Mar. Sci. Tech. Bull. (2015) 4(1):7-12
ISSN: 2147-9666

MARINE SCIENCE AND TECHNOLOGY BULLETIN

Growth and survival performances of Mediterranean mussel (*Mytilus galloprovincialis*, Lamarck, 1819) on different depths in Cardak lagoon, Dardanelles.

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ARTICLE INFO

Article history:

Received: 14.05.2015
Received in revised form: 12.06.2015
Accepted : 03.06.2015
Available online : 10.07.2015

Keywords:

Mussel
Mytilus galloprovincialis
Growth
Depth
Dardanelles

ABSTRACT

This study was conducted at Cardak Lagoon of Dardanelles between August 2009 and March 2010. The average initial and final length of the Mediterranean mussel (*Mytilus galloprovincialis* Lamarck,1819) from different depths (0.5 m, 5 m, 10 m) were measured as 9.75± 0.81 mm - 41.21±3.42 mm, 9.76±0.87 mm - 39.64±2.90 mm, 9.95±0.75 mm - 38.13±2.70 mm and 0.11±0.03 g - 6.56±1.82 g, 0.11±0.03 g - 5.83±1.23 g, 0.11±0.02 g - 4.39±1.00 g, respectively. On the growth of mussels, monthx depth interaction (P = 0.221) and depth (*P* = 0.078) did not show a significant effect, but months were found to be effective (*P* = 0.00). The survival rates of the mussels at 0.5 m, 5 m, 10 m depth were determined as 87%, 87% and 76%, respectively. The difference of the survival rates of the mussels with respect to different months was significant (*P* = 0.011). Nevertheless, the depth had no effect upon the mussel survival rate (*P* = 0.091). It was confirmed that especially the particulate organic matter (POM) detected in water as well as the particulate inorganic matter (PIM) played a significant role in addition to the slight role that the salinity had on the growth performance of the mussels.

Introduction

The current food resources have been rendered insufficient to satisfy the demand that comes with the population growth due to the reasons such as extensive hunting, droughts and inability to manage the sources in a rational manner. Therefore, studies that aim to supply high yield products with high nutrient values are gaining importance. Production of mussels stands as an alternative route for managing the afore mentioned deficit, because mussels are rich in protein, have ability to provide larvae in appreciable amounts, and mussel aquaculture is easy and require low costs. Mussels, pertaining to the *Mytilus* genus, are grown in abundance in the Mediterranean Region. According to FAO, the mussel production in 2012 was 64000 tons in Italy, 24000 tons - in Greece and 14000 tons - in France (FAO 2014). Although, all of these countries are located within the same climate zone with Turkey, the mussel production in Turkey is only 5 tons (FAO 2014), in spite of the fact that there are dense reserves in Eastern Black Sea, Western Black Sea, Marmara Sea and along the coasts of Northern Aegean Sea. Therefore, the suitable regions in our country for mussel production should be identified in a rapid manner and the subsequent production should be initiated. The aim of this study is determine the potential of the mussel culture in Cardak Lagoon. With this purpose in three different depths (0.5 m, 5 m and 10 m) the mussel spats growth performance, survival rates and effects of environmental factors (salinity, temperature, chlorophyll-a, particulate organic matter and particulate inorganic matter) were examined.

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Material and methods

This study was conducted between August 2009 and March 2010 in Cardak Lagoon, Dardanelles located at 40°22' 58'' N, 26°42' 24'' E (Figure 1). The depth of the study area was 15 meters.

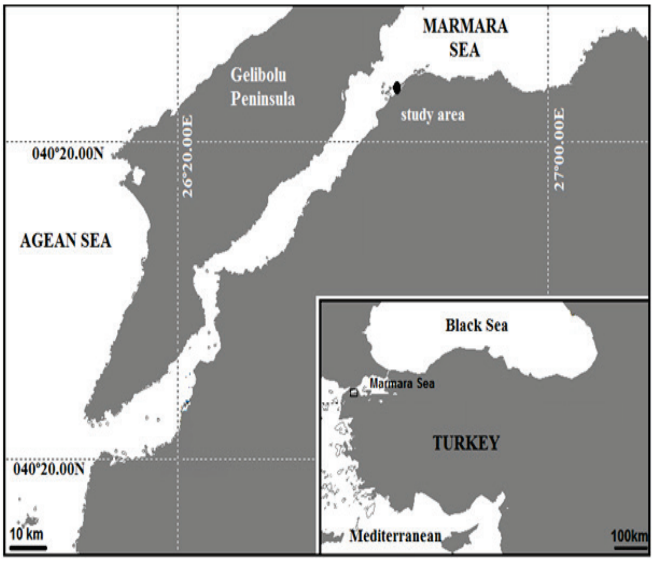

Figure 1. Map of the study area in Cardak, Dardanelles.

A hundred mussels with a length of 9.75±0.81 mm, 9.76±0.87 mm and 9.95±0.75 mm were placed in net bags for hanging from the longline, to be at depths of 0.5 meters, 5 meters and 10 meters. The weight and length of mussels were measured monthly.

Specific growth rate SGR (%) was calculated by the following formula (Chatterji et al. 1984):

$$SGR(\%) : [(\ln L_2 - \ln L_1)/ (T_2 - T_1)] \times 100$$

SGR: Specific growth rate

L_1: Mean shell lengths at time t_1

L_2: Mean shell lengths at time t_2

W_1: Mean mussel weights at time t_1

W_2: Mean mussel weights at time t_2

$t_2 - t_1$: 30 days

Survival rate (%) was determined by the following formula:

$$\text{Survival rate } (\%) = N_t \times 100 / N_0$$

N_t : Number of live mussels after time t

N_0: Number of mussels at the beginning of the experiment.

Temperature and salinity of the water were measured from different depths in situ via YSI 85 Probe at each sampling time. The concentrations of particulate organic matter (POM) and particulate inorganic matter (PIM) as well as the chlorophyll-a were calculated according to Strickland and Parsons (1972).

Statistical Analysis

The variance analyses in the randomized plot trial setting in factorial order as well as the Tukey multiple comparison method were applied in order to determine the differences in growth performances with respect to different months and depths.

Friedman test was used for identifying the effect of different months and depths on the survival rates of mussels.

The Multidimensional Scaling (MDS) analysis was used for analyzing the relations between the growth performances of the mussels in different depths (lenght-weight) and various environmental parameters (temperature, salinity, PIM, POM, chlorophyll-a), (Kruskal and Wish, 1978).

Results

During the study period, the changes in water temperature exhibited similarities at all depths. The lowest water temperature was measured as 8.59°C in February at a depth of 10 meters and the highest one was measured as 24.12°C in September at a depth of 0.5 meters (Figure 2a). The monthly salinity rates in different depths varied between 24.08‰ and 26.35‰. The lowest level of salinity was measured as 24.08‰ in August at a depth of 10 meters while the highest salinity was recorded as 26.35‰ in January at a depth of 10 meters (Figure 2b).

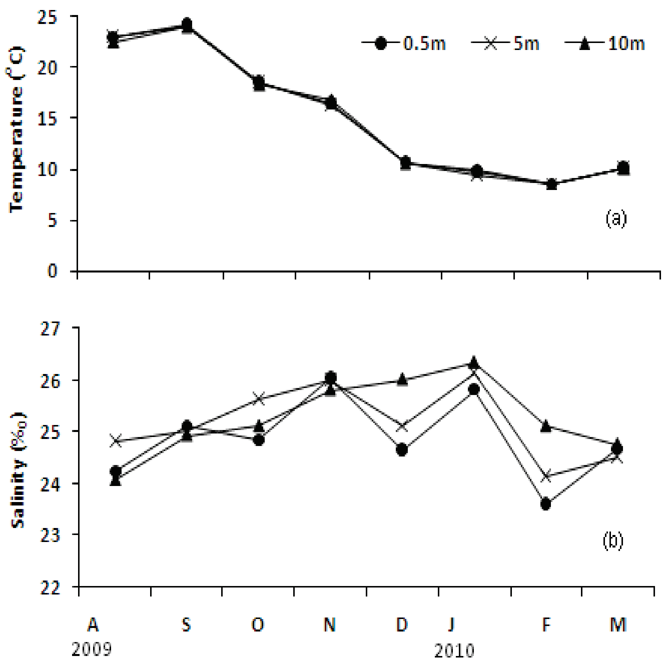

Figure 2. Monthly distribution of temperature (a) and salinity (b).

POM and PIM concentrations of water were variable during the study period. Fluctuations in POM and chlorophyll-a values were almost similar at all depths during the study period except at 0.5 meters in September (for POM). PIM ranged from a minimum of 2.10 mg L^{-1} in September (10 meters) and 2.02 mg L^{-1} in November (all depths) to a maximum of 5.10 mg L^{-1} in December (10 meters) (Figure 3c).

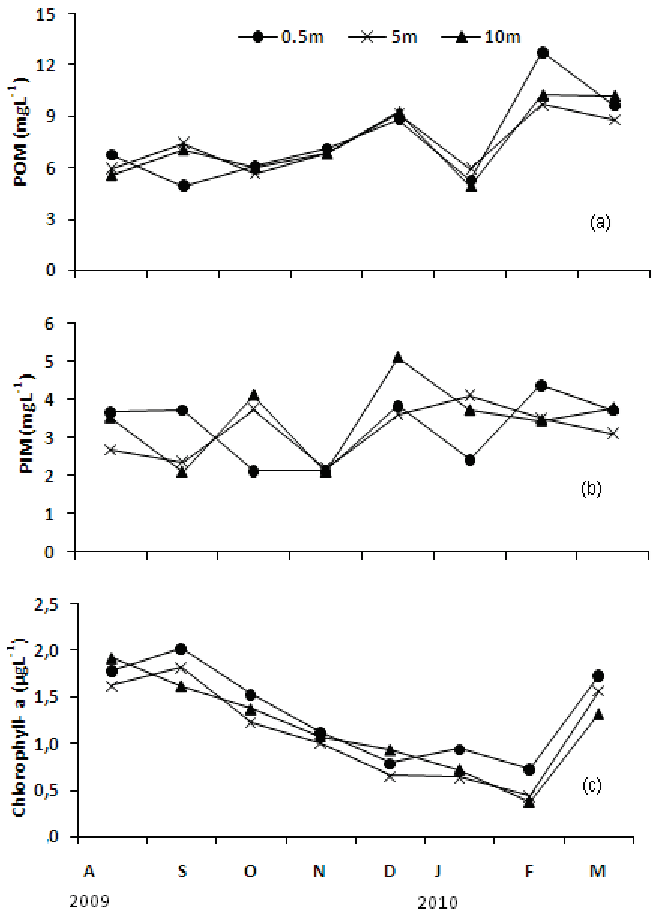

Figure 3. Monthly distribution of POM (a), PIM (b) and chlorophyll-a (c).

Length and weight of the mussels at 0.5 meters reached from 9.75±0.81 mm and 0.11±0.03 g to 41.21±3.42 mm and 6.56±1.82 g, respectively after seven months. Same results for 5 meters and 10 meters were observed at the end of the study (Figure 4a and 4b).

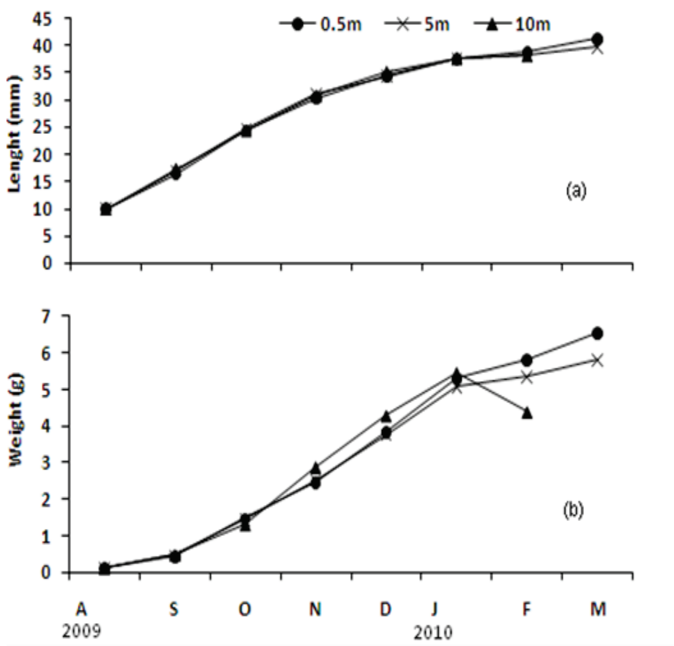

Figure 4. Monthly growth in lenght (a) and weight (b) of mussels.

It was observed that the growth rates of length and weight were higher at the beginning of the study and decreased afterwards. It was also determined that the differences in depth had no significant effect on the growth rates (Figure 5a, 5b).

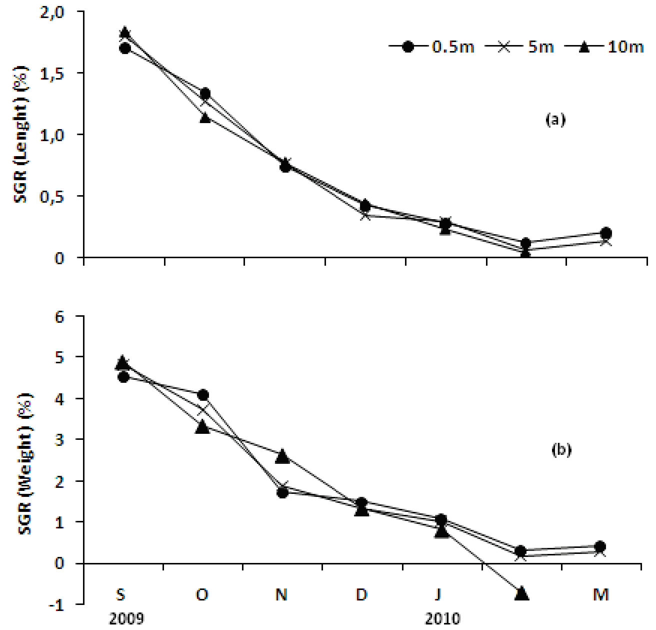

Figure 5. Mussel growth rates in lenght (a) and weight (b).

At the end of the study, the survival rate of the individuals, which were placed to the depths of 0.5 meters and 5 meters were determined as 85%. However, due to the fact that the net bags placed at 10 meters were lost, no data was obtained for this group in March 2010. The survival rate of this group from the previous month was determined as 75%. No significant difference in terms of survival rates was found among the groups (Figure 6).

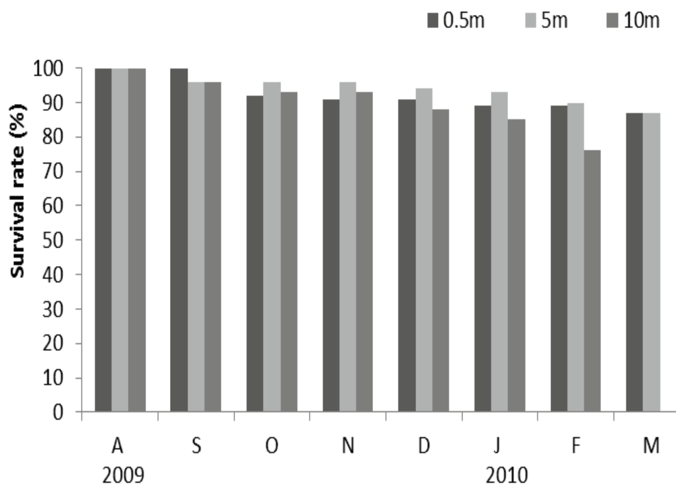

Figure 6. Survival rate of mussels.

The month - depth interaction (P = 0.221) and the effect of depth (P = 0.078) in terms of the growth of the mussels was found out to be statistically insignificant. However, the effect of the months on the growth of the mussels was significant (P = 0.00; Table 1).

Table 1. Tukey results on the length of mussels.

Average Mussel Lenght (mm)			
DATE	N	X ± S_X	Min - Max
August	300	9.819 ±0.047 G	8.10 – 10.99
September	287	16.799±0.118 F	11.12 – 21.87
October	281	24.391±0.156 E	16.82 – 30.66
November	280	30.637±0.166 D	22.13 – 37.70
December	273	34.563±0.183 C	24.35 – 43.07
January	267	37.460±0.194 B	26.53 – 46.01
February	256	38.307±0.186 A	30.77 – 46.89

Remark- 1: The difference between the dates, indicated with different initials is significant.
Remark- 2: Since no significant effect of the depth was observed on the growth of the mussels, the depths are not considered.

Both the months (P = 0.00) and the month- depth interactions (P = 0.00) were observed to have a statistically significant impact on the weight of the mussels (Table 2).

Table 2. Tukey results depending on the weight and depth of mussels.

Average Mussel Weight (g)			
Date	N	X ± S_X	Min - Max
August	300	0,1095 ± 0,01 F	0,06-0,16
September	287	0,4620 ± 0,01 E	0,10-0,93
October	281	1,4062 ± 0,03 D	0,21-3,21
November	280	2,6244 ± 0,05 C	1,05-6,12
December	273	3,9620 ± 0,07B	1,53-9,48
January	267	5,2876 ± 0,08 A	1,81-10,83
February	256	5,2171 ± 0,08 A	1,79-10,02

Remark- 1: The difference between the dates, indicated with different initials is significant.
Remark- 2: Since no significant effect of the depth was observed on the growth of the mussels, the depths are not considered.

According to the Friedman Test, it was revealed that as the survival rate of the mussels varied significantly among the different months (P = 0.011); no significant difference in terms of survival rate was found among different depths (P = 0.091).

Based on the MDS analysis, covering all three different depths; it was found that the length, weight, PIM and POM had a strong relationship among themselves while temperature and chlorophyll- a have a strong relationship between each other (Table 3, Figure 7).

Table 3. General MDS analyses.

Solution Section		
Variables	Dimension 1	Dimension 2
Length	-0.2718	0.0721
Weight	-0.2701	0.0722
Temperature	0.4721	0.0753
Salinity	0.1043	-0.5022
PIM	-0.2320	0.0944
POM	-0.2556	0.1002
Chlorophyll-a	0.4530	0.0881

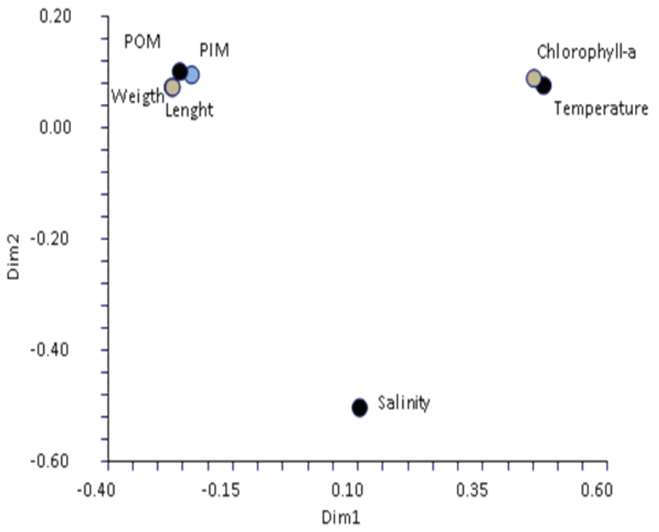

Figure 7.General MDS analysis.

Discussion

The amount of nutrients, (Ogilvie et al. 2004; Lemaire et al. 2006, Yıldız et al. 2013) as well as the environmental conditions such as water temperature (Okumuş and Stirling, 1998; Yıldız and Lök, 2005),and salinity (Ren and Ross, 2005; Lök et al. 2007) play a very important role on the growth performance of mussels. Mussels are organisms taking nourishment by filtering the particles in water. They use organic particles exist in water as suspension. Therefore, the amount of chlorophyll-a and organic materials is important in the environment the mussels are grown (Kumlu, 2001; Lök et al. 2007; Vural, 2011; Yıldız et al. 2013(a,b)). There is an important relation between the concentration of nutrient and growth in mussels. Generally, growth starts with the increase in water temperature and phytoplankton in spring (Yıldız et al. 2006). In this study, it was determined that the amount of POM and PIM dramatically affected the performance of growth. It was observed that these results confirm the results in the studies of Lök, 2000, Karayücel et al. 2002, Yıldız and Lök, 2005, Lök et al. 2007, Yıldız and Berber, 2010. Accordingly, in this study it was determined that salinity was another important parameter in the growth performance of mussels. Although mussels are able to tolerate a wide salinity range (Lök, 2000), the most optimal salinity value is around 15-25‰ (Gosling, 1992). The fact that during the study period, the salinity values were within the optimum limits implied the positive effect on the mussel growth performance.

In Ria de Arousa (Spain), Fuentes et al. (2000) reported that the depth is a major factor that affects the growth of *Mytilus galloprovincialis*, and added that the mussels with a length of 20 mm reached 50 mm within 17 months at a depth of 2.5 m as they reached to 45 mm at a depth of 7.5 m. Therefore, they concluded that the growth performance is faster on regions closer to the surface. Similarly, Kautsky (1982) reported that the growth performance of the mussels reared in Baltic Sea at a depth of 4 m is significantly higher compared to the growth performance of the mussels at a depth of 15 m. Dobretsov and Miron (2001) reported similar results in their study at the Mediterranean Sea. Nevertheless, the studies, conducted by Mallet and

Table 4. Growth *Mytilus galloprovincialis* in the long line system comparisons with other research results.

Study area	Initial length (mm)	Final length (mm)	Increment length (mm)	Survival rate (%)	Time (mounth)	References
Mersin Bay-Turkey	10	56	46	95	12	Lök et al. (2007)
Northern Sicily	10	40	30		12	Sara et al. (1998)
Dardanelles – Turkey	10	29	19	58.33	12	Yıldız and Lök (2005)
Dardanelles- Turkey	11	48	37	43.43	12	Yıldız and Lök (2005)
Gulf of Castellammare	11	58	47		12	Mazzola et al. (1999)
Çardak- Turkey	10	41	31	85	7	Present study

Carver (1991) in Canada, by Karayücel and Karayücel (2000) in Scotland, by Karayücel et al. (2002) in Turkey, by Ogilvie et al. (2004) in New Zealand and by Kravva and Staikou, (2007) in Greece, indicated that the depth has no impact on the growth performance of the mussels. Parallel to those studies, our study also showed that the depth had no effect on the growth performance of the mussels. On the other hand, it was also determined that the monthly differences had an impact on the growth as the growth rates, which were fast especially between August- November, decreased during the winter months. The mussel spats grow faster since they do not utilize energy for reproduction. Further, they gradually make a transition from somatic growth to reproduction phase (Uysal 1970; Yıldız 2004; Yıldız and Lök, 2005; Lök et al. 2007). Aquirre (1979) reported that the mussels reach to sexual maturity at an average length of 35 mm. Yonge (1976) indicated that beginning of maturity was 40 mm in length. Therefore, we can imply that not reaching the sexual maturity within a period of August- November is an important factor for the rapid growth of the spats.

In this study, the mussels with an average length of 10 mm reached to the lengths of 41.21 mm, 39.64 mm and 38.13 mm at the depths of 0.5 meters, 5 meters. and 10 meters, respectively within 7 months period (Table 4). A length of ≤50 mm for mussels are considered as market length. The length growth that had been measured in other studies within 12 months had been achieved only within 7 months in our study. Both our study and other studies, conducted in Black Sea and Aegean Sea prove that if the mussel spats are cultivated in suitable areas by suitable methods, they may reach up to market length within a year period.

The environmental conditions (wind, waves, temperature, amount of nutrients) have an effect on the survival rate of the mussels (Villalba, 1995; Yıldız et al. 2006). Perez and Roman (1979) determined the survival rates of mussels in Galicia Gulf as 80% and further indicated that this rate did not decrease below 86% at the areas sheltered against the wind and waves as the very same rate decreased down to 60%'s at the areas under the impact of strong waves and currents. Mallet and Carver (1991) in their study, conducted in Canada, reported that the mussel losses increased in summer months and the survival rates in summer season often decreased to 35% in surface layers and 25% in the deeper areas. Yıldız et al. (2006) determined the annual survival rates of the mussel spats as 60% at longline system in the Dardanelles. Additionally, in our study, it was revealed that the depth was not a significant factor on the survival rates ($P = 0.091$). However, it was also found that there were differences among the months as well ($P = 0.011$) which corresponded to variable water temperature.

In aquaculture, the aim is to obtain maximum yield from unit area. For this purpose, the areas, which were optimal for the growth of the species, were intended to be determined. There was no difference between depths in terms of mussel growth performances which were quite high. Depending on these results it can be concluded that the area of Lapseki Cardak is suitable for mussel aquaculture.

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