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Morphometric relationship of mediterranean mussels *Mytilus galloprovincialis*, (Lamark, 1819) in Algerian West coasts

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Abstract

Mytilus galloprovincialis is very common in almost Algerian rocky coasts. It shows complex ecological and behavioral characteristics which vary according to the environment where it lives. The aim of this study was to realize the follow-up of the biometric parameters of bivalve molluscs in algerian coastal area, through analyzing the morphometric diversity, by calculating the different relationships. In this investigation, the morphometric diversity of 800 individuals of marine mussels from four rocky sites in the west coasts of Algerian were analyzed. Upon arrival, mussels were inspected and dead animals discarded. Fifty individuals were used for biometric characterization Shell length (L), height (H), and thickness (E). Each mussel was opened with a stainless steel knife. The correlation coefficient was used for regression equations ($Lt=aWt^b$, Lt=AH+b, H=aE+b). The results showed that according to the global scale, the three allometric relations highlighted in this work revealed that the increase of the length shell was less important than those of the height and the thickness. On other hand, the increase of the thickness was slower than the height of all the specimens studied from all sites. The results reflected the adaptive response of the mussel following the physical and the ecological environment where it lives. The variation of the relations: length/height and length/thickness in the mussels from the four studied sites showed that this species had a tendency to grow in height and width faster than the length. This study revealed significant differences between the morphometric characteristics of mussel populations of the four sites.

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Introduction

The marine mussels are very important seafood source around the world and provide cheap source of protein for human (Culha, 2008; Sahin *et al*., 2011). In 2008, annual world mussel production was approximately 1.7mt and about 95% of them came from aquaculture (Sahin *et al*., 2011). The quality requisites of bivalve molluscs are primarily dependent on the quality of the aquatic environment, assuring a healthy product and a safe consumption (Karakoltsidis, *et al*., 1995; Orban, *et al*., 2002). The Mytilus kind, of the family of Mytilidees (Pelecypodes) is mainly defined by the shape of its shell, in particular by its end in final position.

The results clarify the distribution of *M. galloprovincialis* and *M. edulis* taxa in Northeast Atlantic waters: *M. galloprovincialis* extends from the Mediterranean Sea northwards to the English Channel and British Isles, and southwards, probably, to Cite de Cansado (Mauritania), whereas *M. edulis* is found on northern European coasts as far south as the Spanish–French frontier. Accordingly, *M. galloprovincialis* can be regarded as a member of the Mediterranean–Lusitanic subtropical region, and *M. edulis* as a member of the Atlantic boreal region (Golikov, *et al*., 1990; Comesana, *et al*., 1998).

Atlantic and Mediterranean haplogroups of M. galloprovincialis were detected along Atlantic SW Iberian shores along with *M. galloprovincialis/edulis* hybrids (92.2% Atlantic, 3.9% Mediterranean and 3.9% hybrids). In contrast, NW Moroccan populations consisted solely of Atlantic *M. galloprovincialis*.

The Mediterranean populations did not include M. galloprovincialis/edulis hybrids, but both Atlantic (58%) and Mediterranean (42%) lineages were detected. Divergent selection between coastlines and/or indirect larval dispersal by human activities may be the drivers of this geographically structured genetic diversity (Lourenc, 2015).

Mytilus galloprovincialis species are present along Algerian coast and appreciated by consumers for its organoleptic properties and for the competitive price if compared with other bivalves.

However, the natural mussel beds are scarce and mussel farming is not developing along the coastline, which incite local people and fisherman to exploit wild mussel beds, located in polluted sites such as harbor areas which receive a large amount of urban and industrial untreated wastewater. These mussels are collected and commercialized without any sanitary control that may affect Consumer's health.

Growth is frequently measured in bivalves as changes in shell length or weight, but this approach tends to disregard essential features of this phenomenon. For example, growth trajectories often differ for shell and soft tissues according to environmental factors or variations in the reproductive cycle (Hilbish, 1986; Borrero & Hilbish 1988; Dame, 2012). Concerning shell growth itself, shell architecture and organic content are important attributes often subjected to variations between populations. Dynamics of shell formation includes growth in both circumference and thickness (Gosling, 2003) as variables simultaneously contributing to determine size and shape of bivalves. Habitat can be responsible for much of the variation in the relationships between biometric parameters accounting for different aspects of growth in mussels (Rao, 1953; Seed, 1973; Brown & Seed, 1977; Aldrich & Crowley, 1986). Since these relationships are known also to change along the life-span of individuals, the characterization of allometric scaling of these parameters to body size (usually shell length) in different populations constitutes a useful approach in the comparative analysis of habitat effects. In fact such differentiation involves changing relationships between biometric parameters representative of shell and soft tissue dynamics that can be conveniently approached by means of allometric functions. In the Algerian west coast, several studies have been conducted on mussels, however these studies are related to marine biomonitoring and ecotoxicology (Rouane-Hacene *et al*., 2008; Grimes *et al*., 2010; Benali *et al*., 2015; Rouan-Hacene 2015; Gherras, 2016).

For this purpose, the objective of this study, was to realize the follow-up of the biometric parameters of these bivalve molluscs in four sites of this coastal area, (Point de l'Aiguille, Oran Harbor, Mostaganem

Harbor and Honaïne) through analyzing the morphometric diversity, by calculating the ratios with the weight of individuals, the length, the height and the thickness of the shell.

Material and methods

2.1. Collection and preparation of samples

Mussels were collected during four seasons between June 2015 and June 2016. Fifty specimens were collected per station for each of the measured parameters, which represented a total of 200 specimens. Upon arrival, mussels were inspected and dead animals discarded. Fifty individuals were used for biometric characterization. Shell length (L, maximum measure along the anterior-posterior axis), height (H, maximum dorsoventral axis), and width (W, maximum lateral axis), (Taleb, 2007). Each mussel was opened with a stainless steel knife by cutting the adductor muscle and placed with its ventral edge on filter paper to remove the internal water.

Sampling sites

The studied area extends along the western coast of Algeria, from Mostaganem to Tlemcen, as shown in Fig. 1. Four sampling sites were selected, with respect to the main identified pollution sources to follow a presumed contamination gradient westwards: sites (1-4):

S1- Mostaganem Harbour (36° 02' 285"N, 000° 08' 005"W) is a site located close to *Mostaganem wilaya* (nearly 153,000 inhabitants).

S2- Pointe de l'Aiguille (35° 52′ 32.99″ N, 0° 29′ 19″ W) in Kristel, is a rocky area located close to a fishing village east of the Bay of Oran. It is a central area of agricultural activity Furthermore.

S3-Oran Harbour (35°42′58″N, 2°58′53″W) is a zone that is exposed to high levels of anthropogenic pressure (wastewater effluents from nearly 610,000 inhabitants and boat traffic). It has been reported that the site is highly contaminated by heavy metals (Taleb and Boutiba, 2007; El Hadj *et al.*, 2012; Rouane-Hacene & *et al.*, 2015).

S4- Honaine (36° 02' 285"N, 000° 08' 005"W) is a municipality in the wilaya of Tlemcen, located at the extreme north-west of Algeria. There are beautiful beaches Near Honaine.

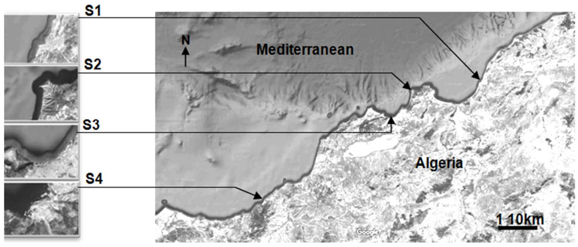

Fig. 1. Map showing the mussel sampling sites, Adapted from Google maps, 2017.

S1: Mostaganem Harbour. S2: Point de l'Aiguille. S3: Oran Harbour. S4: Honaine in Tlemcen.

Statistical analysis

The data are expressed as the mean ± standard error. In order to detect a possible significant difference between the morphometric relationships of the five limpet populations Student's t-test was applied.

One-way analyses of variance (ANOVA) were used to compare means of each parameter among sites. When ANOVA was significant ($P < 0.05$), post-hoc comparison of means was done using Duncan's test. Statistical analyses were performed using the STATISTICA software program (v.10 Statsoft).

Results

The Morphometric averages of the parameters studied (length, height & thickness) by station were recapitulated in (Table 1).

Table 1. Interstitial comparative study of the annual variations of the biometric parameters of *Mytilus galloprovincialis* from Point de l'Aiguille (S1), Oran Harbor (S2), Mostaganem Harbor (S3), and Honaine (S4) (average ± s.e , n = 800).

Paramètres	Site 1	Site 2	Site 3	Site 4
Length	4.96 ± 0.71^{a}	4.87± 0.78^{a}	4.96 ± 0.76^{a}	5.01 ± 0.80^{a}
Height	2.70 ± 0.43^{a}	2.61 ± 0.45^{ab}	2.58 ± 0.33^{b}	2.63 ± 0.40^{ab}
Thickness	1.82 ± 0.27^{a}	1.78 ± 0.28^{a}	1.77 ± 0.24^{a}	1.77 ± 0.26^{a}

L: length (cm); H: height (cm); E: thickness (cm). s. e; standard error.

For each parameter, the different letters indicate significant differences (Duncan's test, $p < 0.05$) between sites.

Table 1 revealed that there were no significant differences ($p>0,05$) in the allometric relationship between the length shell and the thickness. On the other hand, the height of the mussel shell at site 1 was relatively higher compared to the other sites. In addition, there was a significant difference ($p<0,05$) between the mussels of site 1 and site 3.

The global scale has, significant allometric relationships that was highlighted for the three linear parameters measured during the whole period of study (annual cycle), the results of the evolution of the length relationship linking the puissant and linear parameters (Table 2).

Table 2. The set of relationships linking the puissant and linear parameters of *Mytilus galloprovincialis* in the four stations (Mostaganem Harbor), (Point d'Aiguille), (Oran Harbor) and (Honaine) during the Seasons period 2015-June 2016 June.

Station	Parameters	Equation	N	R^2	T	Observation
Mostaganem Harbor	Tt-Wt	$L=0.187W^{2.575}$	200	0.851	20.9**	Minor
	Lt-H	$L=0.391H^{0.665}$	200	0.802	41.321**	Minor
	H-E	$H=0.703E^{0.051}$	200	0.813	27.197**	Minor
Point de l'Aiguille	Lt-Wt	$L=0.173W^{2.645}$	200	0.917	22.363**	Minor
	Lt-H	$L=0.554H^{0.057}$	200	0.861	38.741**	Minor
	H-E	$H=0.579E^{0.261}$	200	0.855	24.64**	Minor
Oran Harbor	Lt-Wt	$L=0.242W^{2.402}$	200	0.804	20.2**	Minor
	Lt-H	$L=0.515H^{0.069}$	200	0.811	37.536**	Minor
	H-E	$H=0.577E^{0.247}$	200	0.809	21.987**	Minor
Honaine	Lt-Wt	$L=0.26W^{2.399}$	200	0.894	22.244**	Minor
	Lt-H	$L=0.465H^{0.317}$	200	0.852	37.854**	Minor
	H-E	$H=0.591E^{0.215}$	200	0.833	25.876**	Minor

Lt: Total length (cm); W: weight (g); H: height (cm); E: thickness (cm).
N: number of individuals; r: correlation coefficient of the regression equations;

Variations of the parameters of the length/weight; length/ hieght and hieght/thickness relationship, the coefficients of determination "r^2" of the total length-weight relationship were close to 1, reflecting a good correlation between the parameters (Table 2). Comparison of length-weight relationships of *M. galloprovincialis* indicated that the value of the slope b varies between 2.645 and 2.399 showing different types of growth.

The global results and allometric equations between the different parameters of the shell (length /weight, length/height, height/width) in the four stations were respectively recapitulated in the tables (3, 4 & 5).

The season's variations of condition factor were related to the fluctuations of sexual cycle, for the *M. galloprovincialis* species. Indeed, the higher values of condition factor were recorded during the sexual resting between winter and spring (table 3, 4 & 5).

The allometric relationships between the different linear variables proved to be significant.
For the length-height relationships, the comparison of the slopes of different rights reveals highly significant differences at the threshold of 5%, which highlights a minor allometry in the four stations: the growth in length of mussels was less rapid than their growth in height.

For the weight-height relationships, the t test on the allometry, highly significant in all stations, indicates a minor allometry in the four stations. This attested to a slower growth in weight than in height.

Table 3. Allometric equations between the length of the shell of *Mytilus galloprovincialis* and its weight in the four stations Mostaganem Harbor) (S1), (Point d'Aiguille) (S2), (Oran Harbor) (S3), and (Honaine) (4) during the Seasons period 2015 -July 2016 July.

Site	Seasons	Equation	N	R²	T	Observation
Mostaganem Harbor	Summer	$Lt=0.144Wt^{2.775}$	50	0.904	11.808**	Minor
	Autumn	$Lt=0.16Wt^{2.67}$	50	0.88	9.849**	Minor
	Winter	$Lt=0.309Wt^{2.281}$	50	0.908	11.590**	Minor
	Spring	$Lt=0.109Wt^{2.943}$	50	0.921	10.992**	Minor
Point de l'Aiguille	Summer	$Lt=0.124Wt^{2.858}$	50	0.937	10.118**	Minor
	Autumn	$Lt=0.222Wt^{2.517}$	50	0.921	13.276**	Minor
	Winter	$Lt=0.216Wt^{2.479}$	50	0.939	11.641**	Minor
	Spring	$Lt=0.113Wt^{2.941}$	50	0.933	9.121**	Minor
Oran Harbor	Summer	$Lt=0.122Wt^{2.882}$	50	0.945	11.126**	Minor
	Autumn	$Lt=0.153Wt^{2.796}$	50	0.941	11.010**	Minor
	Winter	$Lt=0.305Wt^{2.291}$	50	0.954	9.655**	Minor
	Spring	$Lt=0.146Wt^{2.757}$	50	0.932	11.544**	Minor
Honaine	Summer	$Lt=0.202Wt^{2.577}$	50	0.907	11.871**	Minor
	Autumn	$Lt=0.249Wt^{2.428}$	50	0.925	11.603**	Minor
	Winter	$Lt=0.275Wt^{2.344}$	50	0.935	11.692**	Minor
	Spring	$Lt=0.17Wt^{2.674}$	50	0.886	13.003**	Minor

Lt: Total length (cm); Wt: Total weight (g); H: height (cm); E: thickness (cm).
N: number of individuals; r: correlation coefficient of the regression equations;

Table 4. Allometric equations between the length of the shell of *Mytilus galloprovincialis* and its height in the four stations (Mostaganem Harbor), (Point d'aiguille), (Oran Harbor), and (Honaine) during the Seasons period 2015 -July 2016 July.

Site	Seasons	Equation	N	R²	T	Observation
Mostaganem Harbor	Summer	$Lt= 0.429H^{0.482}$	50	0.841	23.039**	Minor
	Autumn	$Lt= 0.354H^{0.735}$	50	0.843	20.778**	Minor
	Winter	$Lt= 0.419H^{0.519}$	50	0.891	19.958**	Minor
	Spring	$Lt= 0.442H^{0.429}$	50	0.835	23.038**	Minor
Point de l'Aiguille	Summer	$Lt= 0.44H^{0.438}$	50	0.827	20.109**	Minor
	Autumn	$Lt= 0.598H^{0.222}$	50	0.84	20.11**	Minor
	Winter	$Lt= 0.608H^{0.29}$	50	0.912	18.056**	Minor
	Spring	$Lt= 0.467H^{0.312}$	50	0.872	25.339**	Minor
Oran Harbor	Summer	$Lt= 0.430H^{0.494}$	50	0.806	22.209**	Minor
	Autumn	$Lt= 0.40H^{0.551}$	50	0.829	23.114**	Minor
	Winter	$Lt= 0.587H^{0.096}$	50	0.918	13.077**	Minor
	Spring	$Lt= 0379H^{0.691}$	50	0.813	23.738**	Minor
Honaine	Summer	$Lt= 0.439H^{0.438}$	50	0.844	21.722**	Minor
	Autumn	$Lt= 0.427H^{0.427}$	50	0.842	21.209**	Minor
	Winter	$Lt= 0.491H^{0.249}$	50	0.92	16.710**	Minor
	Spring	$Lt= 0.318H^{0.962}$	50	0.823	28.234**	Minor

Lt: Total length (cm); H: height (cm). N: number of individuals; r: correlation coefficient of the regression equations;

Table 5. Allometric equations between the height of the shell of *Mytilus galloprovincialis* and its width in the four stations (Mostaganem Harbor), (Point de l'Aiguille), (Oran Harbor), and (Honaine) during the seasons period 2015 -July 2016 July.

Site	Seasons	Equation	N	R^2	T	Observation
Mostaganem Harbor	Summer	$H= 0.527E^{0.375}$	50	0.821	17.806**	Minor
	Autumn	$H= 0.532E^{0.386}$	50	0.83	15.746**	Minor
	Winter	$H= 0.737E^{0.085}$	50	0.853	11.953**	Minor
	Spring	$H= 0.648E^{0.081}$	50	0.826	15.684**	Minor
Point de l'Aiguille	Summer	$H= 0.601E^{0.207}$	50	0.869	13.946**	Minor
	Autumn	$H= 0.481E^{0.459}$	50	0.894	14.797**	Minor
	Winter	$H= 0.596E^{0.258}$	50	0.903	10.972**	Minor
	Spring	$H= 0.512E^{0.435}$	50	0.859	17.682**	Minor
Oran Harbor	Summer	$H= 0.644E^{0.09}$	50	0.829	15.39**	Minor
	Autumn	$H= 0.616E^{0.137}$	50	0.812	16.15**	Minor
	Winter	$H= 0.488E^{0.575}$	50	0.874	9.282**	Minor
	Spring	$H= 0.674E^{0.039}$	50	0.843	16.921**	Minor
Honaine	Summer	$H= 0.605E^{0.197}$	50	0.81	15.035**	Minor
	Autumn	$H= 0.569E^{0.199}$	50	0.84	15.873**	Minor
	Winter	$H= 0.533E^{0.401}$	50	0.856	12.150**	Minor
	Spring	$H= 0.847E^{0.406}$	50	0.802	21.035**	Minor

H: height (cm); E: thickness (cm).

N: number of individuals; r: correlation coefficient of the regression equations;

Discussion

The study of the biological parameters taken into account in this study highlights an excellent correlation of biometric relations for the four sites of study (Fig. 1), and also for summer, autumn, winter, and spring. This variability could be linked to different fac- tors, whether biotic and/or abiotic (Grimes *et al.,* 2004).

The good development of mussels and the good correlation of the three parameters (length, height, total weight) at the polluted sites (mostahanem Harbor and Oran harbor) could be due to the fact that the stations are situated near the urban waste rejection seen as very rich in nutrient salts, which encourages the development of phytobenthos on the medio-littoral and supra-littoral shelf with a strong concentration in spring.

The values of the coefficients of correlation R of the annual period that connect the different linear variables are included between 0.802 and 0.91, which is evidence of a very strong significant correlation between the (length and weight), the (length and height) and the (the height and the thickness) of the shell, as well as the effectiveness of the adjustment to the linear model (Gould, 1966; Alexander, 2010).

The impacts of human activities on biological diversity, from the gene level to the ecosystem level, are most evident in coastal areas (PNUE/PAM. 2004). Indeed, they are exposed to a variety of threats, among which the World Commission on the Environment and Development has been able to cite the causesb (RNO Edition. 2006). Activities that significantly affect ecosystem and biodiversity include marine traffic (oil spills, introduction of exogenous species), industrial activities (chemical effluents), dredging and dumping operations, fishing and mariculture, biological invasions, tourism, etc (PNUE/PAM. 2004).

The comparison between the regression lines that describe the relative growth of morphological characters in the four stations through the testing of the slopes and positions showed the differences related to the geographical origin of this species.

From these results, it can be seen that, whatever the parameter (Pt, L, H, or E) of the mussels, the correlation values coefficient of the regression equations are the following S3> S2> S4> S1 respectively. The reason is that the third site (S3) is largely polluted as well as the second, while the second (S2), third site (S3) and fourth sites (S4) are characterized by anthropogenic (RNO Edition, 2006). and marine activity. Unlike the first site, which considered as a "pristine" area (FAO Fishstat, 2002; Grimes *et al.*, 2010; Gherras, 2016).

The organic matter could come from the urban and industrial wastewaters of Oran city, which are discharged untreated by the sewage outfalls located on either sides of the port. Previous biomonitoring studies in Algerian coastal waters had demonstrated that the urban and industrial wastewaters constituted the main sources of organic matter (Grimes, 2010).

The results of the seasonal variations of the biometric parameters and the *Mytilus galloprovincialis* mussels from the sites of the Point de l'Aiguille, Oran Harbor, Mostaganem Harbor, Honaine of the intra-site, given for each season, it is observed that the coefficients of the correlation values of the regression equations of the mussels of the four sites are very significant ($p < 0.05$). Therefore the highest values are reached at the end of winter as the laying period (Benali *et al.,* 2015; Rouan-Hacene 2015).

The study of the seasons evolution of this relationship at the level of the four stations shows that the mussels have a tendency to grow in height more than in length, which confirms the results of the study carried out on the overall strength (Blay, 1989; Alunno-Bruscia, 2001).

Alternatively, shell distortion was attributed to population density effects through physical compression by surrounding individuals [i.e. interference; e.g. (Browne, 1976)] and was observed in the field in densely packed mussels with higher L/H ratio (i.e. more elongate shells) than mussels in less crowded conditions with more triangular-shaped shells (Seed, 1973; Browne, 1976). There is a similarity to what has been proven in the studies conducted by (Gould, 1966; PNUE/PAM, 2004; Alexander, 2010).

For the study of the season variations of the length-thickness relationship, the results have shown that the correlation coefficients have differed between the four stations in the following order S1> S2> S4> S3. These values reflect the strong correlation between the two variables linear in question. For this model, the results have shown that the length-thickness relationship is a minor allometric dominance. A clear rise was observed at the end of autumn and early winter, which was associated with the reproductive period. During summer, according to the spawning period of *Mytilus galloprovincialis*, the mussel growth fell down because of the reproductive investment. Some authors reported that in the spawning period, shellfish lost a large amount of nutrient reserves (Cossa, 1980). Besides, the environmental conditions such as food availability appeared particularly more favorable for the growth of bivalves during the cold period. Thus, a previous study of the Algerian coastal area showed an increase in the planktonic biomass in autumn (Lalami-Taleb, 1971; Fischer, 1987; Sukhotin, 1994).

The allometric relations highlighted in our study have shown minors allometries, what characterizes the four populations of *Mytilus galloprovincialis* by the height and the thickness of the shell. Thus, in the four regions studied, mussels, living at the level of the upper mediolittoral appear to develop a shell more high and more broadly in order to retain a quantity of water more important. This type of growth is considered to be an adaptive response to physical conditions and ecological environment (Gaspar, 2002; Gaspar, 2001).

Allometric regression models best described changes in soft tissue content (or total animal weight for crustaceans) with shell length for all 10 species. This result is consistent with general trends of scaling with body size in animals (Peters, 1983; Schmidt-Nielsen, 1984), and specific examples of scaling of shell size (usually length) with total or component tissue weight in bivalves (Alunno-Bruscia, 2001; Richardson, 1990; Salkeld, 1995) and with total body weight (Franz, 1993; Absher, 2000). In order to provide one model per species of benthic prey, the combined data from organisms across a wide range of lengths into a single regression.

Several factors may influence the weight of soft tissue relative to shell length, and may be a source of error in our models. Food availability can influence tissue growth, storage and utilization, and can alter the ratio of body mass to shell length (Kemp, 1983; Frechette, 1990; Nakaoka, 1992). Differences in food availability or density between sites, or temporal variability in food density, may therefore alter tissue weight/shell length relationships.

Additionally, changes in shell morphology as a result of phenotypic variation may also influence the weight of soft tissue relative to shell length between locations (Trussell, 2000a; Trussell, 2000b). (Trussell, 2000b) reported differences in shell morphology in response to water temperature and predator abundance that.

Conclusion

The spatial variability of allometries showed that the relative growth linear varies from one station to another. Indeed, the comparison of regression lines representing the relative growth of the height and the thickness relative to the total length as well as the width in relation to the height of the shell reveals significant differences between the four stations. This allows us to infer that the specific characteristics of each of the four biotopes, namely the hydrodynamics and the depth of mounting, do not exercise the same action on the morphometry of the populations of mussels.

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