

Seasonal variations of the biometric indices of *Patella rustica* Linnaeus, 1758 (Gastropoda Patellidae) from contrasted sites of the western Algerian coast

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ABSTRACT

The objective of this study is the evaluation of the resistance of the bioindicative species *Patella rustica* Linnaeus, 1758 (Gastropoda Patellidae) existing in the contrasted sites of the Algerian occidental seaboard through a follow-up of the seasonal variations of biometric indices. It is based on the analysis of biometric parameters of 600 individuals of this Gastropod mollusk from five sites: Madagh (MD), Bouzedjar Harbor (BH), Ain El Turck (AT), Oran Harbor (OH), and Kristel (KR). The seasonal sampling has been carried out and measurements on the height of the shell (H), its length (L), and its total weight (TW) are taken for all the populations of *P. rustica*. The correlation of the different measurements (length-height, length-total weight, height-total weight), with the help of the power curve and following STUDENT “t” test, DUNCAN, and the ACP, reveals the development of its shell first in height, followed in second position by the length, and this for the five sites under study. Weight would thus be the parameter under analysis that evolves the least quickly as compared to the other two biometric parameters involving a generally significant difference between the five sites under study. These results confirm that the growth of this mollusk varies depending on the seasons and relies on many biotic and abiotic factors that also condition the development of the shell and the growth of limpet. This approach represents a good means for environmental evaluation that could be used in biomonitoring programs to indicate the impact of pollution in the short and long term.

KEY WORDS

Algerian occidental coastline; biometric indices; Biomonitoring; *Patella rustica*.

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INTRODUCTION

The totality of the planet’s ecosystems is affected one way or another by the developments of human societies and the various waste rejections that could lead to high pollution levels in the coastal marine ecosystems (Smolders et al., 2003; Rao et

al., 2007; D’Adamo et al., 2008). These waste rejections of urban, agricultural, and industrial origin alter communities and affect the organisms that compose them (Boening, 1999; Viaroli et al., 2005; Warwick, 2005). The port areas, which are considered the most polluted of the coastal regions, threaten the benthic and pelagic communities

(Guerra-García & García-Gómez, 2004). Waste waters, which in many countries are not or only rarely treated, transport and dump their pollutants and organic matters into the coastal waters, thus creating eutrophication and the bio-accumulation of toxic elements in the marine organisms whose transport all along the food chain represents a danger for human health (Boening, 1999; Daby, 2006).

The same observation is valid for Algeria. Thus, during the last decades, the coastal zones have been the site of an accelerated development and a very important demographic pressure. Around 45% of the populations are concentrated on a narrow band of the coast, in particular in the industrial and port zones like Algiers, Oran, Annaba, Arzew, and Skikda (Grimes et al., 2004). According to the same author, the population density in the coastal cities is of 281 inhabitants per square kilometer, while the national population density is of 12.2 inhabitants per square kilometer. This statement highlights the importance of having safe and healthy drinking water for such concentrated population.

Biomonitoring of water quality of the various ecosystems requires the use of sentinel organisms such as the mollusk (Long & Nilson, 1997). The limpet is a gastropod mollusk that has so far been, until now, very little explored to eco-toxicological ends. This mollusk is capable of an extraordinary adaptation to the different variations of ecological factors (Vermeij, 1973; Branch, 1981) and corresponds to the criteria of a good pollution bioindicator: sedentary, sessile, ubiquitous, easy to collect, capable of accumulating and tolerating strong concentrations of exogenous substances of anthropogenic origin (Nakhlé et al., 2006). It offers good resistance to the physico-chemical fluctuations of the environment (temperature, salinity, chemical contaminants, etc.) (Wilson, 1904; Smith, 1935; Dodd, 1955; Damen et al., 1994; Klerkx et al., 2001; Lespinet et al., 2002).

The limpets are invertebrate organisms found in masses on the rocky coasts of the intertidal and subtidal zone (Nakhlé et al., 2003). All the existing species of the genus *Patella* Linnaeus, 1758 (Gastropoda Patellidae) are limited to the North-East Atlantic and the Mediterranean Sea (Ridgway et al., 1998).

Nevertheless, the biomonitoring studies realized on this bioindicator species of the Algerian occidental coast have been performed using a biochemical ap-

proach such as biomarkers measurements, which could be very expensive (Benaissa et al., 2017). For this reason, it is necessary to develop less costly, more practical, and faster approaches based on the monitoring of morphometric parameters in this limpet.

In fact, the morphological variations can inform us of an eventual stress caused on the latter, which can be explained by the change in environmental conditions such as the availability of food and the various anthropic rejections (Beldi et al., 2012).

It is in this perspective that we have realized the follow-up of seasonal variations of the biometric indices through ponderal and linear measurements of the bioindicating species *P. rustica* Linnaeus, 1758 with the concern in the evaluation of the quality of coastal waters of the Algerian occidental coastline.

MATERIAL AND METHODS

Sampling

The choice of the sites is in relation to the different sources of pollution. Our samplings are realized at the level of five sites of the Algerian western coast (Fig. 1):

Madaghl (MD): (35°38'31.89"N; 1°3'31.67"W), non impacted zone, which is found in a bay closed on its extremities by two small capes restricting the action of the winds. The proximity of Habibas Islands, considered as a protected area (MPA), could make of this coastal site a referential station for comparative studies.

Bouzedjar harbor (BH): (35°34'30.05"N; 1°10'6.58"W), zone that benefits from a touristic planning plan that creates an important human frequentation on its site.

Ain El Turck (AT): (35°44'35.13"N; 0°45'15.55"W), the site is situated near a desalination station.

Oran harbor (OH): (35°42'47.87"N; 0°38'40.57"W), open on the south bank of the western Mediterranean Sea. Situated at less than 200 kms from the Iberian coast, the Oran harbor constitutes the first harbor of the western Algeria.

Kristel (KR): (35°49'32.20"N ; 0°29'22.16"W), is relatively healthy and located between two capes forming the large bay of Oran, Cap Ferrat in the north and Cap Falcon in the south-east. It is situated at 28 kms from the Kristel site, and harbors a small and picturesque port where artisanal fishing is practiced.

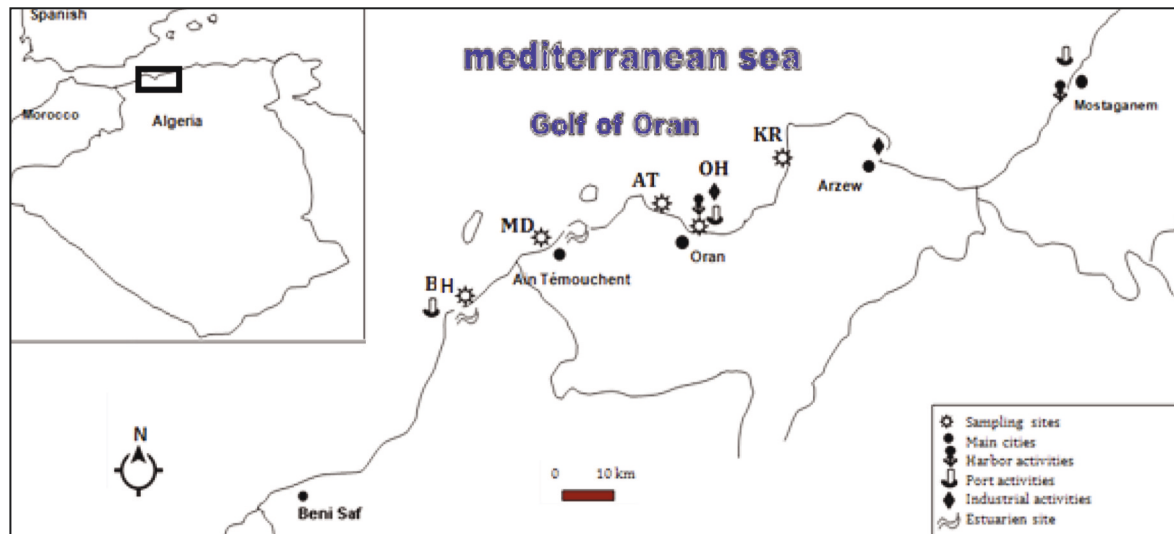


Figure 1. Study area: western Algerian coast.

Experimental sites summary

1. Kristel (KR), Ain El Turk (AT), and Madaghl (MD): considered as relatively healthy sites with a slightly marked anthropic activity (sporadic pollution).

2. Bouzedekar harbor (BH) and Oran harbor (OH): polluted sites found on different geographical positions and substrata.

Collection and preparation of samples of *P. rustica*

The species *P. rustica*, being different from other limpet species and very easy to see and detect to the naked eye, is sought in all favorable environments and handpicked using leverage. Six hundred specimen of *P. rustica* limpet have been collected during the four seasons of the year 2014 to 2015, 30 specimens per season per site. The limpets have been stored in a cooler at 4° C containing seawater of the ambient environment.

In the laboratory, a series of linear measurements using a vernier caliper (to 1/100 th mm), are realized, i.e., the length of the shell (L), the height of the shell (H), and the total weight of the specimen (TW) (hard weight and soft weight) with the help of a precision scale (to 1/100 th g).

The interpretation of these different measurements are correlated with a power curve of the form

$y = ax^b$ (Myers, 1986), which is transformed into a logarithmic function of form: $\log y = \log a + b \log x$. This transformation is the simplest method to linearize the relationship, stabilize the variances and normalize the variables (Myers, 1986). It is admitted that the variables measured are without significant errors, since the method of calculation adopted is that of the least squares.

Statistica 7.0 has been used for inter-sites comparison biological parameters of *P. rustica* using the DUNCAN test; $P < 0.05$), and ACP for the inter-sites and seasonal comparisons, but also the different biometric parameters of the various groups of *P. rustica*.

RESULTS AND DISCUSSION

The biometric parameters show minima and a maxima values respectively for the length of the shell comprised between 19 mm and 36 mm, for the height of the shell (5 mm to 14 mm), and for the total weight of the values of the order of 1.21 g to 7.84 g.

The means and typical gaps are represented in Table 1 as well as the marked significance following the DUNCAN test ($P < 0.05$) between the parameters considered annually and inter-sites. The Annual and seasonal allometric results for *P. rustica* populations are showed in Tables 2, 3, 4, and 5.

The analysis of these tables reveals for all the results related to the relation length-height a strong correlation for three seasons (Winter - Spring - Summer), which order varies from 72% to 93% ($P < 0.05$) (Table 3) for the five sites considered, whereas Autumn is attributed the lowest values (67% to 77%). These values witness a good correlation of the two linear parameters (L–H). We see a good autumnal correlation of 60% and 70%, going up to a strong correlation of the order of 94% for the other three seasons.

The two parameters of L and H and following test “T” show a minor allometry (for the four seasons and for the five sites), which means that L grows more slowly than H.

The annual study of the coupled interaction of TW–L reveals a strong correlation between these latter two with a coefficient of 0.74 and 0.81 ($P < 0.05$) for BH, between 0.54 and 0.91 for KR, 0.68 and 0.96 for AT, 0.77 and 0.90 for MD, 0.69 and 0.90 finally for OH (Table 4). As for the preceding two parameters, the correlation between TW and L varies between strong in autumn to very strong for the other three seasons. Factor b marks a significant minor allometry and sometimes on for the winter, summer, and autumn seasons ($b < 2.5$), which means a less important development of TW than the L of the shell. In addition, factor b marks an isometric in spring ($b > 2.5 \approx 3$), which explains that the TW evolves at the same speed as the L of the shell apart from AT (Baibbat & Abid, 2015).

Finally, the co-evolution of TW and H has in turn revealed a correlation coefficient varying between 0.64 and 0.87 for BH ($P < 0.05$), from 0.64 to 0.91 for KR, 0.52 to 0.90 for AT, 0.70 to 0.90 for MD and finally 0.50 to 0.93 for OH (Table 5). Test T reveals significance between the two parameters and a minor allometry for all the stations and during the whole year, which shows that the H grows faster than TW.

The Morphometric parameters measured in the limpet in the five sites (BH, KR, AT, MD, OH) have been integrated in a multi-varied analysis so as to detect the models of variation. The correlation circle formed by F1 and F2 indicates an axis that shows 88.7% of the total information. The two main components PC1 and PC2 have been identified as representing respectively 33.01% and 18.62% of the total variance.

PC1 is negatively correlated with all parameters. PC2 is positively correlated with the three parameters (L, H, TW) of MD, BH and also with the L parameters of OH and AT. On the contrary, PC2 is negatively correlated with the three parameters (L, H, TW) of KR and also (H and TW) of the OH and AT.

There are of the correlations between the different sampling seasons and F1 and F2 shown 98% of the total information. They represent respectively 96.26% and 1.57% and they also give a good description of most of the studied parameters. PC1 is

Sites Parameters	BH	KR	AT	MD	OH
lengths	27.78±2.83 ^a	26.16±2.38 ^b	24.66±3.30 ^c	23.91±3.46 ^c	27.09±4.23 ^a
height	10.03±1.80 ^a	8.63±1.30 ^b	8.58±1.71 ^b	8.61±1.72 ^b	8.77±1.68 ^b
total weight	3.57±1.11 ^a	3.91±0.84 ^b	3.28±0.83 ^{cd}	3.07±0.95 ^d	3.54±1.46 ^{ac}

Table 1. Averages and standard deviations of the lengths, height, and total weight of limpets collected seasonally at the five study sites.

STATIONS	EQUATION	N	R	ALLOMETRY TEST	ALLOMETRY
BH	L=0.0608H ^{1.5336}	120	0.759	**	Minorante
	P=0.1812L ^{1.2815}	120	0.5809	**	Minorante
	P=0.0009H ^{2.4757}	120	0.6995	**	Minorante
KR	L=8.55H ^{0.5195}	120	0.7045	**	Minorante
	W=0.0083L ^{1.8829}	120	0.6638	**	Minorante
	W=0.2654H ^{1.2444}	120	0.7569	**	Minorante
AT	L=7.3001H	120	0.6766	**	Minorante
	W=0.0153L ^{1.6705}	120	0.768	**	Minorante
	W=0.326H ^{1.0686}	120	0.6613	**	Minorante
MD	L=7.1308H ^{0.5625}	120	0.6468	**	Minorante
	W=0.0084L ^{1.8522}	120	0.785	**	Minorante
	W=0.2921H ^{1.0836}	120	0.5492	**	Minorante
OH	L=8.3932H ^{0.5388}	120	0.4472	**	Minorante
	W=0.0016L ^{2.3094}	120	0.7691	**	Minorante
	W=0.0985H ^{1.6263}	120	0.5876	**	Minorante

Table 2. Overall allometric equations between length, height and total weight of *P. rustica* in the five stations (BH), (KR), (AT), (MD), and (OH) during the four seasons of the year. N: Number of individuals; R: Coefficient of correlation of regression equations; **: Significant Student Test ($P < 0.05$).

STATIONS	SEASONS	EQUATION	N	R	ALLOMETRY TEST	ALLOMETRY
BH	Winter	$L = 8.2528H^{0.5239}$	30	0.8012	**	Minorante
	Spring	$L = 8.9992H^{0.494}$	30	0.8325	**	Minorante
	Summer	$L = 7.4993H^{0.5585}$	30	0.8017	**	Minorante
	Autumn	$L = 8.784H^{0.5123}$	30	0.6838	**	Minorante
KR	Winter	$L = 7.8476H^{0.5693}$	30	0.9145	**	Minorante
	Spring	$L = 12.649H^{0.3573}$	30	0.8619	**	Minorante
	Summer	$L = 7.12H^{0.5776}$	30	0.8828	**	Minorante
	Autumn	$L = 9.2642H^{0.4833}$	30	0.6926	**	Minorante
AT	Winter	$L = 7.3911H^{0.6067}$	30	0.9166	**	Minorante
	Spring	$L = 8.4299H^{0.5092}$	30	0.9253	**	Minorante
	Summer	$L = 6.3764H^{0.6009}$	30	0.9012	**	Minorante
	Autumn	$L = 7.7838H^{0.5146}$	30	0.7649	**	Minorante
MD	Winter	$L = 8.1148H^{0.5579}$	30	0.9085	**	Minorante
	Spring	$L = 5.9738H^{0.6414}$	30	0.9225	**	Minorante
	Summer	$L = 7.113H^{0.5378}$	30	0.936	**	Minorante
	Autumn	$L = 7.6723H^{0.4996}$	30	0.7755	**	Minorante
OH	Winter	$L = 5.767H^{0.706}$	30	0.7244	**	Minorante
	Spring	$L = 12.446H^{0.423}$	30	0.9375	**	Minorante
	Summer	$L = 7.017H^{0.6345}$	30	0.9087	**	Minorante
	Autumn	$L = 8.7414H^{0.4569}$	30	0.6767	**	Minorante

Table 3. Annual allometric equations between shell length of *P. rustica* and its height in the five stations (BH), (KR), (AT), (MD), and (OH) during the study year. N: Number of individuals; R: Coefficient of correlation of regression equations; **: Significant Student Test ($P < 0.05$).

STATIONS	SEASONS	EQUATION	N	R	ALLOMETRY TEST	ALLOMETRY
BH	Winter	$W = 0.0019L^{2.2695}$	30	0.7856	**	Minorante
	Spring	$W = 0.0004L^{2.769}$	30	0.7968	**	Isometric
	Summer	$W = 0.0012L^{2.3496}$	30	0.8131	**	Minorante
	Autumn	$W = 0.0021L^{2.2566}$	30	0.7458	**	Minorante
KR	Winter	$W = 0.0094L^{1.8035}$	30	0.8109	**	Minorante
	Spring	$W = 0.0002L^{2.9906}$	30	0.9122	**	Isometric
	Summer	$W = 0.011L^{1.8068}$	30	0.8916	**	Minorante
	Autumn	$W = 0.0124L^{1.7878}$	30	0.543	**	Minorante
AT	Winter	$W = 0.0104L^{1.7746}$	30	0.8775	**	Minorante
	Spring	$W = 0.0063L^{1.934}$	30	0.944	**	Minorante
	Summer	$W = 0.0023L^{2.3162}$	30	0.9603	**	Minorante
	Autumn	$W = 0.0062L^{1.9393}$	30	0.6781	**	Minorante
MD	Winter	$W = 0.0745L^{1.1778}$	30	0.8573	**	Minorante
	Spring	$W = 0.0003L^{2.9155}$	30	0.9039	**	Isometric
	Summer	$W = 0.0018L^{2.3202}$	30	0.8712	**	Minorante
	Autumn	$W = 0.0189L^{1.5869}$	30	0.7744	**	Minorante
OH	Winter	$W = 0.0015L^{2.3269}$	30	0.8515	**	Minorante
	Spring	$W = 0.0002L^{2.9304}$	30	0.8914	**	Isometric
	Summer	$W = 0.0003L^{2.7545}$	30	0.9037	**	Isometric
	Autumn	$W = 0.0038L^{2.1056}$	30	0.6954	**	Minorante

Table 4. Annual allometric equations between shell length of *P. rustica* and total weight in the five stations (BH), (KR), (AT), (MD), and (OH) during the study year. N: Number of individuals; R: Coefficient of correlation of regression equations; **: Significant Student Test ($P < 0.05$).

STATIONS	SEASONS	EQUATION	N	R	ALLOMETRY TEST	ALLOMETRY
BH	Winter	$W=0.1469H^{1.3794}$	30	0.8472	**	Minorante
	Spring	$W=0.0974H^{1.5712}$	30	0.8751	**	Minorante
	Summer	$W=0.0927H^{1.4659}$	30	0.8136	**	Minorante
	Autumn	$W=0.2055H^{1.3026}$	30	0.6472	**	Minorante
KR	Winter	$W=0.3062H^{1.1385}$	30	0.9117	**	Minorante
	Spring	$W=0.3449H^{1.1477}$	30	0.9072	**	Minorante
	Summer	$W=0.3227H^{1.1224}$	30	0.9105	**	Minorante
	Autumn	$W=0.3749H^{1.1277}$	30	0.6406	**	Minorante
AT	Winter	$W=0.3397H^{1.1054}$	30	0.8479	**	Minorante
	Spring	$W=0.3819H^{0.9946}$	30	0.8909	**	Minorante
	Summer	$W=0.1591H^{1.4204}$	30	0.9015	**	Minorante
	Autumn	$W=0.3281H^{1.0038}$	30	0.5249	**	Minorante
MD	Winter	$W=0.799H^{0.7008}$	30	0.886	**	Minorante
	Spring	$W=0.0498H^{1.9405}$	30	0.8979	**	Minorante
	Summer	$W=0.1484H^{1.3145}$	30	0.9049	**	Minorante
	Autumn	$W=0.4199H^{0.8563}$	30	0.7007	**	Minorante
OH	Winter	$W=0.0448H^{1.9585}$	30	0.8766	**	Minorante
	Spring	$W=0.2972H^{1.2928}$	30	0.9093	**	Minorante
	Summer	$W=0.052H^{1.8632}$	30	0.9332	**	Minorante
	Autumn	$W=0.338H^{0.9993}$	30	0.5079	**	Minorante

Table 5. Annual allometric equations between shell height of *P. rustica* and total weight in the five stations (BH), (KR), (AT), (MD), and (OH) during the study year. N: Number of individuals; R: Coefficient of correlation of regression equations; **: Significant Student Test ($P < 0.05$).

negatively correlated with the two cold seasons, winter and autumn. PC2 is positively correlated with the hot seasons, spring and summer.

DISCUSSION

The study of the biological parameters taken into account in this study highlights an excellent correlation of biometric relations for the five sites of study (Fig. 1), and also for winter, spring, and summer, whereas in autumn this correlation coefficient indicates the lowest values.

This variability could be linked to different factors, whether biotic and/or abiotic (Grimes et al., 2004).

The good development of limpets and the good correlation of the three parameters (length, height, total weight) at the polluted sites (OH, BH) 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

when phytoplanktonic bloom is at its highest level. This explains the isometric development between length and weight. Generally, temperate limpets grow more rapidly in summer due to the increased abundance of food (Brêthes et al., 1994; Vat, 2000). In the present study, the result shows that there would be a good correlation in the summer and spring period of the whole of the *P. rustica* populations. For this reason, the marked R^2 in summer for all the stations under study is very good. According to Davies (1969), *P. rustica* occupies the superior intertidal zone whereas *P. caerulea* Linnaeus, 1758 and *P. ulyssiponensis* Gmelin, 1791 colonize the inferior part of this zone. Grimes et al. (2004) specify that *P. rustica* settles mainly in the inferior medio-littoral where it is found in abundance and where it takes its food resources. This food contributes widely to its physiology development (growth, reproduction) and exerts a direct effect on the speed and duration of gametogenesis phenomena (Lubet, 1980). This explains the slightly important weight obtained in autumn (a period weak in nutrients, but also a period marked by reproduction for *P. rustica* from July to December) (Othaitz, 1994), including

a correlation of the order of 60%, instead of 80% to 96% for the other seasons.

These results are corroborated by Frehi et al. (2007) and Beldi et al. (2012), who approve that the polluted sites are very rich in phytoplankton, which allows *P. rustica* to be a grazing species. The algae cover and the floristic composition play a major role in the abundance of herbivorous (Hereu, 2004).

The *P. rustica* shells present an allometry in their growth in length and in height, because they grow more in height than in length. Our species is considered to be using a strategy of energy conservation due to its unstable environment and its limited food resources. To this effect, it encourages the development of its shell in height in order to be able to store water and thus hydrate itself during prolonged emersion periods (Sokolova & Pörtner, 2003; Prusina et al., 2014).

Moreover, the growth of the shell and of the total weight of our samples is observed at the level of all the chosen sites, whether they are impacted or not. The biometric relations done on *P. rustica* specimens taken from MD, KR, and AT show a correlation which is as important as those taken from the two harbors (OH and BH). This indicates that the limpets of the coastal sector and the two harbors evolve in the same manner and that pollution does not impact on the specimens (same biological equilibrium).

CONCLUSIONS

This study, based on the biometry of *P. rustica*, was realized in order to evaluate the evolution of the latter from the point of view of total weight, and anteroposterior length of the shell, as well as its height at the level of the different sites having a variable pollution rate. We have shown evidence that this species has the capacity to develop in different environments and that it has shown to be a resilient and resistant species. Following these results, *P. rustica* evolves in its environment given the growth of these biological parameters taken into consideration, and this despite the environment.

Finally, it would be interesting to enlarge the spectrum to several other sampling points of this gastropod mollusk *P. rustica* for a wider and complementary study of these biometric parameters.

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