Population analysis of *Tapes decussata* (Bivalvia: Veneridae) in Lake Timsah, Suez Canal, Egypt.

Kandeel El-SayedKandeel
Department of Zoology, Faculty of Science, Fayoum University, 63514 Fayoum, Egypt
kandeel_hashem76@yahoo.com
Kandeel E. Kandeel:Department of Zoology, Faculty of Science,Fayoum University, 63514 Fayoum, Egypt.
kandeel_hashem76@yahoo.com

ABSTRACT

The population of *Tapesdecussata*was abundant in the southern region of Lake Timsah. It was investigated between August 2004and September 2005. Mean abundance and biomass were 76.9 ind.m^{-2} and 5.33 g.m^{-2} (flesh dry weight), respectively over the study period (n=14). Population parameters (growth, mortality and recruitment) were studied by analyzing monthly length frequency data usingFiSATIIsoftware to evaluate the status of the stock. Asymptotic length (L∞) was found to be 50.40mm and growth co-efficient (K) was 0.810 yr^{-1}. The growth performance index (ϕ') was 3.31. Total mortality (Z) was estimated by length-converted catch curve at 2.52yr^{-1}, fishing mortality (F) at 1.24yr^{-1}, and natural mortality (M) at 1.28yr^{-1}. The exploitation rate (E= 0.49 yr^{-1}) indicated that the fishing pressure on*Tapesdecussata* was relatively high. Recruitment pattern was continuous with four pulses per year. These pulses were found to be correlated with the spawning pattern of the species in Lake Timsah.

KEYWORDS

Lake Timsah;*Tapesdecussata*;Veneridae;vonBertalanffy;Recruitment;Mortality

1. INTRODUCTION

Tapes (= Ruditapes) decussata (Linnaeus, 1758) is native to Europe occurring along Atlantic coasts from the British Isles to as far south as Morocco and Senegal, West Africa and into the Mediterranean Sea (Tebble,1966; PoppeandGoto, 1991; WoRMS, 2014). Natural populations of *T.decussata*can be found in sandy and muddy-sand sediments of tidal flats or shallow coastal areas. They are filter-feeders pumping water through the siphons at sediment level, and they can bury in the sediment to a depth of 10-12 cm (Vilela, 1950).This species was first described as *Venusdecussata* (L.) and through the years it has been known by other names (synonymous) of which the most common are *Venerupisdecussata* and *Tapes decussata*. Moreover, this species satisfies many criteria of a bio-indicator organism and is actually used in the national monitoring programs (Phillips and Rainbow, 1993; Kaschl and Carballeira, 1999; Hamza-Chaffai et al., 2000; Smaoui-Damak et al., 2003; El-Shenawy, 2004).

T.decussata is extensively fished along the European Atlantic coast and in Mediterranean lagoons (Vilela, 1950;Breber, 1980;Borsa and Millet, 1992;Ojea et al., 2004;Smaoui-Damak et al., 2006;Serdar et al., 2007).FAO's Yearbook of Fishery Statistics reports a range of yearly production from around 2019 mt in 1995 to 1823mt in 2005(FAO, 2014). Because this production did not satisfy the market, aquaculture production of this species has increased in recent years.

The clam *T. decussate*has penetrated through the Suez Canal and successfully colonized Lake Timsah representing one of the most common venerids in this lake (FoudaandAbou-Zied, 1990; Ghobashy et al., 1992). It exhibited remarkable reproductive effort and spawned several times per year (Kandeel, 2006).

*T. decussate*is the mostimportant commercially harvested mollusk in Lake Timsah.The majority of its natural production is exported to some European countries (Kandeel, 1992;Gabr and Gab-Alla, 2008).Because of its considerable economic importance and the high market demand; over-exploitation of *T. decussata* has largely depleted the natural stocks. In order to assess the sustainable exploitation rate as well as to improve the methods of cultivating *T. decussata*; it is essential to gain information on its ecology and biology which is scarce (Kandeel, 1992; 2006; 2008; Gabr and Gab-Alla, 2008).Therefore, the objectives of this study were to (a) investigate the distribution and abundance of the species in Lake Timsah and (b) analyze the population by estimating the parameters of its growth, recruitment, mortality, and exploitation rate. Such data provides the critical baseline information needed for the conservation and management of the exploited clam population in Lake Timsah.

2. MATERIALS AND METHODS

2.1. 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 north and Suez in the south (Fig.1A).The canal connects two major bodies of water; the Red Sea and the Mediterranean, which differfundamentally both faunistically and hydrographically.

Lake Timsah,the area of this study, is a small and shallow body of water and lies at the middle of the Suez Canal between 30°33`and 30°35` N and 32°16`and 32°19`E.Seawater temperature in the lake varied seasonally from a maximum of 30°C in July to a minimum of 15.9°C in February (Kandeel, 2008). Salinity ranged from 34.8 ‰ at some sites to 42.1 ‰ at others, depending on the freshwater input (Gab-Alla et al., 1990).

2.2. Sampling procedure

An intensive quantitative survey was carried out during summer (August 2004) at 5 sites (El-Taawen, Bridge, Etap, North Island and South Island) to study the distribution and abundance of *T.decussata* in the major geographical areasof Lake Timsah (Fig. 1B). The main characteristics of these sites have been described by Gabr (1991). At each site, a series of transects were located at regular intervals and running perpendicular to the shoreline from the high water mark to maximum depth of 1 m. Along each transect, 4 quadrates (each with an area of 1/16 m^2)were dug to a depth of 10 cm at regular intervals.

El-Taawen area at the southern region of Lake Timsah was chosen for a more detailed study. The area was sampled monthly from August 2004 to September 2005 along transects using quadrates. The quadrates were sieved in the field through 1 mm screen. The clams retained by the sieve were kept in labeled containers filled with 5 % formaldehyde-seawater solution.

2.3. Laboratoryprocedure

In the laboratory, the number of *Tapes decussata*was counted in each transect and the mean density (the mean of all quadrates taken per transect) was calculated as number of individuals.m^{-2}. Monthlymean density (ind.m^{-2}) of*T. decussata* at El-Taawen area was determined.

Shell length (L) (i.e. shell anterior to posterior) of every specimen collected at El-Taawenareawas measured to the nearest 0.1 mm usingaVerniercaliper. Total length measurements were used to produce monthly length-frequency distributions using class intervals of 3-mm size. The size at first maturity was determined for *T. decussata* in Lake Timsah (Kandeel, 1992). The mean length at which 50 % of the population was mature (SM_{50}) was 12.7mm. On the basis of this study, the recruits were defined as individuals with ≤ 12-mm shell length.

The soft parts were then removed from the shells, placed in a drying oven at 60°C for 48h, and weighed to the nearest 0.0001 g (flesh dry weight, FDW) using a single-pan digital balance. Monthly changes in total biomass (gFDW.m^{-2}) were determined for quadrate samples collected at El-Taawen area.

2.4. Data analysis

2.4.1. von Bertalanffy growth parameters

Length-frequency data were analyzed using the FiSAT II (FAO-ICLARM Stock Assessment Tools) as explained in detail by Gayanilo et al. (2005) in the computer software package.The growth parameters; asymptotic shell length ($L\infty$ in mm) and growth coefficient (K, yr^{-1}) of the von Bertalanffy equation (Bertalanffy, 1934) for growth in length, were estimated by means of ELEFAN I (Paulyand David, 1981; SaegerandGayanilo, 1986). 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 $Z/K = -(1+b)/b$

Where $\bar{L}$ isdefined as the mean length computed fromL' upward in a given length-frequency sample, whileL' is the limit of the first length class used in computing a value of $\bar{L}$.

The estimates $L\infty$ and K were used to calculate the growth performance index ϕ' (Munro and Pauly, 1983)using the following equation:

$$\phi' = \log K + 2 \log L\infty$$

Growth performance is a topic related closely to population dynamics of benthic macro-invertebrates (Brey, 1999). This index makes growth of populations and species comparable and likely to be a species-specific feature. In the present study, $\phi'$was used to compare the growth parameters obtained in this work with data from literature about venerid bivalves.

2.4.2. Mortality and exploitation rate

Total mortality (Z, yr^{-1}) was estimated from the slope of the right descending arm of a length-converted catch curve (Pauly, 1983) using FiSAT II, from all months' combined length-frequency measurements. FiSAT outputs Z yr^{-1} as well as the 95% confidence intervals surrounding Z based on the goodness of fit of the regression. Total mortality is comprised of two components: “natural” mortality (M); mortality due to predation, disease, etc., and “fishing” mortality (F, yr^{-1}); mortality due to harvesting by humans, where

$$Z = M + F$$

Natural mortality rate (M) was estimated using Pauly's empirical equation (Pauly, 1980) i.e.

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

Where $L\infty$ is expressed in mm and T, the mean annual water temperature in ^{o}C which here is 25 ^{o}C. Fishing mortality (F,yr^{-1}) was computed by subtracting M from Z. Exploitation rate (E) is the portion of total mortality due to fisheries. It was obtained by the relationship of Gulland (1971).

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

3. RESULTS

3.1. Distribution

The geographical distribution and abundance of *Tapes decussata*in Lake Timsah are shown in Fig. 1B. The species was recorded throughout the surveyed areas of the Lake, being found in only 25.0 and 41.7% of the transects at North and South islands, respectively. The mean densities of all quadrates taken per transect ranged from 20 to 75 ind.m^{-2}in the northern shore (Etap site) and from 25 to 100 ind.m^{-2} in the western shore (Bridge site) where it was recorded in all transects. The highest density was recorded at the southern shore (El-Taawen area), with up to 252 ind.m^{-2}.

3.2. Density

Monthly changes in the population density of *T.decussata* at the southern region of Lake Timsah are shown in Fig.2.The density ranged from 17.3 (in February) to 218.9 (in September 2005) ind.m^{-2}. The average density ±S.D. was 77.6 ±59.2 ind.m^{-2} over the study period.

3.3 Biomass

Marked monthly changes were observed for the total biomass (Fig.3).The values fluctuated between 1.43 and 10.56 gFDW.m^{-2} and showed more or less similar trends in the mean density mode of variation of *T.decussata* at El-Taawen area. Monthly collections throughout the study period (n=14) yielded an average of 5.35±3.00 g FDW.m^{-2}.A marked decline in total biomass was accounted during October, December 2004, February-March, and June 2005(< 3.5 gFDW.m^{-2}).A pronounced rise was observed in November 2004 (8.83) and July2005 (8.57 gFDW.m^{-2}).

3.4. Population structure

Length-frequency distribution of*T.decussata*exhibits considerable seasonal changes (Table 1). The earlier mode (6mm shell length) was recorded during November 2004 and March 2005 where the length class represented 2.4 and7.9 % of the whole population, respectively.The later mode was represented by 20.9 % of the whole population during November 2004 at a length class of 30 mm. The largest animal ever found, in July 2005, was 48.0mm long and represented only 0.4 % of the total population.

Recruitment of juveniles (≤ 12 mm shell length) were found abundantly in most monthly samples (Table 1).The proportion of these juveniles relative to the total population ranged from 15.2 to 70.5 % (Fig. 4).Two minor peaks were recorded in October (31.9 %) and December 2004 (30.0 %) and two major peaks of 69.0 and 70.0 % were observed in March and August 2005, respectively.

3.5. Growth parameters

Monthly length-frequency data for pooled samples collected were entered into the FiSAT and the extreme value theory was applied to find out the maximumlength(L∞) from extreme values. The observed extreme length was 48.0 mm and the computer predicted extreme length was 48.92mm (Fig. 5).The confidence interval was 45.96 to 51.88 mm (95 % probability of occurrence).

The Powell-Wetherall plot is shown in Fig. 6. The corresponding estimates of L∞ and Z/K were 48.93 and 1.787, respectively and the correlation coefficient for the regression line was -0.974 (a= 17.56 and b=-0.359). The growth parameters of *T.decussata*were estimated by using the von Bertalanffy growth formula: L∞=50.4mm and K=0.81 yr^{-1}. For these estimates through ELEFAN I, the response surface (Rn) was 0.174 (Fig. 7).Growth performance index (ϕ') of Munro and Pauly (1983) was estimated to be 3.31.The computed growth curves are shown over the restructured length-frequency distribution in Fig.8.

3.6. Mortality and exploitation rate

Through length-converted catch curve, total mortality (Z) was estimated at 2.52 yr^{-1}(confidence interval CI= -3.38-8.42).The catch curve utilized in the estimation of Z is represented in Fig. 9.The darkened circles represent the points used in calculating Z through least square regression analysis. The correlation coefficient for the regression was -0.984. The intercept (a) and slope (b) ±S.D. of the regression line performed on the selected data points were 8.11 ± 1.38 and -2.52 ± 0.46, respectively.

Estimated value of natural mortality (M) from Pauly's empirical formula is 1.28 yr^{-1}.Fishing mortality (F) was estimated to be 1.24 yr^{-1}.The rate of exploitation (E) was estimated as 0.49.

3.7. Recruitment pattern

Continuous pattern of recruitment was observed. The number of recruitment pulses per year was four (Fig. 10).The relative strength of these pulses was 14.19, 16.02, 8.26 and 15.59 %.

3.8. 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 30.0 mm (Fig. 11). The value of F was 2.85yr^{-1}. The highest values of mean annual catch (in numbers) occurred in the length range between 21.0-27.0 mm.

4. DISCUSSION

ThevereridTapes decussata (Linnaeus, 1758) is indigenous to the Mediterranean Sea (Fouda and Abou-Zied, 1990). It has penetrated through the Suez Canal and successfully colonized Lake Timsah, where it exhibits a high reproductive potential (Kandeel, 1992; 2006). The highest abundance of this species (up to 252ind.m^{-2}) was recorded at the southern region of Lake Timsah around El-Taawen area. The sediment of this area is suitable for larval settlement and adult survival (Mohammed et al., 1992). El-Taawen area may represent the most suitable area for the cultivation of *T. decussata* in Lake Timsah.

For planning and management of bivalve resources, knowledge of various population parameters (growth, recruitment, mortality) and exploitation level (E) of that population is necessary. There are many tools for stock assessment. Of these, FiSAT (FAO-ICLARM Stock Assessment Tools) has been used most frequently in estimating the population parameters of some venerid bivalve species (Albert et al., 2004;Bagher et al., 2007;Jagadis and Rajagopal, 2007;Amin et al., 2009; DelNorte-Campos and Villarta, 2010, and present study) because it only requires length-frequency data. The advantage of this technique is that within a year it is possible to assess for any stock whether you have sufficient length-frequency data. Population parameters are useful bases in comparing the status of exploited resources as they provide valuable information on how exploitation affects the population (Pauly, 1984).

Specific growth rate of *Tapes decussata*in Lake Timsah 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 of Jagadis and Rajagopal (2007) in *Gafrariumtumidum* and Moura et al. (2009) in *Callistachione* are in conformity with the present results.

Since individual growth is a non-linear process, the comparison of growth among different organisms or taxa is very difficult due to the problem of correlation between growth parameters; K and L∞. To overcome this problem, several growth performance indexes have been used (Moura et al., 2009). The growth performance index of Munro and Pauly (1983) (ϕ') is used to compare the growth parameters obtained in our work with those from literature on some venerid bivalves (Table 2). In our study, *T. decussata* displayed higher growth rate (K=0.810yr^{-1}) than did the populations of other venerids. The higher growth rate had been expected, because the species was collected in warmerTimsahwaters (15.9-30°C), whereas the othervenerids were sampled in colder waters. The slowing of growth and the deposition of the annual growth ring in *Chameleagallina* might be related to the decreasing seawater temperature (Gaspar et al., 2004).Some researchers suggest that growth increments are directly or indirectly related to temperature (Gaspar et al., 2004; Moura et al., 2009), while others indicate alternative physical and biological factors that also influence shell deposition (Leontarakis and Richardson, 2005).

*T. decussata*showed lower asymptotic length (L∞ =50.40) than other venerid bivalves (average value=65.3; Table 2). The value of growth performance index obtained in the present study (ϕ' =3.31) is consistent with those previously calculated for other venerid bivalves (average value= 3.08). This result indicates that the growth parameters K and L∞ estimated in the present work are an accurate representation of the considered population, since it has been suggested that values are similar for the same species and genera (Munro and Pauly, 1983; Brey, 1999; Bellido et al., 2000).

The size at first maturation previously estimated for *T. decussata* in Lake Timsah was 12.7 mm shell length (Kandeel, 1992). In our study, the highest values of mean annual catch occurred in the length range between 21.0-27.0 mm (Fig 11). Thus, the bulk of current catches are sexually mature.The percent of juveniles (≤ 12 mm shell length) relative to the total population ranged from 15.2 to 70.5 % through the study period (Fig. 4) indicating high abundance of recruits. This suggests the feasibility of collecting natural spat for management and aquaculture production of*T. decussata* in Egyptian waters.

Four recruitment pulses were derived (Fig. 10). Multiple spawnings (September, December, April and August) and high reproductive output as reported by Kandeel (1992, 2006) provide biological bases for the observed recruitment patterns of *T. decussata*in Lake Timsah. This species had four gametogenic cycles throughout the year and moved rapidly from one cycle to the next without a resting stage (Kandeel, 2006) resulting in almost continuous reproduction. Continuous recruitment of *Venerupisaurea* in the southern region of Lake Timsah is explained, not only by successive spawning events per year but also by good survival of early life history stages and newly settled spats which represent a feed-back to the population (Kandeel, 2013).

*T. decussata*has a great economic importance; being consumed in large quantities in the Suez Canal region, and exported to some European countries (Kandeel, 1992). Thus, they are extensively fished in Lake Timsah. Overfishing could result in depletion or destruction of the natural beds.In the present study, the clam bed can still sustain the fishery, as reportd for *Paphia textile* by Albert et al., (2014). Fishing mortality (F) of *T. decussata*was 1.24yr^{-1}(Fig 9). The high exploitation rate, E, 0.49 indicates seriousoverexploitation of the stock.Regarding sustainable commercial exploitation of this resource, a guideline to prevent recruitment overfishing is imperative. Another guidelineincludes imposing closed seasons during the months of peak spawning activity. These guidelines can restore the stock to a sustainable status.

INDICATION OF FIGURES AND TABLES

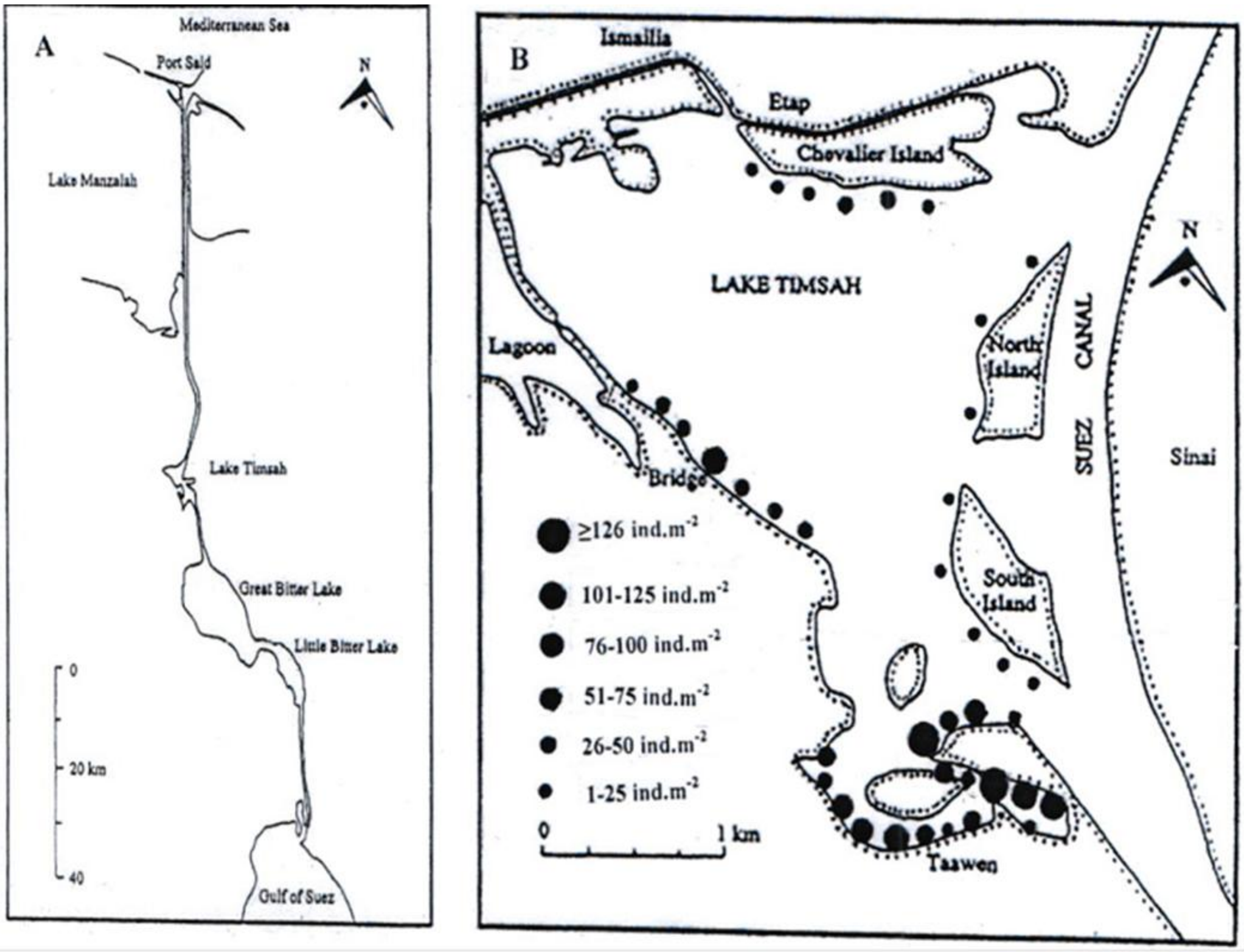


Figure 1: Map of the Suez Canal (A) Showing the distribution and abundance of *T. decussate*in the major geographical areas of Lake Timsah (B).

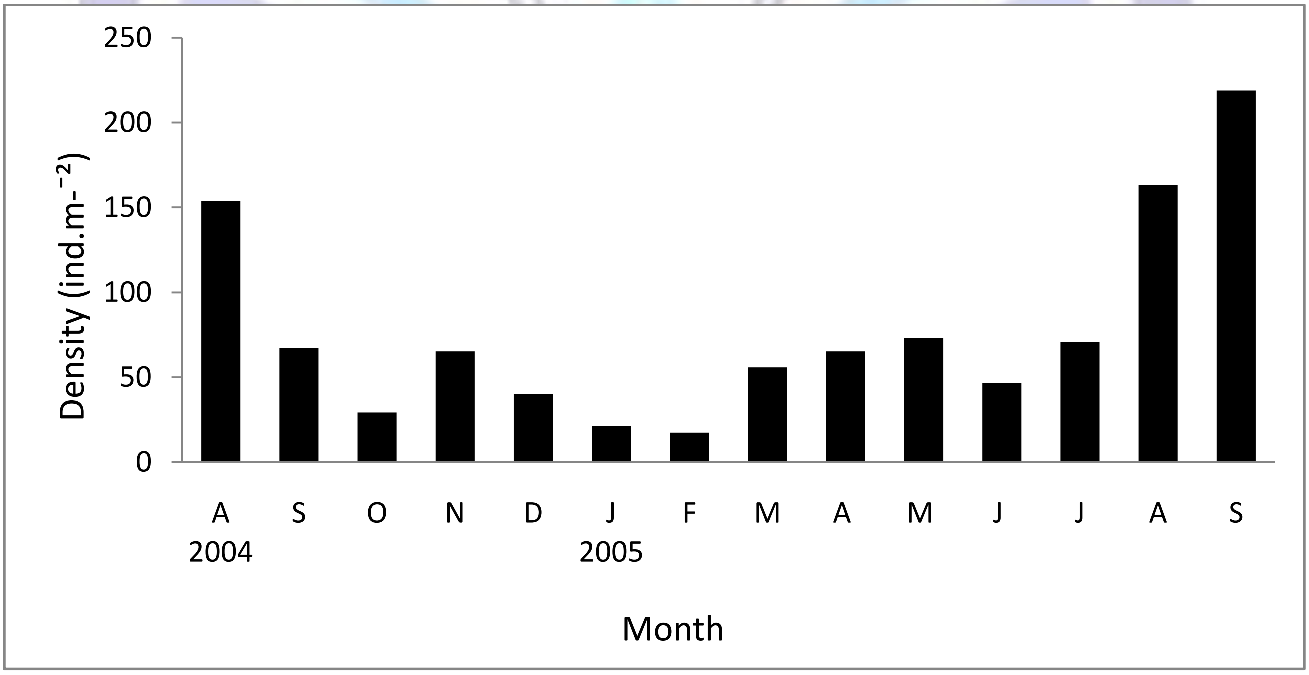


Figure 2: Monthly mean densities (ind.m^{-2}) of *T.decussata* at El-Taawen area, Lake Timsah.

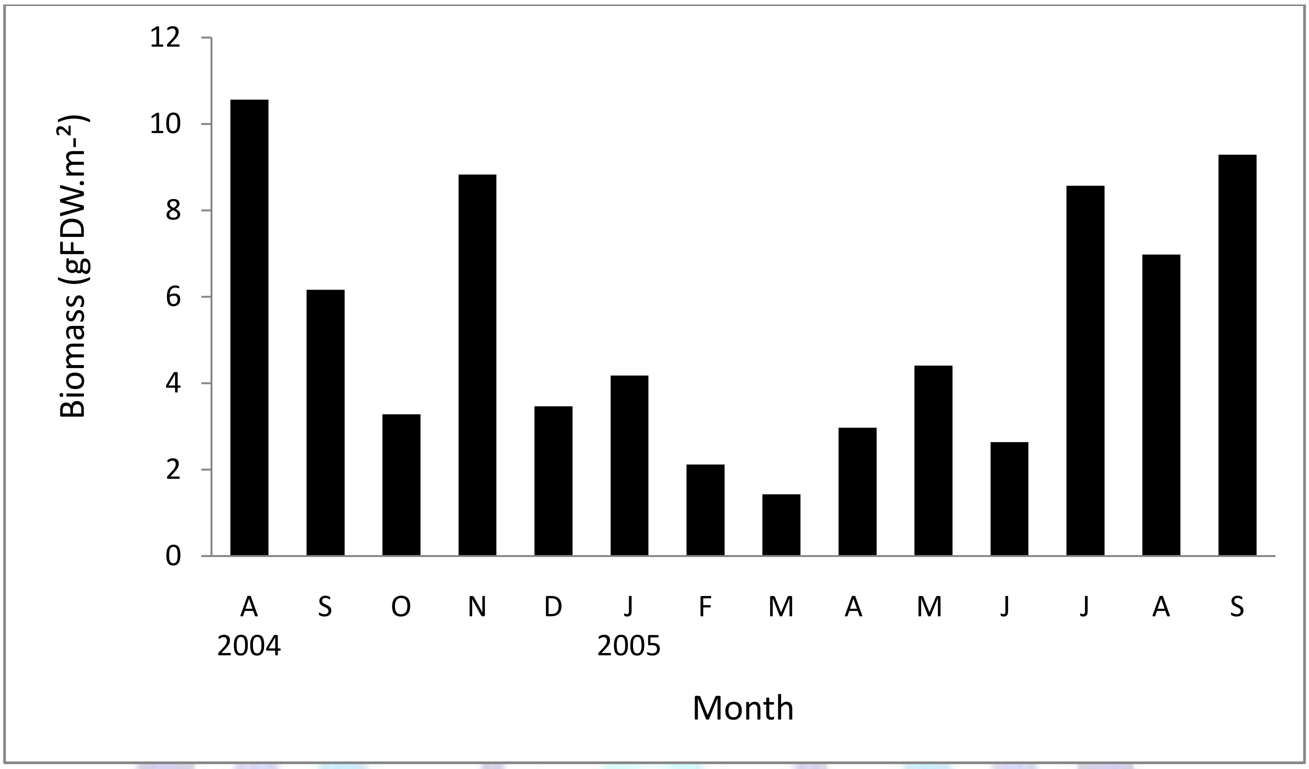


Figure 3: Monthly changes in total biomass (gFDW.m^{-2}) of *T. decussata* at El-Taawen area, Lake Timsah.

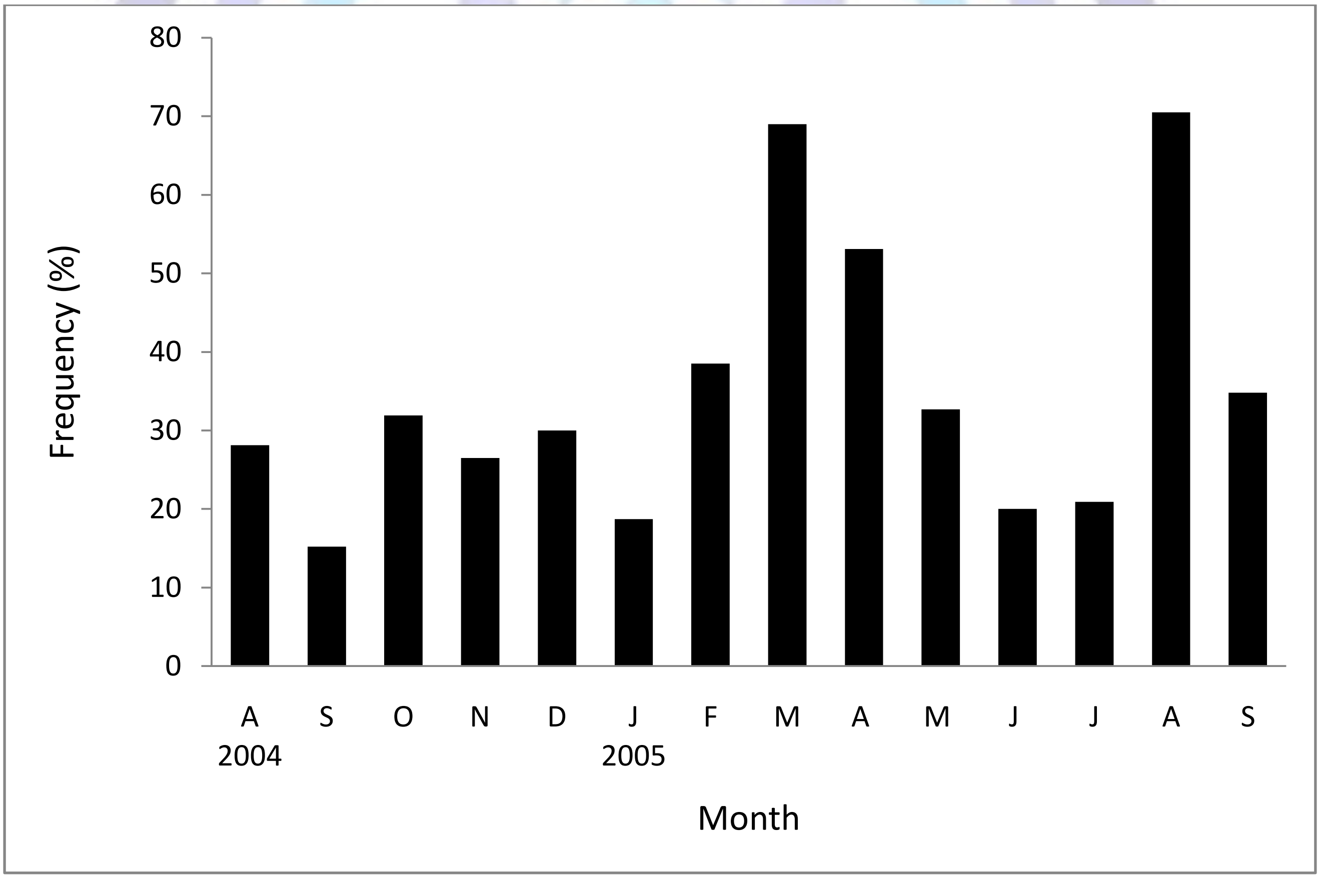


Figure 4: Monthly variation in the proportion of recruited juveniles (≤ 12 mm shell length) relative to the total population of *T. decussata* at El-Taawen area, Lake Timsah.

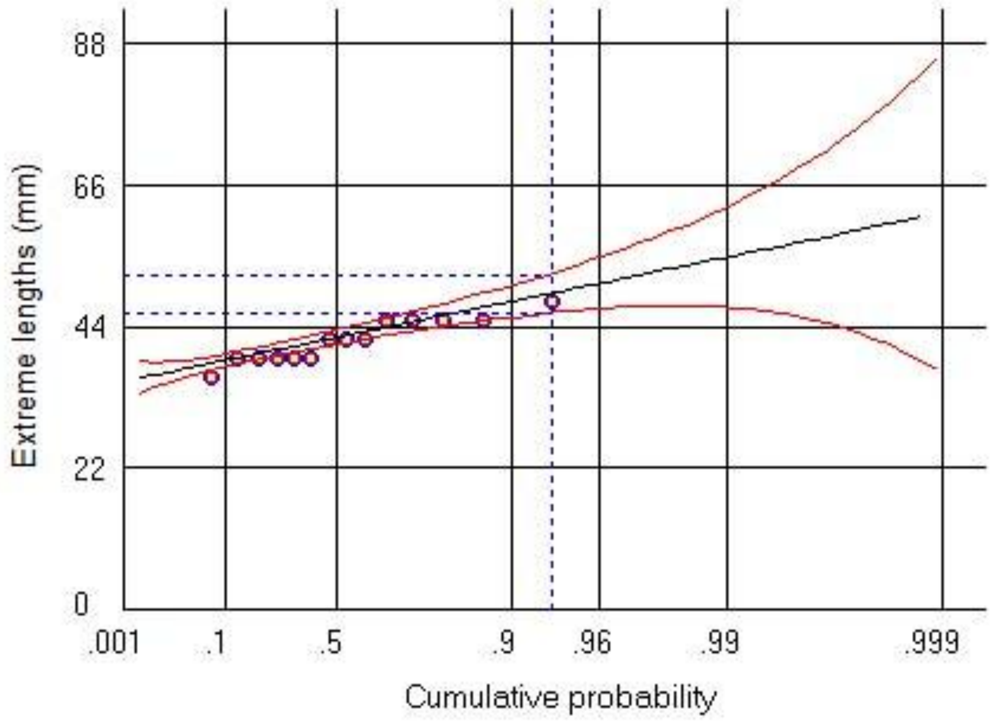


Figure 5: Predicted extreme length of *T. decussata* (48.92 mm) collected from Lake Timsah.

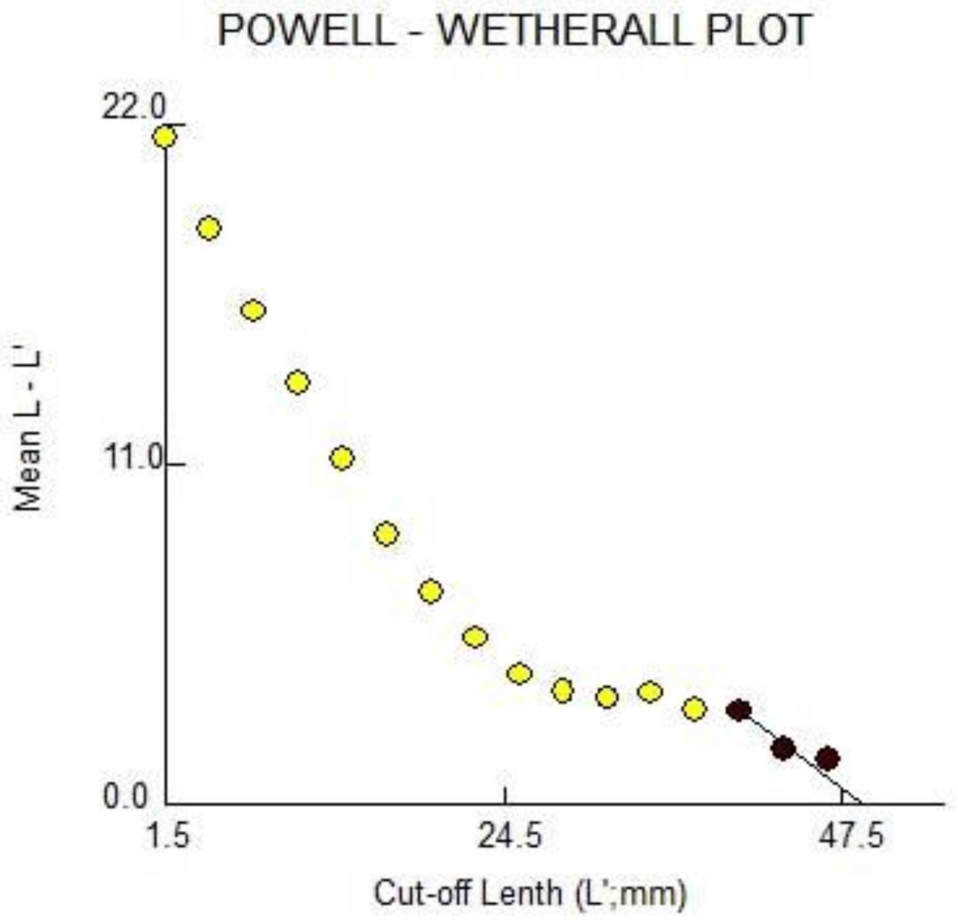


Figure 6: Powell-Wetherall plot of the estimation of L∞ (48.93 mm) and Z/K (1.787) for *T. decussata* in Lake Timsah.

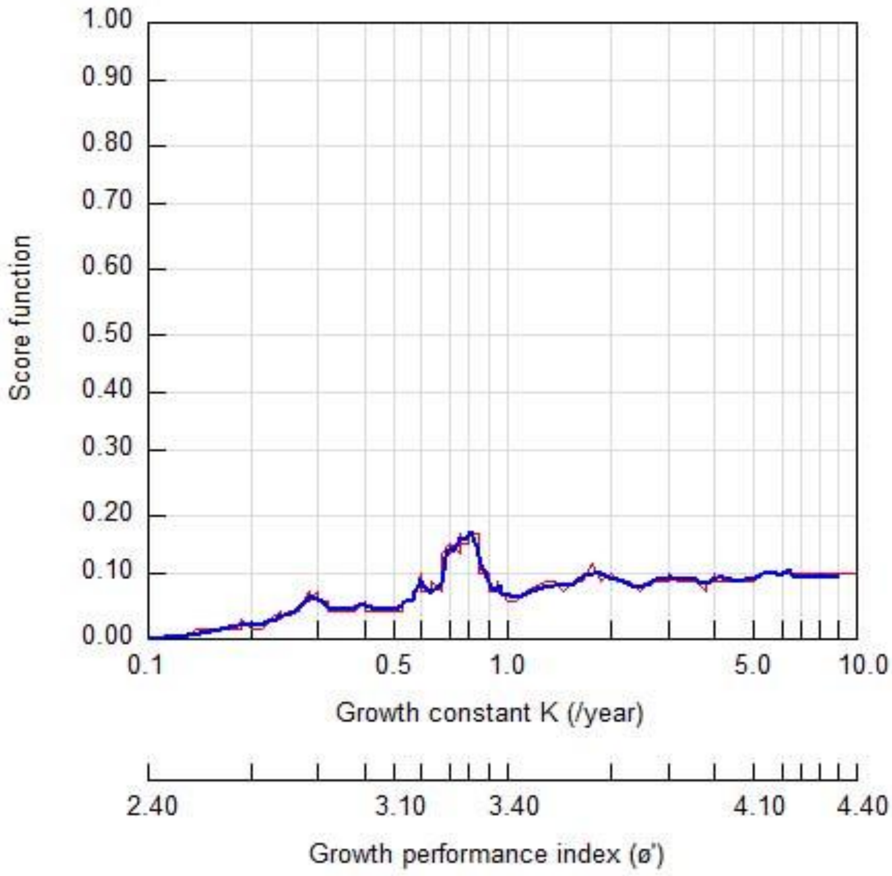


Figure 7: Scan of "K" value for *T. decussata* collected from Lake Timsah

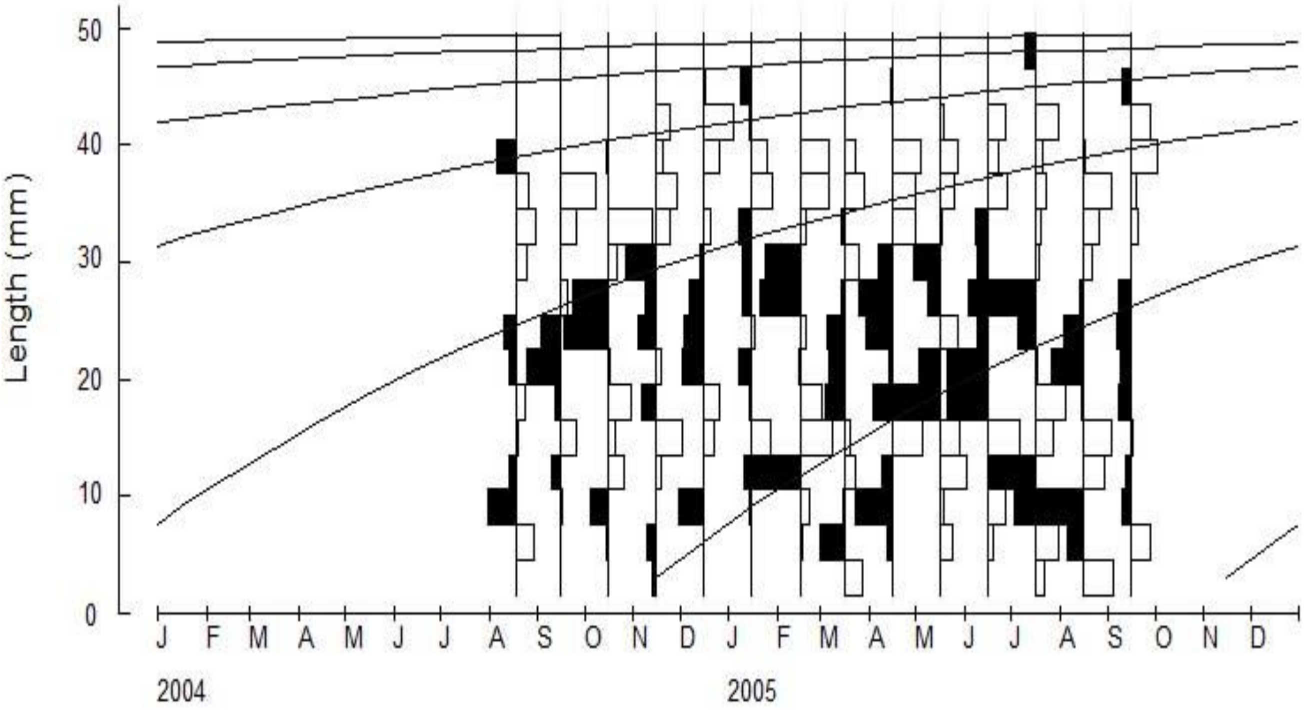


Figure 8: Restructured length-frequency distribution and the estimated growth curves of *T. decussata*, using ELEFAN 1 (L∞ = 50.40 mm and K= 0.810 yr^{-1}).

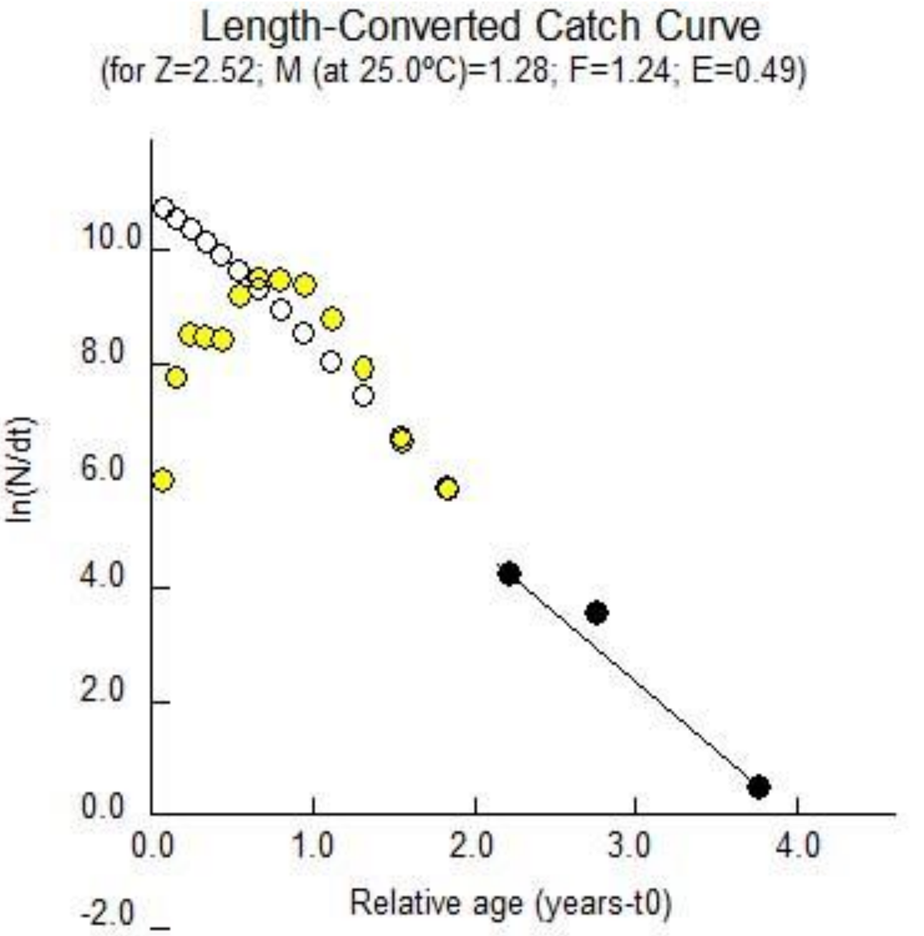


Figure 9: Length converted catch curve of *T. decussata* collected from Lake Timsah.

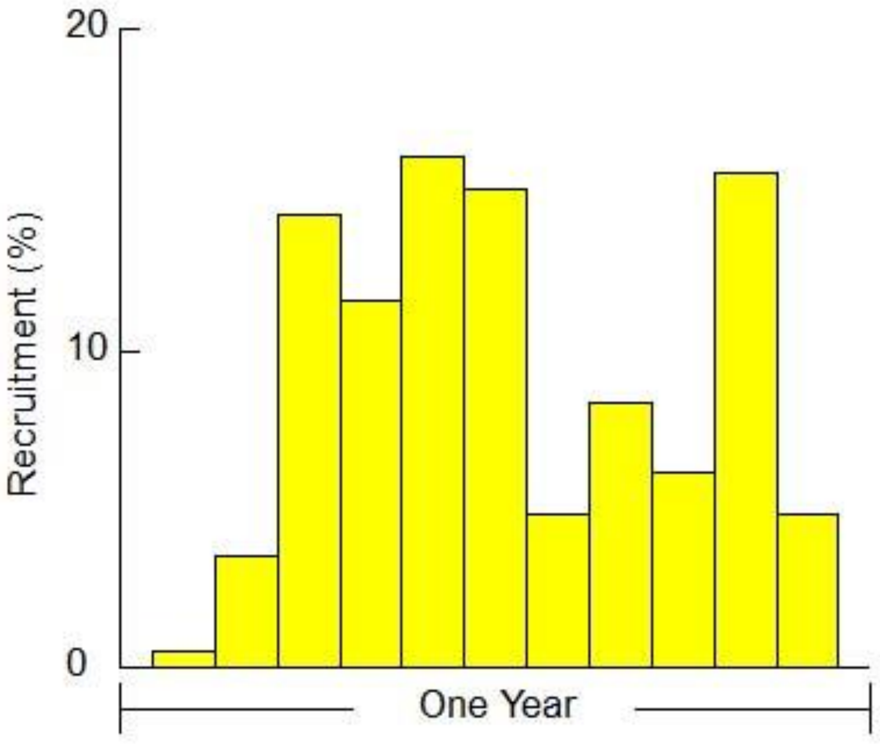


Figure 10: Recruitment pattern of *T. decussata* showing four recruitment pulses in Lake Timsah.

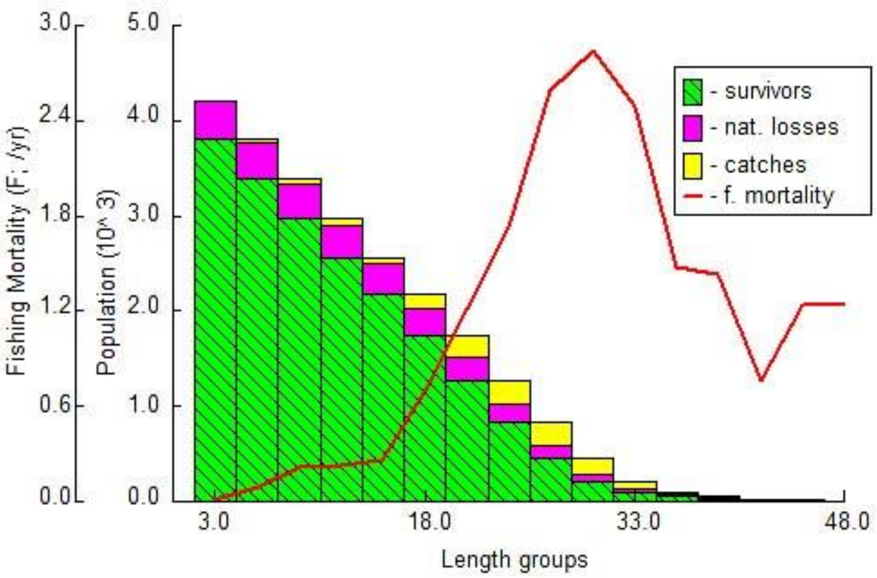
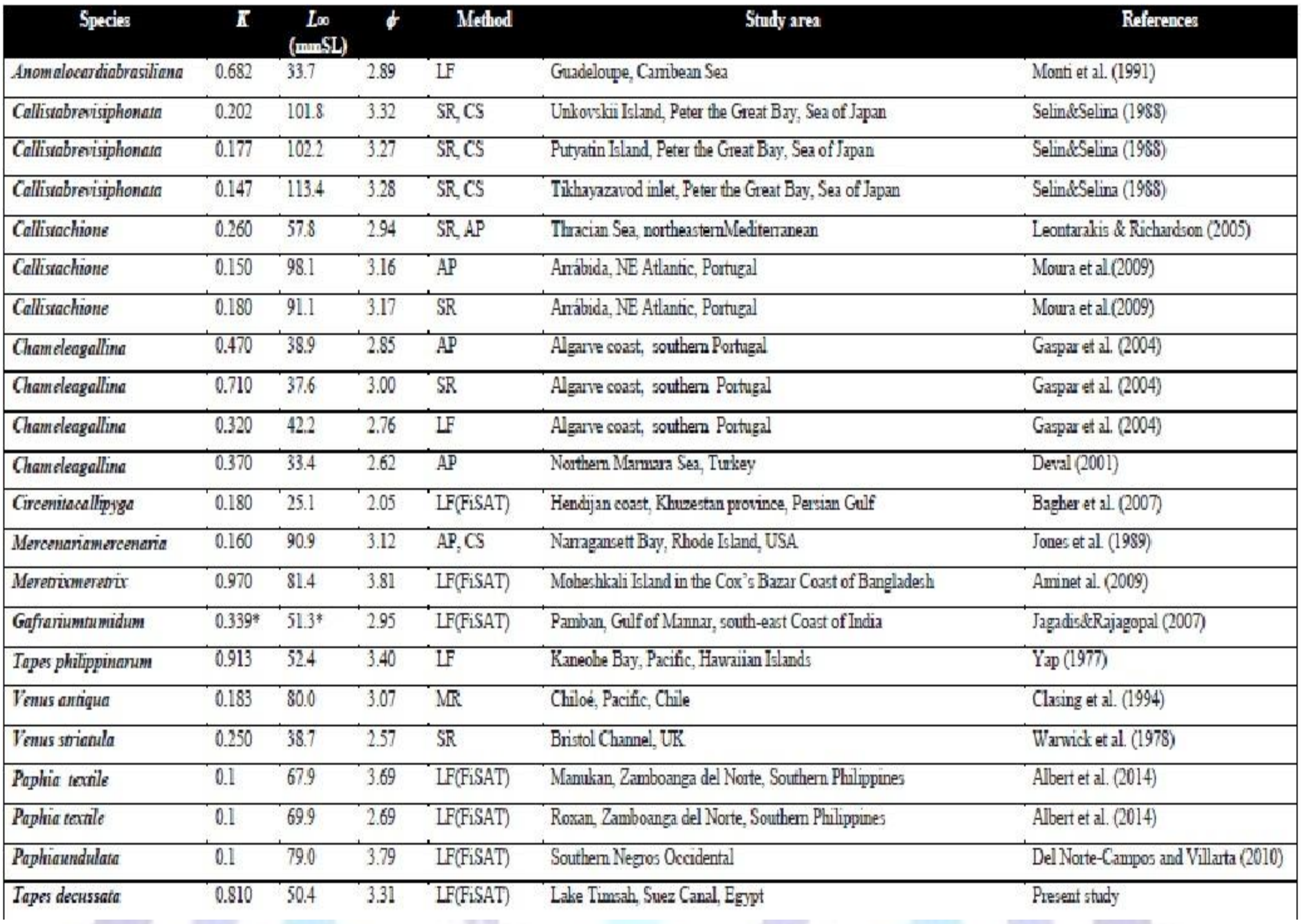


Figure 11: Length-structured virtual population analysis of *T. decussata* collected from Lake Timsah.

Table 1: Percentage-size frequency distributions of *T.decussata* at El-Taawen area, Lake Timsah during the period from August 2004 to September 2005.

	Shell length (mm)																
Date	**3.0**	**6.0**	**9.0**	**12.0**	**15.0**	**18.0**	**21.0**	**24.0**	**27.0**	**30.0**	**33.0**	**36.0**	**39.0**	**42.0**	**45.0**	**48.0**	**N**
Aug2004	-	1.9	16.3	13.8	13.7	8.7	15.6	14.4	9.4	3.1	0.6	0.6	1.9	-	-	-	160
Sep	-	-	3.0	7.3	6.9	15.5	25.3	21.2	10.2	7.8	2.4	0.4	-	-	-	-	245
Oct	-	1.0	2.5	2.0	4.5	6.0	13.9	30.9	26.8	10.4	1.5	-	0.5	-	-	-	201
Nov	1.4	2.4	1.9	3.3	1.4	11.4	9.5	20.9	17.4	20.9	5.2	2.4	1.4	0.5	-	-	211
Dec	-	-	3.2	3.2	4.8	6.0	18.5	19.8	18.1	12.4	6.8	4.8	1.6	0.4	0.4	-	249
Jan 2005	-	-	1.2	2.6	1.9	9.2	15.5	13.0	19.2	15.5	13.6	1.9	1.9	1.9	2.6	-	162
Feb	-	0.8	0.8	3.3	0.8	2.4	9.8	12.2	30.1	26.0	10.6	2.4	0.8	-	-	-	123
Mar	1.2	7.9	5.5	5.5	8.5	17.7	17.7	17.0	10.4	3.7	3.7	0.6	0.6	-	-	-	164
Apr	-	1.6	3.0	2.8	1.8	3.9	12.4	23.4	25.7	17.0	5.0	2.5	0.7	-	0.2	-	436
May	-	0.6	1.7	2.7	5.7	29.4	19.8	7.8	12.4	10.8	5.3	2.3	0.9	0.6	-	-	526
Jun	-	0.2	0.3	1.0	1.9	18.6	23.4	16.5	17.0	10.2	7.5	1.8	1.3	0.3	-	-	617
Jul	0.4	0.4	2.1	3.2	1.8	1.1	11.0	19.5	33.0	12.3	8.8	3.5	2.1	0.4	-	0.4	282
Aug	1.0	8.5	13.2	3.1	2.4	10.8	21.2	18.5	12.3	5.6	2.4	0.4	0.6	-	-	-	489
Sep	-	0.9	4.8	7.5	9.0	15.3	16.1	17.0	14.0	8.3	4.2	2.3	0.2	0.2	0.2	-	577

Table 2: Values of von Bertalanffy growth parameters (K and L∞)and growth performance indices (ϕ') for various venerid bivalve species. Age determination method: LF: length-frequency, SR: surface rings, CS: cross sections, TS: thin sections, AP: acetate peels, MR: mark and recapture.



Species	K	$L\infty$ (mmSL)	ϕ	Method	Study area	References
Anomalocardiabrasiliana	0.682	33.7	2.89	LF	Guadeloupe, Carribean Sea	Monti et al. (1991)
Callistabrevisiphonata	0.202	101.8	3.32	SR, CS	Unkovskii Island, Peter the Great Bay, Sea of Japan	Selin&Selina (1988)
Callistabrevisiphonata	0.177	102.2	3.27	SR, CS	Putyatin Island, Peter the Great Bay, Sea of Japan	Selin&Selina (1988)
Callistabrevisiphonata	0.147	113.4	3.28	SR, CS	Tikhayazavod inlet, Peter the Great Bay, Sea of Japan	Selin&Selina (1988)
Callistachione	0.260	57.8	2.94	SR, AP	Thracian Sea, northeasternMediterranean	Leontarakis & Richardson (2005)
Callistachione	0.150	98.1	3.16	AP	Arrábida, NE Atlantic, Portugal	Moura et al.(2009)
Callistachione	0.180	91.1	3.17	SR	Arrábida, NE Atlantic, Portugal	Moura et al.(2009)
Chameleagallina	0.470	38.9	2.85	AP	Algarve coast, southern Portugal	Gaspar et al. (2004)
Chameleagallina	0.710	37.6	3.00	SR	Algarve coast, southern Portugal	Gaspar et al. (2004)
Chameleagallina	0.320	42.2	2.76	LF	Algarve coast, southern Portugal	Gaspar et al. (2004)
Chameleagallina	0.370	33.4	2.62	AP	Northern Marmara Sea, Turkey	Deval (2001)
Circenitacallipyga	0.180	25.1	2.05	LF(FiSAT)	Hendijan coast, Khuzestan province, Persian Gulf	Bagher et al. (2007)
Mercenariamercenaria	0.160	90.9	3.12	AP, CS	Narragansett Bay, Rhode Island, USA	Jones et al. (1989)
Meretrixmeretrix	0.970	81.4	3.81	LF(FiSAT)	Moheshkali Island in the Cox's Bazar Coast of Bangladesh	Aminet al. (2009)
Gafrariumtumidum	0.339*	51.3*	2.95	LF(FiSAT)	Pamban, Gulf of Mannar, south-east Coast of India	Jagadis&Rajagopal (2007)
Tapes philippinarum	0.913	52.4	3.40	LF	Kaneohe Bay, Pacific, Hawaiian Islands	Yap (1977)
Venus antiqua	0.183	80.0	3.07	MR	Chiloé, Pacific, Chile	Clasing et al. (1994)
Venus striatula	0.250	38.7	2.57	SR	Bristol Channel, UK	Warwick et al. (1978)
Paphia textile	0.1	67.9	3.69	LF(FiSAT)	Manukan, Zamboanga del Norte, Southern Philippines	Albert et al. (2014)
Paphia textile	0.1	69.9	2.69	LF(FiSAT)	Roxan, Zamboanga del Norte, Southern Philippines	Albert et al. (2014)
Paphiaundulata	0.1	79.0	3.79	LF(FiSAT)	Southern Negros Occidental	Del Norte-Campos and Villarta (2010)
Tapes decussata	0.810	50.4	3.31	LF(FiSAT)	Lake Timsah, Suez Canal, Egypt	Present study

*Mean value for males and females; $\phi' = \log K + 2 \log L\infty$

5. REFERENCES

1. Albert, F.,Argente,T.,andEstacion, J.S. 2014. Effect of different harvesting practices on the dynamics of *Paphia textile* (Gmelin 1792) (Bivalvia: Veneridae) populations at two sites in Zamboanga del Norte, Southern Philippines. Environ. Exper. Biol. 12,113–120.
2. Amin, S.M.N.,Zafa,r M., andBarua, M.2009. Population dynamics of Venus clam *MeretrixMeretrix*from the Moheshkali Island in the Cox's Bazar Coast of Bangladesh.Asian Fish. Sci.22, 1031–1043.
3. Bagher,N.S.M.,Negar G.,Preetha K., andSimin D.M. 2007.Population growth of the venerid bivalve *Circenitacallipyga* in the Hendijan coast, Persian Gulf.Pak. J. Biol. Sci. 10, 3185–3189.
4. Bellido, J.M., Pierce, G.J., Romero, J.L., and Millán, M. 2000. Use of frequency analysis methods to estimate growth of anchovy (*Engraulisencrasicolus* L., 1758) in the Gulf of Cadiz (SW Spain).Fish. Res. 48,107–115.
5. BertalanffyL.v.1934.UntersuchungenUberdieGesetzlichkeiten des Wachstums. 1. AllgemeineGrundlagen der Theorie. Roux' Arch. Entwicklungsmech. Org. 131,613–653.
6. Borsa P., and Millet, B.1992.Recruitment of the clam *Ruditapesdecussatus* in the lagoon of Thau, Mediterranean.Estuar.Coast. Shelf Sci. 35, 289–300.
7. Breber, P.1980.Annual gonadal cycle in the carpet-shell clam *Venerupisdecussata* in Venice Lagoon, Italy.Proc. Nat. Shellfish. Assoc. 70, 31–35.
8. Brey, T. 1999. Growth performance and mortality in aquatic macrobenthic invertebrates.Adv. Mar. Biol. 35,153–223.
9. Clasing, E.,Brey, T., Stead, R., Navarro, J., and Asencio G.1994. Population dynamics of *Venus antiqua* (Bivalvia: Veneracea) in the Bahia de Yaldad, Isla de Chiloé, southern Chile. J. Exp. Mar. Biol. Ecol. 177,171–186.

10. Del Norte-Campos, A., and Villarta, K. A.2010.Use of population parameters in examining changes in the status of the Short-Necked Clam *Paphiaundulata* Born, 1778 (Mollusca, Pelecypoda: Veneridae) in Coastal Waters of Southern Negros Occidental.Science Diliman 22, 53–60.
11. Deval, M.C. 2001. Shell growth and biometry of the striped Venus*Chameleagallina* (L.) in the Marmara Sea, Turkey. J. Shellfish Res.20, 155–159.
12. El-Shenawy, N.S. 2004. Heavy–metal and microbial depuration of the clam *Ruditapesdecussatus* and its effect on bivalve behavior and physiology.Environ. Toxicol.19, 143–153.
13. FAO. 2014. *Ruditapesdecussatus* (Linnaeus, 1758). Accessed through Food and Agriculture Organization of the United Nations at http://www.fao.org/fishery/species/3542/en
14. Fouda, M.M,and Abou-Zeid, M.M. 1990. Bivalves of the Suez Canal lakes.Proc. Zool. Soc. Egypt21, 231–240.
15. Gab-Alla, A. A-F.A.,Hartnoll, R.G., Ghobashy, A-F., and Mohammed, S. Z.1990. Biology of penaeid prawns in the Suez Canal lakes. Mar. Biol. 107, 417–426.
16. Gabr,H.R.,and Gab-Alla, A.A-F.A.2008.Effect of transplantation on heavy metal concentrations in commercial clams of Lake Timsah, Suez Canal, Egypt.Oceanologia 50, 83–93.
17. Gabr, H.R.1991.Ecological and biological studies on molluscs of Lake Timsah.M. Sc. Thesis, Suez Canal University, Egypt.
18. Gaspar, M.B., Pereira, A.M.,Vasconcelos, P., and Monteiro, C.C. 2004. Age and growth of *Chameleagallina*from the Algarve coast (southern Portugal): influence of seawater temperature and gametogenic cycle on growth rate. J. Mollus. Stud.70, 371–377.
19. Gayanilo, F.C.Jr, Sparre, P., andPauly, D. 2005. FAO-ICLARM stock assessment tools II (FiSAT)-revised version, User's guide, FAO, Rome.
20. Ghobashy, A.A, Mohammed,S.Z, Gabr, H.R, andBrand, A.R.1992.Community structure and seasonal variation of Mollusca at Lake Timsah (Suez Canal).J. Egypt. Ger. Soc. Zool.7 (B), 145–160.
21. Gulland, J.A. 1971. Estimation of mortality rates. Annex to Arctic fisheries working group report. ICES C. M. Doc. No. 3(mimeograph).
22. Hamza-Chaffai, A.,Amiard, J.C.,Pellerin, J.,Joux, L., and Berthet B. 2000.The potential use of metallothionein in the clam *Ruditapesdecussatus* as a biomarker of in situ metal exposure.Com. Biochem. Physiol. 127(C), 185–197.
23. Jagadis, I., andRajagopal, S. 2007. Age and growth of the Venus clam *Gafrariumtumidium* (Roding) from south-east coast of India. Indian J. Fish.54, 351–356.
24. Jones, D.S, Arthur, M.A,and Allard D.J. 1989. Sclerochronological records of temperature and growth from shells of *Mercenariamercenaria* from Narragansett Bay, Rhode Island. Mar. Biol. 102,225–234.
25. Kandeel, K.E. 1992. Biological studies on the reproduction of some bivalves in Lake Timsah.M. Sc. Thesis, Suez Canal University, Egypt.
26. Kandeel, K.E. 2006. Quantitative assessment of gamete production in two commercially harvested clams, *Venerupisaurea* and *Tapes decussata* (Bivalvia:Veneridae) in Lake Timsah, Suez Canal, Egypt. Catrina 1, 41–52.
27. Kandeel, K.E. 2008.Length-weight relationships and monthly variations in body weights and condition indices of two clam's species*;* *Venerupisaurea* and *Tapes decussata* in Lake Timsah, Egypt.Catrina 3, 111–124.
28. Kandeel, K.E. 2013.Recruitment pattern of commercially harvested clam, *Venerupisaurea* (Bivalvia: Veneridae) at the southern region of Lake Timsah, Suez Canal, Egypt.Thalassia Sal. 35, 11–28.
29. Kaschl, A., and Carballeira, A. 1999. Behavioural responses of *Venerupisdecussata* (Linnaeus, 1758) and *Venerupispullastra* (Montagu, 1803) to copper-spiked marine sediments.Bol. Inst. Esp. Oceanogr. 15, 383–394.
30. Leontarakis, P.K., and Richardson, C.A. 2005. Growth of the smooth clam, *Callistachione* (Linnaeus, 1758) (Bivalvia: Veneridae) from the Thracian Sea, northeastern Mediterranean. J. Mollus. Stud.71, 189–198.
31. Mohammed, S.Z.,Gabr, H.R.,Ghobashy, A.A., and Brand A.R. 1991.Species composition and distribution of benthic molluscs in Lake Timsah (Suez Canal).J. Egypt. Ger. Soc. Zool. 7 (B), 161–174.
32. Monti, D., Frenkie,l, L., andMoueza M. 1991. Demography and growth of *Anomalocardiabrasiliana* (Gmelin) (Bivalvia:Veneridae) in a mangrove, in Guadeloupe (French West Indies). J. Mollus. Stud. 57,249–257.
33. Moura, P., Gaspar,M.B,and Monteiro, C.C. 2009. Age determination and growth rate of a *Callistachione* population from the southwestern coast of Portugal. Aquat. Biol. 5, 97–106.
34. Munro, J.L,and Pauly, D. 1983.A simple method for comparing the growth of fishes and invertebrates.Fishbyte1, 5–6.

35. Ojea, J., Pazos,A.J., Martinez, D.,Novoa, S., Sanchez, J.L, and Abad M. 2004.Seasonal variation in weight and biochemical composition of the tissues of *Ruditapesdecussatus* in relation to the gametogenic cycle. Aquaculture 238, 451–468.
36. Pauly, D.1983. Length-Converted Catch Curves: A Powerful Tool for Fisheries Research in the Tropics (Part I). Fishbyte 1, 9–13.
37. Pauly, D.1984. Fish population dynamics in tropical waters: A manual for use with programmable calculators. ICLARM Studies and Reviews 8, 325 pp.
38. Pauly, D.1980.On the interrelationships between natural mortality, growth parameters and mean environmental temperature in 175 fish stocks.J. Cons. Int. Explor. Mer39, 175–192.
39. Pauly, D.1986.On improving operation and use of the ELEFAN programs. Part II. Improving the estimation of L∞.Fishbyte4, 18–20.
40. Pauly, D., and David, N. 1981.ELEFAN-1 BASIC program for the objective extraction of growth parameters from length frequency data.Meeresforsch 28, 205–211.
41. Phillips, D.J.H, andRainbow,P.S. 1993.Bio-monitoring of the trace aquatic contaminants. Elsevier, New York, 371 pp.
42. Poppe, G.T., and Goto Y.1991. European Seashells.Vol. II.Wiesbaden/Verlag Christa Hemmen, 221pp.
43. Saeger, J., andGayanilo, F.J.1986. A revised and graphics oriented version of ELEFAN I and II basic programs for use on HP/86/87 microcomputers. Technical Report of the Department Marine Fisheries No. 8.
44. Selin, N.I., andSelina M.S. 1988.Production characteristics of the bivalve mollusk *Callistabrevisiphonata* in Peter the Great Bay, Sea of Japan.Sov. J. Mar. Biol. 14,219–223.
45. Serdar, S.,Lok, A.,Kose, A.,Yildiz, H., Acarli,S.,andGoulletquer, P. 2007. Growth and survival rates of carpet shell clam (*Tapes decussatus* Linnaeus, 1758) using various culture methods in Sufa (Homa) Lagoon, Izmir, Turkey. Aquac. Eng. 37, 89–99.
46. Smaoui-Damak, W., Rebai, T.,Berthet, B., and Hamza-Chaffai, A. 2006. Does cadmium pollution affect reproduction in the clam *Ruditapesdecussatus*? A one –year case study.Comp. Biochem. Physiol. 143, 252–261.
47. Smaoui-Damak,W.,Hamza-Chaffai, A.,Berthet, B., and Amiard, J.C. 2003. Preliminary study of the clam *Ruditapesdecussatus* exposed in situ to metal contamination and originating from the gulf of Gabes. Tunisia. Bull. Environ. Contam. Toxicol.71, 961–970.
48. Tebble, N.1966.British Bivalve Seashells.A handbook for identification.Trustees of the British Museum (Natural history).London, 212 pp.
49. Vilela, H. 1950. Vida bentonica de *Tapes decussatus* (L.).Trav. St. Biol. Marit.Lisb.53, 1–120.
50. Warwick, R.M., George, C.L. and Davies J.R. 1978.Annual macrofauna production in a Venus community.Est. Coast. Mar. Sci. 7,215–241.
51. Wetherall, J.A. 1986. A new method for estimating growth and mortality parameters from length-frequency data. Fishbyte4, 12–15.
52. Wilbur, K.M., and Owen, G. 1964. Growth. In: Wilbur K.M.Yonge C.M. (eds.), Physiology of Mollusca. New York, Academic Press, vol.1, pp 211–242.
53. WoRMS 2014. *Tapes decussata* (Linnaeus, 1758). Accessed through: World Register of MarineSpeciesat http://www.marinespecies.org/aphia.php?p=taxdetails&id=422914
54. Yap, W.G. 1977. Population biology of the Japanese little-neck clam, *Tapes philippinarium*, in Kaneohe Bay, Oahu, Hawaiian Islands. Pac. Sci. 31,223–244.