

Growth, age and reproduction of the commercially clams *Venerupis aurea* and *Ruditapes decussatus* in Timsah Lake, Suez Canal, Egypt

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Received ; revised

This study was undertaken of natural population of *Venerupis aurea* and *Ruditapes decussatus* from three sites in Timsah Lake, Suez Canal, Egypt. Population structures, growth characteristic, age and gametogenic cycle of these clams were studied. Dominant size was 20.1-25 mm for both genera. Age ranged from the first to the fifth with the dominance of the third age group in *Venerupis aurea*. Whereas it reached to the sixth age group in *Ruditapes decussatus* with the dominance of the fourth. The male/ female ratio was 1.02: 1 and 1.25:1 for *Venerupis aurea* and *Ruditapes decussatus* respectively. Five stages of gonadal development were observed and seasonal gonadal changes were registered. Comparisons of the present study with that previously obtained on the same genera were reported.

[**Key words:** *Venerupis aurea*, *Ruditapes decussatus*, growth, age, reproduction.]

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Introduction

Infaunal bivalves serve as an important food source not only for humans but also for other marine predators such as worms, snails, crabs and birds¹⁻⁴. Veneridae is the most diverse recent bivalve family, comprising over 800 extant, presumably valid, species in approximately 170 genera⁵. *Venerupis* and *Ruditapes* are two genera of marine clams that belong to the family Veneridae. These genera, together with other clams present one of the main components of mollusc production and makes up about 25% of total mollusk production in the world⁶. *Venerupis* sp and *Ruditapes* sp are widely distributed along the west coast of the U.S.A and Canada as far north as northern British Columbia, France, United Kingdom and Spain, Italy, Russia, China, Turkey, Tunisia in addition to Egypt⁷⁻¹⁴. The Egyptian clams, *Venerupis aurea* (Gmelin, 1791) and *Ruditapes decussatus* (Linnaeus, 1758) are common in Marsa Matrouh, Alexandria, Port Said, Suez, Fayed and Ismailia¹⁵. These clams have a high commercial value locally and as an export commodity¹⁶. Despite the large clam harvests, their repopulation is rapid. TOLL *et al.*¹⁷ stated that adult clams have been shown to repopulate a harvested area in a relatively short period of time. Many studies were conducted in order to understand the ecology and biology of these venerid clams, especially their growth¹⁸ and reproduction¹⁹⁻²⁰. Clams are dioeciously. They attain sexual maturity at an age of one or two years. Spawning can occur either once or twice each year depending on location and environmental condition¹¹. It may also extend throughout the year as reported by Kandeel²¹.

This investigation was undertaken to provide information on the population structure, biometric characters, age, sex ratio and gametogenic cycle of *Venerupis aurea* and *Ruditapes decussatus*. Aim of the current paper is to fill the deficiency of the information in the literature about these important Egyptian clams. Also, it may be considered as a basis for future comparison with populations from other locations and ecological situations. Additionally, comparing our results with the previous works help us to preliminary evaluation the change in the clam population within years at Timsah Lake.

Materials and Methods

The clams were seasonally sampled at regular intervals from January to December 2010 at three sites (Fig. 1):

1-The Bridge site: at which the drainage of domestic and industrial effluents.

2-Taawen site: the commercial fishing took place at it.

3- Etap site: is considered as a control site because it is far from drainage and extensive fishing.

The above three sites locate in Timsah Lake (30° 56' N latitude and 32° 28' E longitude), Suez Canal, Egypt.

Samples were sifted through a 1mm mesh screen. The clams were measured anteroposteriorly (shell length) and dorsoventrally (shell height). Maximum distance on the lateral axis between the two valves of the closed shell (shell width) was also measured (Fig.2) using a digital caliper corrected to 0.1mm. Age of clam was estimated by counting the number of annual growth marks (annuli) on the shell. Clams were accurately weighed using a single pan electronic digital balance with a precision of 0.01g. In this way, total weight of live clam with shell (total weight), weight of flesh without shell (soft tissue weight), the shell without tissue (shell weight) and gonad weight were recorded.

For histological techniques, sections of gonads were fixed in Bouin's solution, dehydrated through an ascending series of ethyl alcohol, clearing in terpineol and embedded in paraffin wax. Sections of 5µm in thickness were stained with Ehrlich's hematoxylin and Eosin then mounted by Canada balsam. Sex determination and maturity stages were examined under standard Lietz Dialux 20 EB research microscope.

Statistical analysis

Minimum, maximum, mean and standard deviation of shell measurements and weights were estimated by subjecting the data to pivot table in the Excel package. Significance between sites was calculated via SPSS computer software programs. Maximum length to which the clam will attain was calculated through FISAT_II program. The relationships between the shell length and either of the shell width, shell height, total weight, soft tissue weight, shell weight and gonad weight were studied by testing each pair of variables in the allometric equation:

$$Y = aX^b$$

This equation can be expressed in the logarithmic form:

$$\text{Log } Y = \log a + b \log X$$

Where, Y is the dependent variable

X is the independent variable

a is a constant (the intercept of the regression line)

b is the regression coefficient that gives the rate at which the variable Y alters with the variable X

Allometry coefficient is expressed by the exponent b of the linear regression equations. When the two variables have the same units of measurements, then the value of b can be tested from unity ($b = 1$, isometric growth; $b > 1$, positive allometry and $b < 1$, negative allometry). In the relations between different types of variables (i.e. between different measuring units), different criteria for allometry and isometry were applied. $b = 3$ corresponds to isometry; $b > 3$, positive allometric growth and $b < 3$, negative allometric growth. The association degree between the variables was calculated by the determination coefficient (R^2).

Results

Population structure of *Venerupis aurea* and *Ruditapes decussatus* was unimodal with the abundance of the class size 20.1- 25 mm (Fig.3.A). There was a variation in the dominant size between sites. *Venerupis aurea* within class size 15.1-20 mm was dominant at Etap site, 20.1-25mm at Taawen site but larger clams (25.1-30mm) were dominant at the Bridge site (Fig 3.B). Whereas *Ruditapes decussatus* within class size 25.1-30 mm was dominate at Taawen and Etap sites but smaller size (20.1-25) was dominate at the Bridge site (Fig. 3.C). With respect to age, the third and fourth age groups were the dominant for *Venerupis aurea* and *Ruditapes decussatus* respectively (Fig. 4.A). All age groups of *Venerupis aurea* were represented at all sites (Fig. 4.B) whereas the youngest individuals of *Ruditapes decussatus* were totally disappeared from the Bridge site (Fig.4.C).

Minimum, maximum and mean shell measurements and weights of the clams are shown in table (1). For each site separately, table (2) shows that the average shell measurements and weights of *Venerupis aurea* were higher at Bridge site than other sites. Meanwhile, the maximum shell measurements and body weighs were recorded at Etap and Taawen sites, respectively. Most of the minimum values were recorded at Etap site. *Ruditapes decussatus* exhibited a similar pattern with slightly difference as shown in table (3). However, there were not significant differences in the morphometric measurements and body weights between sites or even between the genera ($p > 0.05$). Asymptotic length to which the clams will reach was 31.5 and 42 mm for *Venerupis aurea* and *Ruditapes decussatus* respectively (FISAT- II analysis). The relationship between shell lengths and the other measurements and weights are shown in figure (5). *Venerupis aurea* had negative allometric growth except for length-soft tissue weight relationship which was nearly isometric. *Ruditapes decussatus* exhibited similar results (Fig. 6) except for shell length - gonad weight relationship (positive allometry). For each site separately, regression equations of *Venerupis aurea* (Table 4) elucidate that the growth was negative allometry except the soft tissue weight and gonad weight at Taawen and Bridge sites. *Ruditapes decussatus* also had negative growth except for soft tissue weight & gonad weight (Taawen site), total weight & shell weight (Bridge site) and gonad weight (Etap site). With respect to seasons, *Venerupis aurea* had only positive allometric growth in the relations: shell length-

shell weight in summer and shell length - soft tissue weight & shell length - gonad weight in autumn (Table 5). Positive allometric growth of *Ruditapes decussatus* exhibited in shell length - soft tissue weight and shell length- gonad weight in most seasons except spring. However, there is no variation in the growth of both clams between seasons ($p > 0.05$).

Male/female sex ratio of *Venerupis aurea* was 1.02:1 while that of *Ruditapes decussatus* was 1.25:1. Figure (7) shows that females exceeded males only in the oldest age groups. Five stages of gonadal development were detected: early active, late active, ripe, partially spawning and completely spawning stages. When more than one developmental stage was evident within a single clam, the individual was assigned to the reproductive stage that was observed in the majority of follicles. Figure (8.A) shows that 20% female *Venerupis aurea* were in the early active at the second age group and gradually decline to reach 7.14% in the fourth age group then increased to 20% in the fifth age group. Similarly, late active began by the ratio of 40% in the second age group, declined to 7.14% in the fourth age group. Ripe stage was pronounced (37.5%) at the third age group. Partially spawning stage reached its maximum (42.86%) at the fourth age group. Completely spawning individuals were detected in the third (12.5%), fourth (21.43%) and fifth (20%) age groups. On the other hand, early active stage did not detect at all in male *Venerupis aurea*, while late active represent 100% in the first age group. Ripe stage reached about 75% in the third and fifth age groups. Partially and completely spawning reached 40% and 25% at the second and fifth age groups, respectively. For the other species, *Ruditapes decussatus*, early active stage was only detected in the third (female) and first (male) age groups with an equal ratio (40%) (Fig.8.B). Late active stage appeared only in the second and third age groups of females while it appeared in most age groups of males. Ripe stage was detected from the third age group to the oldest clam for both sexes. Partially spawning stage reached its maximum at the sixth (83.33%) and the second (50%) age groups for females and males respectively. Completely spawning stage was noticed in most age groups. Figure (9) elucidates that males of both genera exceeded females at late active and ripe stages but the reverse occurred at partially and completely spawning stages. Comparing the two genera, ripening of *Venerupis aurea* started from the second age group while as it retarded to the third age group in *Ruditapes decussatus* (Fig. 10).

Discussion

Population structure of the clams *Venerupis aurea* and *Ruditapes decussatus* revealed that the size class 20.1- 25mm shell length was the dominant for both genera. Age of *Venerupis aurea* ranged between the first and fifth age group, the third age was the dominant. Whereas individuals of *Ruditapes decussatus* reached the sixth in their ages with the dominance of the fourth age group. The first age group of *Ruditapes decussatus* disappeared from Taawen site. Add to that, the first and second age groups also disappeared from the Bridge site, whereas all ages were found at Etap site. We can explain it as Taawen site was the most exposure site, in Timsah Lake, to extensive fishing (MOHAMMAD, 2002). So, it may be a reason for the disappearance of the youngest individuals at this site, in addition to the pollution to which this site was exposed. Bridge site was more polluted than Taawen site as reported by Mohammad *et al.*²³. They recorded higher levels of the

total dissolved/dispersed petroleum hydrocarbons (TDDPHs) at Bridge site (18.62 μ g/l and 81.40 μ g/g) than at Taawen site (9.52 μ g/l and 9.78 μ g/g) in both water and sediments respectively. Therefore, this may be the main cause for the disappearance of the first and second age groups of this clam at this site. On the other hand, all age groups of *Venerupis aurea* were detected in both sites. This led to the conclusion that *Venerupis aurea* is more adaptive to the environmental condition than *Ruditapes decussatus*.

Growth of both genera was negative allometry except for the soft tissue weight in *Venerupis aurea*, and soft tissue weight and gonad weight in *Ruditapes decussatus*. Shell form of *Venerupis aurea* was slightly elongated and flattened in relation to length at Etap site than that at Taawan site. A similar result was previously recorded by Gabr²⁴ at the same sites (Table 6). She attributed it to the type of sediment in addition to the higher clam density at this site that resulted in food deficiency as the result of interspecific competition. The maximum shell length to which *Venerupis aurea* attained was 40 mm and 30.7 mm for the previous and present study, respectively. It was clear that the previous growth of *Venerupis aurea* was better than that of the present study. We may attribute it to the progress of pollution in Timsah Lake. Mohammad *et al.*²³ stated that oil pollution was in progress in Timsah Lake reaching from 20.09 μ g/l (in 2001) to 38.58 μ g/l (in 2007). On the other hand, the present results disagree with the positive allometry obtained for the H/L and W/L relationships by Gaspar *et al.*²⁵ for *Venerupis rhomboids* that occurred on deeper grounds (below 25m depth). So, the difference in growth may be attributed to the difference of species and depth as *Venerupis aurea* of the present study prefers shallower depth (< 1m). As a result, its negative allometries and consequent elongated and narrow shape improve burrowing efficiency. This enables the clams to avoid predation and other environmental conditions. The environmental conditions not only differ between geographical areas but also with years. This was clear from the previous isometric growth of T.wt/L and Sh.wt/L for the two clams at the same area that was registered by Kandeel²⁶.

Sex ratio of *Venerupis aurea* was 1.02:1 for male and female, respectively. It agrees with the previous work of Kandeel²¹. Whereas that of *Ruditapes decussatus* varied from 1:1 (male: female) in the same previous work to 1.25:1 (male: female) in the present study. It may be suggested that female *Ruditapes decussatus* was more sensitive to pollution that led to its death making males outnumbered it. Sex ratio did not only vary with years but also with locality. Serdar *et al.*²⁷ reported that male/female sex ratio of *Ruditapes decussatus* was 1:1.06 and 1:1.10 at two sites in Turkey. Knowledge of gametogenic cycle of these commercially valuable species is important in aquaculture to be able to improve the methods of cultivating these clams. Histological sections showed five stages of gonadal development of both genera. No resting stage was recorded in the present or previous study²¹ in Timsah Lake, whenever it recorded in other areas^{28, 11, 29-30}. Thus many studies have assessed the importance of geographical locations in defining and controlling gametogenesis²⁹. The continuous reproduction without resting stage may be explained that nutritional value is high and seawater temperature is suitable for gametogenesis. So, proliferation activities continue throughout the year in Timsah Lake. A comparison of data on age at sexual maturity between *Venerupis aurea* and *Ruditapes decussatus* suggests that males of both genera were sexually mature in the first year of their life. The same suggestion was reported by Ponurovsky & Yakovlev¹¹. Disappearance of female individuals in the first age group may be related to the pollution in Timsah Lake at which the youngest females can not withstand it. Also, pollution may differ in affecting reproduction of the two genera. This is clear from the retarding in the ripening and spawning

phases to the second age group in *Venerupis aurea*. So, we can attribute it to the pollution, or *Ruditapes decussatus* may be faster than *Venerupis aurea* in ripening. Additionally, rate of spawning may differ between age groups within the species. The non detection of ripe stage in the youngest and oldest *Ruditapes decussatus* may lead to the assumption that these individuals started immediately to spawn as soon as they became ripe. So, there was no detection of the ripe stage in the first and sixth age groups of *Ruditapes decussatus*.

Present study highlighted the better growth of the clam *Ruditapes decussatus* in Timsah Lake, as it reached to the sixth in their ages. In spite of the non significance between sites, Etap site was the most suitable for this species after recording the youngest and largest clam in it.

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Fig.1. Map showing location of the sampling sites

Fig.2. Schematic representation of bivalve shell measurements (L = length; H = height; W = width).

Fig.3. Size frequency distribution of: (A) *Venerupis aurea* Gmelin, 1791 and *Ruditapes decussatus* Linnaeus, 1758; (B) *Venerupis aurea*; (C) *Ruditapes decussatus*

Fig.4. Age distribution of: (A) both *Venerupis aurea* and *Ruditapes decussatus*; (B) *Venerupis aurea*; (C) *Ruditapes decussatus*.

Fig.5. *Venerupis aurea*; relationships between shell lengths and other measurements and weights

Fig. 6. *Ruditapes decussatus*; relationships between shell length and other measurements and weights.

Fig.7. Sex ratio of *Venerupis aurea* and *Ruditapes decussatus*

Fig.8. Percentage frequency of reproductive cycle stages at different age groups of: (A) *Venerupis aurea*; (B) *Ruditapes decussatus*.

Fig.9. Percentage frequency of the reproductive cycle stages of both sexes of *Venerupis aurea* and *Ruditapes decussatus*.

Fig.10. Percentage frequency of the reproductive cycle stages of the combined sexes of *Venerupis aurea* and *Ruditapes decussatus*.

Table 1. Shell measurements (mm) and body weights (g) of *Venerupis aurea* and *Ruditapes decussatus*.

Measurements and weights	<i>Venerupis aurea</i>		<i>Ruditapes decussatus</i>	
	No.	min-max (mean \pm SD)	No.	min-max (mean \pm SD)
Shell length	175	11.3-30.7 (22.19 \pm 4.42)	134	11.70-40.60 (26.36 \pm 1.51)
Shell height		7.70-19.7 (14.12 \pm 2.53)		8.40-27.00 (17.84 \pm 1.73)
Shell width		4.30-17.80 (8.89 \pm 1.96)		4.90-17.3 (11.7 \pm 1.32)
Total weight		0.24-4.60 (1.86 \pm 0.94)		0.31-10.51 (3.95 \pm 0.99)
Soft tissue weight		0.03-1.63 (0.56 \pm 0.33)		0.06-4.15 (1.32 \pm 0.50)
Shell weight		0.08-3.15 (1.29 \pm 0.66)		0.23-6.71 (2.66 \pm 0.67)
Gonad weight		0.009-0.80 (0.16 \pm 0.02)		0.009-1.48 (0.32 \pm 0.020)

No.: individual counts, min: minimum, max: maximum, SD: standard deviation

Table 2. Average, maximum and minimum values of shell measurements (mm) and body weights (g) of *Venerupis aurea* at the sample sites.

Site	Class size	Average							Maximum							Minimum						
		L	H	W	T.wt	S.wt	Sh.wt	G.wt	L	H	W	T.wt	S.wt	Sh.wt	G.wt	L	H	W	T.wt	S.wt	Sh.wt	G.wt
Taawen	10.1-15	13.80	9.10	4.80	0.40	0.10	0.30	0.01	13.80	9.10	4.80	0.40	0.10	0.30	0.01	13.80	9.10	4.80	0.40	0.10	0.30	0.01
	15.1-20	18.12	11.91	7.56	1.04	0.30	0.75	0.12	20.00	13.20	8.80	1.33	0.46	0.99	0.80	16.30	10.70	6.20	0.73	0.14	0.51	0.02
	20.1-25	22.38	14.44	9.20	1.83	0.61	1.22	0.17	25.00	16.20	11.30	2.74	0.98	1.82	0.40	20.20	11.70	7.20	0.71	0.25	0.21	0.02
	25.1-30	27.04	16.88	10.64	3.03	0.98	2.05	0.31	29.50	18.70	12.80	4.60	1.62	3.15	0.58	25.20	15.30	8.50	1.98	0.53	1.30	0.12
	30.1-35	30.20	18.30	11.80	3.39	1.63	1.76	0.43	30.20	18.30	11.80	3.39	1.63	1.76	0.43	30.20	18.30	11.80	3.39	1.63	1.76	0.43
Total Taawen		22.47	14.39	9.12	1.94	0.63	1.31	0.19	30.20	18.70	12.80	4.60	1.63	3.15	0.80	13.80	9.10	4.80	0.40	0.10	0.21	0.01
Bridge	10.1-15	12.70	8.95	4.85	0.36	0.07	0.29	0.01	14.10	10.20	5.30	0.44	0.09	0.35	0.01	11.30	7.70	4.40	0.28	0.05	0.23	0.01
	15.1-20	18.24	12.08	7.50	1.13	0.34	0.79	0.10	20.00	13.50	8.70	1.61	0.47	1.15	0.20	16.00	10.20	5.50	0.54	0.15	0.38	0.03
	20.1-25	22.33	14.23	9.17	1.79	0.57	1.23	0.17	24.90	15.30	10.70	2.28	0.84	1.69	0.38	20.10	12.60	7.80	1.26	0.36	0.84	0.09
	25.1-30	26.94	16.47	10.80	2.83	0.89	1.93	0.26	29.00	17.50	13.00	3.90	1.27	2.89	0.40	25.10	15.00	9.50	2.23	0.65	1.42	0.13
	30.1-35	30.70	18.30	12.50	4.25	1.59	2.66	0.54	30.70	18.30	12.50	4.25	1.59	2.66	0.54	30.70	18.30	12.50	4.25	1.59	2.66	0.54
Total Bridge		23.27	14.63	9.43	2.09	0.66	1.43	0.19	30.70	18.30	13.00	4.25	1.59	2.89	0.54	11.30	7.70	4.40	0.28	0.05	0.23	0.01
Etap	10.1-15	13.32	11.08	6.45	1.05	0.36	0.69	0.14	14.80	19.70	11.90	4.04	1.21	2.83	0.42	11.40	7.90	4.30	0.24	0.03	0.08	0.02
	15.1-20	17.55	11.14	6.72	0.96	0.18	0.77	0.05	20.00	13.40	8.10	2.80	0.40	2.58	0.15	15.30	9.10	5.40	0.51	0.05	0.23	0.02
	20.1-25	22.59	14.02	9.09	1.65	0.43	1.22	0.10	24.60	15.90	17.80	2.45	0.77	1.68	0.29	20.20	12.20	6.90	1.07	0.26	0.81	0.03
	25.1-30	27.28	17.01	9.76	2.60	0.74	1.86	0.22	29.50	18.40	11.60	3.81	1.02	2.80	0.35	25.20	16.10	4.30	1.03	0.36	0.15	0.02
	30.1-35	30.50	18.60	11.25	3.89	1.09	2.80	0.22	30.70	19.40	12.30	4.24	1.21	3.03	0.22	30.30	17.80	10.20	3.53	0.96	2.57	0.21
Total Etap		20.89	13.35	8.15	1.58	0.41	1.17	0.11	30.70	19.70	17.80	4.24	1.21	3.03	0.42	11.40	7.90	4.30	0.24	0.03	0.08	0.02
Grand Total		22.19	14.12	8.89	1.87	0.57	1.30	0.17	30.70	19.70	17.80	4.60	1.63	3.15	0.80	11.30	7.70	4.30	0.24	0.03	0.08	0.01

L: shell length, H: shell height, W: shell width, T.wt: total weight, S.wt: soft tissue weight, Sh.wt: shell weight and G.wt: gonad weight

Table 3. Average, maximum and minimum values of shell measurements (mm) and body weights (g) of *Ruditapes decussatus* at the sample sites.

Site	class size	Average							Maximum							Minimum						
		L	H	W	T.wt	S.wt	Sh.wt	G.wt	L	H	W	T.wt	S.wt	Sh.wt	G.wt	L	H	W	T.wt	S.wt	Sh.wt	G.wt
Taawen	15.1-20	18.30	12.30	7.50	1.14	0.36	0.78	0.04	19.60	13.20	7.90	1.31	0.44	0.87	0.05	17.00	11.40	7.10	0.97	0.28	0.69	0.02
	20.1-25	22.08	14.96	9.27	2.07	0.65	1.42	0.15	24.70	16.60	10.50	3.38	0.99	2.39	0.27	20.20	12.80	7.30	1.26	0.36	0.81	0.06
	25.1-30	27.45	18.81	11.61	3.72	1.31	2.41	0.34	29.00	20.60	13.60	5.31	2.19	3.12	0.83	25.60	17.00	10.50	2.55	0.82	1.55	0.19
	30.1-35	32.19	22.21	14.19	6.16	2.21	3.96	0.62	34.80	23.70	15.50	7.99	2.87	5.15	1.14	30.20	20.80	13.20	4.33	1.50	2.83	0.36
	35.1-40	36.88	24.80	15.80	9.10	3.62	5.48	1.12	37.80	25.40	16.30	10.03	4.15	6.58	1.48	36.00	23.50	15.00	7.85	3.05	4.80	0.59
Total Taawen		27.26	18.58	11.62	4.14	1.49	2.66	0.41	37.80	25.40	16.30	10.03	4.15	6.58	1.48	17.00	11.40	7.10	0.97	0.28	0.69	0.02
Bridge	20.1-25	23.36	15.46	9.99	2.06	0.81	1.48	0.19	24.90	16.80	11.70	2.76	0.97	1.86	0.30	20.40	13.70	8.30	0.72	0.53	1.04	0.07
	25.1-30	27.60	18.48	11.82	3.91	1.29	2.62	0.33	30.00	20.50	14.40	5.15	1.67	3.50	0.50	25.30	16.20	9.80	2.70	0.86	1.57	0.21
	30.1-35	32.31	21.43	14.11	6.25	2.05	4.20	0.47	34.50	24.00	15.70	7.58	2.59	5.58	0.72	30.20	15.90	9.80	4.99	1.65	3.23	0.29
	35.1-40	36.90	24.20	15.10	8.46	2.66	5.80	0.64	38.60	25.40	16.40	9.68	2.98	6.70	0.94	35.70	23.20	14.10	7.73	2.35	5.32	0.48
Total Bridge		28.15	18.68	12.08	4.77	1.59	3.30	0.38	38.60	25.40	16.40	9.68	2.98	6.70	0.94	20.40	13.70	8.30	0.72	0.53	1.04	0.07
Etap	10.1-15	13.19	10.66	6.50	1.12	0.33	0.79	0.07	14.80	21.20	13.30	5.84	1.89	3.95	0.41	11.70	8.40	4.90	0.31	0.06	0.23	0.01
	15.1-20	17.39	11.86	7.61	1.00	0.26	0.73	0.04	19.70	13.50	9.00	1.46	0.43	1.04	0.15	15.10	10.60	6.50	0.70	0.13	0.49	0.01
	20.1-25	22.20	15.24	9.42	1.99	0.59	1.45	0.09	25.00	17.20	11.10	3.13	0.85	2.28	0.23	20.20	13.70	7.80	1.35	0.39	0.82	0.05
	25.1-30	26.94	17.95	11.18	3.37	1.02	2.35	0.21	29.30	20.10	13.00	4.66	1.38	3.57	0.31	25.10	14.20	8.50	1.86	0.25	1.61	0.08
	30.1-35	33.10	22.81	14.37	6.51	2.22	4.29	0.47	34.90	24.20	15.60	7.67	2.75	4.94	0.76	31.10	21.70	12.80	5.36	0.88	3.88	0.11
	35.1-40	37.18	23.83	15.12	8.18	2.39	5.80	0.63	38.60	25.10	17.20	9.64	3.23	6.41	1.04	35.90	22.50	13.00	7.34	1.49	4.86	0.37
	40.1-45	40.60	27.00	17.30	10.51	3.80	6.71	1.11	40.60	27.00	17.30	10.51	3.80	6.71	1.11	40.60	27.00	17.30	10.51	3.80	6.71	1.11
Total Etap		24.54	16.75	10.49	3.41	1.06	2.36	0.23	40.60	27.00	17.30	10.51	3.80	6.71	1.11	11.70	8.40	4.90	0.31	0.06	0.23	0.01
Grand Total		26.37	17.84	11.27	3.95	1.32	2.66	0.32	40.60	27.00	17.30	10.51	4.15	6.71	1.48	11.70	8.40	4.90	0.31	0.06	0.23	0.01

L: shell length, H: shell height, W: shell width, T.wt: total weight, S.wt: soft tissue weight, Sh.wt: shell weight and G.wt: gonad weight

Table 4. Regression equations and correlation coefficients between shell length and other measurements and weights of *Venerupis aurea* and *Ruditapes decussatus* at the sample sites.

Site	Measurements and weights	<i>Venerupis aurea</i>		<i>Ruditapes decussatus</i>	
		Regression equations	R ²	Regression equations	R ²
Taawen	Shell height	$y = 0.5703x + 1.5334$	0.92	$y = 0.6793x + 0.0665$	0.96
	Shell width	$y = 0.3632x + 0.9389$	0.80	$y = 0.4526x - 0.7184$	0.93
	Total weight	$y = 0.0004x^{2.6819}$	0.88	$y = 0.0002x^{2.9486}$	0.97
	Soft tissue weight	$y = 3E-05x^{3.1154}$	0.86	$y = 2E-05x^{3.3068}$	0.95
	Shell weight	$y = 0.0005x^{2.5173}$	0.70	$y = 0.0003x^{2.7568}$	0.95
	Gonad weight	$y = 3E-06x^{3.4382}$	0.48	$y = 2E-07x^{4.3048}$	0.87
Bridge	Shell height	$y = 0.5063x + 2.847$	0.94	$y = 0.6611x + 0.0662$	0.87
	Shell width	$y = 0.3863x + 0.4495$	0.82	$y = 0.4398x - 0.3057$	0.76
	Total weight	$y = 0.0006x^{2.5735}$	0.93	$y = 8E-05x^{3.2258}$	0.80
	Soft tissue weight	$y = 5E-05x^{3.0093}$	0.90	$y = 0.0001x^{2.7428}$	0.94
	Shell weight	$y = 0.0007x^{2.4206}$	0.90	$y = 1E-04x^{3.0641}$	0.96
	Gonad weight	$y = 4E-06x^{3.409}$	0.73	$y = 3E-05x^{2.822}$	0.71
Etap	Shell height	$y = 0.5081x + 2.7642$	0.72	$y = 0.602x + 1.9778$	0.89
	Shell width	$y = 0.3085x + 1.7292$	0.42	$y = 0.3859x + 1.0238$	0.85
	Total weight	$y = 0.0014x^{2.2654}$	0.68	$y = 0.0006x^{2.6386}$	0.87
	Soft tissue weight	$y = 0.0001x^{2.5887}$	0.59	$y = 8E-05x^{2.8813}$	0.82
	Shell weight	$y = 0.0012x^{2.2199}$	0.47	$y = 0.0006x^{2.5344}$	0.86
	Gonad weight	$y = 0.0004x^{1.7718}$	0.24	$y = 2E-06x^{3.5508}$	0.79

Table 5. Regression equations and correlation coefficients between shell length and other measurements and weights of *Venerupis aurea* and *Ruditapes decussatus* at different seasons.

Season	Measurements and weights	<i>Venerupis aurea</i>	R ²	<i>Ruditapes decussatus</i>	R ²
Winter	Shell height	$y = 0.514x + 2.7698$	0.93	$y = 0.6216x + 0.872$	0.97
	Shell width	$y = 0.3483x + 1.1075$	0.75	$y = 0.3818x + 0.5039$	0.93
	Total weight	$y = 0.0011x^{2.3669}$	0.80	$y = 0.0002x^{2.9732}$	0.89
	Soft tissue weight	$y = 0.0001x^{2.6534}$	0.79	$y = 4E-05x^{3.0305}$	0.87
	Shell weight	$y = 0.0018x^{2.0798}$	0.42	$y = 0.0001x^{2.9281}$	0.98
	Gonad weight	$y = 1E-05x^{2.8905}$	0.38	$y = 2E-06x^{3.5779}$	0.84
Spring	Shell height	$y = 0.4016x + 5.6826$	0.50	$y = 0.4127x + 8.1918$	0.53
	Shell width	$y = 0.3038x + 2.3933$	0.58	$y = 0.2983x + 3.8403$	0.51
	Total weight	$y = 0.0037x^{1.9767}$	0.50	$y = 0.0559x^{1.2935}$	0.33
	Soft tissue weight	$y = 0.0003x^{2.4401}$	0.62	$y = 0.0185x^{1.3069}$	0.32
	Shell weight	$y = 0.0041x^{1.8005}$	0.43	$y = 0.063x^{1.1397}$	0.30
	Gonad weight	$y = 2E-05x^{2.8558}$	0.54	$y = 0.0004x^{1.9908}$	0.34
Summer	Shell height	$y = 0.585x + 1.1573$	0.95	$y = 0.6557x + 0.5329$	0.96
	Shell width	$y = 0.2971x + 1.9935$	0.50	$y = 0.4018x + 0.4545$	0.91
	Total weight	$y = 0.0002x^{2.8866}$	0.96	$y = 0.0003x^{2.816}$	0.96
	Soft tissue weight	$y = 6E-05x^{2.8975}$	0.61	$y = 4E-05x^{3.093}$	0.86
	Shell weight	$y = 5E-05x^{3.3049}$	0.83	$y = 0.0003x^{2.722}$	0.93
	Gonad weight	$y = 0.0051x^{0.973}$	0.07	$y = 3E-06x^{3.3807}$	0.72
Autumn	Shell height	$y = 0.5645x + 1.4687$	0.92	$y = 0.6539x + 0.5654$	0.94
	Shell width	$y = 0.409x - 0.0878$	0.66	$y = 0.4367x - 0.0252$	0.90
	Total weight	$y = 0.0004x^{2.6911}$	0.89	$y = 0.0003x^{2.8644}$	0.98
	Soft tissue weight	$y = 1E-05x^{3.4278}$	0.86	$y = 3E-05x^{3.233}$	0.97
	Shell weight	$y = 0.0006x^{2.4312}$	0.85	$y = 0.0003x^{2.6959}$	0.98
	Gonad weight	$y = 8E-07x^{3.8788}$	0.70	$y = 1E-07x^{4.3969}$	0.91

Table 6. Regression equations in the relationships between shell length and other measurements and weights of *Venerupis aurea* in the present and previous (GABR, 1991) study.

Site	Measurements and weights	Present study	Previous study
Taawen	Shell height	$y = 0.5703x + 1.5334$	$y=0.583x+ 0.733$
	Shell width	$y = 0.3632x + 0.9389$	$y = 0.357x - 0.052$
	Total weight	$y = 0.0004x^{2.6819}$	$y= 3.003x - 3.953$
	Soft tissue weight	$y = 3E-05x^{3.1154}$	$y = 2.997x - 4.386$
	Shell weight	$y = 0.0005x^{2.5173}$	$y = 3.562x - 4.902$
Etap	Shell height	$y = 0.5081x + 2.7642$	$y=0.522x+1.784$
	Shell width	$y = 0.3085x + 1.7292$	$y=0.365x+ 0.064$
	Total weight	$y = 0.0014x^{2.2654}$	$y = 2.732x - 3.609$
	Soft tissue weight	$y = 0.0001x^{2.5887}$	$y= 2.732 - 3.609$
	Shell weight	$y = 0.0012x^{2.2199}$	$y=2.568x - 3.584$