Egyptian Journal of Aquatic Biology & Fisheries
Zoology Department, Faculty of Science,
Ain Shams University, Cairo, Egypt.
ISSN 1110 – 6131
Vol. 25(4): 823 – 837 (2021)
www.ejabf.journals.ekb.eg

Growth rate, condition index and culture potential of the brown mussel *Perna perna* (Linnaeus, 1758) reared in a submerged longline system in Dakhla Bay, Morocco

Omar Izzabaha[1*], Azedine Dergoun[1], Ayoub Bounacir[1], Abderrahim Gjije[1], Elmustafa Ait Chattou[2] and Mohamed Idhalla[3]

1- Aquaculture station of the National Institute of Fisheries Research, 73000 Dakhla, Morocco;
2- Regional Center of the National Institute of Fisheries Research, 73000 Dakhla, Morocco;
3- Department of Aquaculture, National Institute of Fisheries Research, 20100 Casablanca, Morocco.

[*]Corresponding Author: izzabaha@inrh.ma

ARTICLE INFO

Article History:
Received: June 8, 2021
Accepted: July 27, 2021
Online: Aug. 30, 2021

Keywords:
Dakhla bay,
Mussel farming,
Perna perna,
Submerged longline,
Growth.

ABSTRACT

This study is designed to monitor the zootechnical performance of the African mussel "*Perna perna*" in submerged longline at the Boutalha area in Dakhla Bay, for two production cycles carried out during the years 2019 and 2020. The first rearing cycle started on March the 26th, 2019 with a spat of mean size 19.1±3.23 mm, and a mean weight of 0.79±0.32 g. While the second cycle was launched on January the 6th, 2020 by rearing the spat of mean size 22.31 ± 3.12 mm and mean weight of 2.24±1.52 g. A sampling of mussels was done monthly for the growth monitoring and the daily monitoring of physicochemical parameters of the farming medium. The results showed that the growth rate was almost similar for both rearing cycles, with a gain in length/ weight of about 6.57mm/2.75g and 5.98mm/2.86g, respectively for the first and second cycles. The live weight/growing rates recorded respectively for the first and second cycles, once the commercial size (60mm) was obtained, were 20.01±5.24g/ 19.97% and 22.28±6.65g/16.83% achieving a filling rate of 38.07%/37.94%, thereafter the rearing period was 6.5 months/7 months. Regarding the production and biomass, the results revealed that the biomass per longline exceeded the value of 9.5 tons for both cycles.

INTRODUCTION

Aquaculture has emerged as the fastest growing food production sector in the world for nearly two decades. Currently, it has exceeded even fishing as a source of food for humanity **(FAO, 2020)**. This activity has not yet undergone the same trend in Morocco as it has at the international level. The production in Morocco represents only 0.1% of the national fisheries production **(DPM, 2019)**. Furthermore, despite the fact that shellfish farming has been introduced in Morocco since the 1950s, the development of national marine aquaculture is still at an early stage, with a production that does not exceed 895 tons, with shellfish production representing more than half of the total production **(DPM,**

2019). Due to its geographical position, Morocco has several potential sites for the development of marine aquaculture, whether on the Mediterranean or the Atlantic coast. The Dakhla Bay is one of the areas of the Atlantic coastline chosen for piloting the Moroccan shellfish farming activity. In order to diversify shellfish farming in the Dakhla region, a trial of African mussel, *Perna perna*, farming has been carried out using submerged structures installed at 1.5 miles from the Boutalha foreshore.

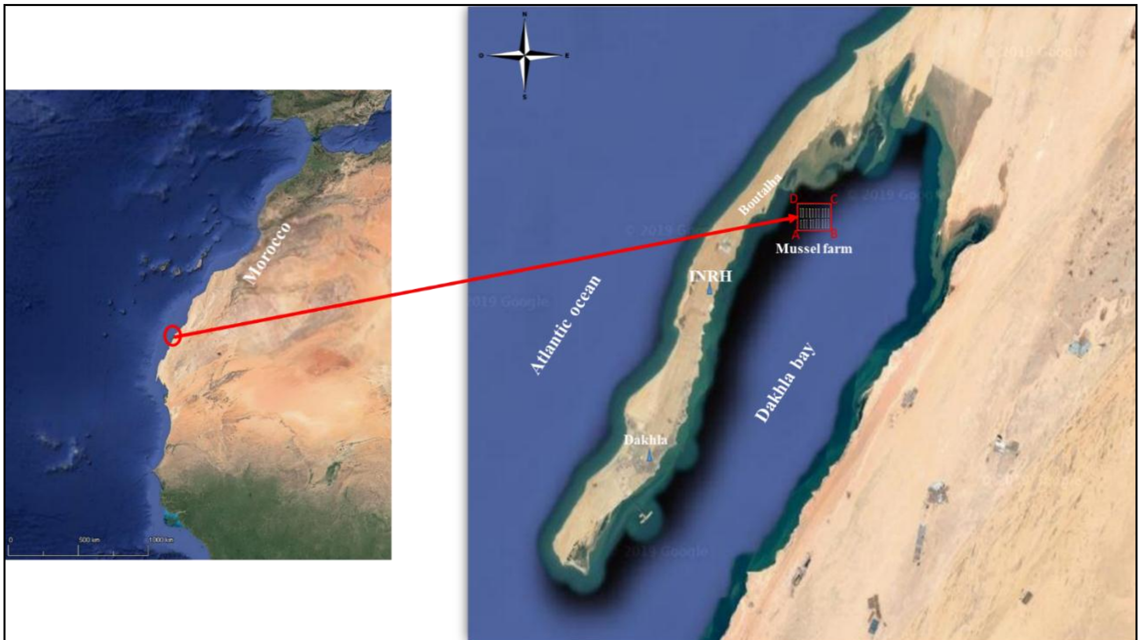
Studies on the growth in natural and farmed mussels have been conducted throughout the world. Those studies have demonstrated that the growth rate depends on several parameters, such as spat age and sources **(Hickman, 1979; Camacho *et al*., 1995)** and the depth and the starting season of breeding **(Eversole *et al*., 2008; Idhalla *et al*., 2018)**. Moreover, parameters included gonadal development **(Thorarinsdóttir, 1996)**, photoperiod and parasitism, dissolved oxygen concentration, nutrient availability expressed by chlorophyll "a **(Rivonker *et al*., 1993; Camacho *et al*., 1995**; **Thorarinsdóttir, 1996)**, water current speed **(Camacho *et al*., 1995)** and density **(Cubillo *et al.*, 2012)**. In Morocco, researches focused on the experimental growth monitoring of *P. perna* and *Mytilus galloprovincialis* mussels on the Atlantic coast **(Shafee, 1992; Idhalla *et al*., 2017; Ait Chattou *et al*., 2018; *Idhalla et al*., 2018)**. According to the previous authors, the growth is mainly affected by temperature, nutrient abundance and gonadal development as well as the interaction between these factors. In M'diq Bay, mussels can reach commercial size after 8 to 9 months of rearing. Moreover, at the PK25 site (North of Agadir), the growth of mussels is fast with respect to weight and length with a market size of 60 mm reached after 7 to 8 months **(Idhalla *et al.*, 2018)**.

This study aimed to emphasize the zootechnical performance of African mussel farming in subsurface systems in Dakhla Bay. In addition, it was conducted to identify the aquaculture potential (growth rate, production ...) of this species in farming. The experiment was carried out during 2019 and 2020 corresponding to the first and the second cycles of farming.

MATERIALS AND METHODS

1. Study area

Boutalha is located in Dakhla Bay along the Moroccan Saharian coastline (23°30'N-16°W), and is considered as one of the most important bays in southern Morocco. It is separated from the Atlantic Ocean by the Oued Eddahab peninsula and has a length of about 37km with a width varying between 10 to 12 km, approximately. Oriented in the NNE-SSW direction, it is connected to the Atlantic Ocean on the South side through a wide channel of about 13 km in width, its area exceeds 400 Km^2 **(Berraho *et al.*, 2019)**. The geographical coordinates of the selected area for the implementation of the mussel farm structures in suspended systems is delimited by the four geographical points A, B, C and D (Fig.1). The farming site chosen for the mussel farm has benefited from several assets which characterize it among the potential sites of the national coastline for the sustainable development of aquaculture **(Izzabaha *et al.*, 2020)**. These include the high primary productivity, the existence of mussel deposits and the sanitary survey.



Position	A	B	C	D
Geographical coordinates	23°49.688' N 15°51.397' W	23°49.559' N 15°51.070' W	23°49.680' N 15°50.952' W	23°49.810' N 15°51.279' W

S

Fig. 1 : Location of the breeding facilities in Dakhla Bay

2. Experimental design

The experimental model is based on subsurface longlines, also known as submerged longlines or sub-floating longlines. This type of system is used to reduce the effects of hydrodynamic forces that may affect the farming structures; decrease marine fouling that accumulates on the longline during farming or optimize the biological processes of the farmed species (collection, growth, survival, etc). The use of surface buoys provides buoyancy support. On the other hand, this structure presents some difficulty in access to the rearing ropes. In order to do this, the mooring line must be moved several meters up to the surface. This manipulation could generate an increase in line strain, anchor pulling and the forces applied to the equipment and the shellfish boat **(Gagnon & Bergeron, 2017)**. The characteristics of the longline used during this study are: Length of the main rope : 100 m; Total number of longline: 20 lines; Number of socks for each line: 140 sock; Distance between the socks: 70 cm; Weight of the block = 2700 kg; Weight of the leg = 1000 kg.

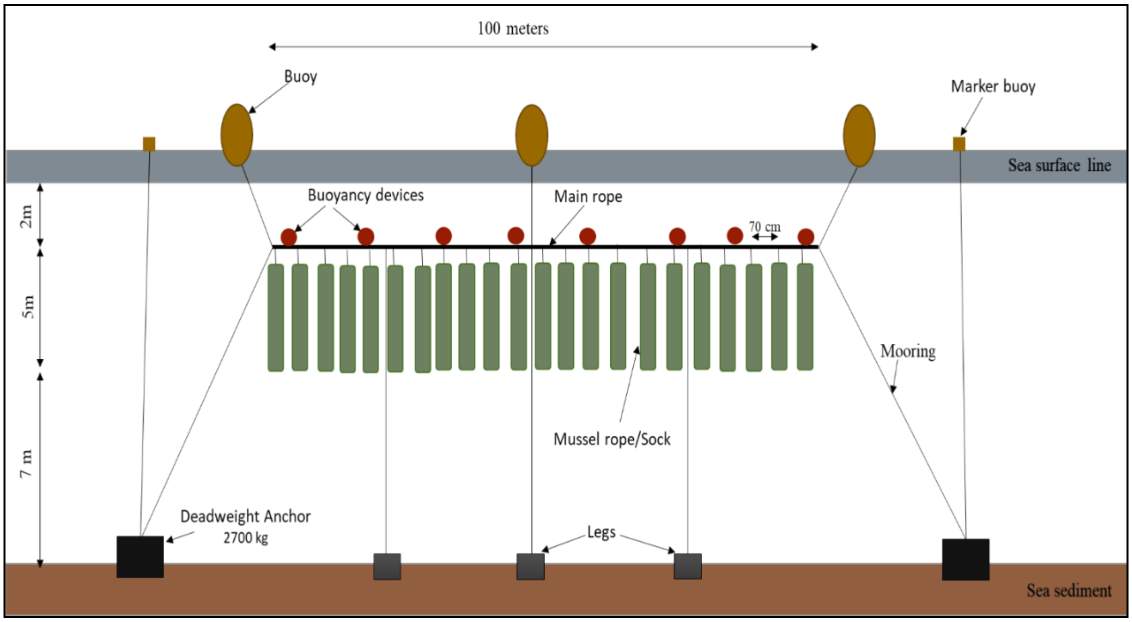


Fig. 2 : Submerged longline design

3. Spat supply

For spat collection, manual harvesting was undertaken using a mallet and a chisel in the natural deposits of Taouarta during 3 days at low tide. The mean size of the spat harvested ranged between 10 and 25 mm. The spat were manually sorted to remove any debris, unwanted shells, algae, and oversized individuals. Then, the socks were prepared on the same day, on a traditional socking table, using a black tubular nylon net. The socks were 6 m in length with a mean weight of about 15 kg/ each. Afterwards, the mussel socks were spirally rolled up on the supporting ropes equipped with wooden cleats. Each supporting rope had a length of 6m and contained 6 cleats of 20 cm, and spaced out by 50 cm. The cleats kept the socks in their cylindrical form. The socks were rolled up individually by the protective net, and then they were installed directly on the longlines.

4. Data collection

For the realization of this study, a monthly random sampling of mussels (20 cm from the sock) was done in order to check the growth progress. In the laboratory, the animals were sorted and cleaned from the epibionts organisms, and then processed by measuring the biometric parameters for monitoring the rearing performance. For each sample, the length and weight parameters of 40 individuals were measured. The linear parameters were measured using a caliper at 1⁄1000 mm of precision, and the mussels were weighed using a 0.001g precision scale.

To evaluate the biometric parameters obtained, a monitoring of the physical-chemical condition of the farming medium was carried out using a multiparameter probe (KOR DSS) in order to provide accurate results for parameters such as temperature, salinity, chlorophyll "a", dissolved oxygen (DO) and turbidity.

The calculation of the condition index (CI) is based on the use of 7 different mathematical relationships **(Davenport & Chen, 1987)**. The CI selected for this study was the following: CI = (Cooked meat weight/total wet weight) x 100

RESULTS

1. Physico-chemical parameters

The physical and chemical parameters of the farming medium are illustrated in Fig. (3). The variation of these parameters always remains in the optimal range for mussel farming activity. The temperature of the waters in the farming area ranged from 17.10°C to 23.64°C (mean T°C = 21.11). The mean annual temperature showed a slight decrease during the first rearing cycle. The lowest and the highest seasonal average values of temperature were recorded in winter and summer, respectively. The variation of salinity was very minor, maintaining values between 36.76 psu as minimum value and 38.92 psu as maximum value, with an average of 37.70 psu. Chlorophyll as an important indicator of primary production, recorded a maximum value of 13.12 µg/l during the month of July 2020, and a minimum value of 2.89 µg/l rated during the month of February 2020, and the mean chlorophyll was around 6.24 µg/l. The other physico-chemical parameters, such as dissolved oxygen, pH and turbidity recorded the mean values of 7.54 mg/l; 8.36 and 5.58 FNU, respectively.

2. Growth in weight and length, and allometric relation

The linear growth curve (Fig. 4) shows a relatively uniform progression of mussel shell length, both for the first production cycle which was started at the end of March 2019, and the second production cycle started at the beginning of January 2020. The commercial size (60 mm) was reached after 6.5 months for the first cycle and after 7 months for the second cycle of rearing, from juveniles of 19.1±3.23mm and 22.31 ± 3.12 mm in average length, respectively. The gain in length was about 6.04 mm per month for the first cycle and 5.50 mm per month for the second cycle.

The mean live weight (Fig. 5) is logically in accordance with the variation in the body size of the reared individuals, in indeed, the final weight at commercial size (60mm) was 20.01±5.24 g and 22.28±6.65 g for the first and second cycle, respectively, given that the initial weight at the beginning of both cycles was Lw_1=0.79±0.32 and Lw_2=2.24±1.52. The weight gain was approximately 4.73 g per month for the first cycle, and 4.17 g per month for the second cycle.

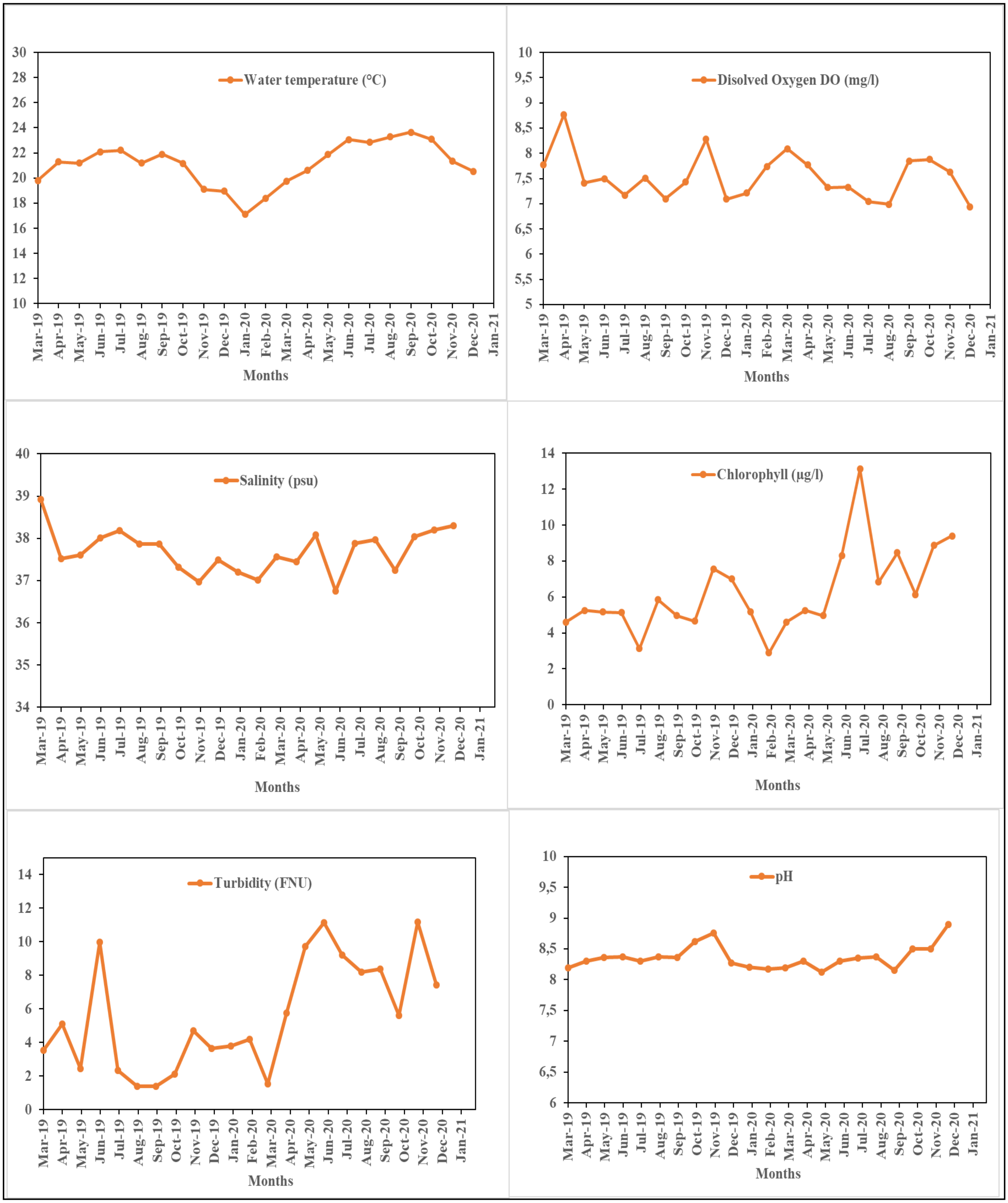


Fig. 3 : Variation in physico-chemical parameters of the farming medium

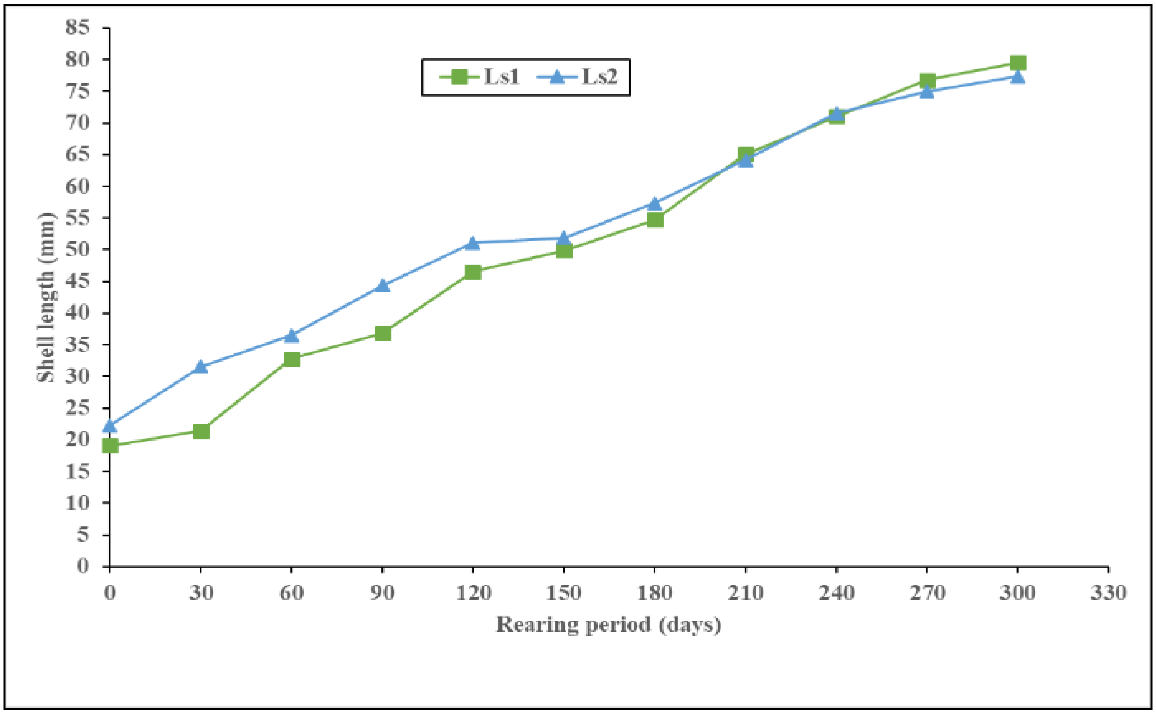


Fig. 4 : Monthly variation of *P.perna* mussel length (Ls1: Mussel length 1st cycle; Ls2: Mussel length 2nd cycle)

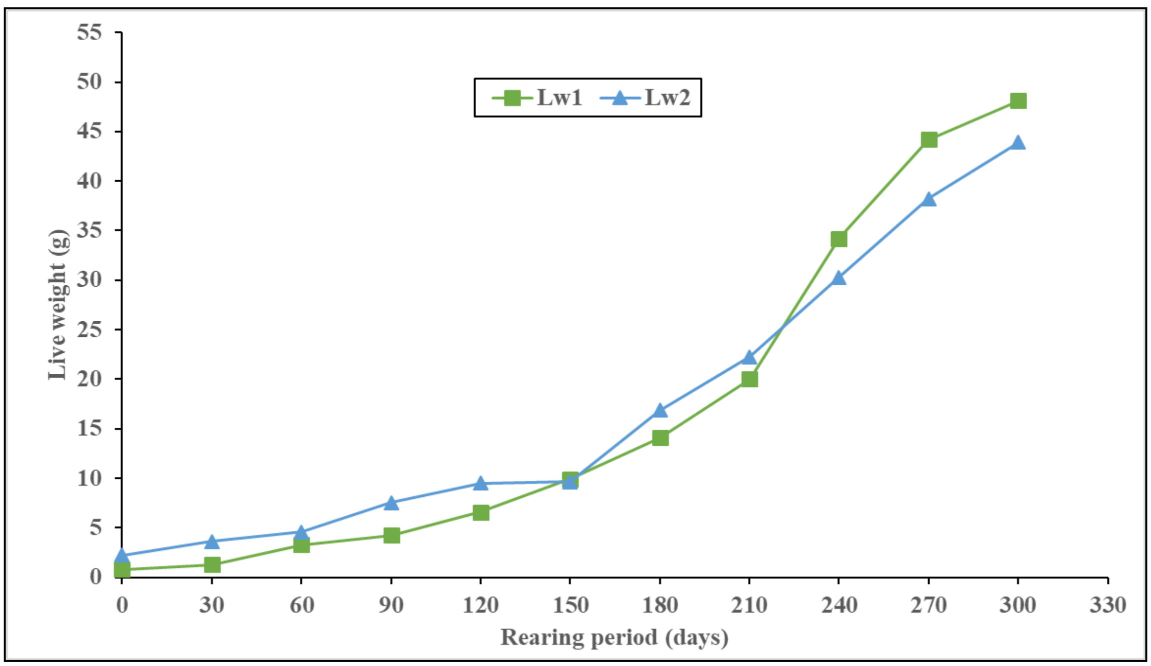


Fig. 5 : Monthly variation of *P.perna* mussel weight (Lw1: live weight 1st cycle; Ls2: live weight 2nd cycle)

The results of the relative growth estimation of *P.perna* mussels by applying the allometric equation, which relates total length to average total weight, are reported in Fig. (6). According to the results recorded, the final equation for the length-weight relationship of the *P.perna* mussel reared using subsurface lines had an allometric coefficient less than 3, which corresponded to a slight minorizing allometry during the study period. This means that the weight of the mussels reared on subsurface lines grew less quickly than their length. From the curve it was observed that, the regression coefficient r^2 obtained was around 1 indicating that the regression equation correctly reflected the relationship between the length and the weight of the individuals.

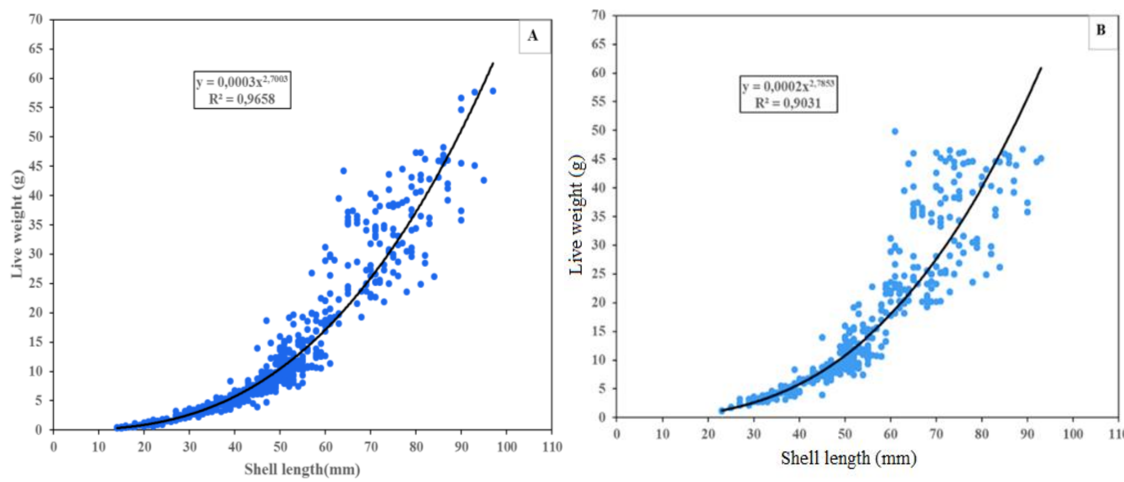


Fig. 6: Length-weight relationship of the farmed mussels (A: 1st cycle; B: 2nd cycle)

3. Sex ratio

Among the mussel *Perna perna* which is a mainly gonochoric species, the distinction of the sexes was relatively easy. Evidently, it is based on the color of the mantle which is whitish in the males and pink-salmon to orange in the females. For this purpose, mussels were cleaned, opened and sexed according to the macroscopic observation of the mantle color. The sex ration was calculated based on the ratio between the number of males to the number of females. The obtained sex ratio for the first cycle was dominated by males for six months out of nine, against two months for females and one month of equality. Likewise, for the second cycle with seven months for males, one month for females and one month of equality (Fig. 7).

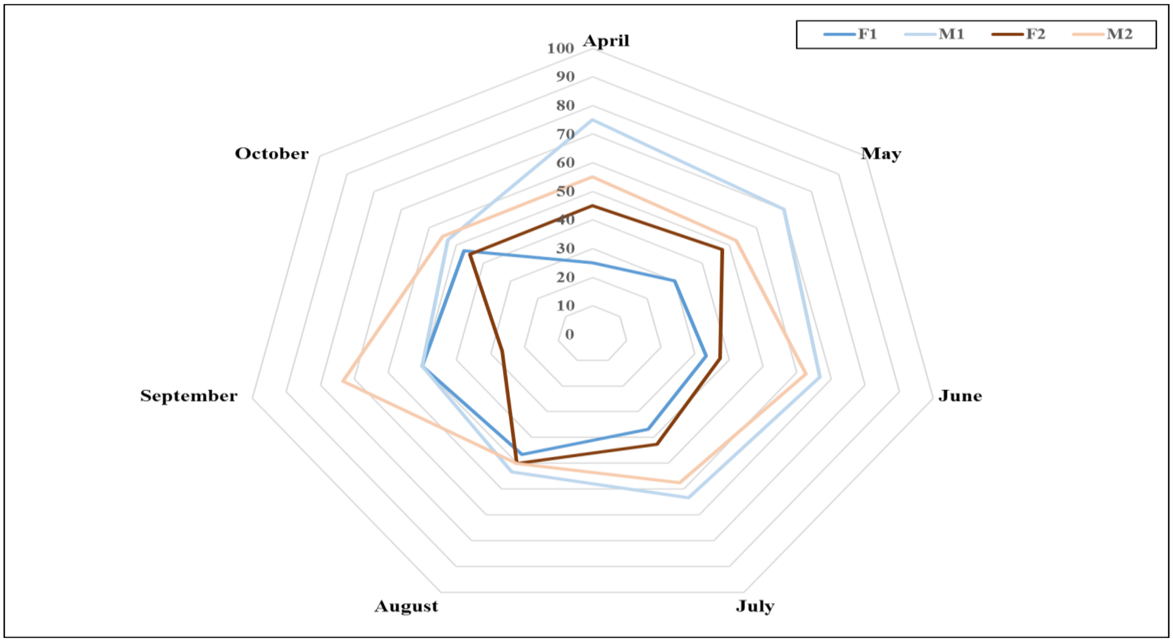


Fig. 7 : Monthly variation of sex ratio

F1, M1 : female, male 1st cycle ; F2, M2 : female, male 2nd cycle.

4. Condition index

During the two rearing cycles of the *P. perna* mussel, the average values recorded of the condition index showed an almost similar progression, except for the month of July when the mussels of the second rearing cycle recorded a maximum spike of 7.85 which means that the mussels were well filled. This is usually attributed to the gonad maturation which directly affects the flesh weight. While, the mussels of the first rearing cycle recorded a minimum spike of 4.92 during the same month of July. The analysis of the two curves (Fig. 8) reveals that a decrease in the CI of the first cycle corresponded to the months of May and September. While, in the mussels of the second cycle it was noticed that, the existence of two marked decreases were in the CI for the two months of May and July.

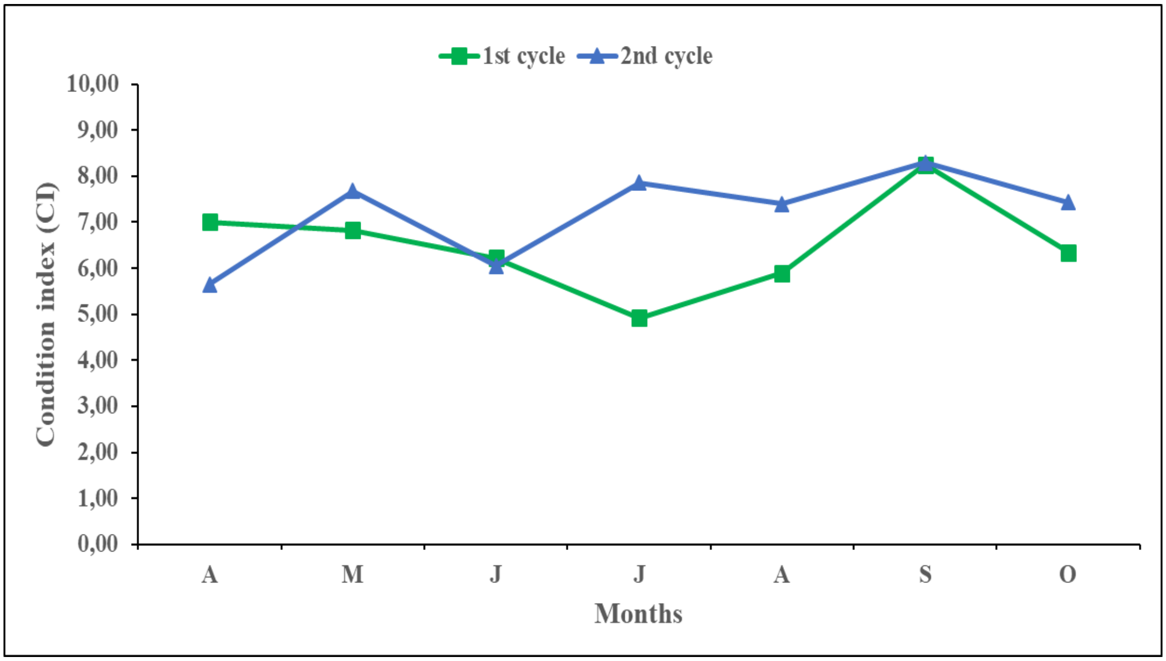


Fig. 8 : Monthly variation of the condition index for the two rearing cycles

5. Production

The biomass per longline exceeded the value of 9.5 tons for both cycles, being only 2.1 tons and 1.4 tons for the first (2019) and second (2020) rearing cycles, respectively. The high production rate at the beginning of the rearing cycle can be attributed to the age and/or size of the mussels (in parallel to the growth rate). Remarkably, organisms possess a natural tendency to have a rapid growth rate during the initial phases of their development **(Marques *et al*., 1998)**. This rate stabilizes around 2-4% from 8 months of rearing. Additionally, during summer the occurrence of an increase of production rate was obvious, and this can be the consequence of the high temperature which directly impacts the chlorophyll concentrations (Fig.9).

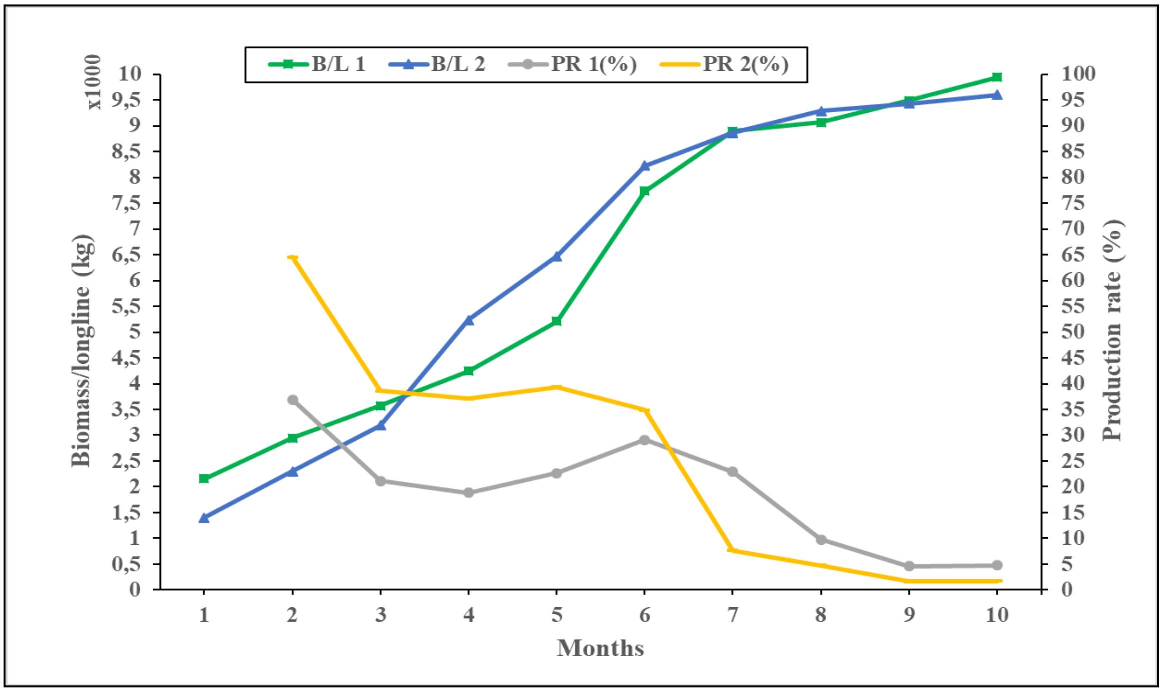


Fig. 9 : Production and biomass progress by longline

B/L1: Biomass per longline related to the first rearing cycle which begun by the end of March 2019;

B/L2: Biomass per longline related to the second rearing cycle which begun in early January 2020;

PR1: Production rate for the first cycle;

PR2: Production rate for the second cycle.

DISCUSSION

According to the results of monitoring the breeding medium parameters throughout the period of this study, it was confirmed that the physico-chemical profile was always kept in the optimum range for mussel growth. The rearing area was proved to be highly potential for aquaculture activity **(Izzabaha *et al*., 2020)**.

Regarding biometry, the results presented in Table (2) reveal that the growth in length and weight was exponentially in the African mussel *P.perna* with the subsurface rearing method established in Boutalha in Dakhla Bay. Notably, a monthly length gain average was scored between the two cycles of about 6.27 mm and a monthly weight gain average of 2.80 g for the two rearing cycles started in 2019 and 2020. The results related to the increase in length permitted the researhers to have an idea on the necessary period for the *P.perna* mussel to reach the commercial size (60mm) and which is between 6,5 to 7 months of rearing.

Several studies have monitored the growth of mussels, especially the *Mytilus galloprovincialis*. These mussels reached the commercial size of 60 mm after 8 months of rearing in the M'diq bay, and after 7 to 8 months in the Agadir bay **(Idhalla *et al*., 2005)**

Successful rearing of any commercially valuable shellfish species depends on the availability of natural spat, the abundance of food, the absence of predators and competitors, and the availability of suitable environmental conditions for rapid growth **(Hickman & Illingworth, 1980 ; Aquini *et al*., 2013 ; Noor *et al*., 2019)**. The monitoring of the physico-chemical parameters of the rearing medium revealed the existence of a very favorable thermal profile for mussel farming activity. Furthermore, Dakhla Bay is characterized with the phenomenon of upwelling which contributes to the waters- enrichment, and consequently, the increase of chlorophyll concentrations as a basic source of food for the shellfish becomes attainable.

For the condition index, which is the most used indicator for monitoring the physiological and health status of organisms **(Bodoy & Masse, 1978)**, it showed one decline during the month of May 2019 and two declines during the months of May 2020 and July 2020. This can be attributed to the reproduction period **(Bodoy & Masse, 1978)**, and also to the stress caused by the breeding manipulation **(Pellerin-Massicotte, 1994)**.

Table 1: Zootechnical assessment at commercial size (60 mm).

Parameters	**Unit**	**1st Cycle**	**2nd Cycle**
Starting date	-	26/03/2019	06/01/2020
Initial length	mm	19.1±3,23	22.31 ± 3.12
Initial weight	g	0.79±0.32	2.24±1.52
Final weight	g	20.01±5.24	22.28±6.65
Monthly length gain	mm	6.57	5.98
Monthly weight gain	g	2.75	2.86
Rearing period	Months	6.5	7
Length growth rate	%	19.97	16.83
Allometric relationship R^2	-	$Y = 0.0003X^{2.7003}$ $R^2 = 0.9658$	$Y = 0.0002X^{2.7853}$ $R^2 = 0.9031$
Mussel filling rate	%	38.07	37.94

CONCLUSION

Based on the obtained results of this study, it is clear that the mussel farming activity can contribute to the development of the aquaculture sector in the region of Dakhla Ouededdahab for the period of rearing which is very short, and for the existence of several sites that can house this kind of activity. The challenge is the spat supply which currently focuses on the harvest from natural deposits, which in return, leads to an overexploitation of natural resources. In this context, it is essential to think about an alternative way of supplying spat, whether through hatchery production or by installing collection facilities around the mussel farms.

REFERENCES

Ait Chattou, E. M.; Abounahel, N.; Kassila, J.; Ouagajjou, Y.; Abouhala, A.; Idhalla, M. and Moukrim, A. (2018). Differential growth of the brown mussel, *Perna perna* (Linnaeus, 1758), in longline and pole cultures in Dakhla Bay (SW Morocco, Atlantic Ocean). *Aquaculture Research*, 00:1-12. http://doi.org/ 10.1111/are.13927

Aquini, E. do N.; Ferreira, J. F. and Magalhães, A. R. M. (2013). Influence of Seed Source on Growth, Sexual Cycle and Mortality of the Brown Mussel, *Perna perna* , in a Culture System: Influence of seed source on growth of mussel perna perna. *Journal of the World Aquaculture Society*, *44*(2), 300–304. https://doi.org/10.1111/jwas.12030

Berraho, A.; Abdelouahab, H.; Larissi, J.; Baibai, T.; Charib, S.; Idrissi, M.; Belbchir, Y.; Ettahiri, O. and Hilmi, K. (2019). Biodiversity and spatio-temporal variability of copepods community in Dakhla Bay (southern Moroccan coast). *Regional Studies in Marine Science*, *28*, 100437. https://doi.org/ 10.1016/j.rsma.2018.10.005

Bodoy, A. and Masse, H. (1978). Quelques parametres permettant de suivre la production organique d'un mollusque bivalve au cours d'un cycle saisonnier. Station marine d'Endoume, colloque national ECOTRON, pp. 753–766.

Camacho, A. P.; Labarta, U. and Beiras, R. (1995). Growth of mussels (*Mytilus edulis galloprovincialis*) on cultivation rafts: Influence of seed source, cultivation site and phytoplankton availability. *Aquaculture*, 138(1–4), 349–362. https://doi.org/10.1016/0044-8486(95)01139-0

Cubillo, A. M.; Peteiro, L. G.; Fernández-Reiriz, M. J. and Labarta, U. (2012). Influence of stocking density on growth of mussels (Mytilus galloprovincialis) in suspended culture. *Aquaculture*, *342–343*, 103–111. https://doi.org/10.1016 /j.aquaculture.2012.02.017

Davenport, J. and Chen, X. (1987). A comparison of methods for the assessment of condition in the mussel (*Mytilus edulis L.*). *Journal of Molluscan Studies*, *53*(3), 293–297. https://doi.org/10.1093/mollus/53.3.293

Eversole, A. G.; Stuart, K. R. and Brune, D. E. (2008). Effect of temperature and phytoplankton concentration of Partitioned Aquaculture System water on freshwater mussel filtration. *Aquaculture Research*, *39*(16), 1691–1696. https://doi.org/10.1111/j.1365-2109.2008.02043.x

FAO. (2020). The State of World Fisheries and Aquaculture 2020. FAO.

Gagnon, M. and Bergeron, P. (2017). Observations of the loading and motion of a submerged mussel longline at an open ocean site. *Aquacultural Engineering*, *78*, 114–129. https://doi.org/10.1016/j.aquaeng.2017.05.004

Hickman, R. W. (1979). AIIometry and Growth of the Green-Lipped Mussel Pema canaliculus in New Zealand. *Marine biology*, 51, 311-327.

Hickman, R. W. and Illingworth, J. (1980). Condition cycle of the green-lipped mussel Perna canaliculus in New Zealand. *Marine Biology*, *60*(1), 27–38. https://doi.org/10.1007/BF00395603

Idhalla, M.; Kassila, J.; Chattou, E. M. A.; Ouaggajou, Y.; El Aamri, F.; Benbani, A. and Nhhala, H. (2018). Depth and Seasonal Effects on the Settlement Density of Two Mussel Species (*Perna Perna* and *Mytilus Galloprovincialis*) in Offshore, Agadir (Morocco). *European Scientific Journal*, *ESJ*, *14*(12), 229-240. https://doi.org/10.19044/esj.2018.v14n12p229

Idhalla, M.; Nhhala, H.; Kassila, J. and Chattou, E. M. A. (2017). Comparative production of two mussel species (*Perna perna* and *Mytilus galloprovincialis*) reared on an offshore submerged longline system in Agadir, Morocco. *International Journal of Scientific & Engineering Research 8*(6), 1203-1213.

Idhalla, M.; Orbi, A. and Moukrim, A. (2005). Croissance des deux moules *Perna perna* et *Mytilus galloprovincialis* en élevage sur filiéres sub-flottantes en mer ouverte dans la baie d'Agadir (Maroc). *Société francaise de la malacologie*, 34:49-64.

Izzabaha, O.; Gjije, A.; Dergoun, A.; Saad, Z.; Chattou, E. M. A.; Chairi, H. and Idhalla, M. (2020). First trial on rearing European sea bass Dicentrarchus labrax in floating cages in Dakhla bay- SW Morocco, Atlantic Ocean. *AACL Bioflux*, 13(3):1557-1569.

Département de la Pêche Maritime. (2019). La mer en chiffres, Maroc.

Noor, N. M.; Nursyam, H.; Widodo, M. S. and Risjani, Y. (2019). Biological aspects of green mussels *Perna viridis* cultivated on raft culture in Pasaran coastal waters, Indonesia. *AACL Bioflux*, 12(2):448-*456.*

Pellerin-Massicotte, J. (1994). Oxidative processes as indicators of chemical stress in marine bivalves. *Journal of aquatic ecosystem health*, 3(2), 101–111. https://doi.org/10.1007/BF00042940

Rivonker, C. U.; Ansari, Z. A. and Parulekar, A. H. (1993). Cultivation of green mussel, *Perna viridis* L., on a floating raft in an estuary along the west coast of India. *Aquaculture*, 112:47-56.

Shafee, M. S. (1992). Production estimate of a mussel population *Perna picta* (Born) on the Atlantic coast of Morocco. *Journal of Experimental Marine Biology and Ecology*, *163*(2), 183–197. https://doi.org/10.1016/0022-0981(92)90048-F

Thorarinsdóttir, G. G. (1996). Gonad development, larval settlement and growth of Mytilus edulis L. in a suspended population in Hvalfjördur, south-west Iceland. *Aquaculture Research*, *27*(1), 57–65. https://doi.org/10.1111/j.1365-2109.1996.tb00966.x