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Morphometric Analysis of the Critically Endangered Fan Mussel (*Pinna nobilis* L.) in Maliakos Gulf (Central Aegean)

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Abstract: A pilot study regarding the transplantation of 100 specimens of the critically endangered *Pinna nobilis* took place in summer of 2019 in Maliakos Gulf (Central Aegean, Greece). In this study we present the relationships between total height (HT, in cm), unburied length (UL, in cm), and shell width (SW, in cm) for *P. nobilis* and the relationship between HT and net weight (W, in g). Length-length relationships were all linear for all cases: $r^2 > 0.900$), whereas the relationship between HT and W was exponential with the value of the exponent b being allometric.

Keywords: total height; wet weight; Pinnidae; Pinna nobilis; Maliakos; Greece

1. Introduction

The fan mussel *Pinna nobilis* L. is the largest endemic bivalve in the Mediterranean Sea, reaching up to 120 cm. Till 2016, natural populations had already declined significantly due to fishing and boat anchoring (Katsanevakis 2006). Because of the species' vulnerability, there is in place a well-established legislative framework protecting the fan mussel at national, EU and international scale (Presidential Decree 67/1981, Council Directive 92/43/EEC and Barcelona Convention respectively). Within the context of designing and performing preliminary actions first to document the transplantation's results and second to propose conservation and management scenarios and solutions, an attempt to transplant alive specimens was implemented in Maliakos Gulf (Central Aegean, Greece). Certain sites of the area have been renowned for thriving populations of the bivalve shellfish with known population structure and recruitment/growth parameters (Theodorou *et al.*, 2015; 2017). The option of transplantation of sedentary organisms might prove to be a solution to protect vulnerable species on condition that the transplantation-induced mortality remains at low levels.

Relationships between different types of lengths, for which limited information seems to be available for Mediterranean species, are very important for comparative growth studies (Binohlan et al., 1998; Froese and Pauly, 1998). Length-weight relationships are also important because they: (a) allow the conversion of growth-in-length equations to growth-in-weight, for use in stock assessment models; (b) allow the estimation of biomass from length observations; and (c) are useful for between-region comparisons of life histories of a certain species (Wootton, 1999).

In this study we report the relationships between total height (HT, in cm), unburied length (UL, in cm), and shell width (SW, in cm) for *P. nobilis* and the relationship between HT and net weight (W, in g). To our knowledge, this is the first study that live specimens of *P. nobilis* used for estimating the height-weight relationship using unburied Length. These relations are important, because offer a

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monitoring tool for the environment and the organism without damaging or sacrificing this endangered species. Also, no information is currently available in the SealifeBase (www.sealifebase.org) (Palomares and Pauly, 2023) on the above-mentioned relationships and only few relationships has been so far estimated for the species in the Mediterranean (Corse: De Gaulejac and Vicente, 1990; Greek Lake: Katsanevakis, 2005; Turkish waters: Acarli et al., 2011; Spain: de Gaulejac & Vicente, 1990, Garcia-March & Ferrer, 1995; Garcia-March, 2006).

2. Materials and Methods

2.1. Study area

Maliakos Gulf is located on the eastern side of mainland central Greece and part of the Aegean Sea (Figure 1; more characteristics of the area in Theodorou *et al.* 2017 and Zgouridou *et al*., 2021). The fan mussel is widely distributed in the coastal zone, having the anterior part of the shell partially buried in soft or hard substrata and is attached by threads of its byssus. On the 12th of June 2019, experienced, local divers removed 100 specimens, covering all visible mollusk sizes from a site near Stylida's port. After the careful removal of mollusks from their natural habitat, paying attention not to lose the byssus threads, certain morphometric and weight parameters were measured were measured on board; total height (HT, in cm), unburied length (UL, in cm), shell width (SW, in cm) and net weight (W, in g) (Figure 2). All length measurements were taken with an accuracy of 0.1 cm and weight with accuracy of 100g. At the same time, fishing vessels were heading towards the transplantation site, about a mile away eastern wards where mollusks were attentively placed, in a depth zone of 5 to 10m. Specimens were divided in two groups: one transplanted in soft bottom, the other in hard substrate. On the 25th of September 2019, the assessment of transplantation took place. Biometric parameters were measured along with the qualitative recording of survival or mortality.

Figure 1. Map of the study area.

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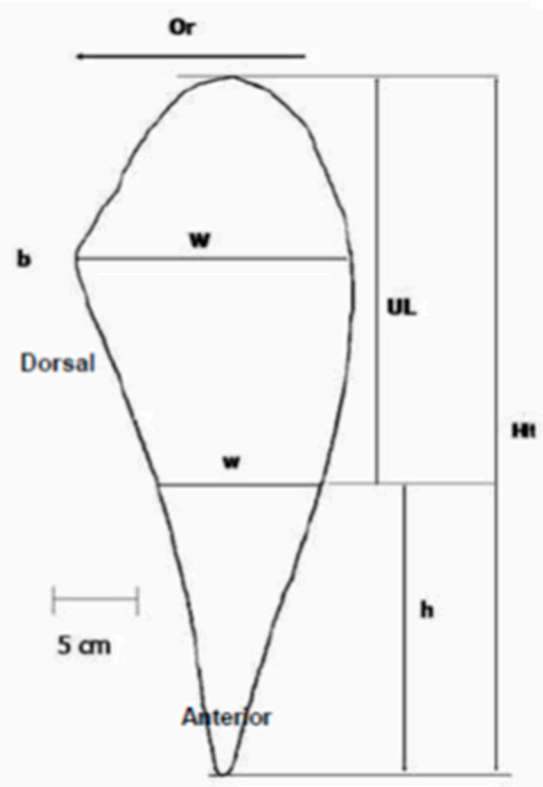

Figure 2. Biometry of *Pinna nobilis* (from García-March and Vicente, 2006). Total height (HT, in cm), unburied length (UL, in cm), shell width (SW, in cm).

2.2. Data analysis

Length-length relationships were estimated using the linear regression Y = a +bX, and length-weight relationship was estimated through the relationship $W=a \cdot L^b$ (Le Cren, 1951), where W is the wet weight, TL the length and coefficients *a* and *b* the intercept of the curve on the weight axis and the slope of the line in the linear slope of the equation, respectively. One-way ANOVA was applied for the comparison of the morphometric measurements between dead and alive specimens. An Analysis of Covariance (ANCOVA; Zar, 2010) was also used to test for differences in the above-estimated relationships between the live and dead specimens. Prior of the use of statistical test, the distributions of the length and weight data were examined whether or not they deviate significantly from the normal distribution by using the Shapiro–Wilk test (Zar, 2010). The comparison of the respective distributions between live and dead specimens was conducted using the Kolmogorov-Smirnov analysis (K-S test) (Zar, 2010). The findings of the present study were also compared with those from the literature in order to investigate the area effect on these relationships.

3. Results and Discussion

Overall, 100 specimens were sampled, from which 70 was alive and 30 dead at the time of sampling. Descriptive statistics of the morphometric measurements were shown in Table 1. For all types of length measurements data were not significant (for all cases: One-Way ANOVA, df =98, F-ratio < 0.85, $p < 0.05$) different between the dead and alive specimens (Figure 3). According to literature, 20 cm of total height length represents the threshold value under which individuals should be considered juveniles (Butler et al., 1993; Richardson et al., 1999).

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Table 1. Descriptive statistics for the morphometric measurements for all specimens and for alive and dead specimens of *Pinna nobilis* sampled in Maliakos Gulf (Central Aegean, Greece) in 2019.

Total Height (Ht)	n	Mean	SD	cv	Minimum	Maximum
-dead	30	47.43	7.70	16.24%	29	67
alive	70	46.47	8.68	18.67%	27	66
Total	100	46.76	8.37	17.90%	27	67
Unburied Length (UL)						
dead	30	28.23	5.39	19.10%	18	42
alive	70	27.13	5.51	20.32%	16	42
Total	100	27.46	5.47	19.93%	16	42
Shell width (SW)						
dead	30	18.77	2.10	11.17%	15	23
alive	70	18.50	2.24	12.13%	13	25
Total	100	18.58	2.19	11.81%	13	25

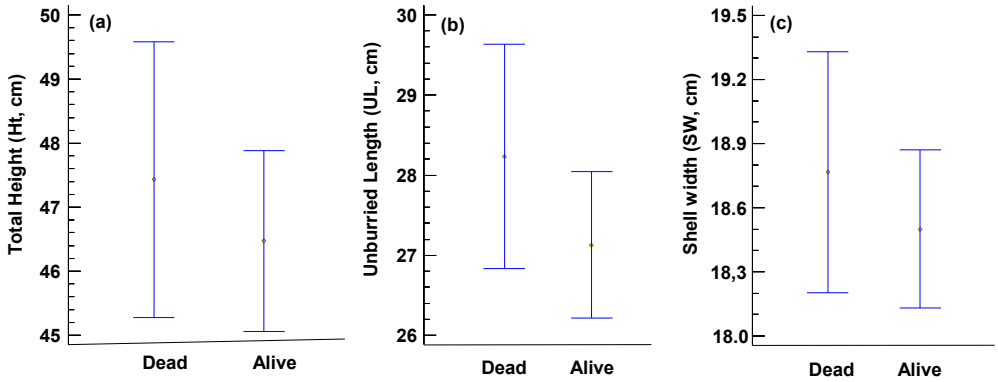

Figure 3. Means of: (a) total height, (b) unburied length, and (c) shell width, the alive and dead specimens of *Pinna nobilis* sampled in Maliakos Gulf (Central Aegean, Greece) in 2019.

The unburied Length frequency distributions between alive and dead specimens of *P. nobilis* exhibited that the height class of the dead sampled specimens peaked at 26 cm, whereas the corresponding for the alive specimens peaked at 23 cm (Figure 3). The comparison of the height distributions between alive and dead specimens was significantly (K-S = 1.80, P<0.05) differed each other at the 95,0% confidence level (Figure 4).

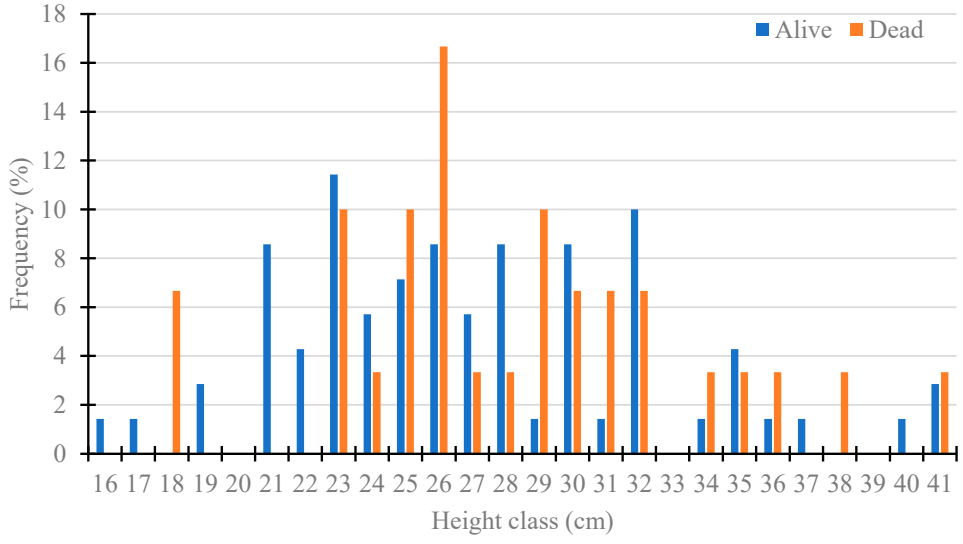

Figure 4. Height frequency distributions for the alive and dead specimens of *Pinna nobilis* sampled in Maliakos Gulf (Central Aegean, Greece) in 2019.

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All length-length relationships were significant (all r2 > 0.425, P < 0.05) with r^2 values ranged from 0.425 for the relationship between unburied Length and Shell width for alive specimens, to 0.913, for the relationship between Height Length and unburied Length for dead specimens (Table 2). There are three more equations found in literature for total shell height (HT) calculation, and there is no data recorded in literature for their mutual comparison. The slope b differed significantly (ANCOVA; df = 98, F-ratio > 28.78, P > 0.05) between dead and alive specimens for all different relationships among the morphometric measurements.

All length-weight relationships were highly significant (P < 0.001), with r^2 values being greater than 0.720 (Table 3). Also, all relationships were negative allometric with the values of the exponent b ranged from 2.159, for the relationship of weight with unburied length for alive specimens, to 2.828, for the relationship of weight with total height for dead specimens (Table 3). In contrast with the above results, Acarli et al. (2011) reveal that the relationships between shell length and total weight followed a positive allometric growth. Apart from the exponential regression, Katsanevakis (2005), to determine the relationship between shell length and maximum width applies a 2nd order polynomial equation.

Table 2. Morphometric relationships between Total Height (Ht, cm)-Shell width (SW, cm), Unburried Length (UL, cm)-Shell width (SW, cm) and Total Height (Ht, cm)-Unburried Length (UL, cm) for all specimens and for alive and dead specimens of *Pinna nobilis* sampled in Maliakos Gulf (Central Aegean, Greece) in 2019. n is the sample size, a and b are the parameters of the linear regression analysis.

Equation	Parameters of the relationship				
	n	a	b	SE (b)	r^2
All specimens					
SW=a + b*Ht	100	9.551	0.193	0.018	0.543
SW=a + b*UL	100	11.019	0.275	0.029	0.472
UL=a + b*Ht	100	0.048	0.586	0.029	0.804
Dead specimens					
SW=a + b*Ht	30	9.397	0.198	0.035	0.527
SW=a + b*UL	30	10.276	0.301	0.047	0.599
UL=a + b*Ht	30	-3.482	0.669	0.039	0.913
Alive specimens					
SW=a + b*Ht	70	9.610	0.191	0.021	0.547
SW=a + b*UL	70	11.297	0.266	0.037	0.425
UL=a + b*Ht	70	1.253	0.557	0.037	0.768

Table 3. Estimated parameters of the Total Height (Ht, cm)-Weight (W, cm) for all specimens and for alive and dead specimens of *Pinna nobilis* sampled in Maliakos Gulf (Central Aegean, Greece) in 2019. n is the sample size; a and b are the parameters of the relationship; SE(b) is the standard error of the slope b; and r^2 is the coefficient of determination.

Equation	Parameters of the relationship $W = a*L^b$				
	n	a	b	SE (b)	r^2
All specimens					
$W=a * Ht^b$	100	0.067	2.572	0.012	0.836
$W=a * UL^b$	100	0.815	2.233	0.021	0.759
Dead specimens					
$W=a * Ht^b$	30	0.025	2.828	0.028	0.829
$W=a * UL^b$	30	0.368	2.462	0.041	0.859
Alive specimens					
$W=a * Ht^b$	70	0.091	2.493	0.016	0.836
$W=a * UL^b$	70	1.052	2.159	0.031	0.720

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The slope b differed significantly (ANCOVA; df = 98, F-ratio > 91.24, P > 0.05) between dead and alive specimens for the relationships among the total and unburied length with weight, exhibiting the fact that the alive specimens exhibited lower b values for the same height (Figure 4).

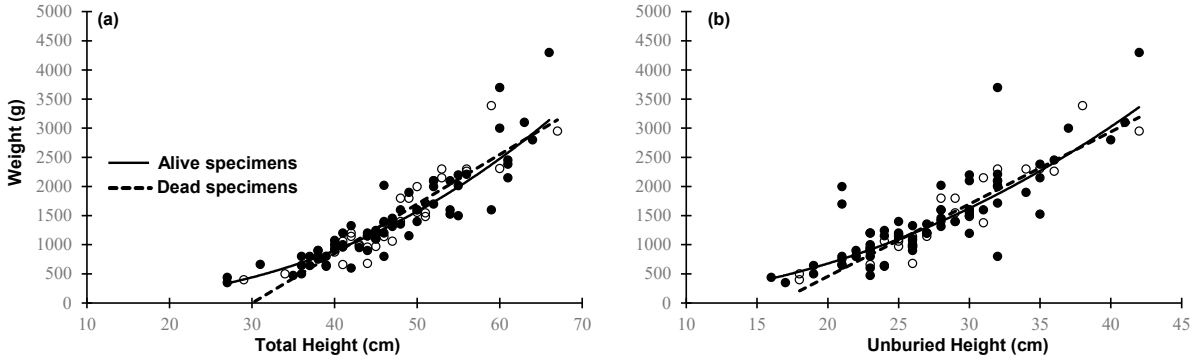

Figure 4. Comparison of length-weight relationships for alive and dead specimens of *Pinna nobilis* sampled in Maliakos Gulf (Central Aegean, Greece) in 2019 for the measurements of: (a) total height and (b) for unburied height.

Six equations on the morphometric characteristics of *Pinna nobilis* have been, so far, but none of them estimated the relations with the unburied length (Table 4). In the present study, the relations incorporated the unburied length might be useful for estimating the total height and the weight, because the measurement of the unburied length is a non-destructive sampling method.

Table 4. Estimated parameters of the relationships on the morphometric paramers for *Pinna nobilis* estimated in the Mediterranean. Ht, is the Total Height in cm),W, is the net Weight in g, UL, is the Unburied Length in cm.

Morphometric parameter	Equation	Reference
Total Height	Ht = 2.186W + 1.651	De Gaulejac and Vicente (1990)
	Ht = 1.790W + 0.500	Garcia-March and Ferrer (1995)
	Ht ¼ = 1.460 + 0.0837W – 0.001W^2	Katsanevakis (2005)
	Ht = 1.290W$^{1.24}$	Garcia-March (2006)
	Ht = 10,259e^{0,0809W}	Tempesta *et al.* (2013)
	UL = 0.048 + 0.586Ht	Present study
	W = 9.551 + 0.193Ht	
Total Weight	W = 0.003Ht$^{3.6451}$	Acarli *et al.* (2011)
	W = 0,067Ht$^{2.572}$	Present study
	W = 0.815UL$^{2.233}$	

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References

1. Acarli, S., Lok, A., Yigitkurt, S., & Palaz, M. (2011). Culture of fan mussel (Pinna nobilis, Linnaeus 1758) in relation to size on suspended culture system in Izmir Bay, Aegean Sea, Turkey. Kafkas Universitesi Veteriner Fakültesi Dergisi, 17(6), 995-1002.
2. Ankon, P., 2017. Genetic and morphological variability of the noble pen shell (Pinna nobilis Linnaeus, 1758) in Nature Park Telašćica and National Park Mljet. Master's thesis. University of Zagreb, Faculty of Science, Division of Biology.

3. Butler, A., Vicente, N., & de Gaulejac, B. (1993). Ecology of the pterioid bivalves Pinna bicolor Gmelin. Mar Life, 3(1-2), 37-45.
4. Binohlan, C.; Froese, R.; Pauly, D., 1998: The length-length Table. pp. 124. In: R. Froese and D. Pauly (eds.) Fishbase 1998: Concepts, design and data sources. Manila, ICLARM. 293 pp.
5. De Gaulejac, B., & Vicente, N. (1990). Ecologie de Pinna nobilis (L.) mollusque bivalve sur les côtes de Corse. Essais de transplantation et expériences en milieu contrôlé. Haliotis, 10, 83-100.
6. Froese, R.; Pauly, D., 1998: Fishbase 1998: Concepts, design and data sources. Manila, ICLARM. 293 pp.
7. García-March JR, Ferrer JF (1995) Biometría de Pinna nobilis L,1758: una revisión de la ecuación de De Gaulejac y Vicente (1990). Bol Inst Esp Oceanogr 11:175–181
8. García-March, J.R., Vicente, N. (2006). Protocol to study and monitor Pinna nobilis populations within marine protected areas. Malta Environment and Planning Authority, MedPAN Project, 17-38
9. Katsanevakis S. (2016). Transplantation as a conservation action to protect the Mediterranean fan mussel *Pinna nobilis*. Marine Ecological Progress Series 546, 113-122.
10. Katsanevakis S. (2006). Population ecology of the endangered fan mussel *Pinna nobilis* in a marine lake. Endangered Species Research, 51-59.
11. Le Cren, E.D. 1951. The length–weight relation-ship and seasonal cycle in gonad weight andcondition in perch (Perca fluviatilis). J. Ani-mal Ecol., 20: 201–219.
12. Palomares, M.L.D. and D. Pauly. Editors. 2023. SeaLifeBase. World Wide Web electronic publication. www.sealifebase.org, version (04/2023).
13. Richardson, C.A., Kennedy, H., Duarte, C.M., Kennedy, D.P., Proud, S.V., 1999. Age and growth of the fan mussel Pinna nobilis from south-east Spanish Mediterranean seagrass (Posidonia oceanica) meadows. Mar. Biol., 133: 205-212.
14. Tempesta, M., Del Piero, D., & Ciriaco, S. (2013). Definition of a new formula for the calculation of the total height of the fan shell Pinna nobilis in the Miramare marine protected area (Trieste, Italy). Ann Ser Hist Nat, 23, 17-22.
15. Theodorou J.A., James R., Tzovenis I., Hellio C. (2015). The recruitment of the endangered fan mussel (Pinna nobilis, Linnaeus 1758) on the ropes of a Mediterranean mussel long line farm. Journal Shellfish Research 34(2): 409-414.
16. Theodorou J.A., James R., Tagalis D., Tzovenis I., Hellio C., Katselis G. (2017). Density and size structure of the endangered fan mussel *Pinna nobilis*, in the shallow water zone of Maliakos Gulf, Greece. Acta Adriatica 58(1), 63-76.
17. Wootton, R. J. 1999. Fish Ecology. Chapmanand Hall, New York, 212 pp.
18. Zar, J. H. 2010. Biostatistical analysis. (5th Edition). Prentice Hall, Upper Saddle River, 255 pp.
19. Zgouridou A., Tripidaki E., Giantsis I., Lattos A., Raitsos D., Anestis A., Theodorou J.A., Kalaitzaki M., Feidantsis K., Staikou A., Michaelidis B. (2021). A survey on the microbial load on edible and economical important marine bivalve species in the Greek Seas. Environmental Microbiology, https://doi.org/10.1111/1462-2920.15765