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Growth Weight and Reproductive Cycle in the Mussel (Mytilus Galloprovincialis) from Cala Iris Sea of Al Hoceima (Northern Morocco)

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Weight variations of the *Mytilus galloprovincialis*

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ABSTRACT

This work aims to evaluate a link between weight variations of the mediterranean mussel *Mytilus galloprovincialis*, condition index and the environmental parameters. In order to determine the growth parameters (shell length, total weight, fresh and dry shell and mass tissue weight) of the bivalve. Sampling *Mytilus galloprovincialis* were collected from the mussel farm located along the coastline of Al Hoceima (Moroccan mediterranean sea), during the period 2016. The environmental parameters were recorded at the same sampling site. The results show that, the physicochemical parameters affect the growth parameters, condition index and the reproductive cycle of *M. galloprovincialis*. The condition index variation is a function of weight, which is itself a function of the sexual cycle as well as the availability of food. The period of the maximum of gain weight was observed in spring and summer periods, which correspond to the high value of the condition index, and was associated with the gonadal maturation. The lowest values of CI observed in February (8.71) and May (8.63) coincided with the spawning periods. The knowledge of the gonad cycle and physicochemical factors that could affect them may constitute a basic data, necessary to choose mussel farming sites, and for a commercial exploitation of the bivalves in this part of the mediterranean sea.

KEYWORDS *Mytilus galloprovincialis*, Al Hoceima coastline, environmental parameters, growth, reproductive cycle.

INTRODUCTION

Marine organisms, especially molluscs, are a good source of nutrients. The consumption of marine mussels provides an inexpensive source of protein and essential nutrient with high biological value for human consumption. Blue growth is a generally accepted long-term strategy to support sustainable growth in the marine sectors. Farming in open ocean/sea waters has been identified as one potential option to increase seafood production, and it has been a focus of international attention for more than a decade [1, 2].

The Mediterranean Sea is a favorable food source because of the large natural river supply of phosphorus and nitrogen, essential nutrients for marine plants and microalgae [3], which constitutes an important nutritional source for shellfish. Also, the sea is suitable due to the favorable salinity, temperature, large coastal areas, food availability, reproductive potential, and socio-economic conditions for mussel cultivation [4-6, 3].

The common mussel *Mytilus galloprovincialis* has created the interest of many biologists for its economic and malacological importance. In Morocco, this interest is particularly increased as an aquaculture species whose the development of its exploitation in the Moroccan Mediterranean is provided by the Halieutis Plan [7].

The growth of mussels is an important biological factor to consider in any mussel farm. This growth is broadly defined as a change in the individual's body shape and biomass. It is particularly dependent, in mussels, on the environmental conditions in which they lead a sedentary life. Mussels respond to these environmental conditions through both morphological and physiological adaptations. Authors (Okumuş and Stirling [8], García et al. [9]; Kerdoussi et al. [6]) had indicated that mussel growth is a function of a number of environmental factors, mainly temperature, salinity, phytoplankton and local hydrodynamics. En relation to the physiological status of mussels, Bouhaimi et al. [10] indicated that different parameters of growth show variations being closely related with different phases of the reproductive cycle for *Mytilus galloprovincialis*. The weight of mussels undergoes a seasonal cycle characterized by periods of loss and gain of animal weight reflecting the stage of gonad development [11]. Azizi et al. [3] shown that *Mytilus* lost up to 40% of the body weight during the spawning period.

The purpose of this study was to examine the seasonal changes in the weight growth parameters and condition index of *M. galloprovincialis* in relation to the environmental factors in the Al Hoceima coastline (Northern Morocco). The relation between the weight growth and the gonadal development cycle of *M. galloprovincialis* was also studied.

MATERIALS AND METHODS

1. Study area, and sample collection

The Mediterranean mussel *M. galloprovincialis* and seawater were obtained from the mussel farming installed in the coastal areas of Al Hoceima. Waters and mussel samples were collected monthly in 2016, from Junuary to December, from five

sampling sites (A, B, F, J and I) (Fig. 1), to ensure homogeneous distribution of samples. Water was sampled by hand into several bottles according to the analytical specifications and transported at +4°C in a cold box to the laboratory until analysis.

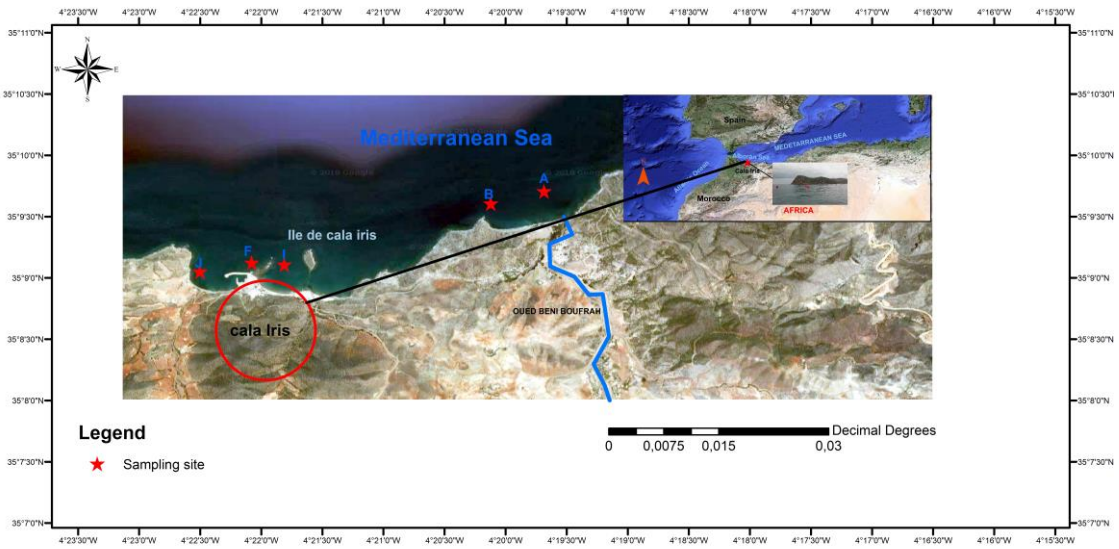


Figure 1: Geographical location of mussel sampling sites along the mussel farming from coastal areas of Al Hoceima (Northern Morocco).

2. Environmental variables

Temperature, salinity, dissolved oxygen and turbidity in sea water were recorded in situ at all sites by means of a multiparameter device (HQd Series portable meters, HACH, Safety Mark), at the same moment that the mussels were sampled. In the laboratory, samples were immediately filtered using Millipore membrane filter paper (Whatman GF/C filters) and chlorphyll *a* were measured by the colorimetric methods according to standard methods recommended for marine waters [12].

3. Growth and condition Index

Fifty-eight samples of bivalves (*M. galloprovincialis*) were collected monthly from five sampling sites (A, B, F, J and I) (Fig. 1), and immediately transported to the laboratory under refrigeration (3 ± 1^0 C) and were brushed, washed and processed on the same day. For each harvested mussel, the morphometric and weight measurements including shell length (SL; mm; anterior-posterior axis), shell height (SH; maximum dorso-ventral axis), shell width (SW; maximum lateral axis), total weight (TW; g; whole body weight) and a weight of the different components (fresh shell weight (FSW; g) and dry shell weight (DSW; g), fresh flesh weight (FFW; g) and dry flesh weight (DFW; g)) were carried out to the nearest 0.1 mm and 0.001 g, using a digital caliper and an analytical balance respectively. The dry shell and flesh weight were obtained by constant heating at 103 °C until a stable weight was reached.

The condition index gives us a clear idea about physiological status of the individuals in a given population [13], and permit estimation of the gonadal tissues lost during the reproductive cycle [14].

The condition index (CI) of mediterrranean mussel was calculated as: the ratio of dry flesh weight (DFW) to total weight (TW) (CI = (DFW/TW) ×100). The condition index allows us to follow the different stages of the *Mytilus galloprovincialis* reproductive cycle [15]. The improvements in accuracy and speed of measurements which are possible with the Cl method permit quite large samples of mussels to be evaluated individually, with a high degree of precision [6].

4. Statistical analysis

All statistical data analysis was done using STATGRAPHICS plus 5. The data were expressed as means and standard deviations, and treated using one-way analysis of variance (ANOVA), followed by Tukey's test, accepting $P < 0.05$ classified as statistically significant.

RESULTS AND DISCUSSION

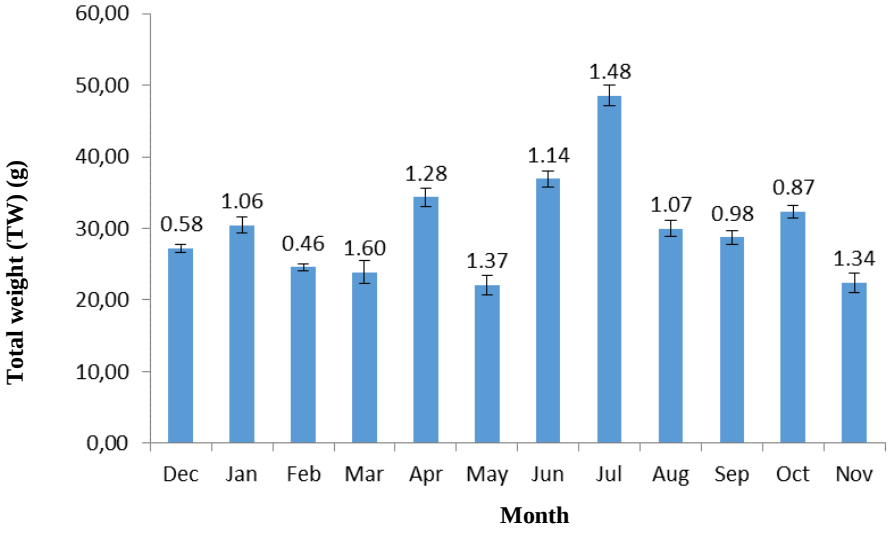
Table 1. Monthly values of the environment parameters of seawater recorded in the Al Hoceima coastline

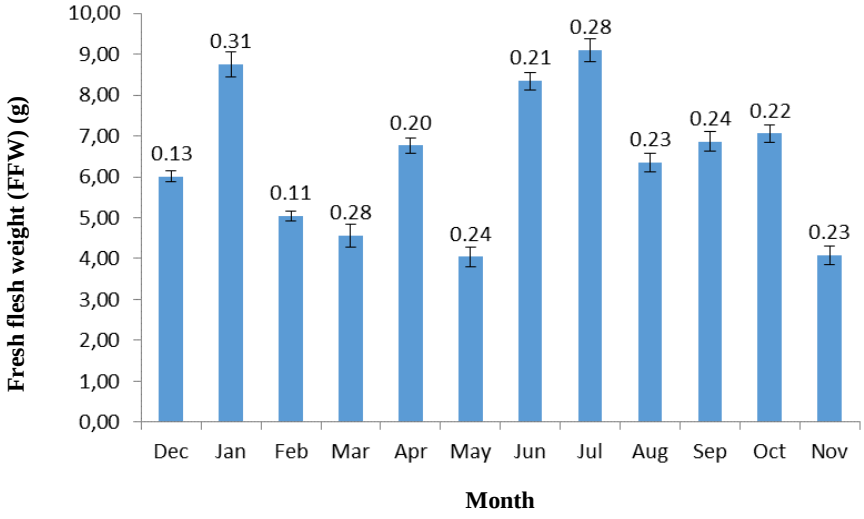
	T (°C)	Sal (psu)	O_2 (mg l-1)	Chl *a* (µg/l)	Turbidity
December	17.46	36.67	9.64	0.5715	0.15
January	17.08	35.62	9.45	0.5340	0.61
February	16.18	36.32	11.88	0.5340	0.93
March	16.55	37.36	11.55	0.5340	0.52
April	17.64	37.60	10.63	0.5340	0.21
May	17.91	37.39	10.12	0.3168	0.74

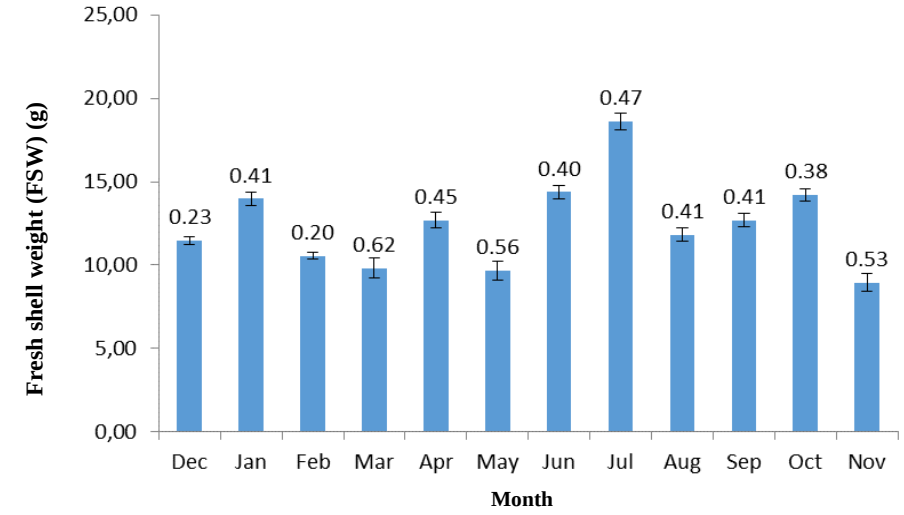
June	19.82	39.41	11.92	0.1335	0.34
July	20.40	40.17	11.20	0.1669	0.46
August	20.67	39.38	11.17	0.2781	0.60
September	20.23	38.32	11.14	1.581	0.25
October	19.79	38.30	10.95	1.054	0.37
November	19.71	38.39	10.73	0.596	0.22

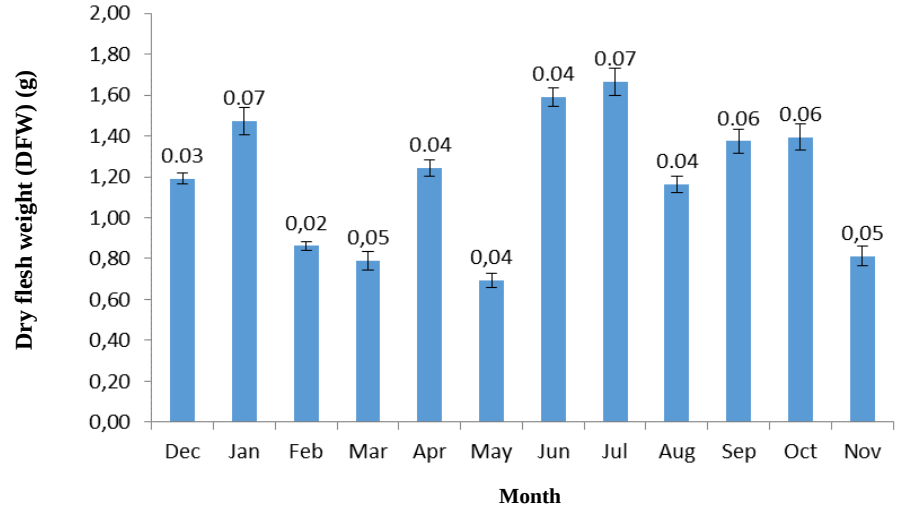
T: temperature; Sal: salinity; O_2: dissolved oxygen; Chl *a*: Chlorophyll *a*.

The temporal variations of the seawater parameters (temperature, salinity, dissolved oxygen, Chlorophyll a, and turbidity) recorded throughout the sampling period are summarized in Table 1. Seawater salinity varied between 35.62 and 40.17 psu, observed in January and July during the experimental period of 2016, respectively. These differences between seasons founded in salinity, revealing the influence of freshwater coming from runoffs [16, 17]. Temperature ranged between 18.16 and 20.67 °C observed in February and August, respectively. The lowest dissolved oxygen was recorded in winter season with a peak in January (9.45 ± 0.338 mg/l), and the highest value was observed in June (11.93 ± 0.217 mg/l). These high values reveal well oxygenated waters in the mussel farming from the Al Hoceima coast regions. Turbidity values were fluctuate between 0.21 and 0.93, recorded in April and February, respectively. Recorded chlorophyll a content shows fluctuations between 0.135 µg/l in June, and 1.58 µg/l in September. Previous investigators (Ceccherelli and Rossi [18]; Lodeiros and Himmelmam [19]; Kerdoussi et al. [6]) have shown that physicochemical parameters and nutritional status, in the coastal marine environnent, can affect growth performance and reproductive cycle of bivalves. The environmental parameters of waters comply with a fundamental role in the reproductive activity and different parameters of growth for mussels. García et al. [9] has indicated that mussel growth is a function of a number of environmental parameters, mainly food and temperature. The environment influences the somatic and reproductive tissue growth of mussels [19, 6].









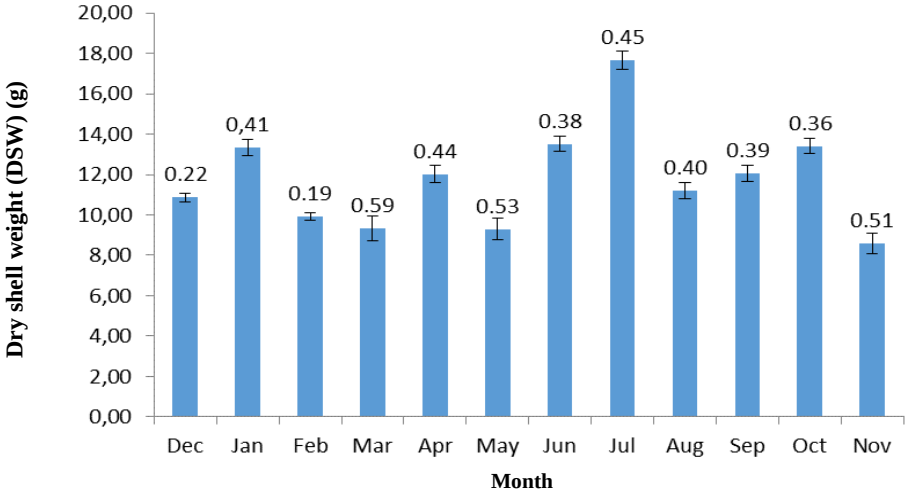


Figure 3: Monthly distribution of different weights (mean ± SD) of the mussel *M. galloprovincialis* (a: total weight (TW); b: fresh flesh weight (FFW); c: fresh shell weight (FSW); d: dry flesh weight (DFW); e: dry shell weight (DSW)) from Al Hoceima Coastal region during the sampling period of 2016.

The total weight of mussel *M. galloprovincialis* oscillates between 22.11 and 48.55 g observed in May and July months respectively (figure 3). The total weight of the Mediterranean mussel *M. galloprovincialis* obtained from the mussel farming installed in the coastal areas of Al Hoceima shows peaks in Abril (34.35 g), June (36.90 g) and July (48.55 g).
The fresh flesh weight of mussels from the mussel farming of Al Hoceima regions shows fluctuation from 4.04 g (May) to 9.10 g (July) (for an average weight of 16.16 g).

Regarding shell weight of *M. galloprovincialis* collected from Al Hoceima coastline, values ranged between 8.96 and 18.60 g observed in November and July, respectively (average weight = 11.98 g) with peaks in June (14.37 g), July (18.60 g) and October (14.22 g).
As regards with the dry flesh weight of mussels from the mussel farming of Al Hoceima coastline, it oscillates between 0.69 and 1.66 g observed in May and July, respectively. The dry flesh weight shows a decresed values in March (0.79 g), May (0.69 g) and November (0.81 g).
The dry shell weight value recorded to the mussels collected from the Al Hoceima coastline are between 8.58 and 17.67 g observed in November and July months, respectively. The values show peaks in June (13.51 g), July (17.67 g) and October (13.40 g).

Reproduction and growth performance of the mediterranean mussel (*Mytilus galloprovincialis*) in the marine area can be affected by many factors, including environmental change, pollution, upwelling, physiochemical, hydrodynamic, food, and physiological status of bivalves. Any factor, exogenous or endogenous, affecting physiological processes may affect growth performance of bivalve. Numerous studies report an influence of physical and chemical factors on the growth of mussels. Among the exogenous factors, the food availability is considered the most important [20]. The endogenous factor as gametogenesis can affect the somatic tissue growth. Authors (Sato [21]; Lodeiros and Himmelman [19]) found that during the gametogenesis, the somatic growth decreases once the energy is allocated to the gonadal production.
Changes in total weight and fresh flesh weight of mussels from the sampling periods were observed between months, with higher values observed in summer. This can be explained that during the reproductive cycle, the weight lost is compensated for bivalves by the intravalvular water for the total weight, and by the occupation of tissues by sexual gametes or reserves and water for fresh flesh weight. Consequently, none of these weight parameters really reflect the state of tissue growth, which heads us to conclude that these weights are not a good predictors of the variations in weight linked to reproduction, as found by Kerdoussi et al. [6]. For the commercial quality, the total biomass produced gives a good information of productivity for mussel farming, but it does not supply a reliable information about the exact proportion of tissue mass relative to the rest of the bivalve.
Many authors (Aloui-Bejaoui et al. [22]) have highlighted the value of studying dry flesh weight when estimating the weight changes of mussels *M. galloprovincialis*, as well as when studying the reproduction period represented by the condition index. The fluctuations of dry flesh weight for mussels collected from the Al Hoceima coastline can depend largely on the degree of the sexual cells maturity, and thus have the advantage of explaining a loss or a gain of weight tissue mass, without taking into account either variations of weight relating to the growth, or the volume of water retained by the bivalve during its sexual cycle. A similar observation was noted by Hickman and Illingworth [23], who indicated that the CI reduction results from an increase in the contents component combined with a decrease in the dry flesh content.

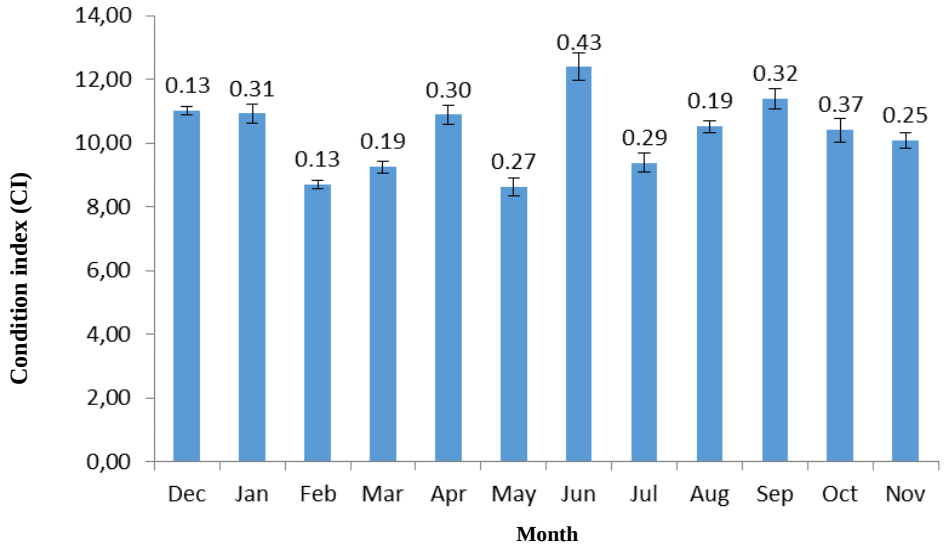


Figure 4: Monthly evolution of the mussel *M. galloprovincialis* condition index (CI) (mean ± SD) collected from the Al Hoceima coastline during the sampling period of 2016.

The condition index (CI) of the mussel *Mytilus galloprovincialis* collected from the sampling sites of Al Hoceima coastline ranged from 8.63 to 12.38 (with a mean of 10.23) observed in May and June months respectively (figure 4). The CI indicate peaks in December (11.02), Jun (12.38) and September (11.38). The CI values coincided with the fatting period, which include the resumption phase of sexual activity (gametogenesis and gonadal maturity). The condition index is frequently used in the literature to describe the reproductive cycle of bivalve molluscs [24]. Several authors agree to interpret as a beginning sexual cells maturation, an increase in the average values of this index and its sudden fall as an emission of gametes [25]. The lowest values of CI were observed in February (8.71), and May (8.63). The lowest levels of CI observed in the *M. galloprovincialis* in these periods coincided with the spawning season. These data are in agreement with Id Halla et al. [26] observation about the spawning season of *Mytilus galloprovincialis* in the Bay of Agadir on the Atlantic coast of Morocco. Therefore, in estimating the mussels' weight-growth, we assumed February and May to be the critical months for mussel-weight decrease due to gamete release.

The condition index reflects the physiological condition of the living organism. The seasonal fluctuation of this condition index can provide an idea about the gonad state and the progress of reproductive cycle of *Mytilus galloprovincialis* and may determine the spawning period. The increased in the condition index coincides with high levels of chlorophyll a and suspended matter, as it indicated in previous works (Villalba [27]; Cuevas et al. [28]). Urrutia et al. [29] showed that in seawater with high nutrient, the excess energy may be shared between the gonad development and somatic tissues growth of the mussel. According to authors (Villalba [27]; Azpeitia et al. [2]) seasonal variations in the condition of *Mytilus galloprovincialis* result from complex interactions between many factors as the nutrition, temperature and salinity, on the metabolic activities of the bivalve, and particularly on the reproduction cycle and growth.

CONCLUSION

The mussel *M. galloprovincialis* has a reproductive cycle that extends throughout the year, with two spawning periods (in the winter and spring seasons). The period of maximum weight gain was observed in summer period for the mussel collected from the Al Hoceima seawater, which coincide with the highest value of the condition index, and was associated with the sexual cells maturity.

Our study suggests that variations in environmental factors in the farming mussels of Al Hoceima coastline have marked effects on growth and gonadal cycle of *M. galloprovincialis*. Furthermore, studies are required to examine the effects of environmental factors on mussel bivalves to further evaluate the aquaculture potential in this region of the Moroccan sea.

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