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Population structure of clam *Venus verrucosa* Linnaeus, 1758 harvested in Thermaikos Gulf, NW Aegean Sea, Greece

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Abstract
Venus verrucosa is an edible bivalve of high commercial value in the area of Thermaikos Gulf, NW Aegean Sea and this study investigates the population structure of the species. In total, 9534 specimens with shell length (L) ranging from 11.84mm to 60.22 mm were monthly sampled at four stations. In the majority of cases, mean L was lower than the minimum landing size of 40mm. The mean abundance of the populations was quite similar in between three of the four stations. In Thermaikos Gulf, *V. verrucosa* displays isometric growth, with mean b value of 3.0544. The value of L_∞ ranged from 60.38mm to 65.63mm, while K ranged from 0.57 to 1.40 with these values being higher than those previously reported in the literature. The Condition Index values corresponded to the population's reproductive activity. A spatial and/or a temporal ban of harvesting the species is suggested for sustainable management of *V. verrucosa* populations in Thermaikos Gulf.

Keywords: Warty venus, population structure, condition index, Aegean sea

1. Introduction
The warty venus, *Venus verrucosa* Linnaeus, 1758 is a highly commercial edible bivalve. It is distributed throughout the Mediterranean and the eastern Atlantic (from Norway to South Africa) [1]. It inhabits sandy and muddy substrates, sometimes with maerl, as well as *Cymodocea nodosa* and *Posidonia oceanica* meadows, at depths up to 30 m [2][3], reaching a maximum length of 60 mm [4].

In Greece, *V. verrucosa* is mainly fished by small-scale fishermen, in the areas of the N Aegean Sea (Thermaikos and Strymonikos Gulfs, Gulfs of Kavala and Ierissos), Evvoikos and Saronikos Gulfs, Central Aegean, and Lesvos and Lemnos Islands [5]. Though the species annual production in Greece showed a declining trend from a peak in 1992 (2199.5 t) to a minimum production of 215.3 t in 2004 [6], it remains the subject of intensive fisheries and has an important market value. In recent years the production of *V. verrucosa* was stabilised around 290 t [6].

The biology of the warty venus has been previously studied mainly in the Adriatic and the N Aegean Sea. With respect to the reproduction, it has been found that in the Adriatic [7, 8, 9] and the Aegean Sea [2], this species reproduces from April to December, with a peak during the summer months. Accordingly, the western parts of the Mediterranean the species shows a prolonged reproduction period throughout the year [10], whereas in the Atlantic the reproduction takes place from April to October [11]. Additionally, information regarding the age and growth of warty venus in the Adriatic Sea [3, 12] and the N Aegean Sea [3] are known, whereas the weight-length relationships are only provided by Arneri *et al*. [13] (data by Apostolidis & Stergiou [14]) in Bari and Manfredonia, Royo and Gómez-Ramblado in Rio Piedras-Spain [15], and Tirado *et al*. in Malaga [10].

Aim of the present study was to investigate the population structure of *V. verrucosa* in the Thermaikos Gulf as it is harvested in real time by professional fishermen and provide information on the allometry and growth of the population. Such information is essential for the stock management of *V. verrucosa* population in the Thermaikos Gulf, which is one of the most important fishing areas in Greece [16]. *Venus verrucosa* has been intensively exploited in the Gulf and at certain sites its populations seem to have already suffered the effects of overfishing, as the personal communication with the fishermen has revealed.

2. Materials and Methods

Samplings of *V. verrucosa* were conducted on a monthly basis, from 4/2007 until 5/2008, at four stations (Paliomana, Agia Triada, Peraia and Karabournaki) in the area of the Thermaikos Gulf, NW Aegean Sea (Figure 1). All samplings were conducted by professional fishermen with SCUBA diving. The duration of each sampling was 30min, during which fishermen collected all the found individuals [17, 18]. All collected samples were stored on ice and transferred to the laboratory for further analyses.

The maximum depth of the water column in each sampling station, temperature, salinity, pH and dissolved oxygen were recorded, using electronic equipment of WTW Germany and Lovibond Checkit micro. Moreover, in order to examine the granulometry of the sediment, samples were also collected using a cylindrical sampler (height=20cm, diameter=7cm, total volume=769.69 cm^2). Sample analysis was done following the methodology presented by Buchanan [19].

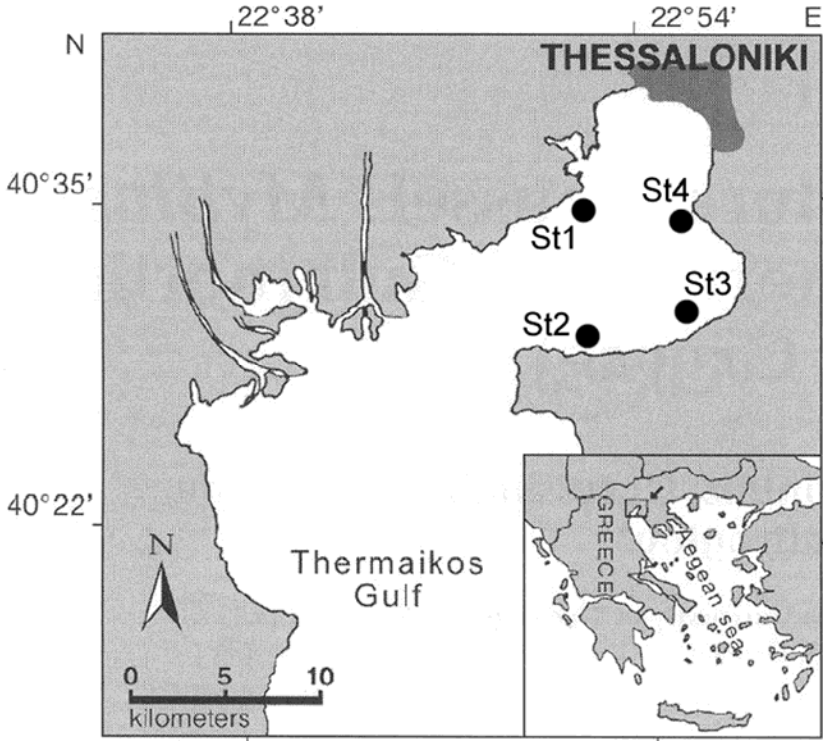

Fig 1: Map, indicating the sampling stations of *Venus verrucosa* in Thermaikos Gulf, NW Aegean Sea (4/2007-5/2008).

In the laboratory, all individuals were measured for total shell length (L, mm), height (H, mm) and width (Wd, mm) using a digital calliper. Total weight (W, g; including cavity fluid), wet body weight (W_w, g) and shell weight (W_s, g) were also recorded. Species abundance was expressed as the number of individuals (N) harvested in 30min of sampling based on the Greece legislation regarding minimum landing size (L_{com}), which in the case of *V. verrucosa* is 40 mm, while the number and the percentage of individuals below and above L_{com} was also recorded.

The relationships between shell length (L, mm), height (H,mm) and width (Wd, mm) with total weight (W, g) were established using the allometric model $Y= aX^b$ [20]. Comparisons of b values between stations, and within station but different seasons, were conducted using Analysis of covariance (ANCOVA) [21].

In addition, length frequency distributions per season and sampling station were constructed. For the definition of the class step, the approaches of Cancela da Fonseca [22] and Snedegor & Cochran [23] were used, setting the step at 5mm. Based on the frequency distributions, von Bertalanfy growth parameters (K, L_∞) were estimated using the non-parametric Scoring of ELEFAN (Electronic Length Frequency Analysis) using FISAT software [24]. ELEFAN is based on the seasonal Von Bertalanfy equation [25].

In order to estimate the condition of the species in the study area, the condition index (CI) suggested by Aguirre [26], was used: $CI = (W_w / W\text{-}W_s)*100$. Comparisons between CI values among stations and seasons were done using two way ANOVA and Fisher's Least Significant Difference (LSD) tests. Finally, for the estimation of spatiotemporal similarities multivariate analysis was employed, namely cluster analysis and multi-dimensional scaling (MDS) [27, 28, 29]. Firstly, the (abundance, and biometric data) × (sampling station and season) matrix was constructed following, data transformation (square root transformation) and the matrix transformation to a triangular one using Bray-Curtis similarity index. The above mention analyses were performed using PRIMER [30].

3. Results

Overall, 9,534 specimens (2,452 in spring 2007, 1,149 in summer 2007, 2,151 in autumn 2007, 1,987 in winter 2008, and 1,795 in spring 2008) of *V. verrucosa*, with a shell length ranging from 11.84mm to 60.22mm, were collected in 52 samplings. In the majority of cases, $L<L_{com}$ (i.e. 40mm), whereas only in three cases (St2 Agia Triada: spring 2007 and winter 2008, and St4 Karabournaki: summer 2007), the percentage of specimens with L< 40 mm was low (Table 1).

Measurements of salinity, temperature, ph and dissolved oxygen showed very low fluctuations, mainly seasonal ones (Figure 2) and no significant differences between stations were recorded as expected by their proximity (Figure 1). As far as

the sediment analysis is concerned, most of them could be characterised as sand to gravel, with bad to medium classification, from negative to symmetric and positive skeweness, and with leptokurtic to mesocurtic curve.

The minimum abundance values of *V. verrucosa* were recorded at station 2 in spring 2007 and the maximum at station 1 in the same season (Table 1). In general, the highest abundance was recorded at stations 1 and 4, followed by station 3. Station 2 showed the lowest abundance, with significant differences from all three other stations (Table 1).

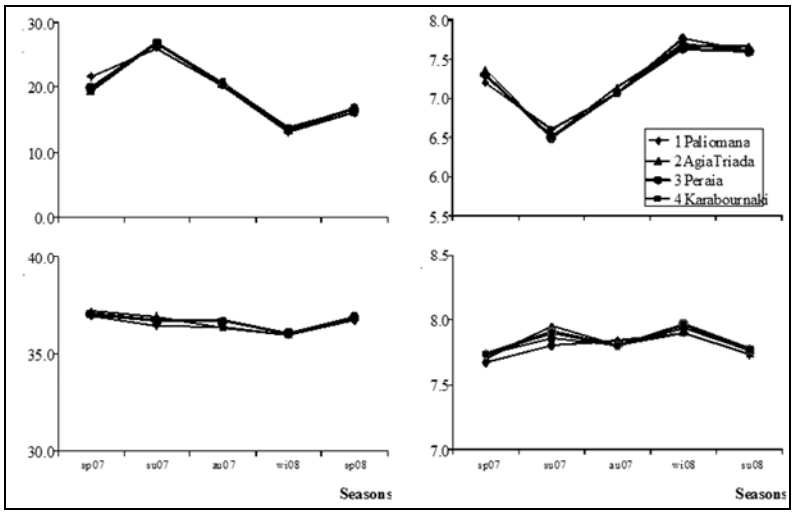

Fig 2: Seasonal variations of salinity (S, psu), temperature (T, ^{o}C), dissolved oxygen (mg/l) and ph in the sampling stations, Thermaikos Gulf, NW Aegean Sea (4/2007-5/2008). Sp07: spring 2007, su: summer 2007, au: autumn 2007, wi: winter 2008, and sp08: spring 2008.

According to two-way ANOVA, there is a statistical difference between the samplings stations and seasons due to differences in shell length (ANOVA: F-value=73.60 and 33.27, sampling stations and seasons, respectively; both cases p<0.01), and weight (ANOVA: F-value=145.40 and 30.74, sampling stations and seasons, respectively; both cases p<0.01). Fisher (LSD) test revealed that there is a complete separation of the populations as far as weight is concerned, whereas the populations of stations 1 and 3 are similar with respect to length and differ from the other two stations. In the contrary, Fisher (LSD) showed that there is a great resemblance between samples of different seasons, with only spring 2008 differentiating.

Length-frequency distributions of *V. verrucosa* are presented in Figure 3. One peak is observed at all stations except the summer and autumn at station 2, where two peaks are formed. The estimated von Bertalanffy growth parameters L_{∞} and K are given in Table 3. The value of L_{∞} was found to be the same at stations 1, 3 and 4 (L_{∞}=60.38) and somewhat higher at station 2 (L_{∞}=65.63). Correspondingly, the values of parameter K ranged from 0.57 (station 2) to 1.40 (station 1) (Table 2).

Table 1: Number of individuals per season and station for *Venus verrucosa* in Thermaikos Gulf, NW Aegean Sea (4/2007-5/2008), totally and in relation to minimum commercial size (L_{com} = 40 mm).

Sampling station	Season	N	N/h	N $L>L_{com}$	% $L>L_{com}$	N $L<L_{com}$	% $L<L_{com}$
1 (Paliomana)	sp07	1007	336	332	33.0	675	67.0
	su07	419	210	93	22.2	326	77.8
	au07	567	189	108	19.0	459	81.0
	wi08	858	286	118	13.8	740	86.2
	sp08	489	163	82	16.8	407	83.2
2 (Agia Triada)	sp07	93	31	72	77.4	21	22.6
	su07	71	36	34	47.9	37	52.1
	au07	168	56	42	25.0	126	75.0
	wi08	138	46	87	63.0	51	37.0
	sp08	369	185	86	23.3	283	76.7
3 (Peraia)	sp07	705	235	130	18.4	575	81.6
	su07	448	224	67	15.0	381	85.0
	au07	844	281	178	21.1	666	78.9
	wi08	392	131	148	37.8	244	62.2
	sp08	409	136	96	23.5	313	76.5
4 (Karabournaki)	sp07	647	216	196	30.3	451	69.7
	su07	211	106	119	56.4	92	43.6
	au07	572	191	232	40.6	340	59.4
	wi08	599	200	129	21.5	470	78.5
	sp08	528	264	136	25.8	392	74.2

N = number of individuals caught, N/h = number of individuals per half an hour of fishing operation, N $L>L_{com}$ and N $L<L_{com}$ = number of individuals with length (L) higher and lower than L_{com}, respectively, % $L>L_{com}$ and % $L<L_{com}$ = percentage of individuals with L higher and lower than L_{com}, respectively. Sp07: spring 2007, su: summer 2007, au: autumn 2007, wi: winter 2008, and sp08: spring 2008.

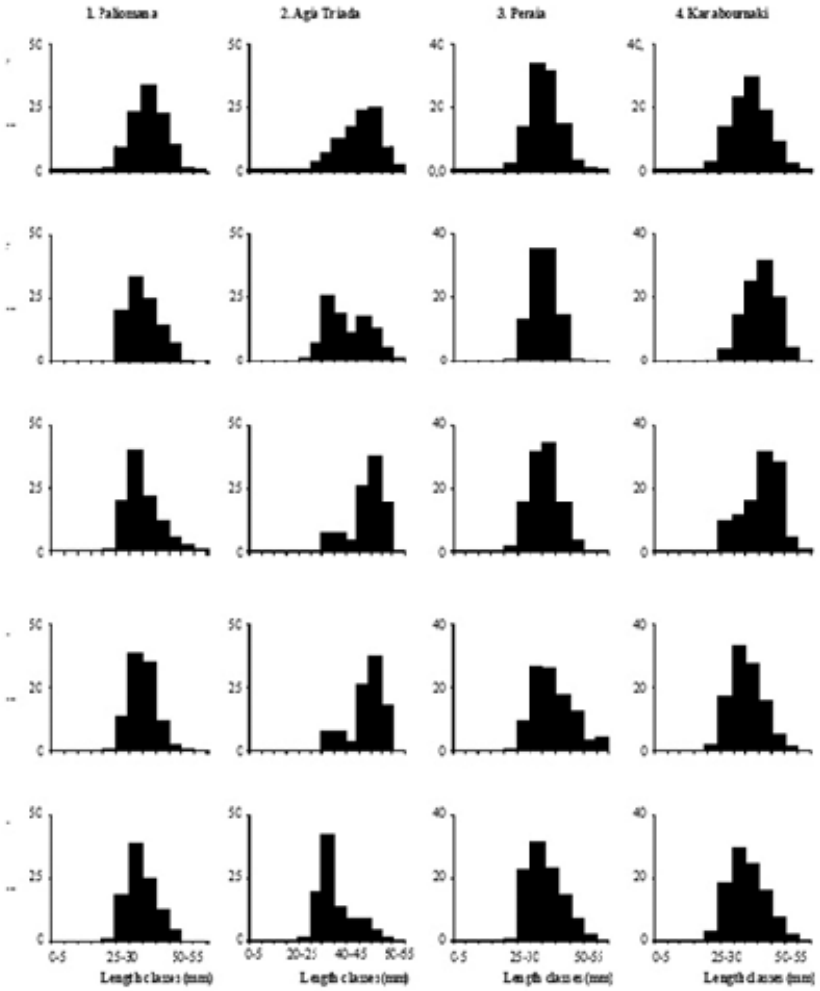

Fig 3: Length-frequency distributions of *Venus verrucosa* in the four different sampling stations in Thermaikos Gulf, NW Aegean Sea (4/2007-5/2008). From top to bottm: spring 2007, summer 2007, autumn 2007, winter 2008 and spring 2008.

Table 2: Von Bertalanffy growth parameters for *Venus verrucosa*, according to the relevant literature and the present study.

Area	Date	Length range(mm)	Age range (years)	N	L_∞	K	t_0 (years)	Reference
Bari, Italy					42.8	0.260	-1.34	Arneri *et al*. 1991*
Gulf of Manfredonia, Italy					53.4	0.280	-1.26	Arneri *et al*. 1991*
Trieste Gulf					75.4	0.189		Brizzi *et al*. 1992*
Genova Gulf, Italy					57.8	0.157	1.04	Vacchi *et al*. 1996*
Bari, Italy	5/1992-4/1993	18-48	1-10	252	44.9	0.253	-0.43	Arneri *et al*. 1998
Gulf of Manfredonia. Italy	5/1992-4/1993	20-59	1-12	273	54.1	0.352	-0.37	Arneri *et al*. 1998
Maliakos Gulf. Greece	5/1992-4/1993	27-63	2-16	144	54.2	0.298	-0.36	Arneri *et al*. 1998
Gulf of Thessaloniki. Greece	5/1992-4/1993	20-59	1-12	305	52.1	0.324	-0.34	Arneri *et al*. 1998
Alexandroupoli. Greece	5/1992-4/1993	17-51	1-15	283	43.4	0.360	-0.34	Arneri *et al*. 1998
Kastela Bay. Croatia	5/2008	19.8-58.7	1-10	67	55.97	0.27	-0.21	Peharda *et al*. 2013
Pag Bay. Croatia	10/2008	23.2-60.0	1-12	114	57.89	0.20	-0.45	Peharda *et al*. 2013
Starigrad-Paklenica. Croatia	10/2008	23.5-55.9	1-12	76	52.38	0.23	-0.74	Peharda *et al*. 2013
Mali Ston Bay Croatia	11/2008	26.2-56.0	2-14	101	51.41	0.26	-0.46	Peharda *et al*. 2013
Istria Island	3/2009	33.0-52.1	2-11	109	48.20	0.31	-0.25	Peharda *et al*. 2013
Paliomana. Greece	4/2007-5/2008	12.9-58.02		3340	60.38	1.40		Present study
Agia Triada. Greece	4/2007-5/2008	16.00-60.22		839	65.63	0.57		Present study
Peraia. Greece	4/2007-5/2008	11.84-59.85		2798	60.38	1.20		Present study
Karabournaki. Greece	4/2007-5/2008	12.38-55.41		2557	60.38	0.94		Present study

* Data from Apostolidis and Stergiou (2008)

L_∞=asymptotic length (mm), K= growth coefficient (yr^{-1}), t_0= age at length zero (years).

Table 3: Parameters of the relationships between weight and shell length, height and width, per station and season, for *Venus verrucosa*, Thermaikos Gulf, NW Aegean Sea (4/2007-5/2008).

Sampling station	Season	N	Weight-Length relationship parameters				Weight-Height relationship parameters				Weight-Width relationship parameters			
			a	b	$SE_{(b)}$	R^2	a	b	$SE_{(b)}$	R^2	a	b	$SE_{(b)}$	R^2
1 (Paliomana)	sp07	1007	0.0004	2.9627	0.020	0.96	0.0007	2.8942	0.022	0.94	0.0046	2.661	0.017	0.96
	su07	419	0.0004	2.9499	0.027	0.97	0.0005	3.016	0.026	0.97	0.0042	2.6838	0.027	0.96
	au07	567	0.0002	3.1788	0.023	0.97	0.0002	3.2678	0.022	0.98	0.0044	2.6858	0.019	0.97
	wi08	858	0.0003	3.0359	0.022	0.96	0.0004	3.0697	0.020	0.96	0.0027	2.8307	0.020	0.96
	sp08	489	0.0002	3.1572	0.025	0.97	0.0003	3.0945	0.024	0.97	0.0038	2.723	0.023	0.97
2 (Agia Triada)	sp07	93	0.0003	3.045	0.085	0.93	0.0013	2.7502	0.090	0.91	0.0098	2.4593	0.073	0.93
	su07	71	0.0002	3.1419	0.056	0.98	0.0004	3.0629	0.054	0.98	0.0041	2.6946	0.049	0.98
	au07	168	0.0002	3.2188	0.039	0.98	0.0002	3.2245	0.036	0.98	0.0068	2.5374	0.042	0.96
	wi08	138	0.0002	3.1588	0.046	0.97	0.0002	3.2245	0.036	0.98	0.0035	2.747	0.035	0.98
	sp08	369	0.0004	3.0037	0.026	0.97	0.0004	3.059	0.021	0.98	0.0023	2.8748	0.022	0.98
3 (Peraia)	sp07	705	0.0005	2.886	0.025	0.95	0.0006	2.9417	0.023	0.96	0.0034	2.7505	0.021	0.96
	su07	448	0.0005	2.8871	0.044	0.91	0.0006	2.9303	0.042	0.92	0.003	2.756	0.042	0.91
	au07	844	0.0006	2.8394	0.024	0.94	0.0009	2.8277	0.022	0.95	0.0043	2.6749	0.023	0.94
	wi08	392	0.0003	3.0378	0.023	0.98	0.0004	3.029	0.021	0.98	0.0025	2.8577	0.020	0.98
	sp08	409	0.0003	3.0584	0.025	0.98	0.0004	3.0731	0.022	0.98	0.0029	2.8119	0.021	0.98
4 (Karabournaki)	sp07	647	0.0003	3	0.021	0.97	0.0004	3.0223	0.021	0.97	0.0028	2.8165	0.019	0.97
	su07	211	0.0003	2.9793	0.052	0.94	0.0004	3.0167	0.051	0.94	0.005	2.6153	0.051	0.93
	au07	572	0.0003	3.0677	0.023	0.97	0.0004	3.0614	0.020	0.98	0.0033	2.768	0.018	0.98
	wi08	599	0.0002	3.1551	0.021	0.97	0.0003	3.139	0.019	0.98	0.0037	2.746	0.018	0.98
	sp08	528	0.0001	3.3245	0.025	0.97	0.0002	3.2847	0.025	0.97	0.0023	2.8761	0.020	0.98

Sp07: spring 2007, su: summer 2007, au: autumn 2007, wi: winter 2008, and sp08: spring 2008, N: number of individuals, a and b: parameters of the relationship, $SE_{(b)}$: standard error of b, R^2: coefficient of determination.

Table 4: *p*-values as resulted from Analysis of Covariance. Between different seasons per station for *Venus verrucosa*. Thermaikos Gulf. NW Aegean Sea (4/2007-5/2008). Bold typing indicates cases where $p<0.05$.

Sampling station	Relationship	Combination of Seasons									
		SP07-SU	SP07-AU	SP07-WI	SP07-SP08	SU-AU	SU-WI	SU-SP08	AU-WI	AU-SP08	WI- SP08
1 (Paliomana)	W-L	0.72	0.00	0.02	0.00	0.00	0.01	0.00	0.00	0.54	0.00
	W-H	0.00	0.00	0.00	0.00	0.00	0.09	0.03	0.00	0.00	0.43
	W-Wd	0.48	0.35	0.00	0.04	0.95	0.00	0.27	0.00	0.21	0.00
2 (Agia Triada)	W-L	0.35	0.04	0.21	0.54	0.25	0.81	0.02	0.32	0.00	0.00
	W-H	0.00	0.00	0.00	0.00	0.01	0.29	0.94	0.06	0.00	0.10
	W-Wd	0.00	0.33	0.00	0.00	0.03	0.36	0.00	0.00	0.00	0.00
3 (Peraia)	W-L	0.98	0.18	0.00	0.00	0.31	0.00	0.00	0.00	0.00	0.54
	W-H	0.80	0.00	0.01	0.00	0.02	0.03	0.00	0.00	0.00	0.15
	W-Wd	0.90	0.02	0.00	0.04	0.07	0.02	0.21	0.00	0.00	0.11
4 (Karabournaki)	W-L	0.68	0.03	0.00	0.00	0.09	0.00	0.00	0.01	0.00	0.00
	W-H	0.94	0.16	0.00	0.00	0.36	0.01	0.00	0.01	0.00	0.00
	W-Wd	0.00	0.08	0.01	0.02	0.00	0.00	0.00	0.38	0.00	0.00

Sp07: spring 2007. su: summer 2007. au: autumn 2007. wi: winter 2008. and sp08: spring 2008. W: weight; L: shell length; H: shell height and Wd: shell width.

The relationships between weight and shell length, height and width were all found statistically important ($R^2>0.91$, $p<0.01$) (Table 3). The value of b of the weight-length relationship ranged from 2.8394 to 3.3245 (median=3.0414, mean±standard deviation=3.0544±0.12) (Table 4). Comparisons of b-values of weight with shell length, height and width for different combinations of seasons across sampling stations revealed significant differences, mainly in the case of weight-length, at stations 1 and 4 (Table 4, ANCOVA: $p<0.05$ in 8 out of 10 combinations, in both stations). The least differences were recorded in the same type of the relationship at station 2 (Table 4, ANCOVA: $p>0.05$ in 7 out of 10 combinations). Comparisons of b-values for different combinations of sampling stations across seasons did not show differences for the relationship of weight-height during summer (Table 5, ANCOVA: $p>0.05$), whereas the relationship between weight-width differed in all combinations during summer (Table 5, ANCOVA: $p<0.05$).

The mean values of CI ranged from 42.28 (autumn, station 1) to 71.07 (winter, station 2) (Table 6). ANOVA analysis revealed that CI values are strongly affected both by sampling station (F-value= 4.61, $p<0.01$) and season (F-value= 5.22, $p<0.01$), whereas Fisher LSD analysis showed that there is significant resemblance between CI values in stations 1, 3 and 4, with station 2 being significantly different. Correspondingly, there was a great similarity of CI values compared among seasons with only autumn displaying a difference.

According to multivariate analysis (Figure 4), at a level of 79.18% similarity (MDS stress<0.01), two groups were formed: group A, including all samples from station 2 except for that of spring 2008; and group B including all samples from stations 1, 3 and 4. At a similarity level of 89.40%, two subgroups within group B, there are two subgroups formed. The first subgroup included spring 2007 samples (stations 1, 3 and 4), whereas the second one all the remaining samples (Figure 4).

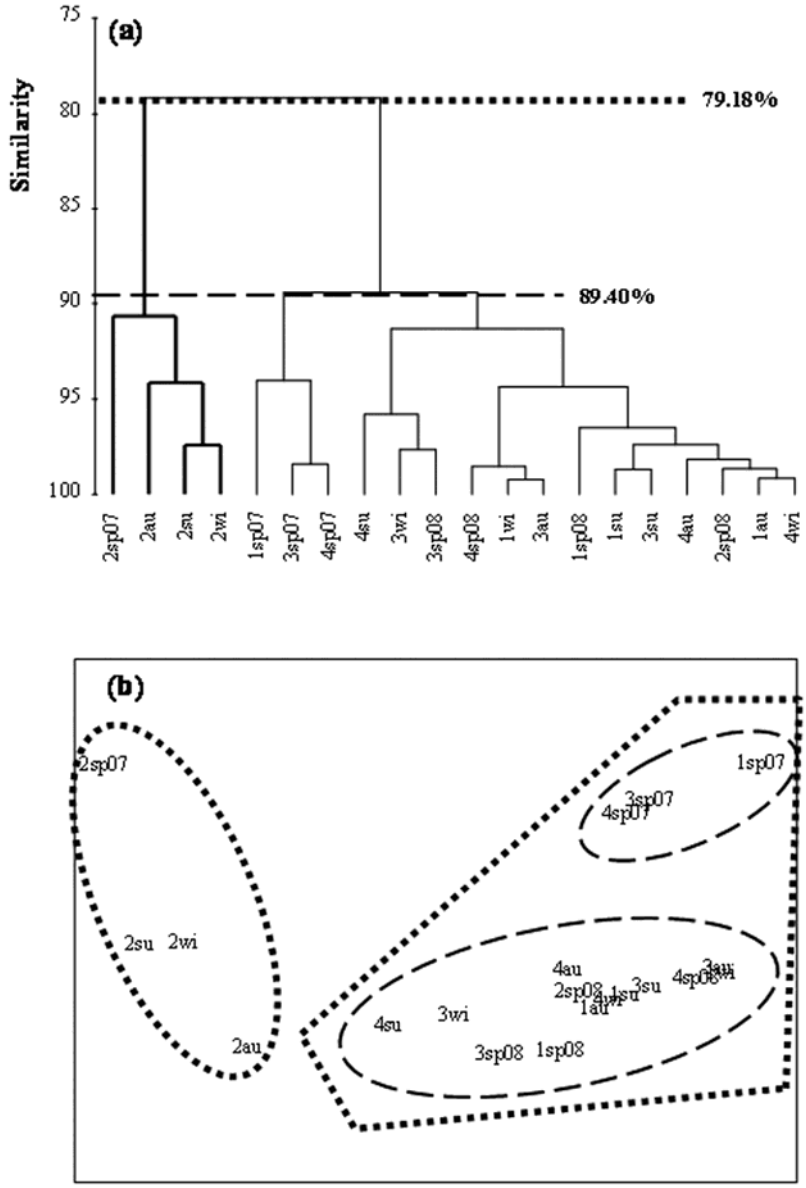

Fig 4: Cluster analysis (a), and multi-dimension scaling (b) results for *Venus verrucosa* in Thermaikos Gulf, NW Aegean Sea (4/2007-5/2008). Numbers indicate stations (for details see Fig.1). Sp07: spring 2007, su: summer 2007, au: autumn 2007, wi: winter 2008, and sp08: spring 2008.

Table 5: *p*-values as resulted from Analysis of Covariance between different stations per seasons for *Venus verrucosa*. Thermaikos Gulf. NW Aegean Sea (4/2007-5/2008). Bold typing indicates cases where $p<0.05$.

Season	Relationship	Conbination of Stations					
		1-2	1-3	1-4	2-3	2-4	3-4
spring 2007	W-L	0.19	0.00	0.20	0.00	0.48	0.00
	W-H	0.16	0.16	0.00	0.00	0.00	0.00
	W-Wd	0.00	0.00	0.00	0.00	0.00	0.00
summer 2007	W-L	0.00	0.22	0.58	0.00	0.00	0.19
	W-H	0.37	0.07	0.99	0.07	0.55	0.20
	W-Wd	0.84	0.14	0.20	0.38	0.29	0.00
autumn 2007	W-L	0.37	0.00	0.00	0.00	0.00	0.00
	W-H	0.29	0.00	0.00	0.00	0.00	0.00
	W-Wd	0.00	0.72	0.00	0.00	0.00	0.00
winter 2008	W-L	0.01	0.95	0.00	0.01	0.94	0.00
	W-H	0.16	0.16	0.01	0.02	0.78	0.00
	W-Wd	0.04	0.35	0.00	0.01	0.98	0.00
spring 2008	W-L	0.00	0.01	0.00	0.12	0.00	0.00
	W-H	0.28	0.52	**0.00**	0.65	**0.00**	**0.00**
	W-Wd	**0.00**	**0.00**	**0.00**	**0.04**	0.97	**0.03**

W: weight. L: shell length. H: shell height. and Wd: shell width.

Table 6: Mean value and standard deviation (SD) of condition index for Venus *verrucosa*. Per season and sampling station. Thermaikos Gulf.

NW Aegean Sea (4/2007-5/2008).

Sampling Station	Season	mean	SD
1 (Paliomana)	sp07	64.45	15.03
	su07	62.36	8.60
	au07	42.28	10.12
	wi08	57.96	9.55
	sp08	46.72	6.22
2 (Agia Triada)	sp07	60.01	16.22
	su07	60.89	16.07
	au07	60.73	18.21
	wi08	71.07	16.11
	sp08	45.88	5.09
3 (Peraia)	sp07	55.63	7.24
	su07	49.19	6.99
	au07	46.38	7.28
	wi08	56.55	8.57
	sp08	51.93	8.01
4 (Karabournaki)	sp07	63.82	16.01
	su07	56.49	24.79
	au07	51.78	11.77
	wi08	56.85	16.78
	sp08	51.03	5.43

sp07: spring 2007. su: summer 2007. Au: autumn 2007. wi: winter 2008. sp08: spring 2008.

4. Discussion

Venus verrucosa is a typical species of SVMC biocoenoses (calm water muddy sands) [31], which are characterized as transitional regarding the floral and faunal composition and can be found along the eastern coast of Thermaikos Gulf. The populations of *V. verrucosa* in the Gulf live on sandy and gravel substrate, but can also dwell on biogenic detritus [32]. Usually found burrowing down to 50mm, it is a typical suspension feeder. The warty venus is intensively exploited in Thermaikos Gulf and many concerns have been raised by fishermen and scientists about the sustainability of its populations (C. Chintiroglou, personal communication).

The mean abundance of the investigated populations were quite similar in stations 1, 3 and 4, whereas station 2 differed, having a restricted population density, with a declining trend. This fact could be attributed to the heavy exploitation that the populations at station 2 have been subjected since the 1980's (C. Chintiroglou, unpublished data), an overexploitation that is still on-going. This is also reflected in the length frequency distributions of the individuals, which in station 2 showed a different pattern than the other stations (Figure 3), as well as by the results of multivariate analyses where station 2 clearly separated from the other stations (Figure 4).

Venus verrucosa in Thermaikos Gulf, according to the presented results, shows an isometric growth, with the mean value of the parameter b of 3.0544. Tirado *et al*. [10] reported b value ranging from 1.8409 -3.6641 (mean 3.13) in the area of Malaga (Spain), whereas in Italy Arneri *et al*. report b-values of 3.33 (in Manfredonia) and 3.21 (in Bari) [13]. All the above mentioned values are similar to those estimated in Thermaikos Gulf (range: 2.8394-3.3245). It should be noted that all regions are located within a certain latitude range between 41º 37' N to 36º 43' N implying that biological rhythms are similarly affected by the photoperiod [33].

The von Bertalanffy growth parameters of *V. verrucosa* have been previously studied in the Mediterranean (Table 2). The lowest L_∞ value has been reported from Alexandroupoli, Greece (L_∞=52.1) [3], whereas the highest from Trieste (L_∞=75.4) [34]. In general, the L_∞ and K resulted from the present study are higher than those previously reported (Table 2). This could be attributed to the relatively wider size range of the examined individual and the significantly higher sample size in this study.

Condition indices are mainly used for the examination of the physiological status of a given population, and many such indices have been proposed [35]. The values they can get are influenced by many factors, such as individual size, season, parasites, and local environmental conditions [35]. The use of such condition indices can be a useful management tool, especially when this is correlated with biometry of the individuals [35]. Based on the results presented here, the distribution of the CI of *V. verrucosa* populations is within the limits of the reproductive period (May-November). The CI values were higher in spring and summer and follow the reproduction pattern of the species and differences should be attributed to biometry of the individuals and biotic/abiotic factors.

The management measures for the populations of *V. verrucosa* have been previously proposed for the Spanish coasts by Tirado *et al*. [10]. These authors suggested prohibition of fishing activities during March and April, since this is the period of a strong reproductive activity of *V. verrucosa*. In the Thermaikos Gulf, the reproduction of this species begins in May-June and is quite prolonged [2]. Therefore, one of the management measure for the stocks of *V. verrucosa* in this area is to ban its fisheries during June and July. Such a measure would have minimal socio-economic effects on the small-scale fishermen in the area, since (a) sea shell fisheries is more intense during fasting, that does not coincide with the proposed banned period, and (b) during summer months there is an increased demand for fishes, due to tourism, offering an alternative fisheries activity to local small-scale fishermen. Another stock management measure could be, instead of a temporal banning, a spatial one, i.e. a periodic closure of specific areas for a time lag of 3-4 years. This 3-4 year banning is proposed on the basis that the species in the investigated area reaches sexual maturity at length of 19-22 mm, a size attained during the second year of its life [2]. Therefore, with this measure, warty venus would have adequate time for reproduction and recruitment, in order to re-establish sustainable and exploitable populations.

5. Conclusions

The study of the populations of the venus clam *Venus verrucosa* in the Thermaikos Gulf, Greece showed a significant variation in the abundance of the species in the study locations, as a result of different harvesting intensity. The allometry and growth parameters also showed spatial and temporal differentiations, in accordance with the pressure applied on the populations by small-scale fisheries. These measurements along with data on the Condition Index are essential for developing a proposal for sustainable management of the warty venus populations in the gulf, considering previous studies and the needs of the local community. However, prior to the enforcement of any management plan, further spatiotemporal surveys in the area are needed, in order to fully understand the biology and ecology of the species.

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