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RECRUITMENT PATTERN OF COMMERCIALLY HARVESTED CLAM, *VENERUPIS AUREA* (BIVALVIA: VENERIDAE) AT THE SOUTHERN REGION OF LAKE TIMSAH, SUEZ CANAL, EGYPT

SUMMARY

The recruitment pattern of the venerid *Venerupis aurea* was monitored from August 2004 to September 2005 to investigate the feasibility of collecting natural spat for management or maricultural purposes. Three sites of varying adult densities were chosen in the southern region of Lake Timsah, Suez Canal, Egypt. Recruitment is used, herein, to refer to juveniles of generally less than 9 mm shell length. The separation between juveniles and adults was based on the size at onset of maturity. Recruitment of *V. aurea* was continuous throughout most of the year and varied significantly among the three sites. Monthly collections yielded an average of 687.1, 239.5, and 115.3 spat m^{-2} at sites I, II, and III, respectively. Higher abundance of recruits occurred during the period from November 2004 to March 2005. The average density of juveniles for this period (n = 5) was 1508.0, 293.6, and 262.4 ind. m^{-2} at the three sites, respectively. The data suggest that the survival of recruits is probably influenced by abiotic factors, particularly sediment composition, rather than by biotic factors such as adult-juvenile interactions. The growth in length for juveniles from site I is accompanied by growth in weight (isometric growth). At site II and III, weight increased relatively slower than length indicating negative allometric growth.

INTRODUCTION

Most intertidal invertebrates depend on the successful settlement and recruitment of dispersing larvae to maintain populations. Settlement, defined as the process during which the larva descends from the plankton to the sea bottom and attaches itself to the suitable substrate with the byssus, is difficult to measure in the field and is usually inferred from recruitment data (GOSLING, 2003). Recruitment has been defined as the process of successful colonization after a specified amount of time (SEED and SUCHANEK, 1992). Recruitment is an operational term: it also refers to the first age class in a population, includes the settlement and survival of settled individuals, and is influenced by events occurring during the planktonic stage and settlement processes, as well as post-settlement mortality (KEOUGH and DOWNES, 1982). WOODIN (1991) emphasized that "Recruitment is a process of fundamental importance because it is the background upon which all subsequent interactions with the community take place". When recruitment fails, organisms do not have the opportunity to interact as adults (UNDERWOOD and DENLEY, 1984). Successful recruitment to the adult population may be highly variable in space and time, reflecting the demographic diversity of a population (HUGHES, 1990; DEFEO *et al*., 1992; MAXIMOVICH and GUERASSIMOVA, 2003; ENDERLEIN and WAHL, 2004; ALFARO, 2006; DEGRAER *et al*., 2007).

The Suez Canal connects the northern end of the Red Sea, at the top of the Gulf of Suez, to the Mediterranean Sea at Port Said. It has a total length of about 162 km and includes several shallow lakes (Fig. 1). Of these, Lake Timsah, the study area, is a shallow body of water lying 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. Recruitment pattern of many marine species, including economically important shellfish species has not received any attention in the Lake Timsah ecosystem. Studying the recruitment of marine benthic invertebrates has been hampered by several methodological difficulties, including sampling frequency, an ability to follow larval and post-larval or juvenile cohorts, and difficulty in calculating growth and mortality rates (CHICHARO and CHICHARO, 2001). For these reasons, recruitment studies have usually considered only larger and more easily identifiable individuals, resulting in under-estimation of the effective overall recruitment (POWELL *et al*., 1986). In our study, recruitment is used to refer to clams less than 9-mm shell length and retained on a sieve with a mesh size of 1-mm. These clams were not found to be reproductive (see results) and can grow to 28 mm in a single year (ABOU-ZIED, 1991). Therefore, any clams less than 9.0 mm would be juveniles and would have settled relatively recently. Thus, there is no plenty of time for the processes that can decouple settlement and recruitment (e.g., dispersal, mortality, differential growth rates).

The family Veneridae (Rafinesque 1815), also known as Venus clams, is a group of marine bivalve molluscs. Many of the most important edible species are commonly known simply as clams, and they make up a significant part (38% of reported landings in 1980) of the world fishery of edible bivalves (BOURNE, 1986). The venerid *Venerupis aurea* (Gmelin 1971) is endemic to the Mediterranean Sea (FOUDA and ABOU-ZIED, 1990). It has penetrated through the Suez Canal and successfully colonized Lake Timsah, where it is now the most abundant bivalve species in the lake (GHOBASHY *et al*., 1992), and exhibits a high reproductive potential (KANDEEL, 1992; 2006). The southern region of Lake Timsah around El-Taawen area is the main fishery ground for *V. aurea*. The fishery ground covers a large area of high density clams (MOHAMMED *et al*., 1991). The sediment of this area is suitable for larval settlement and adult survival.

Due to its considerable commercial importance and market demand, over-fishing of *Venerupis aurea* has resulted in a decline of natural beds, thereby boosting the demands for an aquaculture industry as an alternative source. To improve the efficiency of commercial culture of this species, more detailed information on its biology is required. The primary objectives of this study were: (1) to identify temporal variation in recruitment and determine optimum periods to collect natural spat for maricultural purposes; (2) to determine whether recruitment pattern varies among sites with different adult densities; (3) to relate recruitment abundance to sediment characteristics; and (4) to obtain useful information on allometric growth of recruits in natural populations. Such information is necessary for further studies on population dynamics of *V. aurea*, the management of the fishery, and assessing the potential of this species for aquaculture in Egyptian waters.

MATERIALS AND METHODS

Sampling

Venerupis aurea was collected monthly from August 2004 to September 2005 at three sites (Fig. 1). These sites were selected at the southern region (El-Taawen) of Lake Timsah and represented by different adult population densities. Site I is approximately 550 m long and lies on a small island adjacent to the beach at Taawen club. For the majority of the site, the water is shallow (<1 m) for a considerable distance offshore. KANDEEL (unpub. data) found that the highest abundances of *V. aurea* in Lake Timsah were recorded at that site, where population densities ranged from 1016 to 6672 ind. m^{-2} throughout the study period. The mean value ± SD was 3930 ± 1738 ind. m^{-2}. Site II extends about 624 m along the northern shore of the shallow semi-enclosed Taawen bay which is used extensively for both recreational purposes and commercial fishing. Population densities of *V. aurea* varied from 877 to 3758 ind. m^{-2} ($\overline{X}$ ± SD = 1780 ± 803 ind. m^{-2}). Site III extends approximately 442 m parallel to the shore. *V. aurea* was found in low abundances compared to the previous two sites. The values varied between 348 and 1896 ind. m^{-2} ($\overline{X}$ ± SD = 1141 ± 560 ind. m^{-2}).

At each sampling site, four randomly selected squares (each measuring 25 x 25 cm) were dug to a depth of 10 cm and sieved in the field through 1-mm screen. The materials retained by the sieve were kept in labeled containers filled with 5% formaldehyde-seawater solution.

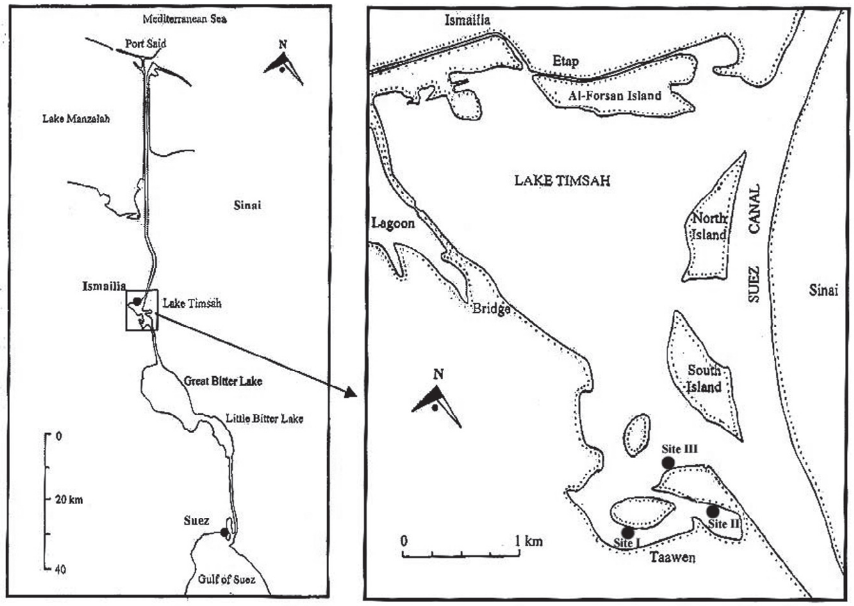

Fig. 1. Map of the Suez Canal showing sampling sites (•) in Lake Timsah.

Sediment analysis

Sediment characteristics including organic matter content were determined following the methods described in BUCHANAN (1984). Sediment samples were collected from the three sites using a 5-cm diameter corer taken a sediment depth of 10-cm. Three replicate cores were taken at each site. 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 ($Sk_q\varphi$) 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.

Size at onset of maturity

The shell length at which the gonad begins to develop from the rudimentary virgin state (sexually undifferentiated or juvenile gonad) to the state of gonad sexually differentiated was taken to be the size at onset of sexual maturity. A smear of gonad was taken from each individual starting from 6.0 mm up to 36.0 mm shell length. Sexual products (mature oocytes/spermatozoa) were examined microscopically. The percentages of sexually mature clams were plotted against shell length (mm). The length at which 50% of the clams are mature (SM50) was then estimated for samples collected from site I during October-November 2004. At this autumn period, the majority of the population was sexually mature (KANDEEL, 1992).

On the basis of the microscopic examination of the gonads and determining the size at sexual maturity, each population of *V. aurea* was categorized into two groups: juveniles and adults. In contrast, DELGADO and DEFEO (2007) categorized the population of *Donax hanleyanus* into three components; recruits, juveniles, and adults.

Recruitment abundance

In the laboratory, all individuals of *V. aurea* were sorted from each sample. Shell length (maximum distance on the anterior-posterior axis) was measured to the nearest 0.1 mm using a vernier caliper. Small specimens (<3 mm shell length) were measured under a dissecting microscope with an ocular micrometer. In this study, individuals of length less than 9.0 mm were referred to as juveniles and their abundance was used as an indicator of recruitment. The separation between juvenile and adult stages was based on the minimum size of maturity (see results). Recruited juveniles were tallied to determine their abundance (ind. per m^2). The percentage occurrence of these juveniles relative to the total population of *V. aurea* was also estimated throughout the study period.

One-way analysis of variance (ANOVA) was used to compare the variation in the abundance of recruits at the three sites. The degree of association between adult density and juvenile density was also assessed by Pearson correlation analysis. Because the number of recruits changed substantially over time, all raw data for recruitment numbers per m^2 were log transformed [ln(X+1)].

Biometric studies
Size parameters, such as shell length, shell height (maximum distance on the dorsal-ventral axis, across the shell middle axis), shell width (maximum distance on the lateral axis, between both valves of the closed shell; to the nearest 0.1 mm) and total weight (to the nearest 0.0001g) were measured.

The biometric relationship between (1) length and total weight and (2) length, height and width were investigated by linear least-squares fit to log-transformed data:

$$\text{Log } Y = a + b \text{ log length} \qquad \text{or } Y = a \text{ length}^{b}$$

where Y = a dependent variable (total weight, height or width); a = intercept (initial growth coefficient); b = slope (relative growth rate of size parameters). The degree of association between size parameters was calculated by the determination coefficient (r^2). Additionally, an analysis of variance (ANOVA) was used to estimate variance ratio (F) and the significance level of r^2.

The deviation of the b value of the regression function from the isometric value (i.e. length-weight relation: b = 3; length-height-width relation: b = 1) was analyzed by means of a t-test, as expressed by the following equation (MONTI *et al.*, 1991):

$$t_s = (b - \beta)/s_b$$

where t_s = t-test value; b = slope; β = isometric value of the slope; s_b = standard deviation of the slope (b). A significant deviation indicates a negative ($b<3$ or $b<1$) or positive ($b>3$ or $b>1$) allometric relationship.

The estimation of the weight-length relationship was carried out in two occasions; winter (January-March) and summer (July-September) 2005. The slopes (b) and intercepts (a) of these relationships were compared between the two seasons and also between the three sites by applying one-way analysis of variance (ANOVA). Statistical analysis was carried out using MINITAB software (version 13, 2000). Significance levels of statistical tests were set at P =0.05.

RESULTS

Sediment characteristics
Sediment particle size distribution data at three sites in the southern region of Lake Timsah are shown in Fig. 2. The histograms are unimodal. The dominant sediment particle size was the 0.125-mm size class (φ=3) at the three sites. Sediment characteristics including the statistical parameters derived from the

cumulative frequency curves are listed in Table 1. On the basis of the Wentworth scale, the sediments were described as medium sand at site I, and as fine sand at sites II and III. The quartile deviation (QDφ) ranged from 0.55 to 0.70. Thus, the sediment particles fell within the moderately well sorted categories as defined by FOLK (1974). Sites I and II have negatively skewed sediments (-0.05) indicating the presence of a higher coarse fraction. On the other hand, samples from site III were skewed towards the fine particles (positively skewed, Sk_q φ= +0.10). The highest percentage of organic content (2.3%) occurred at site III, where the highest proportion (17.3%) of fine sediment (<0.063 mm) was recorded. Site I exhibited the highest proportion (12.7%) of coarse particles and the lowest content of organic matter (1.1%).

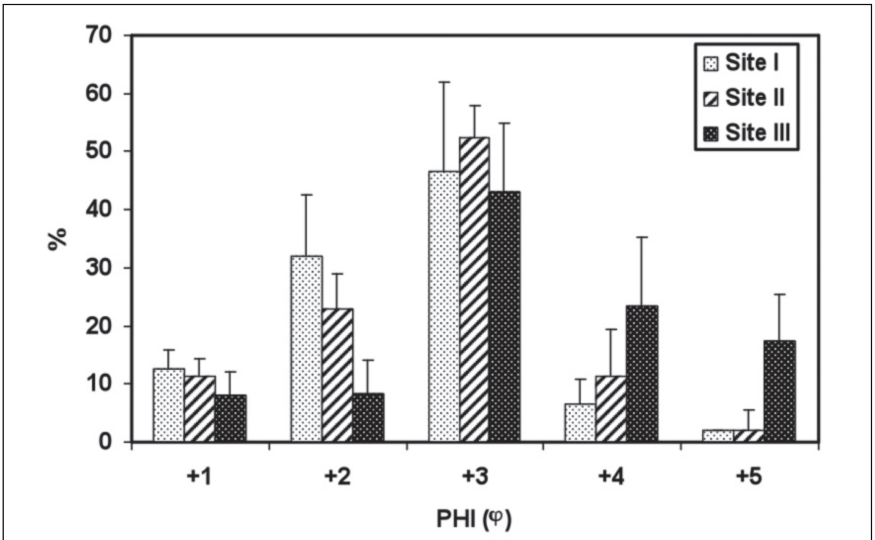

Fig. 2. Sediment particle size distributions for the three sites at the southern region of Lake Timsah. Vertical bars indicate SD of the mean. n = 3 for each plot.

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_qφ)	Mean% organic content
I	12.7	2.0	2.1	Medium sand	0.55	Moderately well sorted	-0.05	1.1
II	11.3	2.0	2.3	Fine sand	0.65	Moderately well sorted	-0.05	1.7
III	8.0	17.3	2.8	Fine sand	0.70	Moderately well sorted	+0.10	2.3

Table (1): Sediment characteristics at the three sites in the southern region of Lake Timsah.

Size at onset of maturity

The extent of the relation between maturation and shell length of *V. aurea* collected from site I is presented in Fig. 3. The minimum size of adults was 9-mm shell length indicating an early stage of maturity. The largest size of juveniles was 12-mm shell length. The size at which 50% of the clams showed signs of maturity (SM50) was calculated as 10-mm shell length.

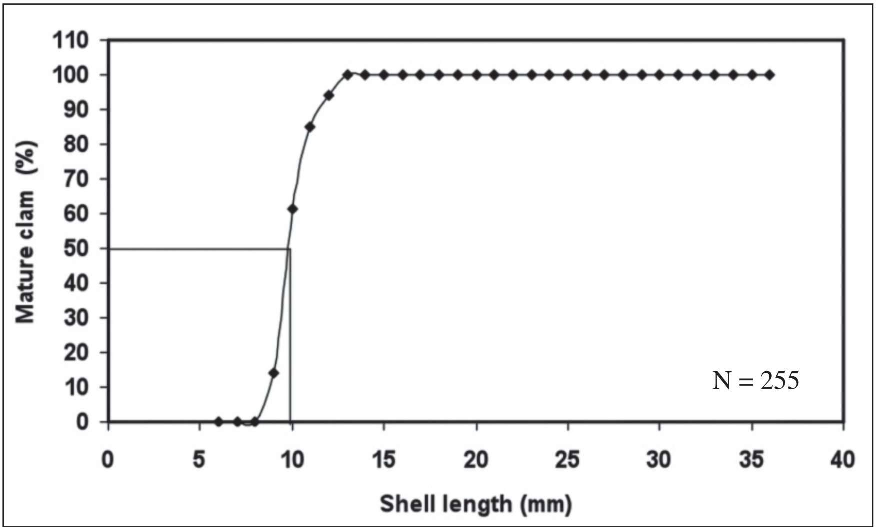

Fig. 3. The percentage of maturity plotted against shell length (mm) of *V. aurea* collected from site I during October-November 2004. The size at 50% maturity (10 mm shell length) is demonstrated. N=sample size.

Recruitment abundance

Monthly variations in the density of recruited juveniles (ind. per m^2) and the proportion of these juveniles relative to the total population of *V. aurea* collected from the three sites in the southern region of Lake Timsah are shown in Figures 4 and 5, respectively.

Recruited juveniles were registered throughout the study period with the exception of April and June 2005 at site III. The maximum density of juveniles was 2808 in December 2004, 1340 in August 2005, and 716 in January 2005 ind. per m^2 at sites I, II and III, respectively. One-way ANOVA tests showed no significant seasonal variation in density of recruits at site I ($F_{(3,8)} = 0.95$, $P>0.05$) and site II ($F_{(3,8)} = 0.67$, $P>0.05$). Moreover, a significant seasonal variation was recorded at site III (ANOVA, $F_{(3,8)} = 10.23$, $P=0.004$). The average density of juveniles over the study period (n=14) was 687.1, 239.5 and 115.3 ind. per m^2 at sites I, II and III, respectively. Juveniles were well represented during the period from November 2004 to March 2005.

The average density of juveniles during this period (n=5) was 1508.0, 293.6 and 262.4 ind. per m^2 at the three sites, respectively. Results from a one-way ANOVA test comparing juvenile abundance among the three sites throughout the study period revealed that the density of juveniles at site I was significantly higher ($F_{(2,39)} = 5.04$, P=0.011) than that at sites II and III.

Recruited juveniles represented relatively high proportions of the population in most months (Fig. 5). Maximum proportion of juveniles relative to the total population of *V. aurea* was 48.9% in December 2004, 48.1% in August 2005, and 38.2% in January 2005 at sites I, II and III, respectively. Average proportion of recruited juveniles throughout the study period was 15.3%, 13.3%, and 8.8% of the whole population at sites I, II and III, respectively. During the period from November 2004 to March 2005, the average proportion of juveniles was 33.0%, 21.9%, and 19.2% of the total population at the three sites, respectively.

The relationship between the abundance of adults and juveniles for monthly samples of *V. aurea* collected from the three sites during the period from November 2004 to March 2005 is shown in Fig. 6. The Pearson correlation coefficient between $\log_e$ (adult density+1) and $\log_e$ (juvenile density +1) were 0.793 (site I), -0.797 (site II) and -0.087 (site III) indicating a non-significant (P>0.05) correlation between the two variables.

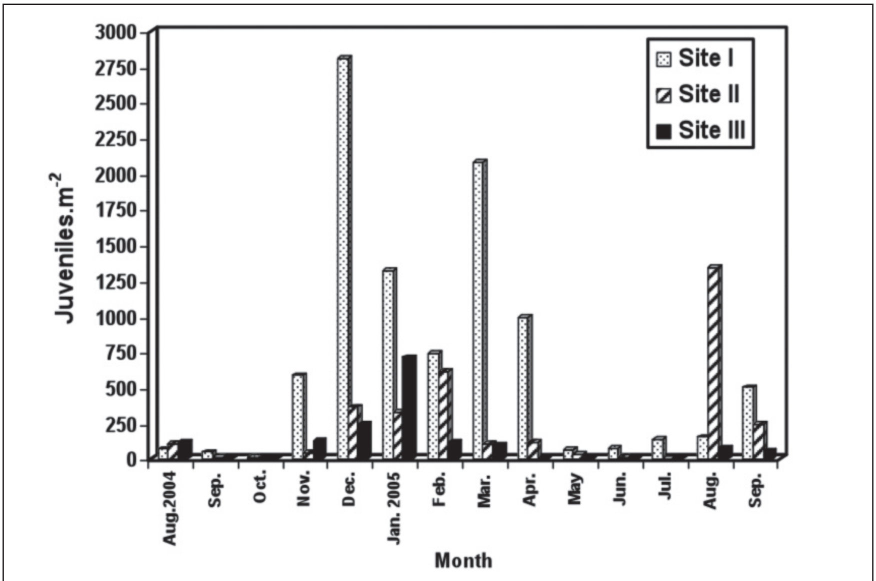

Fig. 4. Monthly changes in the density (ind. m^{-2}) of recruited juveniles (shell length 3-9 mm) of *V. aurea* collected from the three sites in the southern region of Lake Timsah.

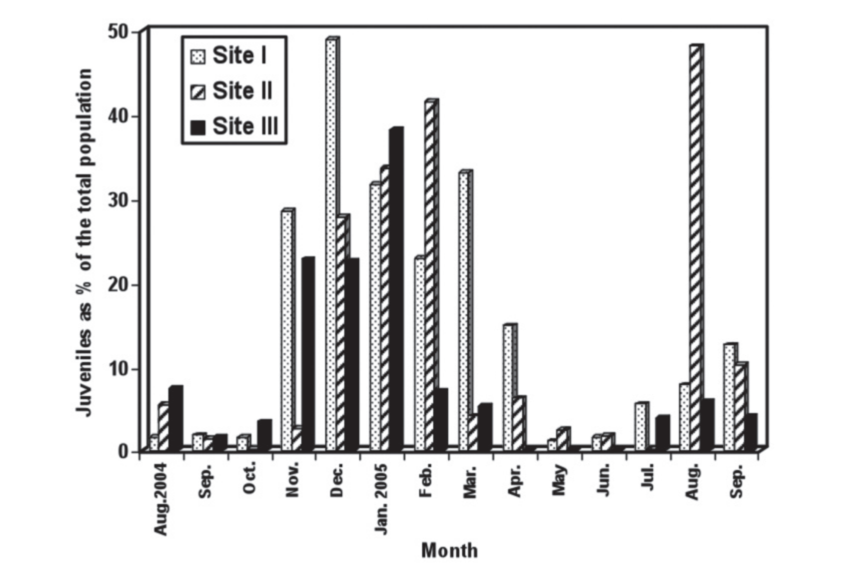

Fig. 5. Monthly changes in the percentage of recruited juveniles (shell length 3-9 mm) relative to the total populations of *V. aurea* collected from the three sites in the southern region of Lake Timsah.

Biometric studies

Table (2) shows the results of regression analysis between (1) length and total weight and (2) length, height and width for recruited juveniles of *V. aurea* in Lake Timsah. A highly significant ($P<0.0005$) isometric relationship was found for both height and width in relation to length. This reveals that the growth in length is an accompanied by growth in height and width. Total weight showed an isometric relationship with shell length at site I. At sites II and III, total weight grows relatively slower than shell length (negative allometric growth). The spatial comparison of the relationships between total weight and shell length did not show any significant differences (ANOVA, $F_{2,3} = 0.52$, $P>0.05$ for intercepts; $F_{2,3} = 0.74$, $P>0.05$ for slopes), indicating homogeny between the three sampling sites. The comparison of this relationship showed a significant difference between summer and winter ($F_{1,4} = 10.08$, $P=0.034$ for intercepts; $F_{1,4} = 7.17$, $P=0.05$ for slopes).

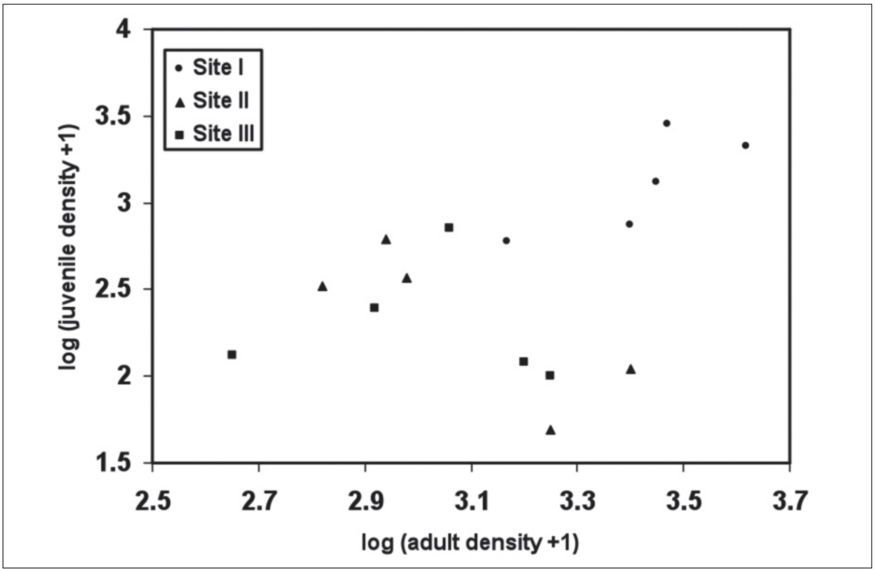

Fig. 6. Relationship between the abundance of adults and recruits for monthly samples of *V. aurea* collected from the three sites in the southern region of Lake Timsah during November 2004-March 2005 period.

DISCUSSION

In the present study, sexual maturity of *Venerupis aurea* was reached at 10 mm during October-November 2004. KANDEEL (1992) reported that the size at onset of maturity for *V. aurea* from Lake Timsah varied seasonally. The length at which 50% of the clams were mature (SM50) ranged from 9.0 to 15.4 mm throughout the year. Higher temperature during summer and autumn (18.2-29.9°C) is important for an early onset of maturity (KANDEEL, 1992). ABOU-ZIED (1991) determined the size of *V. aurea* from Lake Timsah at the age of one year to be 28 mm shell length. Therefore, *V. aurea* matures and spawns at an earlier age than has been reported for long-lived species, such as the cold water species *Arctica islandica* that can delay breeding for some years (THOMPSON *et al.*, 1980). The Manila clam, *Venerupis japonica* at Hood Canal, Washington, developed sexual products at 5-15 mm or greater and spawned at 20 mm shall length (HOLLAND and CHEW, 1974). SM50 of Lake Timsah population of the venerid *Tapes decussata* was 14.0 mm and 11.4 mm shell length during April-May and August-September 1989, respectively (KANDEEL, 1992).

Natural recruitment of *V. aurea* in the southern region of Lake Timsah was extremely high. Juveniles were registered throughout most of the year (Fig. 4; 5) indicating continuous recruitment. Multiple spawnings and high reproductive output as reported by KANDEEL (2006) provide a biological basis for the observed recruitment patterns of *V. aurea* in Lake Timsah. This species had four gametogenic cycles throughout the year (KANDEEL, 2006) and moves rapidly from one cycle to the next without a resting stage resulting in almost continuous reproduction. Similar continuous recruitment patterns have been reported for the mytilids *Modiolus arcautulus* and *Brachidontes variabilis* in the Suez Canal Lakes (KANDEEL, 2002).

Dependent variable (Y)	Log *a*	*b* ±SD	β	*t*	*P*	Allometric relationship	Determination coefficient (R^2)	*F*	*N*
Height	-0.16	0.98±0.01	1	2.00	NS	isometry	0.988	8340.2	103
Width	-0.52	1.05±0.02	1	2.50	NS	isometry	0.970	3265.2	103
Weight									
(a) Winter 2005									
Site I	-3.55	2.68±0.08	3	4.00	NS	isometry	0.928	1008.1	80
Site II	-3.44	2.56±0.06	3	7.33	<0.05	-allometry	0.973	1766.3	51
Site III	-3.34	2.47±0.07	3	7.57	<0.05	-allometry	0.967	1381.4	49
(b) Summer 2005									
Site I	-3.20	2.40±0.10	3	6.00	NS	isometry	0.910	576.3	59
Site II	-3.17	2.31±0.05	3	13.80	<0.025	-allometry	0.983	2426.8	44
Site III	-2.19	2.07±0.11	3	8.45	<0.05	-allometry	0.913	357.3	36

Table (2): Regression analysis of allometry in recruited juveniles of *V. aurea* collected from the southern region of Lake Timsah (independent variable (x) assumed: length). Value of *t*-test (*t*), significance level of *t*-test for allometry (*P*), determination coefficient (R^2), variance ratio (*F*) and number of observations (*N*) are also given. All regressions were highly significant (0.0005), SD = standard deviation, β = the isometric value of the slope, NS = non significant (P>0.05).

Venerupis aurea in Lake Timsah exhibited a small synchronization in spawning between individuals in the same population (KANDEEL, 1992; 2006) indicating poorly defined seasonal reproductive cycles. This mode of reproduction makes precise prediction of spawning events or subsequent recruitment pulses difficult (HOOKER and CREESE, 1995). Endocrine and environmental timing of reproductive events that require external fertilization and as such the need for a significant part of a population to achieve maturity at the same time has been studied mainly for epidemic spawners such as corals and polychaetes (BABCOCK *et al.*, 1992; HARDEGE *et al.*, 1998a). Temperature, day length, and lunar periodicity are amongst the key environmental cues that bring about the spectacular mass spawning events that are often fine tuned via chemical signals (ANDRIES, 2001). In bivalves such as *Mytilus edulis*, chemical cues associated with phytoplankton blooms that signal food availability may also be involved in timing of reproductive events (STARR *et al.*, 1990).

Continuous recruitment of *V. aurea* in the southern region of Lake Timsah is explained not only by successive spawning events per year but also by high survival rates of early life history stages (BARBER and BLACK, 1991) and newly-settled spats. The sediment of this region is a suitable substratum for larvae of *V. aurea* settlement. Following Folk's classification (FOLK, 1974), the sediment particles fell within the moderately well sorted categories (Table 1). Results from a one-way ANOVA test comparing juvenile abundance among the three sites throughout the study period showed that the density of juveniles at site III was significantly lower than that at sites I and II ($F_{(2,39)} = 5.04$, P=0.011). Site III has positively skewed sediments ($Sk_q\varphi$ = + 0.10) indicating the presence of a relative excess of fine sediment (17.3%). The samples of sites I and II skewed towards the coarse particles (negatively skewed, $Sk_q\varphi$ = -0.05). The proportion of coarse sediment was greatest (12.7%) at site I, which is also the site that exhibited a significantly higher abundance of juveniles compared to sites II and III. These results are in apparent agreement with the results obtained for the scallop, *Pecten jacoboeus* in Lake Vouliagmeni, Korinthiakos Gulf, Greece (KATSANEVAKIS, 2005), and for *Soletellina alba* in Hopkins River Estuary, Victoria, Australia (MATTHEWS, 2006). 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 (GRIAG and JONES, 1966; DRISCOLL, 1968).

High survival of early recruits that may be due to better food and water quality at site I could also explain the higher density of juveniles there. Another factor that may cause spatial variation in recruitment of *V. aurea* at Lake Timsah is differences in the standing stock of this species in the different sites. However, since there is no current evidence for a correlation between the abundance of adults and juveniles, the importance of this factor cannot be sufficiently assessed. 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, larval supply, or epibenthic predation.

Studying the correlation between the abundance of adults and juveniles of suspension feeding bivalves may clarify potential adult-juvenile interactions. Such studies are important in determining the influences of adults on settling larvae and recruitment (WILLIAMS, 1980). A negative correlation between large numbers of adults and juveniles has been reported for *Tapes japonica* (WILLIAMS, 1980), *Mesodesma mactroides* (DEFEO *et al.*, 1992), *Nuculoma tenuis* (HARVEY and GAGE, 1995), *Cerastoderma edule* (BACHELETE *et al.*, 1992; RICHARDS *et al.*, 2002) and *Mya arenaria* (MAXIMOVICH and GUERASSIMOVA, 2003). These bivalves can have a deleterious impact on their own recruitment by ingesting their larvae. As a consequence of the threat of filial cannibalism in these species, larvae settle away from the adults at juvenile-dominated sites (WOODIN, 1974). Juvenile sites have been reported in a large number of mainly filter-feeder species; not exclusively bivalves but also anemones and polychaetes. In the latter, chemical cues emitted by adults have been shown to deter juveniles from settlement (WOODIN, 1976; HARDEGE *et al.*, 1998b). In contrast, significant positive correlations were obtained between maximal recruitment and adult abundance (MCGRORTY *et al.*, 1993; HARRIS *et al.*, 1998) in *Mytilus edulis*. According to several authors (MILEIKOVSKY, 1974; WOODIN, 1976; MOHAMMED, 1992; NIELSEN and FRANZ, 1995), the presence of adults is of prime importance to enhance the chances of settling and/or settled larvae to survive.

The populations of the suspension feeder *V. aurea* at the three sites in Lake Timsah are characterized by densely-packed assemblages of adults. In most months, recruited juveniles represented high proportions of the populations. Pearson correlation analysis between the densities of adults and juveniles during the period from November 2004 to March 2005 was not significant at the three sites (Fig. 6). This indicates that densities of adults do not influence recruitment abundance as in the tellinid clam *Macoma balthica* (L.) and the edible cockle *Cerastoderma edule* (L.) (BOUMA *et al.*, 2001). Thus, the population of *V. aurea* fails to support the hypothesis formulated by WOODIN (1976) who suggested that the densely-packed suspension-feeding bivalves inhibit successful larval settlement by any larvae including their own and consequently reduce the appearance of new recruitments. Woodin's hypothesis was also rejected by WILLIAMS (1980), KANDEEL (1992), MOHAMMED (1992), and CROOKS (1998) but supported for polychaetes (HARDEGE *et al.*, 1998b). Nevertheless none of these studies examined direct interactions between adults and juveniles such as settlement inducer or deterrent chemical signals that WOODIN (1974; 1976) suggested as the basis of the observed inhibition. This may represent an interesting area of future research that could have direct implications for aquaculture developments in *V. aurea* in Egypt.

Shell morphometric relationships are highly variable among bivalve species and between different geographical areas (GASPAR *et al.*, 2002; MARIANI *et al.*, 2002; HWANG et *al.*, 2007). Height/length and width/length morphometric relationships for recruited juveniles of *V. aurea* revealed isometric growth (b = 1) in Lake Timsah. Similar findings were detected for the venerids *Dosinia lupinus* and *Venerupis rhomboides* from the Algarve coast, southern Portugal (GASPAR *et al.*, 2002). This isometric type of growth may be explained by the species' autoecology and environmental conditions (GASPAR *et al.*, 2002). The total weight of juveniles from site I increased isometrically with shell length (b = 3) indicating an equal increment in length and weight. At sites II and III, total weight increased relatively slower than length indicating negative allometric growth. These variations on the relative growth may be related to differences in sediment type and food availability. The sediments were described as medium sand at site I and fine sand at sites II and III.

Recruitment is of fundamental importance to community structure because it is the foundation upon which all subsequent interactions within the community take place. Our study reiterates that *V. aurea* in Lake Timsah displays high abundance of recruits throughout an extended recruitment period. Combined with a small size at adult sexual maturation, this species could be an important species for mariculture. Aquaculture production of this clam in Egyptian waters will rely on the collection of post-set juveniles (spat) from natural habitats and the successful recruitment of *V. aurea* in Lake Timsah. This is potentially possible because the costs involved in using a natural seed source are generally less than those involved in using a hatchery source. To establish mariculture whilst protecting the natural resources in the lake, it is necessary to establish and apply management plans for a sustainable exploitation of this potentially lucrative resource. Further research on the abundance of clam settlement on artificial collectors at various spatial and temporal scales in Lake Timsah would allow more targeted spat collection activities.

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