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POPULATION DYNAMICS OF *VENERUPIS AUREA* (BIVALVIA: VENERIDAE) IN TWO DIFFERENT CLAM'S BEDS IN LAKE TIMSAH, SUEZ CANAL, EGYPT

SUMMARY

The clam *Venerupis aurea* (Gmelin, 1971) is one of the most commercially important bivalves in Lake Timsah, Suez Canal. Population dynamics for this clam was explored from August 2015 to September 2016 at two clam beds; Taawen site and Etap site of different sediment characters, population densities and fishing exploitation in the lake. The average density of the species at the exploited Taawen site (3,930 ind. m^{-2}) was significantly higher (one way ANOVA, $P = 5.15$) than at unexploited Etap site (1,141 ind. m^{-2}). Length frequency data were analyzed by FiSAT software for estimation of population parameters to evaluate the status of the stock. Asymptotic length ($L\infty$) was similar (36.57 mm) in the two beds. Growth coefficient (K) was higher in Etap site (0.36 yr^{-1}) than in Taawen site (0.28 yr^{-1}). The theoretical lifespan (T_{max}) was higher in Taawen site (12.4 years) than in Etap site (9.7 years). Total mortality (Z) was estimated by length-converted catch curve at 0.81 and 0.98 yr^{-1}, fishing mortality (F) at 0.11 and 0.22 yr^{-1} and natural mortality (M) at 0.70 and 0.76 yr^{-1} for Taawen site and Etap site, respectively. The estimated value of the exploitation rate (E) was higher in Etap site (0.23) than in Taawen site (0.14). The recruitment pattern was continuous with two major peaks in the two beds and was found to be correlated with the spawning pattern in the species. Recruited juvenile relative to the total population all over the study period was higher in Taawen site (34.50%) than in Etap site (20.47%). Overexploitation can only be mitigated by imposing stringent restrictions in terms of the minimum size for exploitation (12 mm shell length) and closed seasons during the spawning peak (September, December and April).

INTRODUCTION

Veneridae is the most diverse recent bivalve family, comprising over 800 extant, presumably valid species in approximately 170 genera (Mikkelsen *et al.*, 2006). *Venerupis* is a genus of marine clams that belong to the family Veneridae. This genus together with other clams presents one of the main components of mollusk production and makes up about 22% of the total mollusk production in the world (FAO, 2015).

Veneridae represents the most abundant and successful group of bivalves in Lake Timsah (Fouda and Abou-Zied, 1990; Ghobashy *et el.*, 1992; Mohammed *et al.*, 1992). According to Ansell (1961), members of the Veneridae are suspension feeders and shallow-burrowing in relatively soft substrata. *Venerupis aurea* (Gmelin, 1791), locally know as smooth Gandofly, is the most common Venerides in Lake Timsah and a popular shellfish resource harvested mainly for food. The species is endemic to the Mediterranean Sea and have penetrated through the Suez Canal and successfully colonized Lake Timsah (Fouda and Abou-Zied, 1990). This species was first recorded from the Canal by Tillier and Bavay (1905).

V. aurea is of great economic importance, being consumed in large quantities in the Suez Canal region, and also being exported to some European countries. Thus, it is extensively fished in Lake Timsah. Overfishing could result in depletion or destruction of its natural beds.

In spite of the commercial importance and increasing demand of *V. aurea*_in Egypt, there have been few detailed studies on its biology in the region of the Suez Canal. Quantitative estimates of individual gamete production in natural populations of Lake Timsah were studied by Kandeel (2006). Weight-length relationships and monthly changes in body weights and condition indices in relation to water temperature and gonadal cycle were also studied (Kandeel, 2008). Recruitment pattern of *V. aurea* was investigated at three sites of varying adult densities in the southern region of Lake Timsah (Kandeel, 2013). Mohammad *et al.* (2014) investigated population structures, growth characteristic, and age and gametogenic cycle of the species in Lake Timsah. The present study provides the first data available on the population dynamics of *V. aurea*. This study analyzes two different populations of *V. aurea* in Lake Timsah by estimating the parameters of their growth, recruitment, mortality, and exploitation rate. The knowledge of such data of commercially exploited bivalve species is a crucial requirement for the successful management of the fishery (Gaspar *et al.*, 2004).

MATERIALS AND METHODS

Study area

The Suez Canal lies between 29° 55` and 31° 25` N and 32° 15` and 32° 35` E. It extends approximately 163 km between Port Said in the N and Suez in the S (Fig. 1).The canal connects the Red Sea and the Mediterranean, which differ fundamentally both faunistically and hydrographically. Lake Timsah, the area of the present study, is a small and shallow water body and lies at the middle of the Suez Canal between 30°33`and 30°35` N and 32°16`and 32°19`E. It has a surface area of about 15 km^2 and a depth ranging from 6 to 13 m.

Sampling procedure

Venerupis aurea was collected monthly from August 2015 to September 2016 at two sites; exploited Taawen site and unexploited Etap site (Fig. 1). At each site, four randomly selected quadrates (each with an area of 116/ m^2) were dug to a depth of 10 cm and sieved in the field through 1 mm screen.

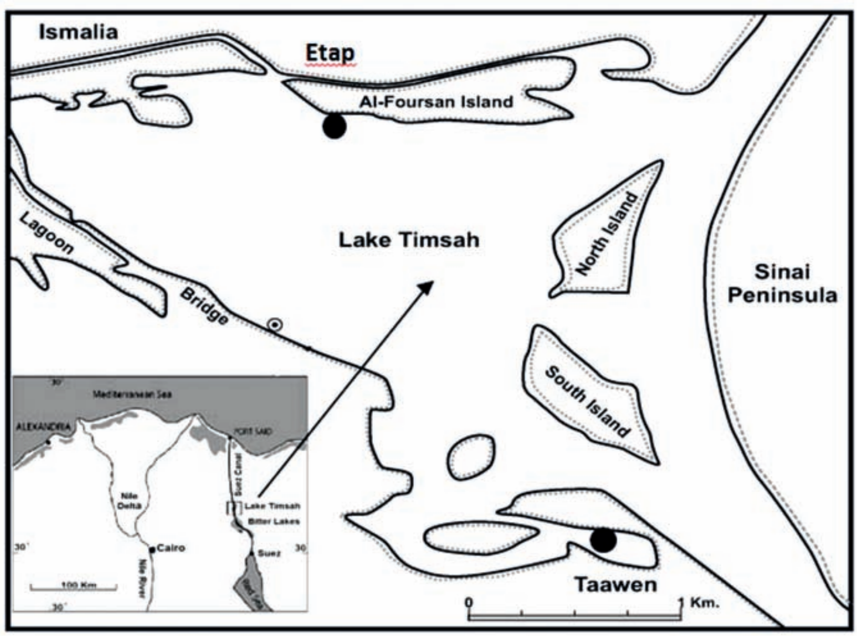

Fig. 1. Map of the Suez Canal showing sampling sites (•) in Lake Timsah.

The clams retained by the sieve were kept in labeled containers filled with 5% formaldehyde-seawater solution. Sediment samples were also collected from the two sites using a 5-cm diameter corer taken a sediment depth of 10-cm. Three replicate cores were taken at each site.

Taawen:
this site is in Taawen bay at the S region of Lake Timsah. Taawen bay itself is shallow semi-enclosed bay of water used extensively for commercial fishing the venerides *V. aurea* and *Tapes decussata*. *V. aurea* was found in the greatest densities in the S part of Lake Timsah (Taawen Site) but also it was found in smaller numbers in all other regions of the Lake. Sand and gravel are the dominant sediment types at this site. The associated mollusks were *T. decussate*, *Modiolus arcutulus* and *Cerithium scabridum*. Water temperature ranged from 15 to 35°C over the study period and salinity ranged from 36 to 44‰.

Etap:
this site is in the N Lake Timsah. For the majority of the site the water is shallow for a considerable distance offshore. Etap site is far from extensive fishing. Sediment type is muddy sand. Empty shells and dead individuals of *V. aurea* were found in this site during sampling. The associated mollusks were *T. decussata*, *Cerastoderma glaucum,* and *Cyclope neritea*. This site was characterized by a high number of species but with low numbers of individuals. Water temperature ranged from 14.8 to 28.4°C and salinity ranged from 34 to 40‰ over the study period.

Laboratory procedure

In the laboratory, shell length (SL) (i.e. anterior to posterior tips of the shell) of each clam was measured to the nearest 0.1 mm using a Vernier caliper. Length measurements were used to produce length-frequency distribution for each sample collected from the two sites using class intervals of 1 mm size.

Data analysis
Sediment analysis

Sediment characteristics including organic matter content were determined following the methods described in Buchanan (1984). Sediments were dried to constant weight at 60 °C. Dried sediment sub-samples (100 g) were shaken for 15-min intervals using a mechanical shaker with nested sieves to separate the sediments into 0.5, 0.25, 0.125, 0.063 and < 0.063 (i.e. collecting pan) mm particle fractions. Sediments are described by a transformation of particle size (mm) to the phi (φ) units:

$$\varphi = -\log \text{ of sediment particle size (mm)}$$

The weight percentages of each fraction were used to construct cumulative curves (Buchanan, 1984). From these curves, the median diameter (Mdφ), the quartile deviation (QDφ) and the quartile skewness (Skq φ) were calculated as measures of the central tendency, the degree of scatter and the degree of asymmetry of the grain size frequencies, respectively. The percent organic matter was calculated from the weight loss on ignition of sediment from a dry 5-g sub-sample placed in electric muffle furnace at 600°C for 1h.

Abundances

The abundance (ind. m^{-2}) of *V. aurea* at Taawen site and Etap site were determined and compared using one way ANOVA.

Von Bertalanffy growth parameters

Monthly length-frequency data were analyzed using the FiSAT II software as explained in detail by Gayanilo *et al.* (2005). The growth parameters; asymptotic shell length ($L\infty$ in mm) and growth co-efficient (K, yr^{-1}) of the Von Bertalanffy Growth Formula (VBGF) were estimated by means of ELEFAN-I (Pauly and David, 1981; Pauly and Morgan, 1987). Additional estimates of $L\infty$ and Z/K values were obtained by plotting $\bar{L}$ minus L′ on $\bar{L}$ (Wetherall, 1986 as modified by Pauly, 1986), i.e.

$$\bar{L} - L' = a + b\,\bar{L}$$

Where, $L\infty = -a/b$ and $Z/K = -(1 + b)/b$

$\bar{L}$ is defined as the mean length computed from L′ upward in a given length-frequency sample, while L′ is the limit of the first length class used in computing a value of $\bar{L}$.

The estimates of $L\infty$ and K were used to compute the growth performance index, Φ' (Pauly and Munro, 1984) using the equation:

$$\Phi' = \log(K) + 2\log(L\infty)$$

The negative correlation between $L\infty$ and K invalidates comparison based on individual parameters (Pauly and Munro, 1984). As a result, comparison of the growth performance of population of bivalve is better fitted by Φ' (Valiky, 1990). This index also enables comparisons of the growth performances of specimens at different sampling sites and also with other of closely-related species.

The inverse von Bertalanffy growth equation (Sparre and Venema 1992) was used to find the lengths of *V. aurea* at various ages. Then VBGF was fitted to estimates of length-at-age curve using non-linear squares estimation procedures (Gayanilo *et al.*, 2005).The VBGF is defined by the equation:

$$L_t = L_\infty [1 - e^{-K(t - t_0)}]$$

Where, L_t = mean length at age t, L_∞ = asymptotic length, K = growth coefficient, t = age of the *V. aurea*, and t_0 = the hypothetical age at which the length is zero (Pauly and David, 1981). t_0 was computed according to Lopez (1979):

$$t_0 = 1/ K\ln [(L\infty - Lc) / L\infty]$$

Lc is the average length (mm) of recruits representing the first observed mode. In this study, Lc was 5 mm in Taawen site and 4 mm in Etap site.

The theoretical maximum age; longevity (T_{max}) was calculated for each population using the following equation constructed by Michaelson and Neves (1995),

$$T_{max} = \frac{1n\ L_\infty + Kt_\circ}{K}$$

Mortality and exploitation rate

Total mortality (Z, yr $^{-1}$) was estimated by length-converted catch curve method (Pauly, 1983a; 1990). FiSAT outputs Z yr $^{-1}$ as well as the 95% confidence intervals surrounding Z based on the goodness of fit of the regression.

Natural mortality rate (M) was derived through the empirical equation of Pauly (1980):

$$\text{Log}_{10} M = -0.0066 - 0.279 \text{ Log}_{10} L\infty + 0.6543 \text{ Log}_{10} K + 0.4634 \text{ Log}_{10} T$$

Where, L∞ is expressed in mm and T, the mean annual surface habitat temperature which were 27° C and 25° C over the study period at Taawen and Etap sites, respectively.

Once Z and M were obtained, then fishing mortality rate (F, yr $^{-1}$) was estimated using the relationship: F = Z – M, where Z is the total mortality, F, is fishing mortality; mortality due to harvesting by humans, and M is natural mortality; mortality due to predation, disease, etc.

The exploitation rate (E) is the portion of total mortality due to fisheries and was obtained by the relationship of Gulland (1971):

$$E = F/Z = F/ (M + F)$$

Recruitment pattern

In the present study, recruitment was defined as the period when juvenile individuals are captured by a 1-mm mesh size sieve. The minimum size at maturity for *V. aurea* collected from Lake Timsah was 12 mm shell length during summer (Kandeel, 2017). Thus, recruits were defined as individuals with < 12-mm shell length. The percentage occurrence of these recruits relative to the total population was estimated throughout the study period.

Also, the routine in FiSAT reconstructed the recruitment pulses from a time series of length-frequency data to determine the number of pulses per year and the relative strength of each pulse using the VBGF parameters (Moreau and Cuende 1991; Pauly, 1983b). Normal distribution of the recruitment pattern (%) was determined by NORMSEP (Pauly and Caddy, 1985) in FiSAT.

Virtual population analysis

Length-structured virtual population analysis (VPA) modified from Jones and Van Zalings (1981) was adapted to accommodate length-frequency data representing mean annual catch at length.

RESULTS

Sediment characters

Sediment characteristics including the statistical parameters derived from the cumulative frequency curves are listed in Tab. 1. On the basis of the Wentworth scale, the sediments were described as medium sand and fine sand at Taawen site and Etap site, respectively. The quartile deviation (QDφ) indicates that the sediment particles fell within the moderately well sorted categories as defined by Folk (1974). The two sites have negatively skewed sediments (- 0.05) indicating the presence of a higher coarse fraction. The highest proportion (12.7%) of coarse sediment (> 0.5 mm) and the lowest content of organic matter (1.1%) were recorded at Taawen site.

Tab. 1. Sediment characteristics at Taawen site and Etap sit in Lake Timsah.

Site	Coarse sediment >0.5 mm (%wt.)	Fine sediment <0.063 mm (%wt.)	Median diameter (Mdφ)	Wentworth scale	Quartile deviation (QDφ)	Categories of sorting	Quartile skewness ($Sk_q\varphi$)	Mean% organic content
Taawen site	12.7	2.0	2.1	Medium sand	0.55	Moderately well sorted	-0.05	1.1
Etap sit	11.3	2.0	2.3	Fine sand	0.65	Moderately well sorted	-0.05	1.7

Population size

The population size of *V. aurea* at Taawen site ranged from 1,016 ind. m^2 (in October 2015) to 6,672 ind. m^2 (in April 2016) throughout the study period (Fig. 2). The mean value (X) ± S.D. = 3,930 + 1,738 ind. m^2. At Etap Site, *V. aurea* was found as not abunddant (one way ANOVA, *P* = 5.15) if compared with Taawen site. The values of Etap site varied between 348 ind. m^2 (in October 2015) and 1,896 ind.m^2 (March 2016) (Fig. 2). (X ± S.D. = 1,141 + 560 ind.m^2).

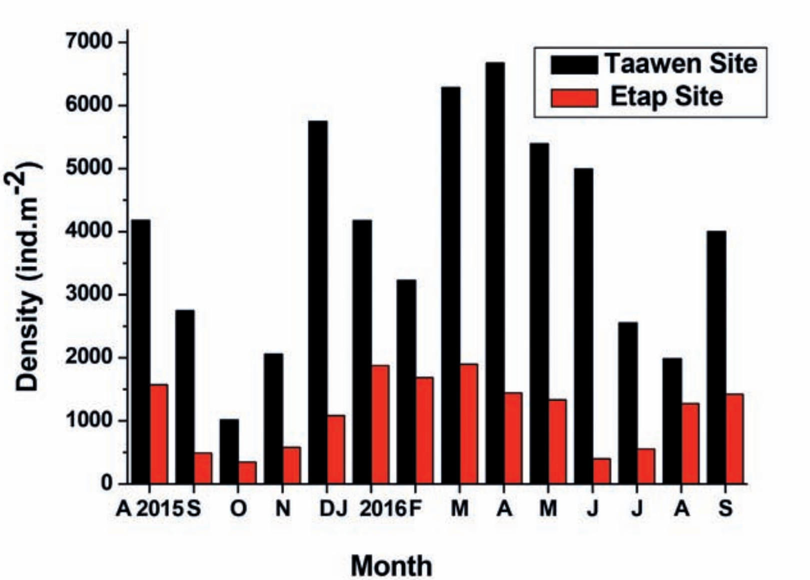

Fig. 2. Monthly densities (ind.m^{-2}) of *V. aurea* at Taawen site and Etap site, Lake Timsah.

Population structure

Variations in the percentage occurrence of the different size classes of *V. aurea* collected from Taawen site and Etap site were presented in Fig. 3. The broad length range varied between 2 - 31 mm and 2 - 35 mm of shell length for the two sites, respectively. Two peaks were observed corresponding to individuals with 10 and 18 mm shell length in Taawen site and with 9 and 18 mm shell length in Etap site. Individuals with a shell length of > 8 and < 21 mm comprised 75.6% and 69.0% of the total population in Taawen and Etap site, respectively. Large-size individuals (> 22 mm SL) represented only 11.62 and 24.61% for total samples collected from Taawen site and Etap site, respectively. The largest animal ever found was 35.8 and 36.4 mm shell length in the two sites, respectively.

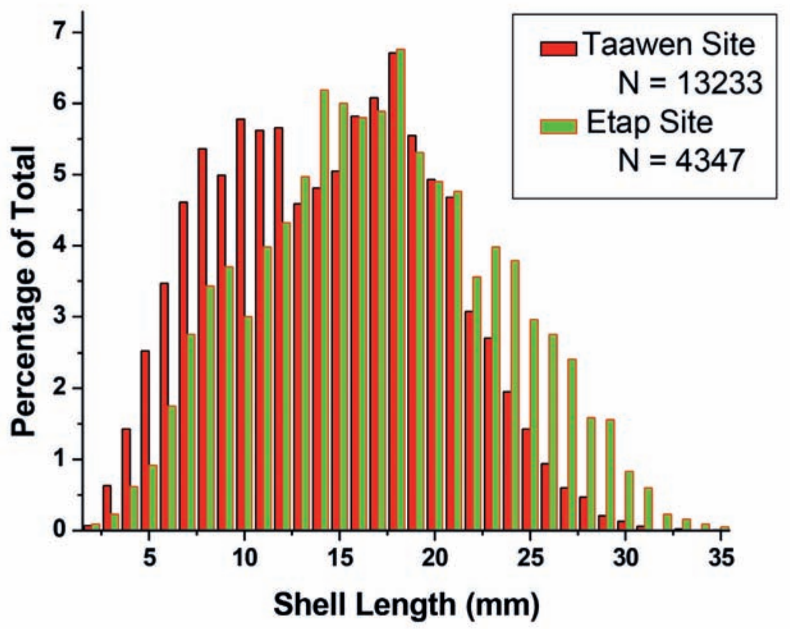

Fig. 3.Variations in the percentage occurrence of the différent size classes of *V. aurea* collected from Taawen site and Etap site throughout the study périodes. N = number of individuels examined.

Growth parameters

The observed extreme length (35.00 mm) and the computer predicted maximum length (34.05 mm) were similar in Taawem site and Etap site (Fig. 4 and Fig. 5). The range of 95% confidence interval for the maximum length was 32.43 – 35.67 mm for the two beds.

The Powell-Wetherall plot is shown in Figure 6 for Taawen population. The corresponding estimates of L∞ and Z/K were 26.89 mm and 1.46, respectively and the correlation coefficient for the regression line was -0.985 (*a* = 10.93 and *b* = -0.407). For Etap population (Fig. 7), the estimates of L∞ and Z/K were 33.17 mm and 3.57, respectively and the correlation coefficient for the regression line was -0.992 (*a* = 7.25 and *b* = -0.219).

The ELEFAN-I (Electronic Length Frequency) Analysis program estimated asymptotic length (L∞) and growth co-efficient (K) of the Von Berttalenfy Growth Formula (VBGF). L∞ was similar (36.75 mm) in the two studied populations. K was 0.28 yr^1 and 0.36 yr^1 for clams collected from Taawen site and Etap site, respectively. For these estimates through ELEFAN-I, the response surface (Rn) used for the curves were 0.178 (Fig. 8) and 0.156 (Fig. 9) for the two sites, respectively. Figure 10 and Figure 11 show von Bertalanffy growth curves superimposed on restructured length frequency histograms for *V. aurea* collected from Taawen site and Etap site, respectively. Growth performance index (*Φ'*) of Pauly and Munro (1984) was 2.58 and 2.69 in the two sites, respectively (Tab. 2).

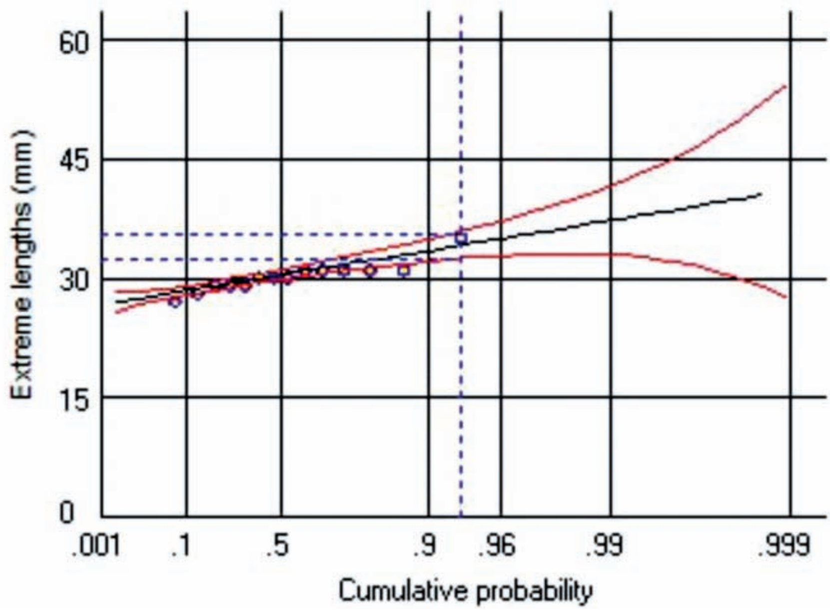

Fig. 4. Predicted extreme length of *V. aurea* (34.05 mm) collected from Taawen site.

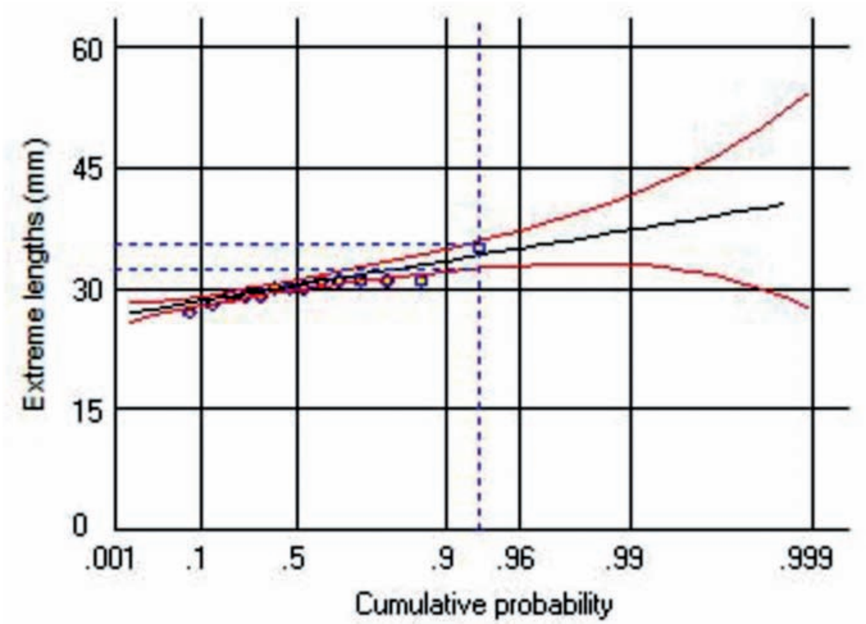

Fig. 5. Predicted extreme length of *V. aurea* (34.05 mm) collected from Etap site.

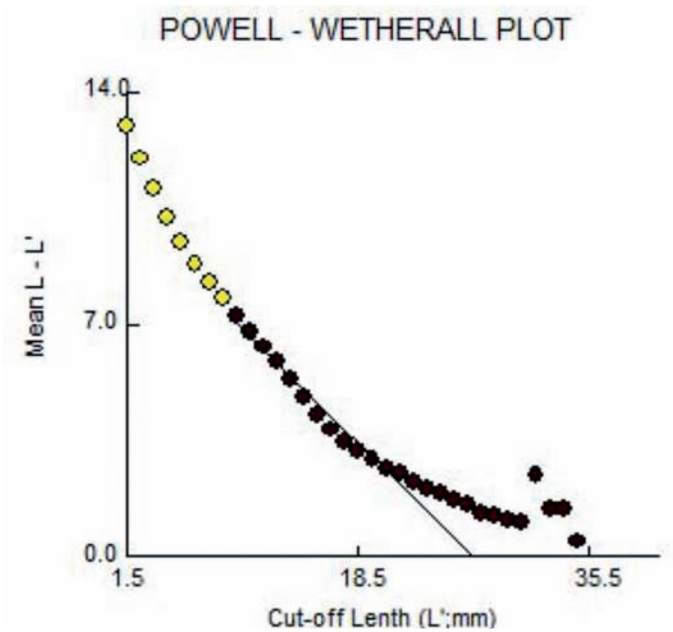

Fig. 6. Powell-Wetherall plot of the estimation of L∞ (26.89 mm) and Z/K (1.46) for *V. aurea* collected from Taawen site.

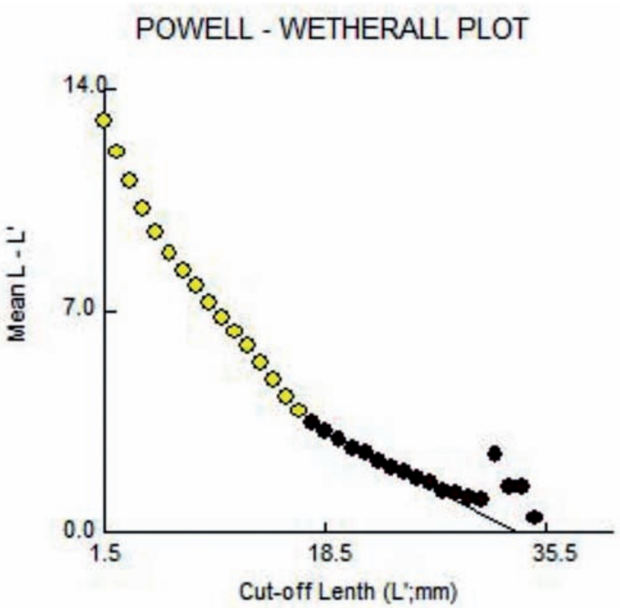

Fig. 7. Powell-Wetherall plot of the estimation of L∞ (33.17 mm) and Z/K (3.57) for *V. aurea* collected from Etap site.

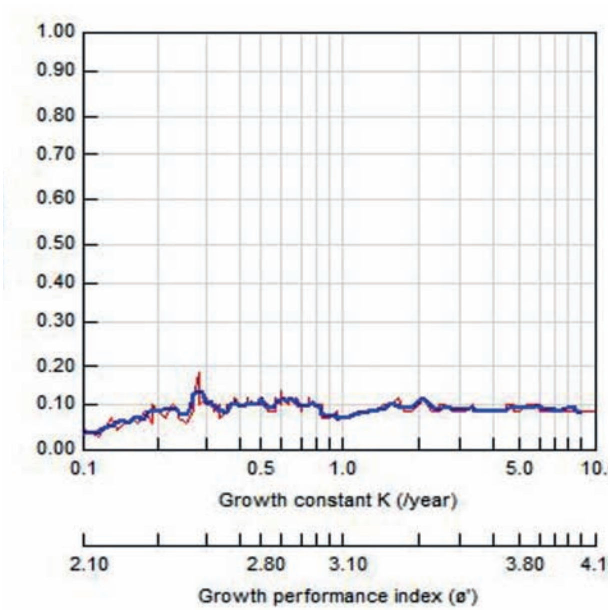

Fig. 8. Scan of "K" value for *V. aurea* collected from Taawen site.

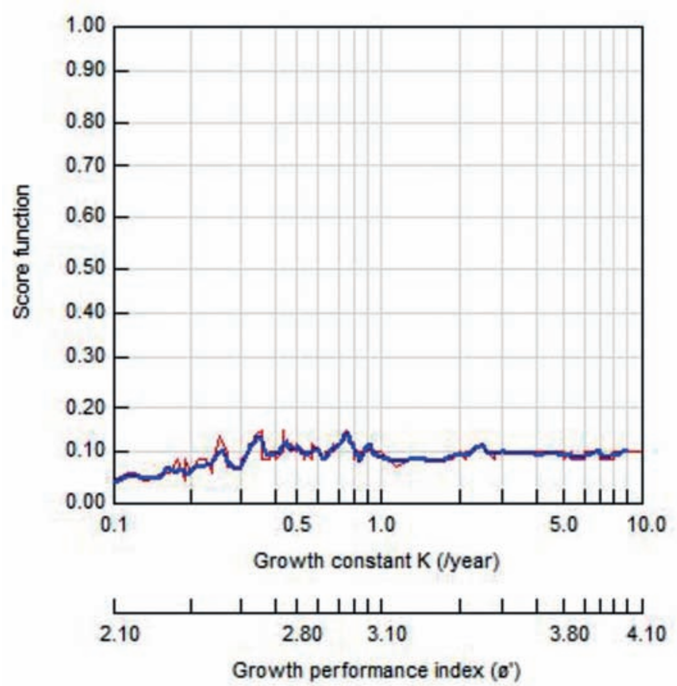

Fig. 9. Scan of "K" value for *V. aurea* collected from Etap site.

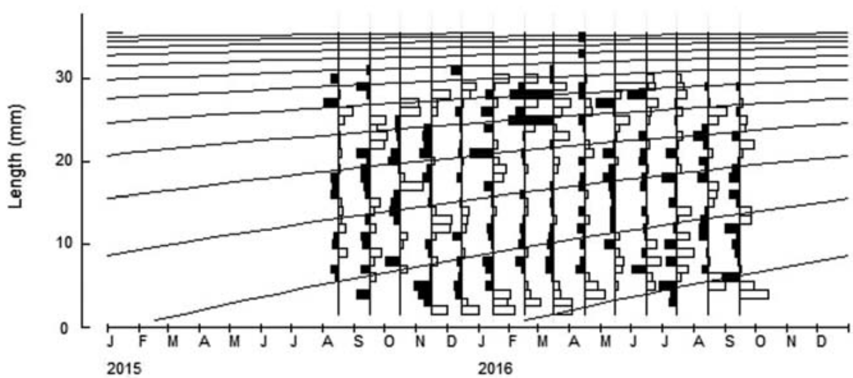

Fig. 10. Von Bertalanffy growth curves ($L\infty$ = 36.75 mm, K= 0.28 yr^{-1} and Rn = 0.178) superimposed on restructured length frequency histograms of *V. aurea* in Taawen site using ELEFAN 1.

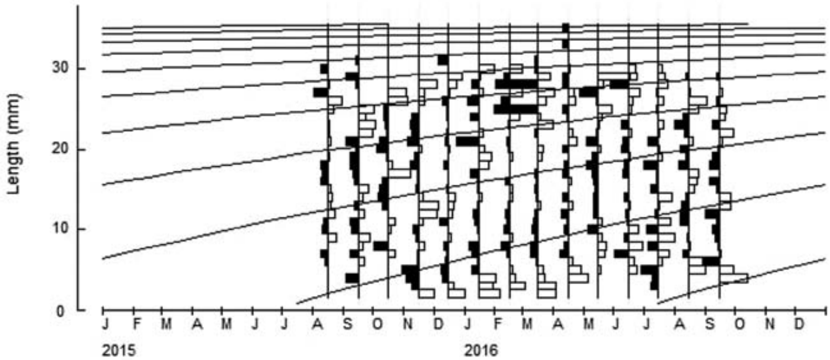

Fig. 11. Von Bertalanffy growth curves (L∞ = 36.75 mm, K= 0.36 yr^{-1} and Rn = 0.156) superimposed on restructured length frequency histograms of *V. aurea* in Etap site using ELEFAN 1.

Tab. 2. Population parameters of *V. aurea* collected from Taawen site and Etap site.

Population parameters	**Taawen site**	**Etap site**
Asymptotic length (L∞) in mm	36.75	36.75
Growth co-efficient (K) yr^{-1}	0.28	0.36
The theoretical age of birth (t_0) yr^{-1}	-0.52	-0.32
Growth performance index (Φ')	2.58	2.69
The theoretical maximum age (T_{max}) yr	12.4	9.7
Natural mortality (M) yr^{-1}	0.70	0.76
Fishing mortality (F) yr^{-1}	0.11	0.22
Total mortality (Z) yr^{-1}	0.81	0.98
Exploitation rate (E)	0.14	0.23
Length range (mm)	2-35	2-36
Sample number (N)	13233	4347
Mean population density (ind/m^2)	3930	1141
Recruits relative to the total population	34.50 %	20.47 %

Age and growth

Using von Bertalanffy growth parameters (L_∞, K, t_0), relationship between length and age is defined as follows:

$$L_t = 36.75\,[1 - e^{-0.28\,(t + 0.52)}] \qquad \text{Taawen site}$$

$$L_t = 36.75\,[1 - e^{-0.36\,(t + 0.32)}] \qquad \text{Etap site}$$

Curves of age and shell length for *V. aurea* in the two sites are illustrated in Fig. 12. Most individuals were in the younger age groups. The sizes attained at Taawen site were 12.8, 18.6 and 23.0 mm at the end of 1st, 2nd and 3rd years of age, respectively. For Etap population, the sizes attained were 13.9, 20.8 and 25.6 mm at the end of these ages, respectively. Therefore, the average growth rate of *V. aurea* through the first three years of life was higher in Etap site (10.9 mm. yr^1) than in Taawen site (9.9 mm. yr^1). The theoretical maximum age (lifespan) was higher in Taawen site (12.4 years) than in Etap site (9.7 years)

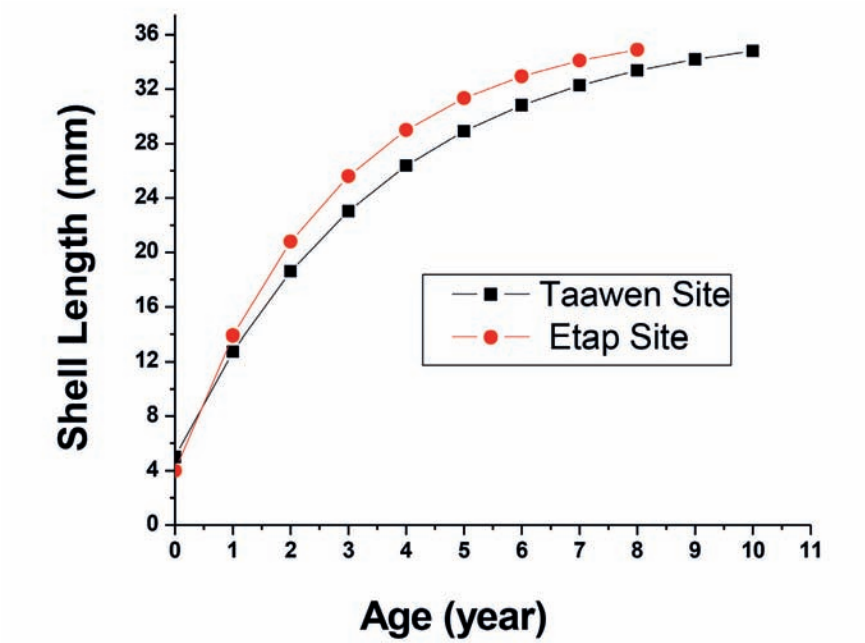

Fig. 12. Von Bertalanffy growth curves in terms of age and size based on calculated growth parameters for *V. aurea* collected from Taawen site and Etap site.

Mortality and exploitation rate

Length-converted catch curve analysis produced total mortality (Z) for *V. aurea* was 0.81 yr^1 (confidence interval; CI = 0.25 - 1.36) and 0.98 yr^1 (CI = 0.31 – 1.66) for Taawen site and Etap site, respectively. The catch curves utilized in the estimation of Z are represented in Fig. 13 and 14 for the two sites, respectively. The darkened circles represent the points used in calculating Z through least square regression analysis. For Taawen samples, the correlation coefficient (*r*) of the regression was -0.9755. The intercept (*a*) and slope (*b*) ±S.D. of the regression line performed on the selected data points were 7.42 ± 1.01 and -0.81 ± 0.13, respectively. On the other hand, the correlation coefficient of Etap samples was -0.9753. The intercept (*a*) and slope (*b*) ± S.D. of the regression line were 7.30 ± 0.99 and -0.98 ± 0.16, respectively.

Estimated value of natural mortality (M) from Pauly's empirical formula was 0.70 yr^{1} in Taawen site and 0.76 yr^{1} in Etap site. Fishing mortality (F) was estimated to be 0.11 and 0.22 yr^{1} and the rate of exploitation (E) was 0.14 and 0.23 at the two sites, respectively (Tab. 2).

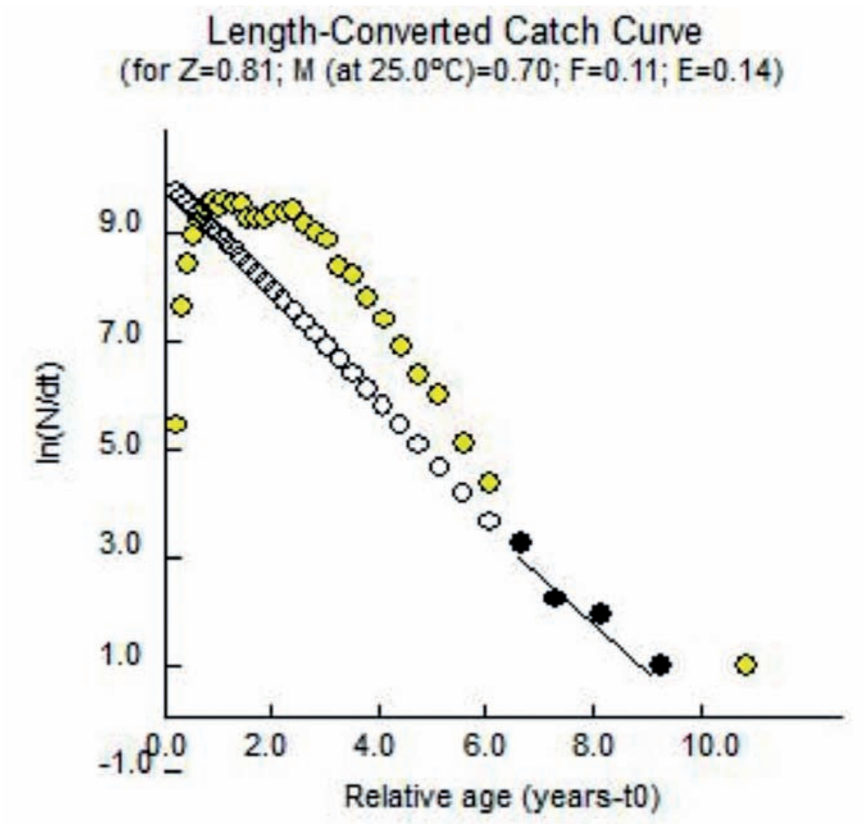

Fig. 13. Length converted catch curve of *V. aurea* collected from Taawen site. Solid dots are those used in calculating the parameters of the straight line, the slope of which (with sign changed) is an estimate of Z. Open dots represent clams not used in mortality estimation.

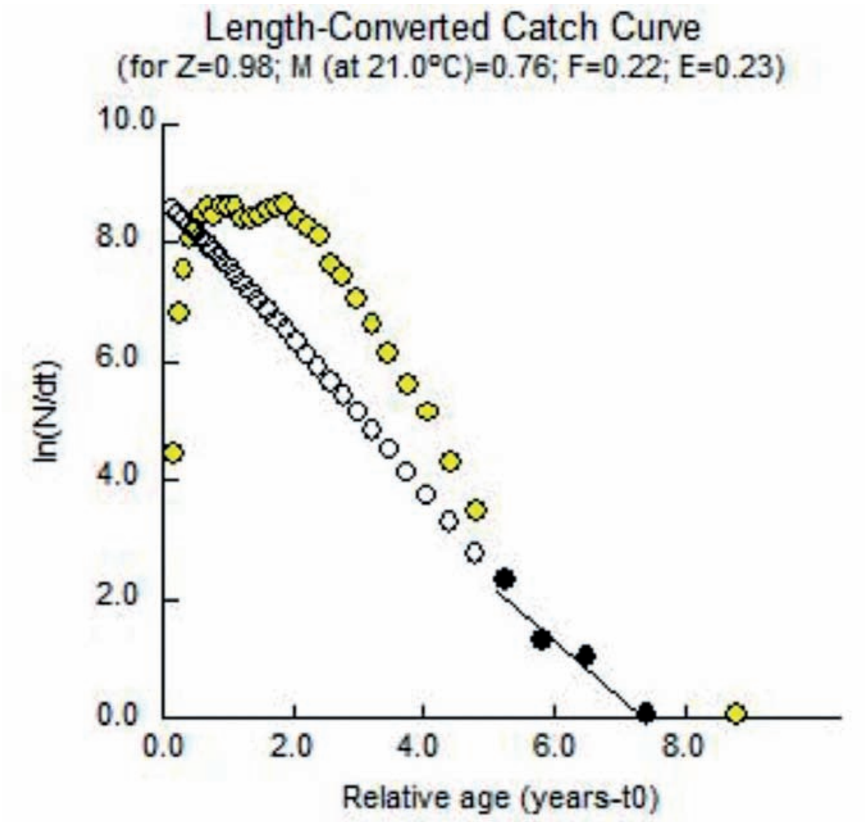

Fig. 14. Length converted catch curve of *V. aurea* collected from Etap site. Solid dots are those used in calculating the parameters of the straight line, the slope of which (with sign changed) is an estimate of Z. Open dots represent clams not used in mortality estimation.

Recruitment pattern

The recruitment pattern for *V. aurea* was continuous during the 14-months study period, and two major peaks were observed during December 2015 (68.80%) and March 2016 (65.18) at Taawen site (Fig. 15).

For Etap site, one maximum was observed during January 2016 (63.54%) and one minimum during August 2016 (26.05%). The recruitment pattern (%) generated by FiSAT at the two sites was also continuous throughout the year with two major pulses. The relative strength of these pulses was 8.21 and 18.29% recruitment for Taawen site (Fig. 16) and 5.36 and 16.80% recruitment for Etap site (Fig. 17).

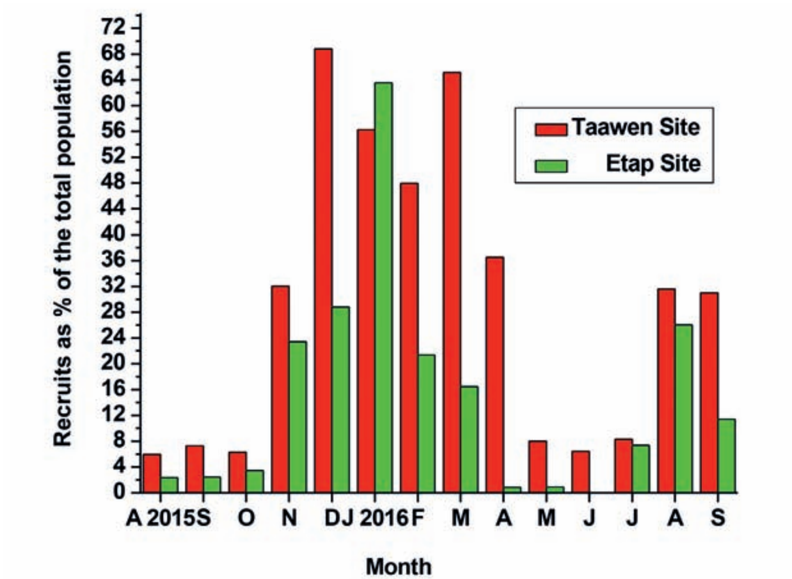

Fig. 15. Monthly variation in the proportion of recruited juveniles (< 12-mm shell length) relative to the total population of *V. aurea* at Taawen site and Etap site.

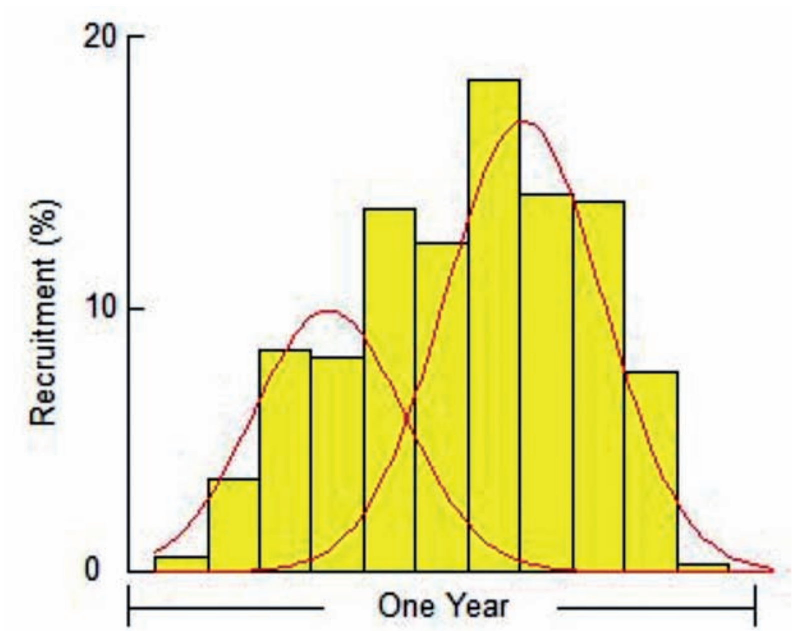

Fig. 16. Recruitment pattern of *V. aurea* from Taawen site showing two major recruitment pulses within a year.

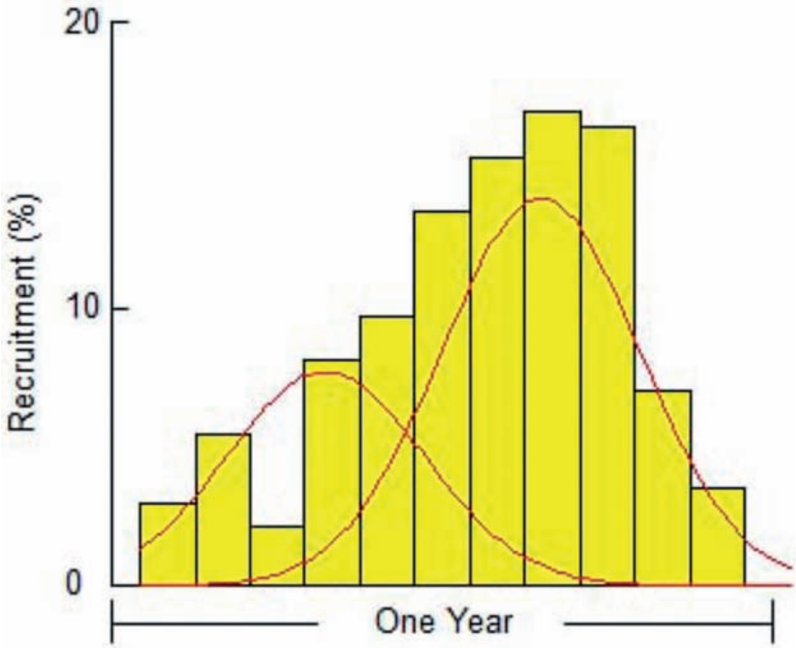

Fig. 17. Recruitment pattern of *V. aurea* from Etap site showing two major recruitment pulses within a year.

Virtual population analysis

The results of length-structured virtual population analysis (VPA) indicated one major peak of fishing mortality (F) in the length group of 18.0 (1.5 yr^{1}) and 21.0 (0.6 yr^{1}) mm for Taawen site (Figure 18) and Etap site (Fig. 19), respectively. Mean annual catch (in numbers) was obvious in Taawen site and the highest values were recorded in the length range between 7.0 - 20.0 mm. On the other hand, mean annual catch was relatively rare in Etap site.

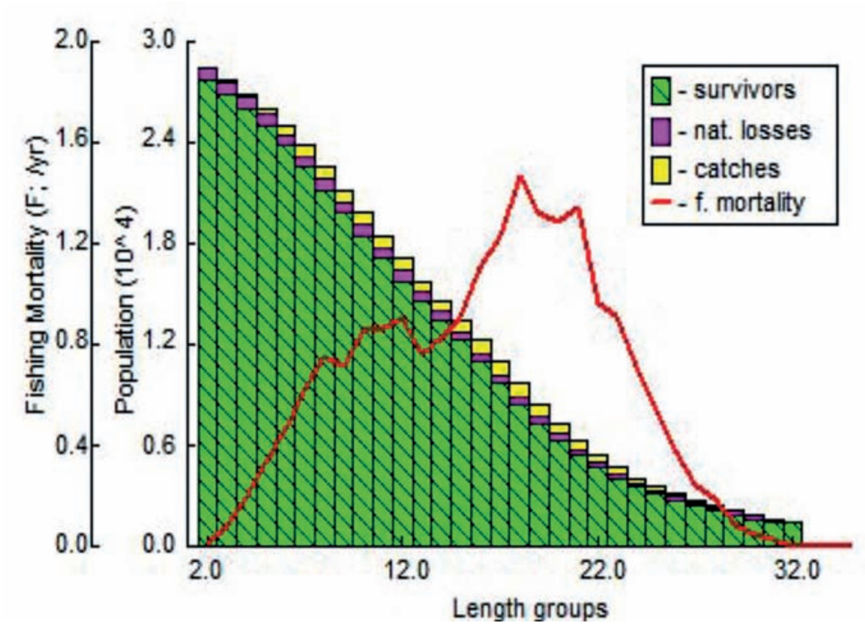

Fig. 18. Length-structured virtual population analysis of *V. aurea* collected from Taawen site.

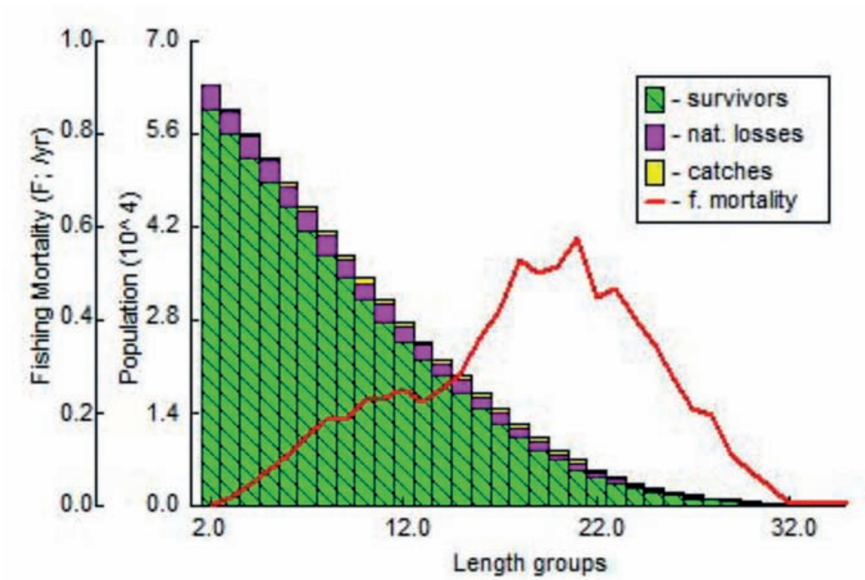

Fig. 19. Length-structured virtual population analysis of *V. aurea* collected from Etap site.

DISCUSSION

Population parameters (growth, recruitment, mortality) are useful bases in comparing the status of exploited resources as they provide valuable information on how exploitation affects the population (Pauly, 1984).

The conventional von Bertalanffy growth model has been found to be a good description of bivalve growth (Vakily, 1992), which is confirmed in the current study for *V. aurea* in Lake Timsah. Specific growth rate of the species in the Lake was observed to be faster in the first year of its life and declines more and more slowly as the organisms' increase in age. Wilbur and Owen (1964) reported that the decrease in the relative growth with an increase in age is known in bivalves. The observations on venerides by Jagadis and Rajagopal (2007) on *Gafrarium tumidum*, Juric *et al.* (2012) on *Venerupis decussata* and Kandeel (2016) on *Tapes decussata* are in conformity with the present results.

The broad length range of *V. aurea* varied between 2-31 and 2-35 mm shell length for Taawen site and Etap site, respectively (Fig. 3). Clams with a shell length comprised between 8 and 21 mm represented 75.6% and 69.0% of the total population in the two sites, respectively. Growth data suggested that the age of these dominant clams was ≤ 3 years. According to Mohammad (2014), population structure of *V. aurea* revealed that the size class 20-25 mm shell length was the dominant and the age ranged between the first and fifth age groups. Thus, *V. aurea* is a fast growing species that reaches commercial length at the age of one year. The species talked roughly 3 years to reach 23.0 and 25.6 mm shell length in Taawen site and Etap site, respectively (Fig. 12). The average growth rate through the first three years of life was higher in Etap site (10.9 mm yr^{1}) than in Taawen site (9.9 mm yr^{1}). However, growth in bivalves is greatly influenced by biological and environmental factors and is known to vary widely from population to population and even within the same species and population (Broom, 1982; Wolff, 1987; Vakily, 1992).

Von Bertalanffy growth parameters, K and L_∞ revealed a growth performance (Φ') of 2.58 and 2.69 for Taawen site and Etap site, respectively. The higher growth performance of *V. aurea* at Etap site (Φ' = 2.69) was mainly due to high growth co-efficient (K = 0.36 yr^{1}) compared to Taawen site (K = 0.28 yr^{1}) where clam abundance was higher. A mean abundance of 3,930 ind. m^{-2} and a maximum of 6,672 ind. m^{-2} were recorded. On the other hand, the clam bed at Etap site had a mean abundance of 1,141 ind. m^{-2} and a maximum of 1,896 ind. m^{-2}.

Total mortality (Z) at the unexploited Etap site (0.98 yr^{1}) was higher than Z at the exploited Taawen site (0.81 yr^{1}). Also, natural mortality (N) was higher in Etap site (0.76 yr^{1}) than in Taawen site (0.70 yr^{1}). Mean annual catch (in numbers) was relatively rare in Etap site (Fig. 19). The highest total mortality (Z) at unexploited site than at the exploited one was recorded for the veneride *Megapitaria squalida* at Magdalina Bay, Mexico (Schweers *et al.*, 2006).

Growth performance index of *V. aurea* in the two studied beds is in the range (3.70 – 2.95) of reported values for the different species of *Venerupis* and *Venus* (Tab. 3) indicating the accuracy of these values. This indicates that the growth function (*Φ'*) can truly be used to characterize not only similar species (Pauly and Munro, 1984) but also related species as in the case of the venerid species (Del Norte-Campos and Villarta, 2010; Moura *el al.*, 2013).

Tab. 3. Comparison of the von Bertalanfy growth parameters and corresponding overall growth performance between the different species of *Venerupis* and *Venus*.

Species	K (year^{-1})	L∞ (mm)	Φ'	Ageing method	Study area	Reference
Venerupis aurea	0.28	36.75	2.58	LF(FiSAT)	Taawen site, Lake Timsah, Suez Canal, Egypt	Present study
Venerupis aurea	0.36	36.75	2.69	LF(FiSAT)	Etap site, Lake Timsah, Suez Canal, Egypt	Present study
Venerupis decussata	0.57	37.91	2.91	AP	Pag Bay, eastern Adriatic Sea	Jurić (2012)
Venerupis pullastra	0.31	49.98	2.89	SR	Mira Estuary, Portugal, Atlantic Ocean	Guerreiro & Rafael (1995)
Venerupis pullastra	0.43	45.5	2.95	SR	Ria de Aveiro, Portugal, Atlantic Ocean	Maia *et al.* (2006)
Venerupis pullastra	0.29	54.3	2.93	AP	Ria de Aveiro, Portugal, Atlantic Ocean	Maia *et al.* (2006)
Venus verrucosa	0.25	44.9	2.71	CS	Bari, Italy, Adriatic Sea	Arneri *et al.* (1998)
Venus verrucosa	0.35	54.1	3.01	CS	Gulf of Manfredonia, Italy Adriatic Sea	Arneri *et al.* (1998)
Venus verrucosa	0.30	54.2	2.94	CS	Gulf of Maliakos, Greece, Aegean Sea	Arneri *et al.* (1998)
Venus verrucosa	0.32	52.1	2.94	CS	Bay of Thessaloniki, Greece, Aegean Sea	Arneri *et al.* (1998)
Venus verrucosa	0.36	43.4	2.83	CS	Alexandroupolis, Greece, Aegean Sea	Arneri *et al.* (1998)
Venus antiqua	0.18	80.0	3.07	MR	Islde Chiloe, Pacific, Chile	Clasing *et al.* (1994)
Venus striatula	0.25	38.7	2.57	SR	Bristol Channel, UK	Warwick *et al.* (1978)
Venus striatula	0.23	32.9	2.40	SR	Millport, Scotland	Ursin (1963)
Venus corrugata	0.31	49.9	2.89	SR	Mira Estuary, Portugal, Atlantic Ocean	Guerreiro & Rafael (1995)
Venus corrugata	0.43	45.5	2.95	SR	Ria de Aveiro, Portugal, Atlantic Ocean	Maia *et al.* (2006)

LF: length-frequency, SR: surface rings, CS: cross sections, AP: acetate peels, MR: mark-recapture, *Φ'*: growth performance index.

Kandeel (2017) reported that the minimum size at sexual maturity for *V. aurea* collected from Lake Timsah was 12 and 15 mm SL during summer and winter seasons, respectively. Mean annual catches were obvious in Taawen site and the highest values were recorded in length range between 7.0 – 20.0 mm (Fig. 18). Thus, the majority of catches are immature (SL > 12 mm) indicating overfishing of recruits.

Recruitment pattern was continuous throughout the year with two major peaks during December and March at Taawen site (Fig. 15). For Etap site, one minor peak was observed during August and one major peak during January. This annual pattern of recruitment was confined by FiSAT method. Recruitment pattern coincides with spawning pattern which was continuous throughout the year in a poorly defined pattern (Kandeel, 2006). This mode of reproduction makes precise prediction of spawning events or of subsequent recruitment pulses very difficult (Hooker and Creese, 1995). However, mass spawning of *V. aurea* were observed in September, December and April (Kandeel, 2006).

Recruited juvenile relative to the total population all over the study period (Fig. 15) was higher in Taawen site (34.50%) than in Etap site (20.47%). This indicates the successful settlement and recruitment of the clam larvae (Gosling, 2003). Successful recruitment to the adult population may be highly variable in space and time, reflecting the demographic diversity of a population (Alfaro, 2006; Degraer *et al.*, 2007).

The southern region of Lake Timsah around Taawen area is the main fishery ground for *V. aurea* which covers a large area of high density clams (Mohammed *et al.*, 1991). Also, the present study showed that the population size of *V. aurea* at Taawen site was found as higher than that of Etap site (Fig. 2) indicating that sediment characteristics of this site are suitable for larval settlement and adult survival as reported by Mohammed *et al.* (1992). On the basis of the Wentworth scale, the sediments of Taawen site were described as medium sand. The quartile deviation (QDφ) indicates that the sediment particles fell within the moderately well sorted categories as defined by Folk (1974). The highest proportion (12.7%) of coarse sediment (> 0.5 mm) and the lowest content of organic matter (1.1%) were recorded this site (Tab. 1). According to Ansell (1961), *V. aurea* is adapted to coarser sediments. Some studies attributed the increased abundance of suspension feeders such as *V. aurea* in coarse sediments to increased current velocities that bring larger quantity of food per unit time than would be the case in areas with low gravel content (Driscoll, 1968). Strasser *et al.* (2003) observed regional differences in bivalve recruitment in the Wadden Sea and reported that these differences may be related to changes in environmental conditions or differences in biotic factors such as standing stock or larval supply.

The present results therefore highlight the urgent need to manage this resource. This can only be mitigated by imposing strict management guidelines that should include (1) fishing only sizes that are sexually mature (> 12 mm SL), and (2) imposing closed seasons during the major spawning peaks (September, December and April). These guidelines, albeit unpopular due to their initial short-term impact on fisher livelihoods, can restore the stock to a suitable status if properly implemented, thereby assuring a more stable income for the fishers. However, the state of early maturity and reproduction throughout the year may enable *V. aurea* compensate the fishing pressure. In addition, further studies on the distribution of the species in relation to the grain size of the sediment, substrate selectivity off settling larvae and dispersal of juvenile specimens should be conducted.

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