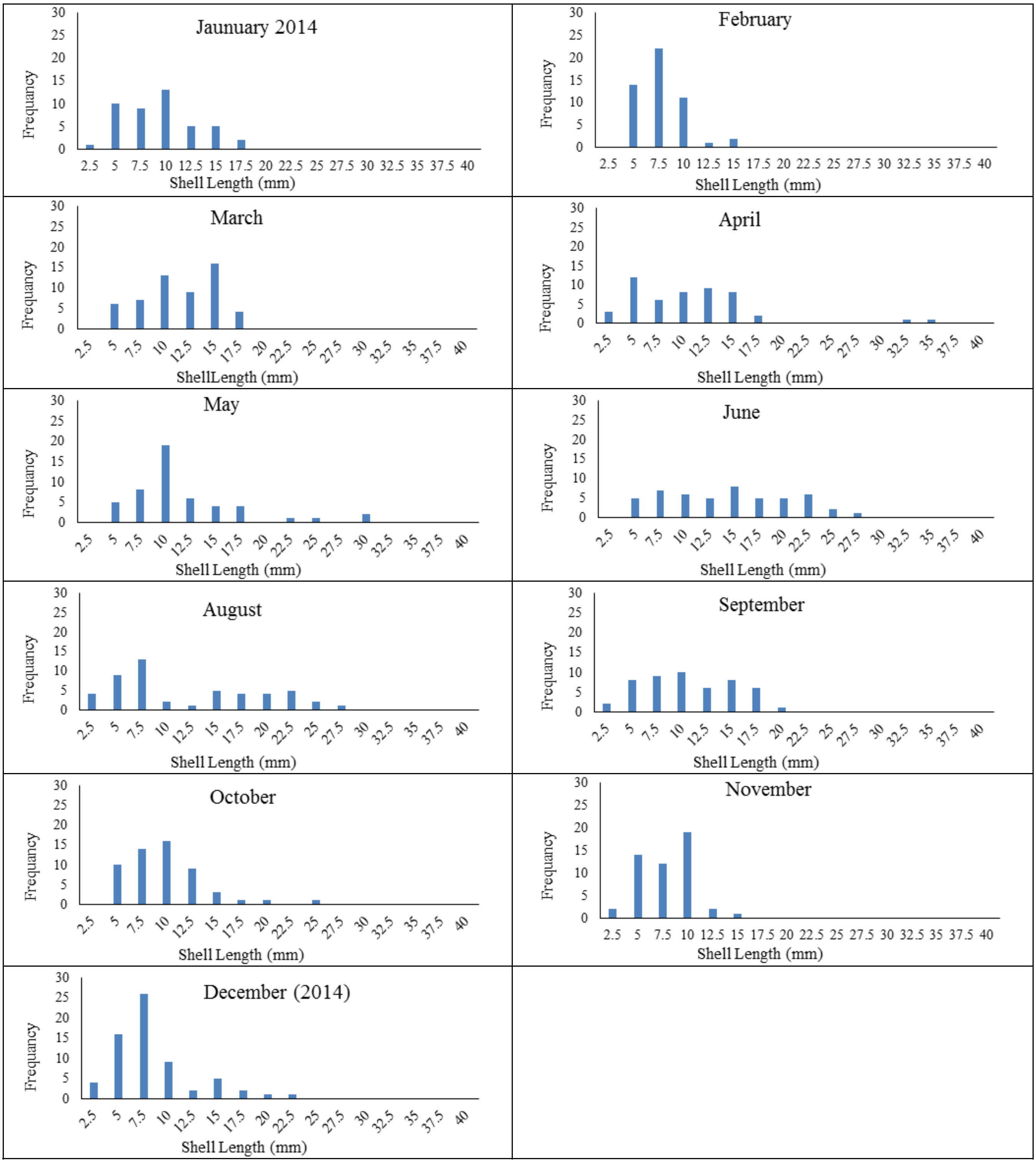

Fig. 9: Monthly variations in size frequency distribution for *B. pharaonis* from Ain Sokhna.

DISCUSSION

In biological studies, the allometric relationships reflect growth patterns in several aquatic animals and may describe rates of wide range of metabolic processes and can use for description the relationships between increments in lengths associated with an increase in weight (Bagenal and Tesch, 1978). In nature, some individuals of the same age or lengths show different weights and the difference could be due to the physiological conditions and to the environmental factors (Seed, 1968; Winberg, 1971; Lee, 1986; Gasper *et al*., 2002).

The present results revealed that, the two populations of *Brachidontes pharaonis* at Adabia and Ain Sokhna being stable during this study, with shell lengths varied from 2.8 to 37.3 mm at Ain Sokhna and from 3.6 to 33.2mm at Adabia. However, the individuals of this species attained larger sizes at Ain Sokhna than those reported at Adabia. This may be attributed to occurrence of wide and extensive areas of rocky substrates and reef flats at Ain Sokhna which accommodate suitable sites for escaping from hazard conditions particularly effects of temperature, salinity, radiations and predation at the upper littoral zones, in addition to providing vast spaces between individuals at reef flats. On contrast, at Adabia, the individuals of this species are aggregated on rock boulders at the upper intertidal zones which are completely exposed during low tide during summer.

The obtained results also exhibited better environmental conditions reflected by increasing shell size compared with other world localities. At both sites, the maximum shell length reached above 33 mm at Adabia and 37 mm at Ain Sokhna, which agree well with that reported by Sara *et al*. (2008) for the same species, where larger individuals were varied from 30-36 mm during spring and summer, represents 5 and 6.3 % of the total populations at Sicily (Mediterranean Sea), and with Zenetos, *et al*., (2005), for those collected from the Indo-Pacific regions which increased into 40 mm but larger than those specimens of the same species collected from different localities including Suez Gulf, Suez Canal, Bardwil, and Marsa Alam by Radwan (2014) with shell sizes from 5 - 30 mm. But in contrast to that recorded from Hong Kong by Morton (1988), and from India (Rajagopal *et al*., 2003), which reached about 20 mm and 22 mm in maximum length, respectively. Also, decreasing shell length was clearly recorded along the Red Sea and the eastern Mediterranean. Along the Red Sea coasts, Gilboa (1976) mentioned that the mean shell length decreased to about 18 mm maximum at the northern limits of the Gulf of Aqaba, as well as from Suez Gulf at Suez (Mohammed, 1992, 1997). The remarkable decreasing in shell length may be attributed to effect of unfavorable environmental conditions, or high predation.

In the biometric relationships studies, the constant “b”, or what is also known as the coefficient of allometry or coefficient of regression expresses the rate of change of the relative animal body shape during the growth process (Laxmilatha, 2008). The length- weight relationship for the whole population of *B. pharaonis* showed regression coefficients b=2.376 at Ain Sokhna compared with 2.112 at Adabia. These coefficients are allometric, but showed slightly heavier individuals at Ain Sokhna. These values are clearly lower than an isometric regression (b=3) for the two populations but are very similar to that recoded by Wilbur and Owen (1964), and Sara *et al. (*2008) for the same species from Mediterranean Sea. Sara *et al. (*2008) recoded that the allometric values are varied from the minimum (2.0) during winter to 2.6 and 2.7 during summer and autumn, respectively. They also were higher (2.4) in submerged during summer and autumn than those emerged (2.2) , but lower than that recorded by Radwan (2014) for those collected from Lake Timash (Suez Canal), Gulf of Suez, Marsa Alam (Red Sea), Bardawil Lagoon, and Port Said (Mediterranean Sea) which varied from 2.38, 2.76,2.78, 2.97, and 2.71, respectively.

On the other hand seasonal variations in slopes of the two populations at Adabia and Ain Sokhna stations were significant. The maximum regression coefficient (b) was 2.22 obtained during winter and increased to 2.59 during summer for the two stations respectively. However, it decreased to lowest value during autumn being

2.004 and 2.303 for the two populations respectively. From previous results it is evident that the population of Ain Sokhna is different from that at Adabia. This may be due to the immersed population of Adabia all year around, so they exposed to low temperatures which limited their physiological activity which are in agreement well with Bayne (1976) and Sara *et al. (*2000). For confirmation, Sara *et al*. (2000) observed a decrease in the physiological activity of *B. pharaonis* which corresponded to low winter temperatures. But the population of Ain Sokhna was partially exposed to air and slightly higher temperature due to nature of it′s habitat.

The relationships between shell length and shell breadth as well as shell length and shell width for *B. pharaonis* showed linear relations between these variables. This indicates to broader and wider shell for this species at both sites. However, the individuals of this species have wider and broader shells at Ain Sokhna which indicates to presence of vast and available habitats which agree with those reported on other bivalve species such as the green mussel (Thejasvi *et al*., 2014). The value of regression coefficient "b" is allometric and has 0.663 and 0.740 for breadth –length relationship at Adabia and Ain Sokhna , respectively, increased slightly to 0.746 and 0.853 for length- width relationships at the same sites, respectively.

The relative condition factor (kn) showed an isometric growth and good well-being of this species all over the year without any significant seasonal variations. The two populations of *B. pharaonis* showed the same pattern of Kn within its size class being 1.22 and 1.24 at first recorded size class (5mm) which decreased to less 1 during small size classes from 5mm to 15mm, then increased again at the following classes and averaged 1.01 ±0.13 and 1.02±0.22 for Adabia and Ain Sokhna, respectively. This may be predicting that its maturation occurs in this size interval which consumes more energy. These results are in well agreement with Radwan (2014).

The size frequency distribution for *B. pharaonis* populations at Adabia and Ain Sokhna show that, this species was stable during the period of study. The population at both sites composes of at least five size classes. It was represented by early juveniles (from 2.5 to <5.0 mm), small side (from 5.0 to <12.50 mm), medium size (from 12.50 to <17.50 mm), larger individuals (between 17.50 and < 25.0 mm), and oldest individuals (>25.0 mm).

The monthly fluctuations were clearly observed and showed recruitment of juveniles in most months of the year with exception only February, April, June and September at Adabia, February, March, May, June, and October, in addition to disappearance of old and adult individuals in other months particularly September and November at Ain Sokhna. This events lead to increasing modes of size classes from three modes during these months to at least 4 or five modes in next month.

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ARABIC SUMMERY

علاقات الطول والوزن في مجتمعات محار الماء براكيدونتس فاراونيس من السواحل الشمالية الغربية لخليج السويس.

عواد عبده محمد السيد[١]، نجاة المبروك عون ابراهيم، عمرو محمد ناصف[١]، منتصر على الحمادي [٣]، حسام أحمد المكاوي[١]

١- كلية العلوم –جامعة الازهر- القاهرة
٢- كلية العلوم بصبراته- جامعة الزاوية- ليبيا
٣- معهد علوم البحار والمصايد، البحر الأحمر- الغردقة

تم دراسة العلاقة بين الطول والوزن في أفراد مجتمعي نوع براكيدونتس فاراونيس *Brachidontes pharaonis* من ذوات المصراعين(الرخويات Mollusca) والمجمعه شهريا من المنطقتين بين المديه والمغمورة بمنطقتي الأدبيه والعين السخنه بالجزء الشمالى الغربي لخليج السويس خلال الفتره من يناير ٢٠١٤ الى ديسمبر ٢٠١٤ . وأوضحت هذه الدراسه أن العلاقة بين الطول والوزن لجميع الأفراد علاقة اعتماد شرطية، يصل معامل الاعتماد إلى ٢,١١ و٢,٣٨، للمنطقتين على الترتيب، وتوضح هذه القيم أن هناك ارتفاعا ملحوظا فى الطول على حساب الوزن خاصة فى منطقة الأدبيه. وعلي الجانب الاخر كانت قيم معامل الاعتماد لعلاقة الطول بعرض وسمك الصدفه أقل من الواحد الصحيح وتمثل بالقيم ٠,٦٦، ٠,٧٤ فى منطقة الأدبيه ولكنها ارتفعت قليلا فى العين السخنه لتصل إلى ٠,٧٤ ، ٠,٨٥على الترتيب. وتبين النتائج أن مؤشر معامل الحالة النسبي (kn) يتراوح من ٠.٨٣- ١.٢٢ بمتوسط ١.٠١ ± ٠.١٣ في مجمتع الأدبية ومن ٠.٦٧ – ١.٤١ بمتوسط ١.٠٢± ٠.٢٢ في مجتمع العين السخنة، غير أنه يتباين في الأحجام المختلفة حيث يصل ذروته في الأحجام الصغيرة أقل من ٢.٥ مم بينما يتناقص في الأحجمام المتوسطة التي تترواح ما بين ٥- ١٢.٥ مم ثم يزداد في الأحجام الناضجة والكبيرة، كما أوضحت دراسة التوزيع التكراري للحجوم في مجتمع هذا النوع بالمنطقتين أنه يتمثل بخمس أحجام مختلفه مما يدل على وجود استقرار نسبى من خلال دخول أفراد جديدة يافعة تعوض نسبة الوفيات بالمجتمع.