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Estimated Growth of the Mediterranean Mussel *Mytilus Galloprovincialis* from a Polluted Natural Environment in Atlantic Coast of Morocco

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Abstract: Absolute and relative growth was studied for the first time in the mussel *Mytilus galloprovincialis* from a polluted natural environment. Four sampling stations in two locations along the coast of El Jadida city and neighboring wastewater discharges were chosen to this purpose: Station H located at the Haouzia site and the J_1, J_2 and J_3 stations located in Jorf Lasfar site; with a larger metal pollution. Total weight and total length were measured to estimate different growth parameters. Growth curves analysis related to each stations reveals substantial difference in growth patterns between mussels of Jorf Lasfar site (J_1, J_2 and J_3 stations) and Haouzia (station H). The growth parameters were as follow: The lowest value of asymptotic length ($L\infty$) estimated at 7.2 cm for station H individuals and between 7.5 and 7.9 cm for those of Jorf Lasfar site. The Growth constant (K) is between 0.2 and 0.24 / year and the growth performance index (ǿ) is relatively low for mussels at both sites. Length-weight relationship indicated isometric growth with b statistically close to 3 for all surveyed stations.

Keywords: *Mytilus Galloprovincialis*, Growth Parameters, Absolute Growth, Lengths-Weight Relationship, Relative Growth, Atlantic Coast

1. Introduction

El Jadida province has experienced during the last decade a great touristic, industrial, agricultural and demographic development. However, these activities generate more or less identified pollution carried by numerous sewage discharges dumping directly into the sea. To assess this pollution, most of the scientific work uses marine biodiversity as a model to characterize pollutants for public health or toxicological monitoring purposes and unfortunately neglects the effect of that pollution on species themselves.

Among many species of particular interest in marine biomonitoring, we have the Mediterranean mussel *Mytilus galloprovincialis* which is widely used in various global marine environmental quality monitoring programs [1-2]. Indeed, this filter-feeder bivalve, characterized by a wide geographical distribution makes it an excellent bio monitor. For almost two decades, a local monitoring program has been established by our research team, adopting, among other, *M. galloprovincialis* as a biological model to assess the health status of El Jadida coastline [3-8].

Information about *Mytilus galloprovincialis* growth is a cornerstone for a better understanding of various population parameters. In fact, growth is an important biological factor generally defined in an individual as a change in body shape, biomass, or volume. In mussels, it depends on the environmental conditions in which they live a sedentary life. Individuals respond to these conditions by both morphological and physiological adaptations. The shell length is the most commonly used growth indicator in mussels [9]. It is a reference metric parameter to which is linked either another metric or weight value (relative growth), or age of the individual (absolute growth). In this context, the purpose of this study is to assess the pollution effect on *Mytilus galloprovincialis* growth. It aims to estimate for the first time the relative and absolute growth of the Mediterranean mussels from different stations of a polluted natural environment.

2. Methods

2.1. Study Area and Sampling

Mussels were collected monthly at low tide from four stations (Figure 1) of El Jadida Atlantic coastline, from January to December 2017:

i. Station H: Located 1 Km to the North of El Jadida, (Coordinates 33°14’40.2”N 8°28’25.9”W).

ii. Station J_1: located 22 Km to the South of El Jadida, and 3.5 Km South of Jorf Lasfar phosphate plants industrial discharge (Coordinates 33°05’43.2”N 8°38’46.3”W).

iii. Station J_2: Located 4 Km South of Jorf Lasfar phosphate plants industrial discharge (Coordinates 33°04’24.0”N 8°40’05.6”W).

iv. Station J_3: Located 5.5 Km South of Jorf Lasfar phosphate plants industrial discharge (Coordinates 33°03’32.1”N 8°41’03.4”W).

At each station, 20 mussels of different sizes were collected per month, and transported to the laboratory in containers with seawater. The animals were rinsed and cleaned. The different biometric measurements were taken using a vernier caliper (at 0.1 cm) and the weight measured with a precision scale (at 0.001 g). pH, temperature, dissolved oxygen and salinity were measured in the field using a multi-parameter meter (WTW, Model Multi 340i).

Figure 1. *Sampling stations (H, J1, J2 and J3) and study area of El Jadida coastline.*

2.2. Linear Growth Estimation

Information about growth parameters are obtained by length-frequency analysis. The simulated length-frequency distributions can be analyzed either by means of parametric or nonparametric approach. Measurements of growth in relation to time provide an expression of growth rate. Growth in length can usually be modelled by using an asymptotic curve that tapers off with increasing age. A number of mathematical functions have been used to describe growth curves, including the Gompertz, the logistic, and a range of straight-line and exponential approximations [10-11]. Among all the models, the von Bertalanffy growth function (VBGF) is the most frequently used to describe growth in many marine organisms. The function was derived by considering growth as the balance between anabolic and catabolic processes in an organism [12]. In our study, the growth model used is non-seasonal version of Von Bertalanffy (VBGF). To estimate absolute linear growth parameters and relative growth, mussels were grouped in interval widths of 0.25 cm. Iterations were made using FISAT II 1.2.2 software [13-14].

2.2.1. Absolute Growth Parameters (L∞, K, ǿ)

The asymptotic length (L∞) and the growth constant (K) are obtained by the equation (1) and allowed us to plot the theoretical growth curves:

$$Lt = L\infty \times (1 - e^{-K(t-t_0)}) \quad (1)$$

Where:
Lt: Length at age t (cm).
L∞: Asymptotic length (cm).
K: growth constant (year-1).
t_0: Hypothetical age at Lt = 0 (year).
t: Hypothetical age at a given total length Lt (year).

Conversion of length into hypothetical age is done with the inverse VBGF:

$$t(L) = t_0 - 1/K \times \ln(1 - L/L\infty) \quad (2)$$

Growth performance index (ǿ) is an important tool to compare growth curves of different populations of the same species [15]. This index is calculated with the formula (3):

$$ǿ = \mathrm{Log}_{10}K + 2 \times \mathrm{Log}_{10}\,L\infty \quad (3)$$

2.2.2. Length-Weight Relationship

The length-weight relationship, which describes mussel shape changes depending on the size, is given by the following formula (4):

$$Wt = a \times Lt^b \quad (4)$$

Wt: Mussel total weight (g)
Lt: Mussel total length (cm)
a: Regression intercept
b: Regression slope

The regression slope (b) is compared with the critical value 3 using "t" student statistics test (0.001 thresholds). This allowed to include the relationship whether in the isometric range (b = 3) or allometric range (negative allometric; b<3 or positive allometric; b > 3) [16].

3. Results

3.1. Physicochemical Parameters

The station's water temperature shows distinct variations between the two sites: Haouzia and Jorf Lasfar. The highest values are recorded at the end of the spring period with a maximum in May, ranging between 21.4°C and 20.3°C respectively in H and J_3 (Figure 2A).

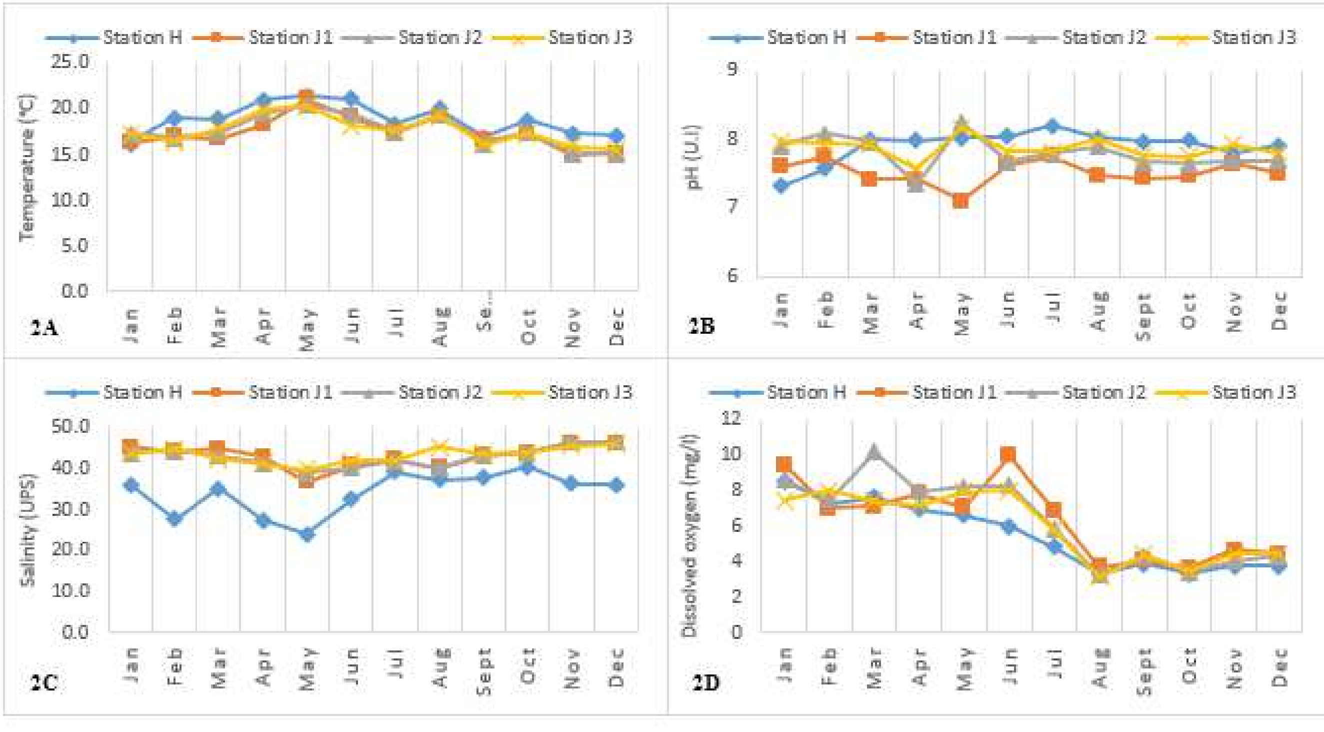

Figure 2. Physicochemical parameters spatiotemporal variations in prospected stations (H, J_1, J_2 and J_3) from El Jadida coastline.

The pH values at the four stations are between 7.1 and 8.2 (Figure 2B). The salinity of the Haouzia site is relatively low. The minimum and maximum values are 24 mg / l and 40.4 mg / l respectively in May and October. In Jorf Lasfar site, the minimum and maximum salinity values are recorded in May and December, 36.8 mg / l in J_1 and 46.6 mg / l in J_2 (Figure 2C). Dissolved oxygen levels show seasonal fluctuations with high values in winter and spring, with 8.6 mg / l in H and 10.2 mg / l in J_2. The lowest levels are noted in summer, 3.3 mg / l and 3.2 mg / l respectively in H and J_2, J_3 (Figure 2D).

3.2. Length Frequency

Mussel's length frequency distribution from the prospected stations H, J_1, J_2 and J_3 is shown in figure 3.

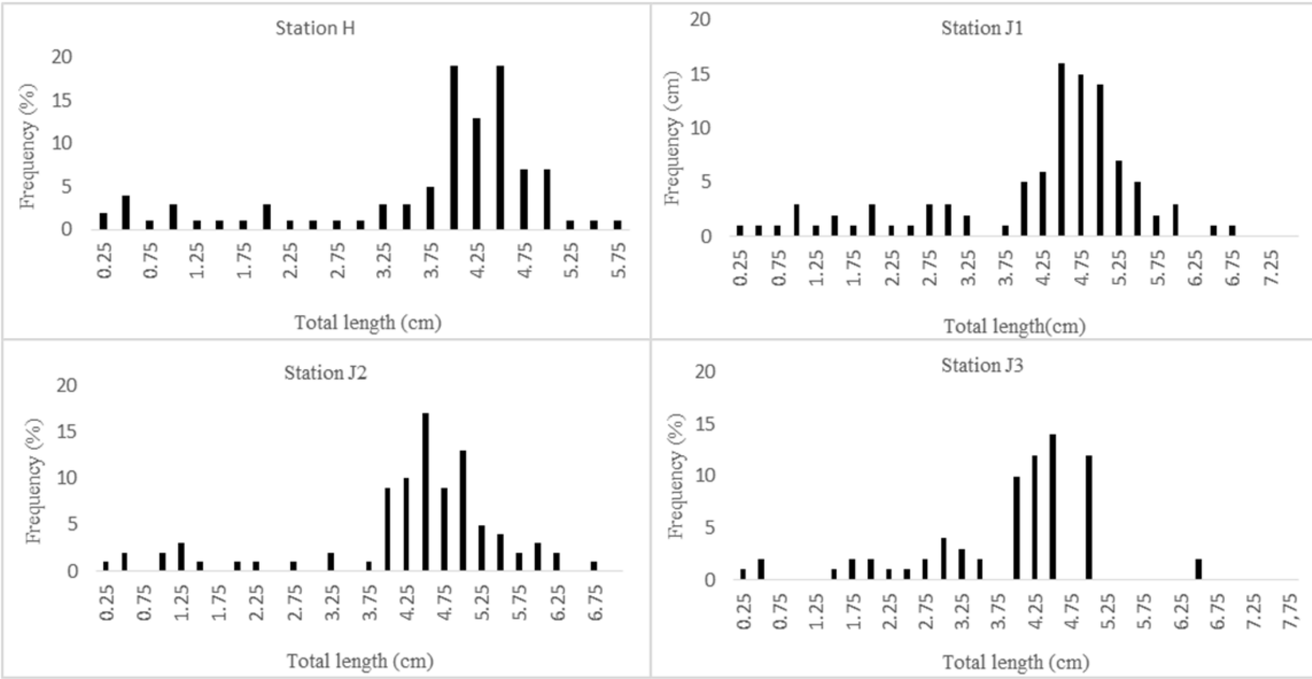

Figure 3. *Length frequency distribution of Mytilus galloprovincialis in prospected stations (H, J_1, J_2 and J_3) from El Jadida coastline.*

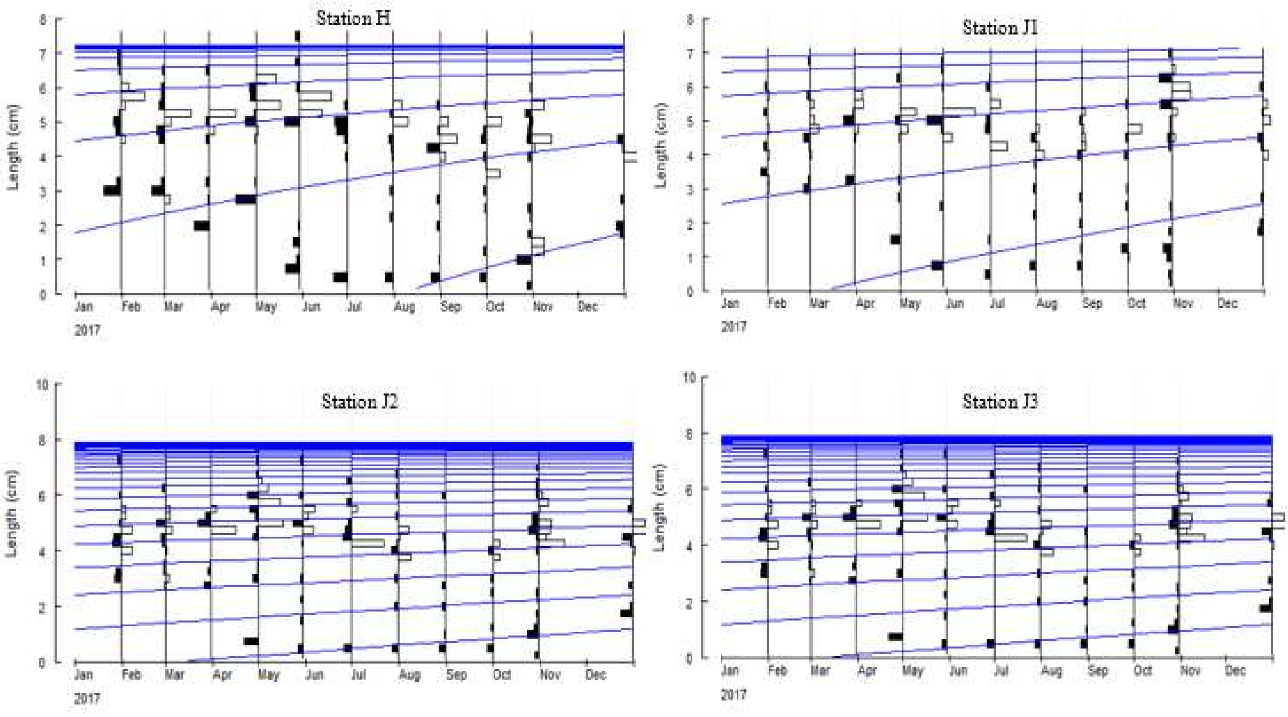

Figure 4. *Growth curves according to non-seasonal Von Bertalanffy model of Mytilus galloprovincialis in prospected stations (H, J_1, J_2 and J_3) from El Jadida coastline.+*

The total length spectrum of station H mussels (Haouzia site) is between 0.25 and 5.75 cm, with a maximum frequency of 19 % for lengths between 4 and 4.5 cm. For Jorf-Lasfer site, the length spectrum is between 0.25 and 7.25 cm in J_1, between 0.25 and 6.75 cm in J_2 and between 0.25 and 7.75 in J_3. The highest frequencies are recorded for the length 4.5 cm in the three stations; with a maximum frequency of 16 % in J_1, 16.9 % in J_2 and 15% in J_3 (Figure 3).

3.3. Estimated Growth Parameters (L∞, K, ǿ)

Growth parameters of the Mediterranean mussel are obtained from figures 4 and 5. The lowest L∞ is estimated for station H mussels with 7.2 cm. The maximum value is 7.9 cm for J_2 and J_3 mussels and 7.5 cm for those of J_1.

Growth constant (K) indicate a maximum value at station H is about 0.24 / year. The minimum value is 0.2 / year for J_2 and J_3 mussels. For those of J_1, K is 0.22 / year.

The growth performance index (ǿ) is relatively low at the four study stations. The maximum value is 1,096 for J_2 and J_3 mussels. The minimum value is 1,093 for those of J_1. Station H mussels have a ǿ of 1.095.

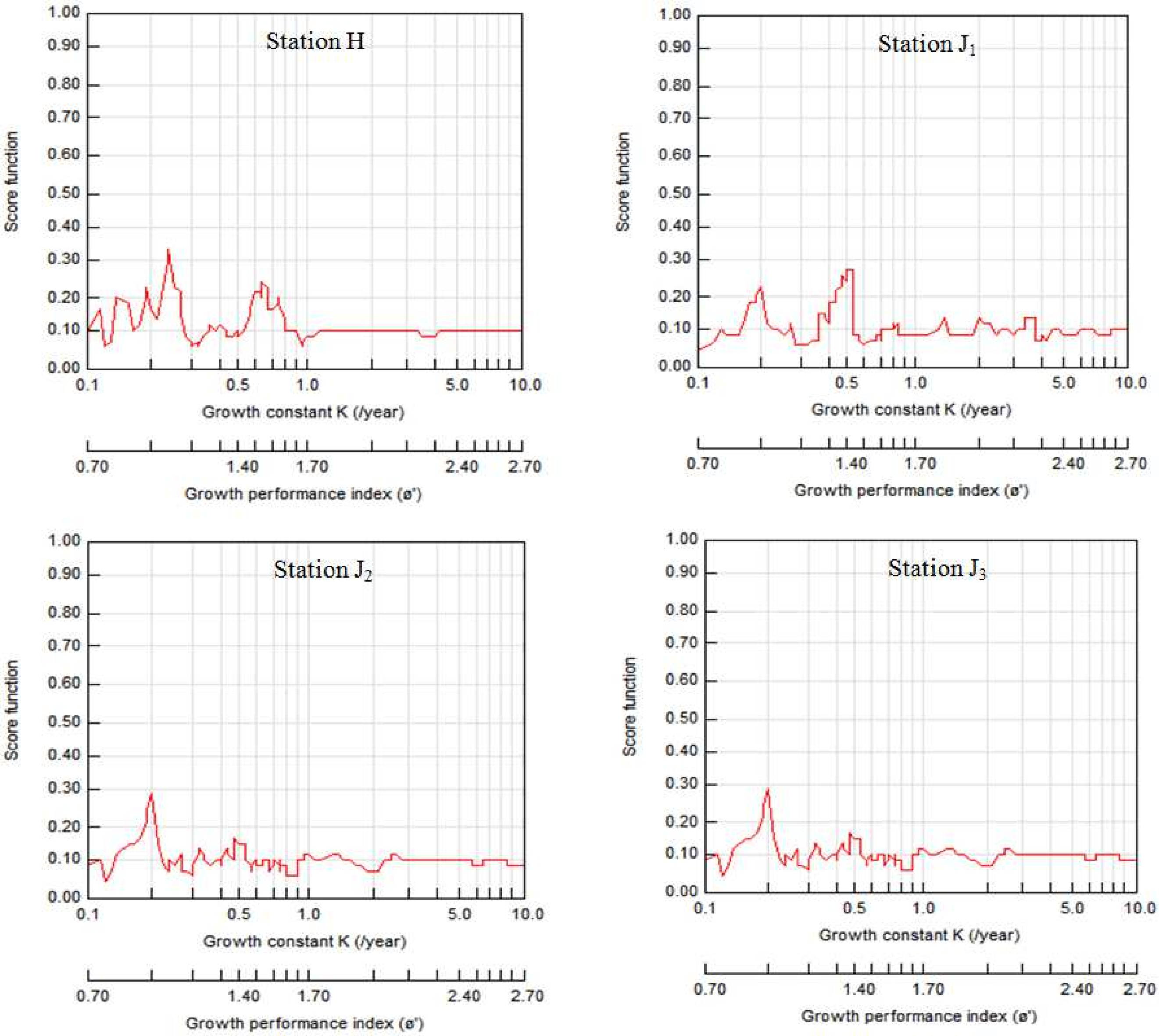

Figure 5. *Growth constant (K) and growth performance index (ǿ) of Mytilus galloprovincialis in prospected stations (H, J_1, J_2 and J_3) from El Jadida coastline.*

Hypothetical age (t_0) estimation shows a similarity for mussels in all stations. Values are as follow: 0.054 years; 0.055 years; 0.056 and 0.056 years respectively for H, J_1, J_2 and J_3 mussels. The relative total lengths reached at different ages by *M. galloprovincialis* in the four study stations are shown in figure 6.

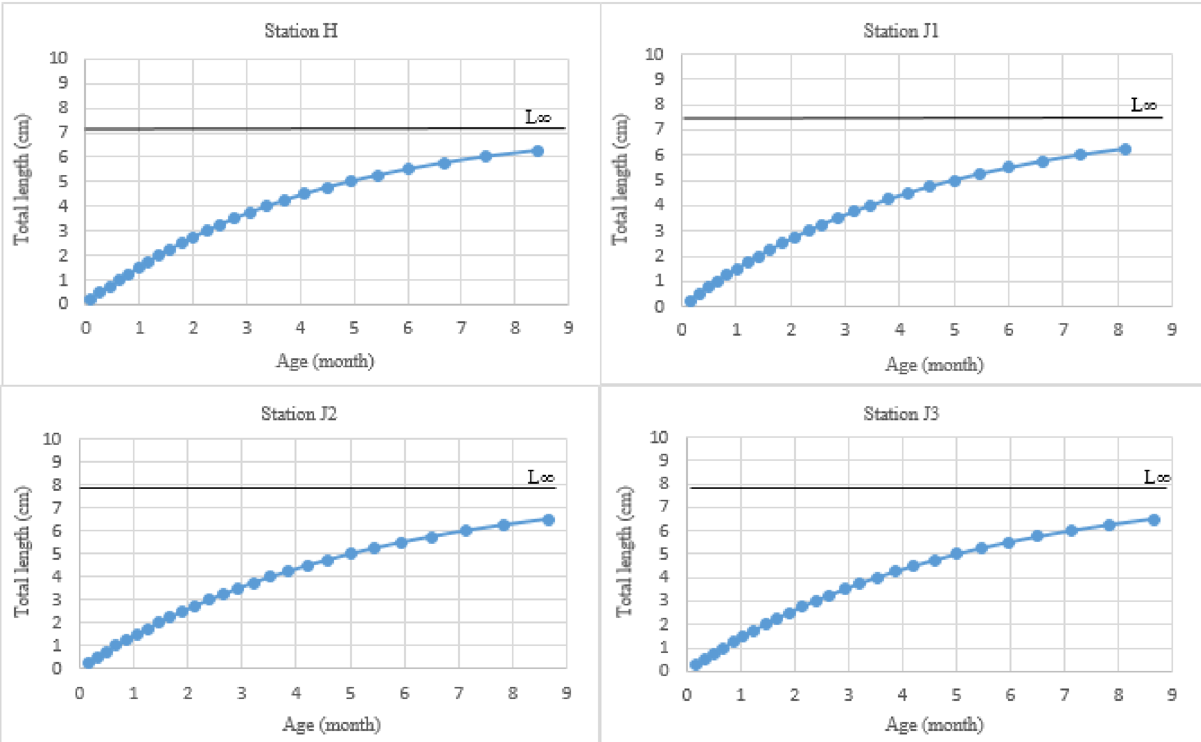

Figure 6. *Hypothetical growth of Mytilus galloprovincialis in prospected stations (H, J_1, J_2 and J_3) from El Jadida coastline.*

Hypothetical age of station H mussels with a total length of 3 cm is 2.2 months, while it is 2.3 months for J_1 mussels and 2.4 months for J_2 and J_3 mussels. Station H animals reach a total length of 6 cm at hypothetical age of 7.46 months, while those of J_1 reach it at 7.3 months and at 7.13 months for J_2 and J_3.

3.4. Length-Weight Relationship

The results of length-weight relationship of *M. galloprovincialis* from the four study stations are shown in figure 7.

The coefficient of determination (R2) values is greater than 0.96 for all stations, indicating a good fitness. The regression slope (b) is 2.68; 2.95; 2.91 and 2.93 respectively for H, J_1, J_2 and J_3 stations. The statistical analysis shows no significant difference between stations (close to 3); the relationship is isometric.

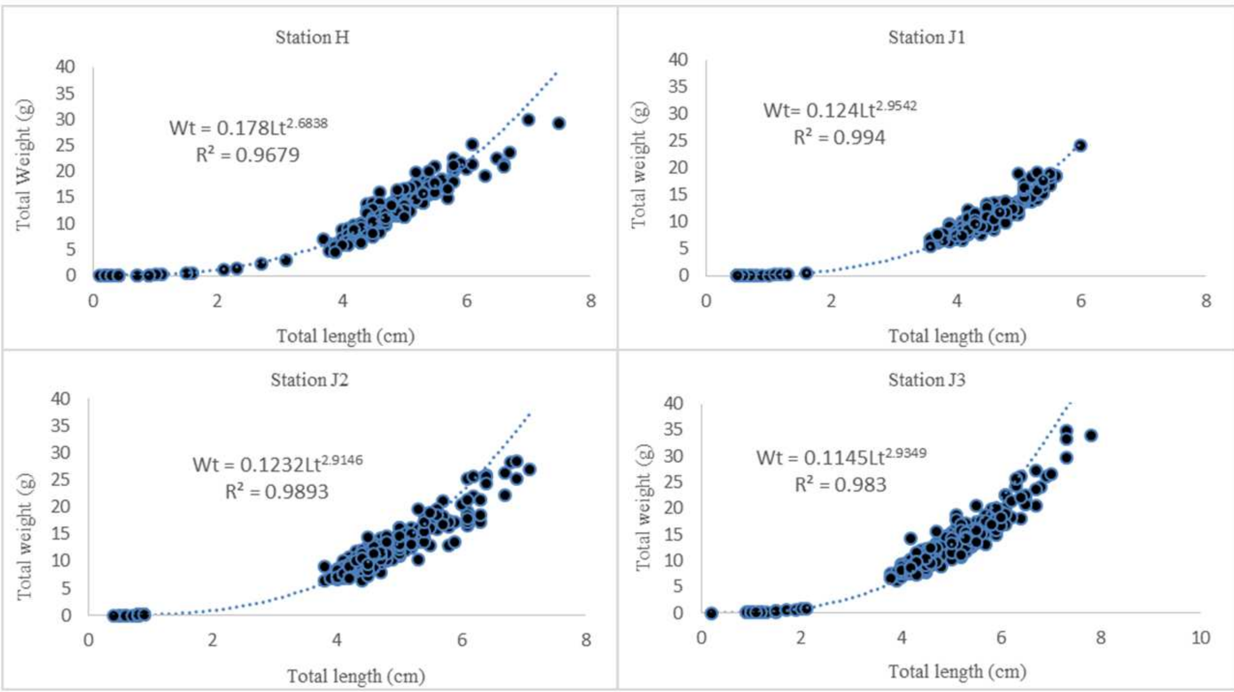

Figure 7. *Length-weight relationship with regression equation of Mytilus galloprovincialis in prospected stations (H, J_1, J_2 and J_3) from El Jadida coastline.*

4. Discussion

The estimate based on non-seasonal Von Bertalanffy equation (VBGF) of *Mytilus galloprovincialis* from a polluted natural environment allow to highlight a difference in growth patterns in Jorf Lasfar site mussels (J_1, J_2 and J_3 stations) compared to those of Haouzia site (station H). L∞ is higher (> 7.4 cm) and the growth coefficient (K) is lower (<0.22 / year). However, the performance index (ǿ) and the hypothetical age of the animals remain substantially identical in both sites. These estimates align with changes in the physicochemical parameters of the environment, including those of temperature and salinity. Jorf Lasfar site houses phosphate-processing plants in addition to the surrounding industries (industrial waste) and Haouzia site receives mixed discharges with urban dominance. High metal bioaccumulation has already been reported in *M. galloprovincialis* from the Jorf Lasfar site by our research team [17-18-6].

Bivalves growth is influenced by both environmental factors [19] and breeding periods. The main factors are temperature, sestonic load, organic matter particles, and phytoplankton biomass [20-21], highlighting the dominant influence of the nutrient value of seston on linear growth and tissue production in mussels. Physicochemical measurement (temperature, salinity, pH, dissolved O2) in the water of the four prospected stations shows no abnormality. Samples were taken monthly to make up for seasonal effects and changes in the breeding cycle.

Growth estimation based on length frequency data has been studied previously for fish and invertebrate stocks assessment [19-21]; using the Von Bertalanffy growth function (VBGF). This function has been adapted by several authors [22-23], taking or not into account the seasonal effect on growth and studying population dynamics [24-25]. The absolute growth parameters obtained in the present study are compared with those of the literature. The L∞ and K are respectively 8.1 cm and 0.1 / year for Cap Ghir mussels natural site (Moroccan Atlantic Ocean) [26] and are 9.52 cm and 0.113 / year for Agadir Bay mussels culture site (National Institute for Fisheries Research [27]. The obtained results are in conformity with those of Lake Bizert (Mediterranean Sea) [28], with 7.3 cm and 0.13 / year. The length-weight relationship at the four study stations reveals the same trend of evolution with b close to 3, which is in conformity with similar studies [29], the relationship is isometric.

5. Conclusion

The data obtained emphasized that linear growth estimated by the Von Bertalanffy function (VBGF) seems well adapted to evaluate the effect of pollution in the mussel Mytilus galloprovincialis. In fact, the estimation of absolute and relative growth appears to be substantially identical in the animals of the two sites. However, we put in perspective to superimpose index data (soft tissue) to this study and to integrate other biometric measurements in order to highlight the pollution effect on the Mediterranean mussel growth.

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