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Growth Performance Assessment of the Gilthead Sea Bream Fingerlings (*Sparus aurata*, Linnaeus, 1758) in Fish Cage Practice in Dakhla Bay (Morocco)

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ABSTRACT

The aim of the present investigation is to assess the growth performance of gilthead seabream fingerlings (*Sparus aurata*) farmed in marine cages at Boutalha site in Dakhla Bay in Morocco for a period of fifteen months (March 2018 - July 2019). Fingerlings were imported from a European hatchery (50.000 individuals), with an average initial weight of 3.68 ± 0.16g and an average initial length of 6.23 ± 0.53cm. Specimens were placed in fish nurseries and treatments were duplicated in two batches, with 25.000 individuals/ batch. The physicochemical parameters, recorded during the study period, were within the optimal ranges for obtaining the appropriate growth and the survival of gilthead sea bream. In terms of growth performance, average weight (AW), daily growth rate (DGR), and the specific growth rate (SGR) were estimated to fall within the range of 512 ± 19.71g, 1.13 ± 0.08 g/day, and 1.09 ± 0.12 %/day, respectively for the first batch, and 520.29 ± 22.40g, 1.15 ± 0.06 g/day and 1.10 ± 0.15 %/day for the second batch. The relationship between the total body weight (TBW) of gilthead sea bream and total body length (TBL) could be expressed as: $TBW_1 = 0.039\ TBL^{2.892}$ (n =315, R^2 = 0.91) for batch 1 and $TBW_2 = 0.0035\ TBL^{2.935}$ (n =318, R^2 = 0.90) for batch 2. The final equation of the length-weight relationship of the two gilthead sea bream batches has an allometry coefficient close to 3, which represents isometric growth. Concurrently, the recorded final biomass values, as well as the feed conversion rate, amounted to 11.58 T and 1.18 ± 0.31, respectively for batch 1 and 11.65 T and 1.19 ± 0.34 for batch 2. These trials also demonstrate, for the first time, that the growth of gilthead sea bream is technically feasible, and indicates a potential for improvement through the implementation of a model project which is technically feasible at Dakhla bay.

INTRODUCTION

Worldwide, aquaculture is still widely viewed as a forward-looking sector and it represents one of the strongest growth food resource sectors. According to the Food and Agriculture Organization of the United Nations (FAO), more than half of the fish marketed throughout the world comes from aquaculture, and this share is expected to reach 75% by 2030 **(FAO, 2018).** Remarkably, global production of marine aquaculture amounted to 30.76 million tons in 2018, of which the share of marine fish farming was 7.33 million tons **(FAO, 2018)**. In Morocco, the marine aquaculture sector is still far from being sufficiently developed despite the significant existing potential of the region as the production estimates reaches a value of 380,000 tons **(ANDA, 2017).** It is required to ensure that all the opportunities offered to develop this activity are fully exploited **(ANDA & DEPF, 2018).** Notably, the marine aquaculture products accounts for less than one per mil of the total fish production **(FENIP, 2010)**. Marine aquaculture production reached 812 tons only for the year 2020, mostly composed of table oyster production of two sites; Oualidia and Dakhla **(DPM, 2020)**. Currently, only a single fish species represents the total output of the Moroccan fish farming **(DPM, 2020).** The European sea bass (*Dicentrarchus labrax*) is reared in floating cages in M'diq Bay, the fish is also produced at an experimental stage in the Dakhla Bay **(Izzabaha *et al*, 2020)**. It accounts for 26% of marine aquaculture production in Morocco, with an estimated production of 205 tons in 2020 **(DPM, 2020)**. Nevertheless, Morocco intends to increase and diversify its fish farming, the current trend is directed towards fish cage breeding to farm new fish species, such as meager (*Argyrosomus regius*), turbot (*Psetta maxima*) and gilthead sea bream (*Sparus aurata*) **(ANDA, 2017)**.

The gilthead sea bream is a marine fish with a high added commercial value. The fish should also be of aquaculture interest and is produced mainly in the Mediterranean Sea. World production of sea bream has been growing almost continuously since the 1980s. In 2016, the global production of gilthead sea bream reached 186,000 tons **(FAO, 2017)**. Nowadays, this species is viewed as an interesting capital asset for boosting the development of the Moroccan marine fish farming potential **(ANDA, 2017)**.

Since the year 2000, Dakhla Bay in Morocco has been identified as a potential area for the development of marine fish farming **(Saad *et al*., 2013; Hilmi *et al*., 2017; Berrahou *et al*., 2019; Izzabaha *et al*., 2020).** In this context, and given the hydrodynamic and bathymetric specificities of the Dakhla Bay and in affirmation of the state's vision to aggressively support and upgrade fish farming in Dakhla region, the National Institute of Fisheries Research (INRH) has built an experimental fish farm in the Dakhla Bay for conducting trials on the rearing of fish stocks with a proven economic interest in cage fish farming for the first time on the Atlantic coast of the Morocco kingdom.

The current study is part of an overall research program carried out by the aquaculture station (INRH), a unit falling within the scope of the Dakhla Regional Centre of the National Institute of Fisheries Research. It aimed at contributing to the introduction and rapid growth in the farming of fish species, notably gilthead sea bream in Dakhla Bay. In addition, the study was conducted to provide informative data about the zootechnical and economic performances of gilthead sea bream reared in Dakhla Bay **(DPM, 2019)** to assist the public authorities and the private investors in boosting fish farm activities in the Dakhla Oued-Eddahab region.

MATERIALS AND METHODS

1. Study area

This study was conducted in the Boutalha site in Dakhla Bay on the southern edge of the Atlantic coast of Morocco, along a NE-SW axis between 23°35’N and 23°55’N (Fig. 1). It spreads over a length of 37 km and a width varying between 11 and 12 km. Its farm footprint exceeds 400 sq km **(Hilmi *et al*., 2017)**. The rationale for choosing Dakhla for this project was based on the following criteria (Tab. 1): The location is well-protected from bad weather conditions **(Izzabaha *et al*., 2020).** It has a Saharan temperate; semi-arid climate, influenced by the Canaries cold current, whose average temperatures remain around 20°C **(ANDA, 2015)**. The recorded seawater temperature of the studt site is favourable for fish growth, with relatively slight fluctuations throughout the year **(Hilmi *et al*., 2017; Izzabaha *et al*., 2020)**. Hence, the area is particularly marked by a low bathymetry, varying between 0 and 20 m and is exposed to intense winds, especially at the entrance of the Bay and the surrounding areas, with values between 1 and 2 m/s **(Hilmi *et al*., 2017)**. It should be noted that the average depth of the selected site is sufficient enough for easy installation of rearing structures, in addition to the low turbidity of water and the average content of dissolved oxygen (D.O) which are within the standards required for fish farming.

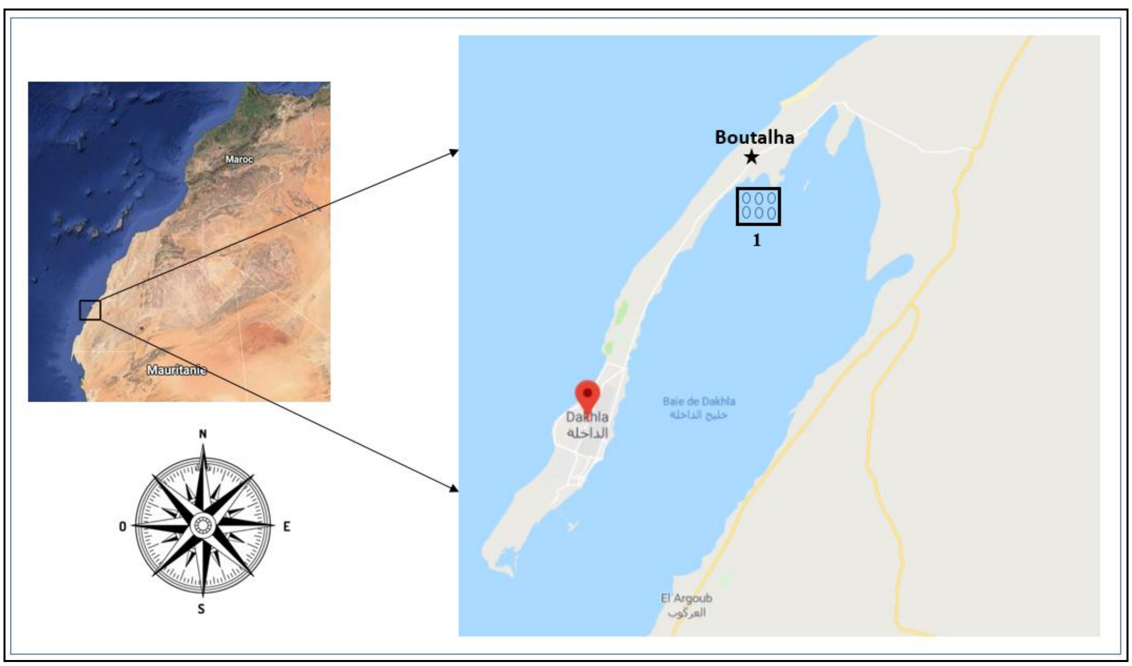

Fig. 1. Geographical location of the pilot fish farm of INRH

Table 1. Hydrodynamic and physico-chemical characteristics of the oceanographic data of the site selected for hosting the INRH fish farm **(Saad *et al*.,2015; Hilmi *et al*., 2017; Berraho *et al*., 2019; Izzabaha *et al*., 2020)**

Parameter		Value
Nature of the material on the sea bottom		Sandy and muddy substrates
Predominant wind direction		N to NE
Depth (m)	low tide	12
	high tide	14.5
Wind speed (m/s)	Min	0.5
	Max	> 9
Speed of marine currents (m/s)	Min	0.9
	Max	1.3
Temperature (°C)	Average	20.19
	Min	16.8
	Max	24.5
pH	Min	7.5
	Max	9
Dissolved Oxygen (mg/l)	Min	5
	Max	9.4
Salinity (‰)	Min	36.5
	Max	39
Chlorophyll (µg/l)	Min	4.5
	Max	13.1
Turbidity (NTU)	Min	1.2
	Max	9.8

2. Fish farming structures

The breeding trial was conducted on INRH sea farm equipped with two types of fish farming structures: A cubic cage was constructed from high-density polyethylene (HDPE) material for pre-on-growing and fitted with four ponds and six circular HDPE cages for on-growing. The main characteristics of the different structures are shown in Figs. (2, 3). The Cubi cage is square-shaped and made up of four small ponds; each pond is square, with sides of approximately 5 m long; a net-cage with a 4 m water depth, and a mesh size of 6 and10 mm. To hold it in place, the structure was moored to the seabed by 4 anchors of 2.7 tons and kept afloat on the surface of the water by means of 4 buoys of 500 L (Fig. 2). The on-growing cages were circular in shape, with a diameter of 12 m and a net-cage of 5 m of depth and three types of mesh size, 10, 15 and 20 mm. These cages were fixed to the bottom using 14 anchors of 2.7 tons, and maintained to float on the surface by 12 buoys of 500 L (Fig.3). Each on-growing cage, with a cylindrical cage form, has a total volume of 565 m^3. The buoyancy of circular cages was accomplished primarily by two 200 mm diameter HD polyethylene tubes which were interconnected by PE legs on which the mesh pockets were fixed. These feet are attached by their upper part to a 110 mm diameter polyethylene (PE) tube. It is important to note that those cages are quite flexible and designed to withstand 6 m swells. They were set up perpendicularly to the direction of the prevailing winds, which are generally NNE in the area. The service boat used for carrying out the various maintenance and monitoring operations at sea is a flat-bottomed polyester boat (length: 5.4m, width: 2m, depth: 0.87, draught: 0.87, weight: 550 (including 25kg of ballast) and gauge: 1,98tx) with a 40 horse power outboard engine. The hull has a platform that is sufficient enough for conducting work on board.

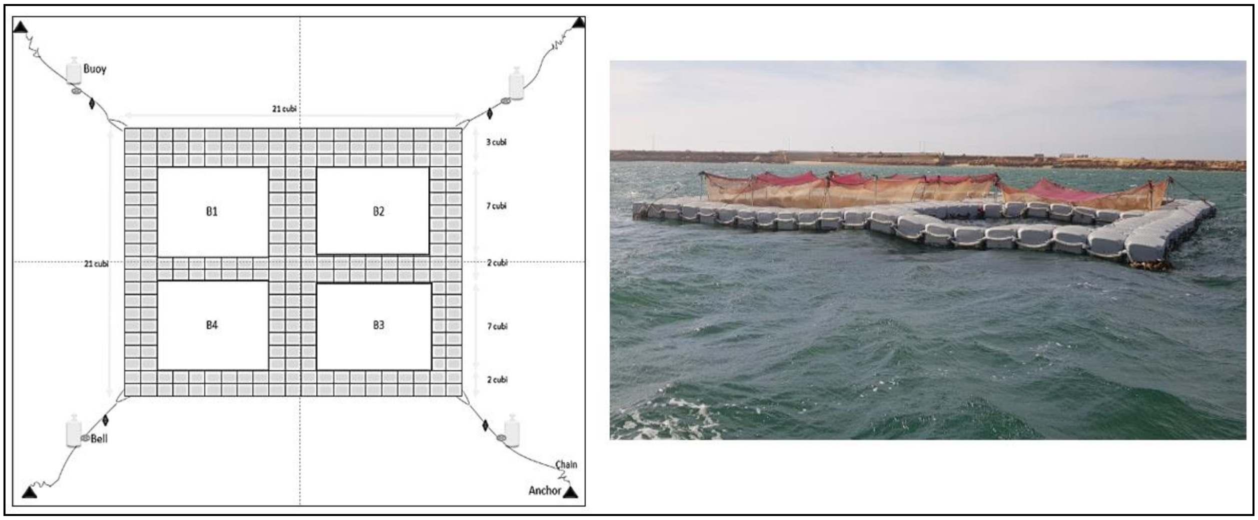

Fig. 2 . Basic components of the Cubi cage

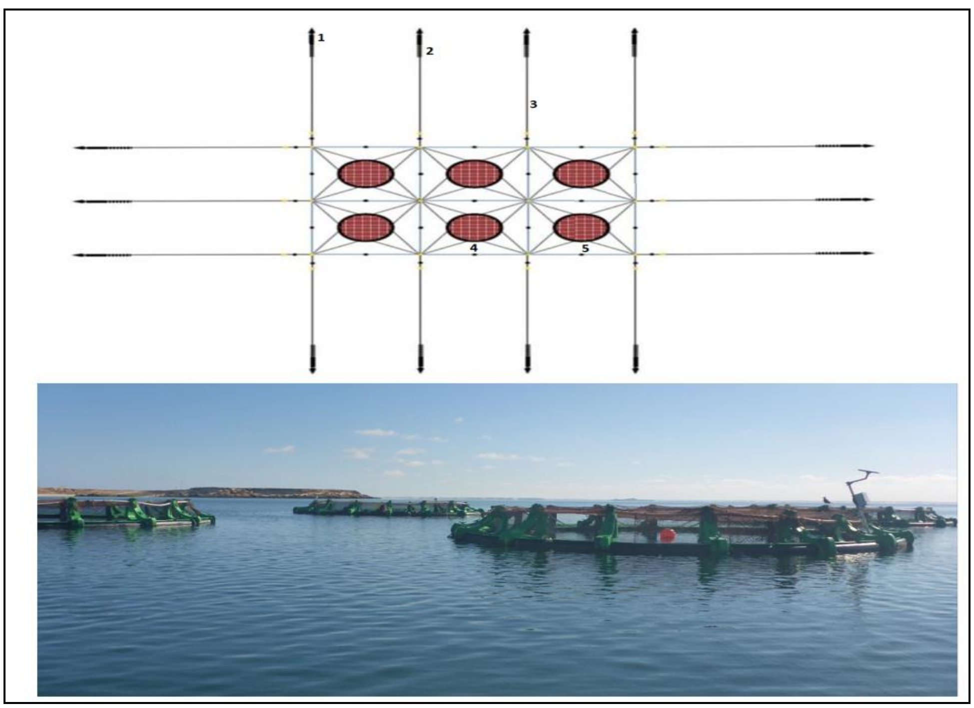

Fig. 3. Basic components of circular-shaped floating cages **(1:** Anchor, **2:** Chain of 3m length, **3:** Towing hawser of 40m length, **4:** Cage containing 1 and 5 batches **5:** Cage containing batch 2

3. Experimental design

The experimental test was carried out in the National Fisheries Research Institute (INRH) pilot fish farm mounted in the Boutalha area (Dakhla Bay in Morocco). It lasted for 15 months from March 2018 to July 2019. A total number of 50.000 live fries of gilthead sea breams (*Sparus aurata*, Linnaeus, 1758) were used in the experiment. They were imported from a French hatchery, with an initial average net weight of 3.68 ± 0.16 g. These fingerlings were transported from France to Dakhla in tanks installed on a specialized flat-bed truck.

On arrival, the fish fry of the species *Sparus aurata* were released in duplicates (for analysis and statistical processing of the data) into batch 1 and 2, each of which containing a stocking density of 25.000 individuals. Then, the two lots were subjected to a 3-day acclimatization period during which they received anti-stress treatment enriched with vitamin C. Subsequently, the fingerlings were put into water in pre-ongrowing cages, with an initial rearing density of 0.98 Kg/m^3 (Table 2). After a four-month pre-on-growing period, fish from the two batches having reached average weights of 41.02 ± 2.09 g and 43.81 ± 3.02 g, were transferred to the on-growing circular-shaped cages, with initial densities of 1.71 Kg/m^3 and 1.75 Kg/m^3, respectively (Table 2).

Table 2. Characteristics of the two gilt-head seabream batches during the try-out and start-up pre-on-growing and on-growing phases

Parameter (unit)	batch 1	batch 2
Characteristics of the breeding structures		
Depth of rearing cage site (m)	12	12
Volume of pre-on-growing cage (m^3)	100	100
Volume of on-growing cage (m^3)	565	565
Initial characteristic features of rearing during pre-on-growing phase		
Initial stocking density of fry put into water	25 000	25 000
Initial average net weight of fry (g)	3.68 ± 0.16	3.68 ± 0.16
Age of fry on arrival (days)	122	122
Initial stocking density of fry (Kg/ m^3)	0.98	0.98
Initial characteristic features of rearing during on-growing phase		
Initial average net weight of fish (g)	41.02 ± 2.09	43.81 ± 3.02
Age of fish (days)	242	242
Initial stocking density (Kg/ m^3)	1.71	1.75

4. Growth parameters

During the rearing period, a constant and timely monitoring of fish physiological and biological behavior was performed. However, the sampling and monitoring methodology of fish growth relied on carrying out a weekly sampling during the pre-ongrowing period and a bimonthly sampling during the on-growing stage to adequately assess growth of the stock and the feed quantity to be distributed. With regard to the sampling operation, work was interested in pulling the breeding net of every single batch during each rearing phase in order to concentrate the stock in a bag-like net, making it possible to get a homogeneous sample (individuals at the head and tail of the lot). Then, a sample of 200 fish was randomly collected and placed in a container prepared with an anesthetic, i.e. a low-dose clove oil (5ml/1m^3 of seawater) **(Chanseau *et al*., 2001)** used to immobilize fish during the weighing operation. This facilitates reading the weight values recorded in the scale (with an accuracy of 0.1g) during the weighing operation and getting an idea about the total fish length. Data collected through sampling are used to compute the growth parameters referred to in Table (3). Similarly, fish mortality was regularly recorded on a daily basis by divers, whose tasks were to observe, remove, examine and also count the dead fish, either on the surface of the cages or at the bottom of the fish net. The recorded mortalities adjust both the stocking density and the feeding diet when sustained losses are significant.

At the end of the rearing period, more than 300 individuals selected randomly from each batch were measured. These individuals were used for the purpose of computing the size-weight relationship and the condition factor.

The condition factor can be calculated on the basis of weight and length data of the two batches used for allometric growth, which describes the health condition and well-being of the farmed fish. The most commonly used condition factor to establish length-weight relationship is Fulton's and Ricker's factor.

$k = W.100/L^3$; With W is weight in grams and L for total Length in cm.

This CF, also known as the fat mass ratio, is commonly used to indirectly estimate the health status of fish; it is based on the hypothesis that fish mass and length increase isometrically. Thus, the higher the CF ratio is, the larger the fish is. However, this isometric assumption is not always confirmed and it is preferred to calculate the CF of each fish based on the length-weight relationship of a given population. If the slope 'b' value in the length-weight relationship is significantly greater than 3 (meaning that fish growth is allometric), it is statistically invalid to use the Fulton's formula. In our case, the two sampled batches of gilthead sea bream had an isometric relationship.

Table 3. Growth parameters for computed monitoring growth performance of gilthead sea bream

Parameter (unit)	Equation
Survival rate (%)	SR = 100 x (Final number of fish – Initial number of fish) / Initial number of fish
Biomass (T)	B = ABW x Final number of fish
Gained Biomass (T)	B_G = initial biomass – final biomass
Breeding density (Kg/m^3)	D = B/ breeding volume
Average weight gain (g)	AWG = ABW_f (g) – ABW_i
Average daily weight gain (g/day)	ADWG = (ABW_f – ABW_i) / number of days
Feed conversion ratio	FCR = Amount of feed dispensed/B_G
Specific growth rate (%/day)	SGR=100x[ln (ABW_f) – ln (ABW_i)] / breeding period
Condition factor	$k = W \times 100/L^3$
Size - weight relationship	$TBW = a\ TBL^{b}$

(ABW = Average Body Weight, TBW = Total Body Weight of fish(g), TBL = Total Body Length of fish (cm))

5. Feeding

During the two grow-out periods, seabreams were fed an extruded feed pellet imported from « Aller-Aqua », a Danish company. The fish received three meals per day (morning, noon and afternoon). Feeding was introduced manually throughout the experiment. Granulometry, feed composition as well as the daily feed intake were calculated based on fish size, water temperature and by reference to data (Table 4) provided by « Aller –Aqua » company.

Table 4. Granulometry and composition of industrial feed used during the breeding cycle (FW: Fish Weight, GP: Crude Protein, FM: Fat Matter)

Phase	Caliber (mm)	Date of administration	Characteristics						
			FW (g)	CP (%)	FM (%)	Vitamins			
						A (IU/Kg)	D3 (IU/Kg)	E (mg/Kg)	C (mg/Kg)
Pre-ongrowing	1.1	14/03/2018 to 31/03/2018	2-4	52	17	10000	1750	200	300
	1.3	01/04/2018 to 10/05/2018	4-10	56	18	10000	1750	200	300
	1.5	11/05/2018 to 12/06/2018	10-15	56	18	10000	1750	200	300
	2	13/06/2018 to 04/08/2018	15-50	48	15	10000	1750	200	300
Ongrowing	4	05/08/2018 to 01/10/2018	50-300	42	20	10000	1750	200	150
	5	02/10/2018 to 20/11/2018	300-450	42	20	10000	1750	200	150
	6	21/11/2018 to end of cycle	> 450	41	19	8000	1400	160	90

6. Water quality

The on-farm physical and chemical parameters, temperature (T), pH, D.O, chlorophyl a (chl-a) were monitored on an ongoing basis (every single hour) throughout the breeding cycle. Measurements were carried out using an EXO2 YSI multiparameter probe installed at a water depth of 3 meters and connected to an on-farm data logger. Data transfer from the logger to the PC was performed on an hourly basis.

7. Cage maintenance

In the course of the breeding cycle, regular net- cleaning and disinfection was done once every month. Nets were replaced for the fish size got bigger by increasing mesh size on the basis of the gradual increase in fish size to ensure a better water removal in the cages and a better handling of the metabolic farm discharges, including uneaten feed remnants (Table 5). This helps maintaining the optimal concentrations of the dissolved oxygen in the sea farm, which contributes to the ongoing well-being of fish and improves their growth performance. Remarkably, no chemical agents were used during the on-farm breeding cycle.

Table 5. Dimensions of net mesh-sizes used on basis of fish weight

Net mesh-size (mm)	Average weight of fish (g)
6	less than 15
10	15 - 80
15	80 - 200
20	More than 200

8. Statistical analysis

Data were determined and analyzed using Statistical Package for Social Sciences (SPSS), version 24.0. The Student's t-test was used to compare the means of the recorded growth parameters for the two batches of gilthead sea bream. The data were checked for normality, and homogeneity was made prior to using the Student t-test. The probability threshold was significant at $p < 0.05$ value. Likewise, the relationship between size and weight was determined using the least squares regression method, as well as the correlation between growth and environmental parameters (temperature, salinity and dissolved oxygen).

RESULTS AND DISCUSSION

1. Environmental parameters

During the study period, the average daily temperature values recorded at farm site ranged from 16.2 ± 0.81°C to 24.3 ± 1.1°C, with an average of 20.77 ± 2.61°C (Fig. 4a). It was noticed that, those temperatures are in the optimal range for the growth of gilthead sea bream **(Person-Le Ruyet *et al*., 2004)**. Notably, the temperature amplitudes recorded in Dakhla Bay are lower than those in the Mediterranean (Nador Lagoon and Tunisia), whose temperatures rise from a minimum of 12.8°C in Nador Lagoon (previously operated by MAROST), 13.5°C in Tunisia and 13.75°C in Turkey to a maximum of 28°C for Nador Lagoon, 29°C in Tunisia and 23.85°C in Turkey **(Bendag, 1995 ; Vardar and Yıldırım, 2011).** Identically, **Llorente and Luna (2013)** showed that temperature differences between sites have a direct impact on both growth and the conversion rate of gilthead sea bream. The higher the annual average water temperature is, the shorter the growth period becomes, since it plays a key role in regulating the entire metabolism by acting on biochemical and enzymatic reactions **(Person-Le Ruyet *et al*., 2004)**. This forms one of the reasons accounting for the best growth performance displayed by gilthead sea bream breeding in floating cages in Dakhla Bay. The measured dissolved oxygen contents (Fig. 4b) vary between 6.33 and 9.81 mg/l, at an annual average rate of 7.78 ± 1.54 mg/l, which is within the range of the recommended values for sea bream cage farming. These high levels in dissolved oxygen contents are attributed to the richness of chlorophyll at Dakhla Bay (according to data received from the probe, the average concentration over the experimental period was 3.73 ± 1.22 µg/l, on the one hand, and thanks to the blowing of strong winds, all undoubtedly contribute to sea water oxygenation, on the other hand). Salinity monitoring indicates that this parameter has almost been constant during the study period (Fig. 4c), with some fluctuations falling within the ranges of 36.48 – 38.94 ‰ at the farming site. Notably, these recorded average salinity values correspond to the optimal range of salinity required for gilthead sea bream growth, which is generally between 30 ‰ and 37 ‰ **(CNEO, 1983)**. Fig. (4d) shows that, the pH varied from 8.22 to 8.53, with an annual average of 8.53± 0.16. These pH values are in the range of favorable pH values for fish farming; between 7.5 and 8.5 **(Hellin, 1986)**, without ever reaching the lethal pH.

Consequently, it can be concluded that the recorded physico-chemical parameters of Dakhla Bay water (temperature, salinity, pH and dissolved oxygen) are within the ranges required for the farming of gilthead sea bream. Hence, ranges were proved advantageous for growth performance **(CNEO, 1983; Hellin, 1986)**.

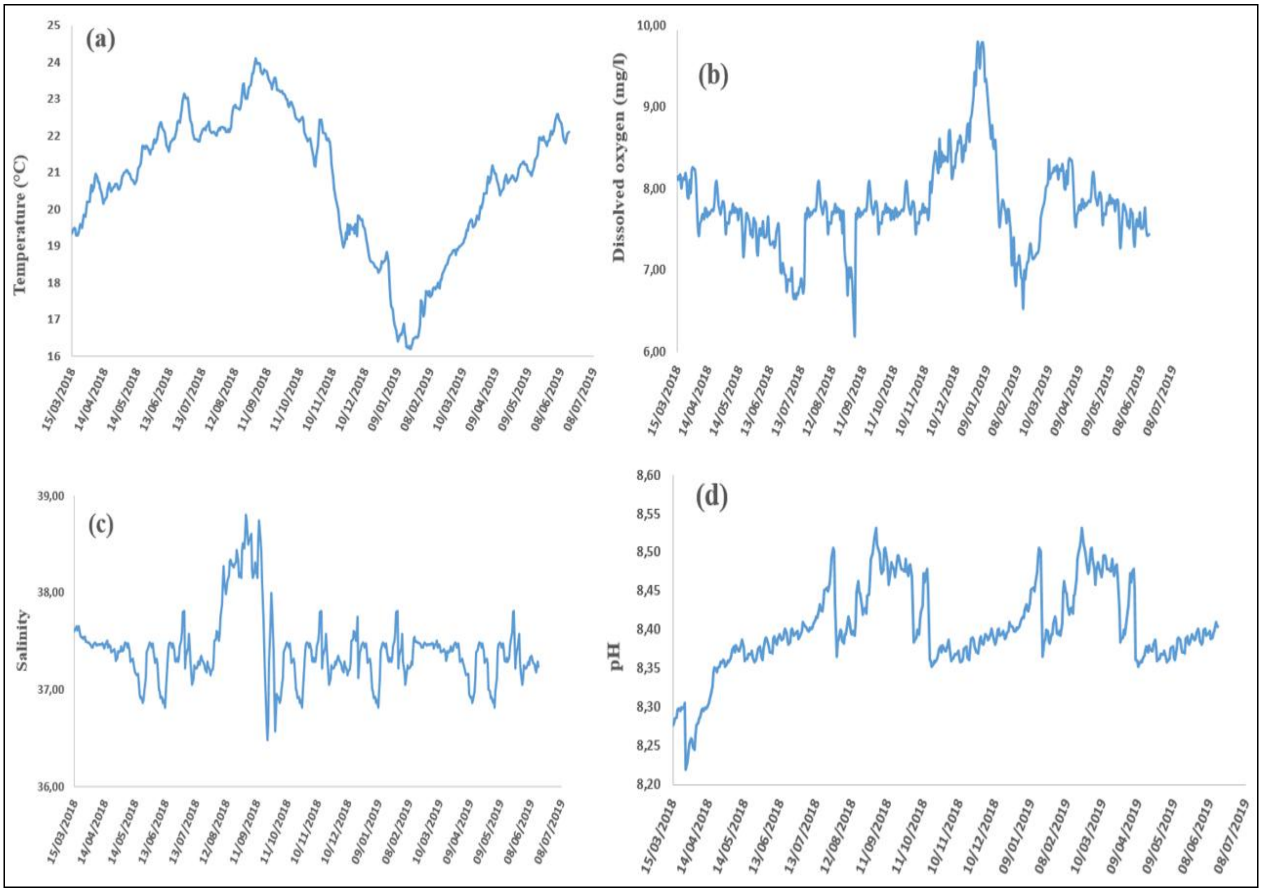

Fig. 4. Histograms showing **(a)** Monitoring of temperature; **(b)** Dissolved Oxygen; **(c)** Salinity and **(d)** pH during the study period

2. Growth parameter

In addition, Table (6) summarizes all the growth parameters of the gilthead sea bream recorded during this breeding period. During the pre– growing phase, the average weight evolution of the two batches of sea bream fingerlings reared in cubic cages is reported in Table (6) and depicted in Fig. (5a). The average weight of sea bream increased to 41.02 ± 2.09 g, with an average weight gain of 10.03± 0.71g/month for batch 1. While in batch 2, an average weight of 43.81 ±3.02g was recorded, with an average weight gain of 10.73g/month. It is worth noting that, an accelerated increase in the speed of growth was recorded starting from the second month for the two batches. This acceleration is mainly driven by the rise in ocean temperature during the study period (Fig. 4a). Additionally, it can be related to the good adaptation of the fingerlings of the two batches. Statistical analyses revealed no statistically significant differences in both batches (Student's t- test, p value < 0.05).

Data in Fig. (5b) and Table (6) reveal that, the growth of the two batches of gilthead sea bream juveniles is almost homogeneous during the ongrowing phase, and the growth rate recorded in both batches is significant in the first five-month period; from August to December. This acceleration is no doubt linked to the rise in water temperature. Thereafter, a continued downturn in the rate of growth is very discernible as from the ninth month onwards. There are two reasons to provide an explanation for this course of action: bad weather conditions and decrease in rearing medium temperature. During this period, the average weight of the sea bream witnessed an increase reaching 512 ± 19.71 g, with a recorded average weight gain of 42.83± 1.15 g/ month for batch 1, and an average weight of 520.29 ± 22.40 g with average weight gain of 43.32 ± 1.32g/month for batch 2. It is worthy to mention that, the statistical analysis shows that the growth of the two batches is identical since no significant difference was detected between the two batches (Student's t- test, p value > 0.05).

Table 6. Growth parameters recorded for the two gilthead sea bream batches reared in floating cages at Dakhla Bay

Parameter (unit)	**Rearing phases**			
	Pre-ongrowing		**Ongrowing**	
	Batch 1	**Batch 2**	**Batch 1**	**Batch 2**
Initial age of fish (Month)	4		9	
Final age of fish (Month)	8		19	
Average initial weight (g)	3.68 ± 0.16[a]	3.68 ± 0.16[a]	41.02 ± 2.09[b]	43.81 ± 3.02[b]
Average final weight(g)	41.02 ± 2.09[a]	43.81 ± 3.02[a]	512.00 ± 19.71[b]	520.29 ± 22.40[b]
Initial size (cm)	6.23 ± 0.53[a]	6.23 ± 0.53[a]	11.6 ± 1.41[b]	12.1 ± 1.52[b]
Final size (cm)	11.6 ± 1.41[a]	12.1 ± 1.52[a]	28.71 ± 3.15[b]	27.96 ± 3.05[b]
Initial stocking density (kg/m^3)	0.98[a]	0.96[a]	1.71[b]	1.75[b]
Final stocking density	10.02[a]	13.84[a]	20.41[b]	20.61[b]
Conversion ratio	0.76[a]	0.78[a]	1.39[b]	1.4[b]
Average weight increase (g/month)	10.03 ± 0.71[a]	10.73 ± 0.63[a]	42.83 ± 1.15[b]	43.32 ± 1.32[b]
Specific growth rate (%/d)	2.01[a]	2.06[a]	0.77 ± 0.09[b]	0.75 ± 0.11[b]
Mortality rate (%)	2.4[a]	2.11[a]	9.18[b]	10.2[b]

The values belonging to the same line in each phase and having a different exponent are significantly different with (Student's t- test, p value > 0.05).

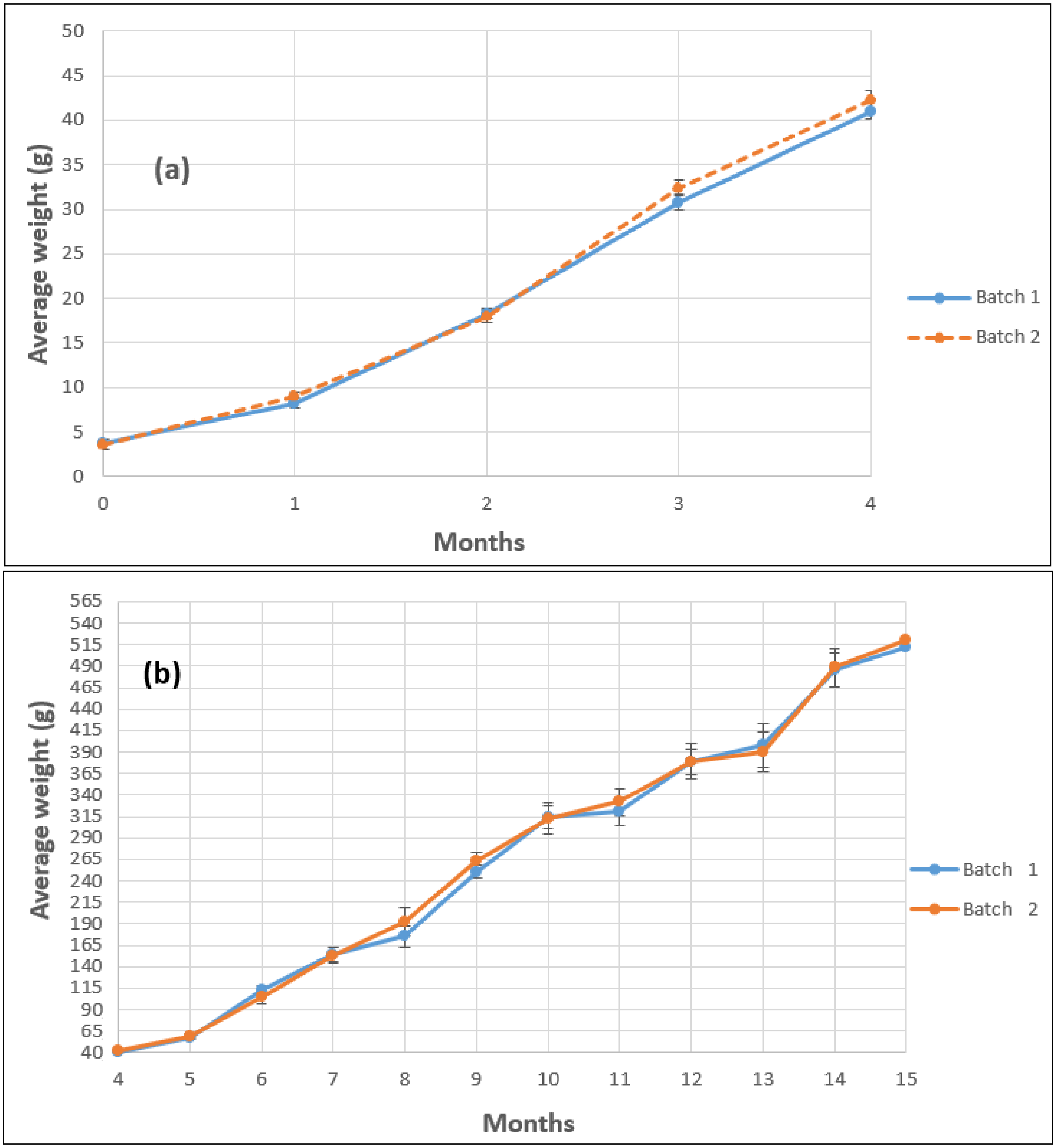

Fig. 2. A histogram showing growth evolution of gilthead sea bream farming in Dakhla Bay; **(a)** Pre-ongrowing phase and **(b)** ongrowing phase

The yielded findings suggest that, the growth pattern for the two batches was identical, without any significant differences, and growth speed of the two batches was quite remarkable. The concomitant result accruing was a final average weight around 520g for batch 1 and 512g for batch 2 after 15 months, with an initial average weight of 3.68g for the two batches.

For the curve related to the changes in water temperatures in the specific location of the farming site (Fig. 4a), it was noticed that it falls within the optimal range for breeding the gilthead sea bream, with an annual average of 20,77 ± 2.61°C, and a daily thermal spread of no more than 1°C. According to Stauffer (1973), the three key factors with direct impact on fish growth are: initial size, feed ration, and water temperature. Accordingly, several authors have confirmed that water temperature has a direct influence on the growth rate as well as on the conversion rate **(Hernandez *et al*. 2007)**. This fast growth rate of the gilthead sea bream witnessed a gradual decrease when the temperature was close to 12°C and 32.2°C **(Llorente & Luna 2013)**.

Towards the end of the cycle and as shown in Table (6), the specific growth rates recorded in the two batches amounted to 1.10 ± 0.12 %/ day and 1.11 ± 0.19 %/ day, respectively. These values are significant and for the second time they account for the exceptional performances of gilthead sea bream reared in Dakhla Bay. In this context and according to findings in the study of **Bjornsson *et al*. (2001)**, the specific growth rate is low and/or equal to zero when the temperature is low. Conversely, a significant rate is obtained at optimum temperature, this was more noticeable in September when water temperature averages 24.3°C, and the fish specific growth rate is about 2. 05% per day for batch 1, and 1. 91% per day for batch 2. However, when the temperature was 16.2°C in February 2019, this rate was very low, recording no more than 0.65%/day for both batches. This is a further proof that, if feed conditions as well as a temperature close to the optimal range for the gilthead sea bream breeding are met, they can have implications for achieving optimum value of the specific growth rate. Similarly, the individual growth rate of most captive fish is widely determined with respect to water temperature **(Britton *et al*., 2010)**.

3. Feed conversion ratio

Monitoring of feed behavior of sea bream fry was carried out through direct observations upon feed distribution, in order to determine their acceptance of feedstuff. Observations showed that the fish consumed the feed with a greater degree of appeal during both pre-on-growing and on-growing phases. With respect to Fig. (6), the evolution of fish biomass of the two farmed batches is synchronous with the quantity of distributed feed. This is well-corroborated by the positive linear correlation between these two variables. Furthemore, the determination coefficient of batches 1 and 2 are around 0.994 and 0.995, respectively. The results were processed and exhibited no statistically significant differences (Student’s t- test, p value < 0.05) in the evolution of biomass as a function in the two batches 1 and 2.

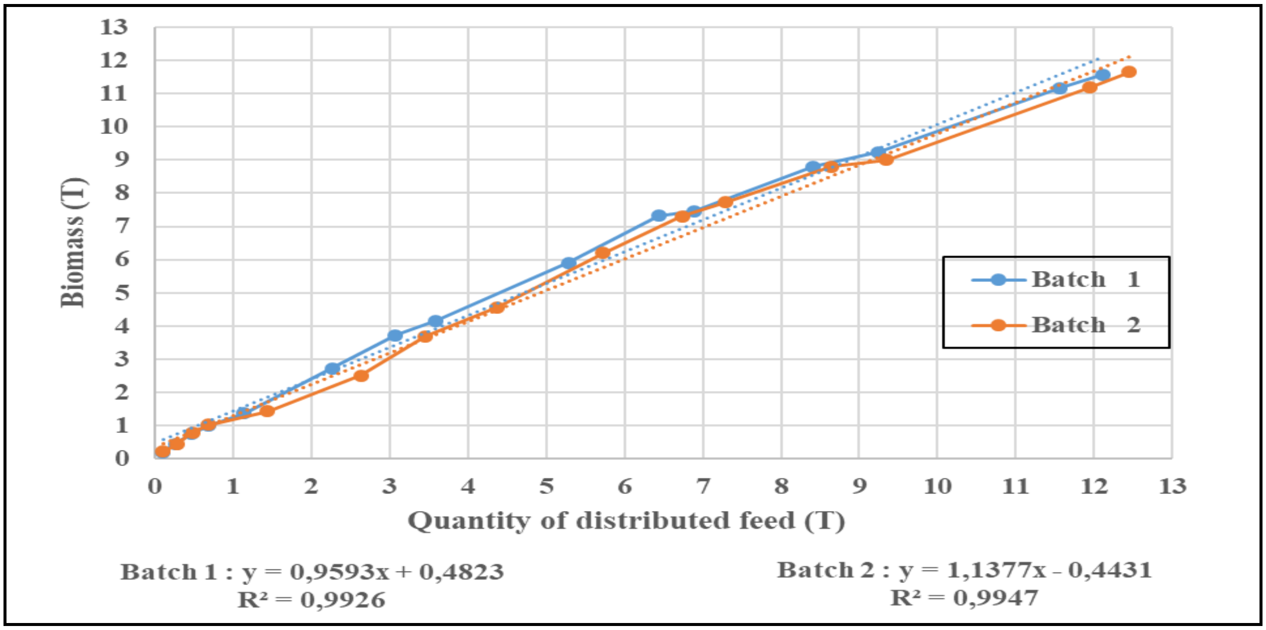

Fig. 3: A histogram showing trends in biomass for quantity of distributed feed

As shown in Fig. (7), the monthly feed conversion ratio (FCR) of the two batches have values approximately close to each other, with some variations recorded during the months of August-2018, February-2019 and April-2019. This finding may be accounted for the poor distribution or the disruption of growth due to bad weather conditions prevailing during those months, in addition to the stress resulting from the transfer and caging operations of fingerlings.

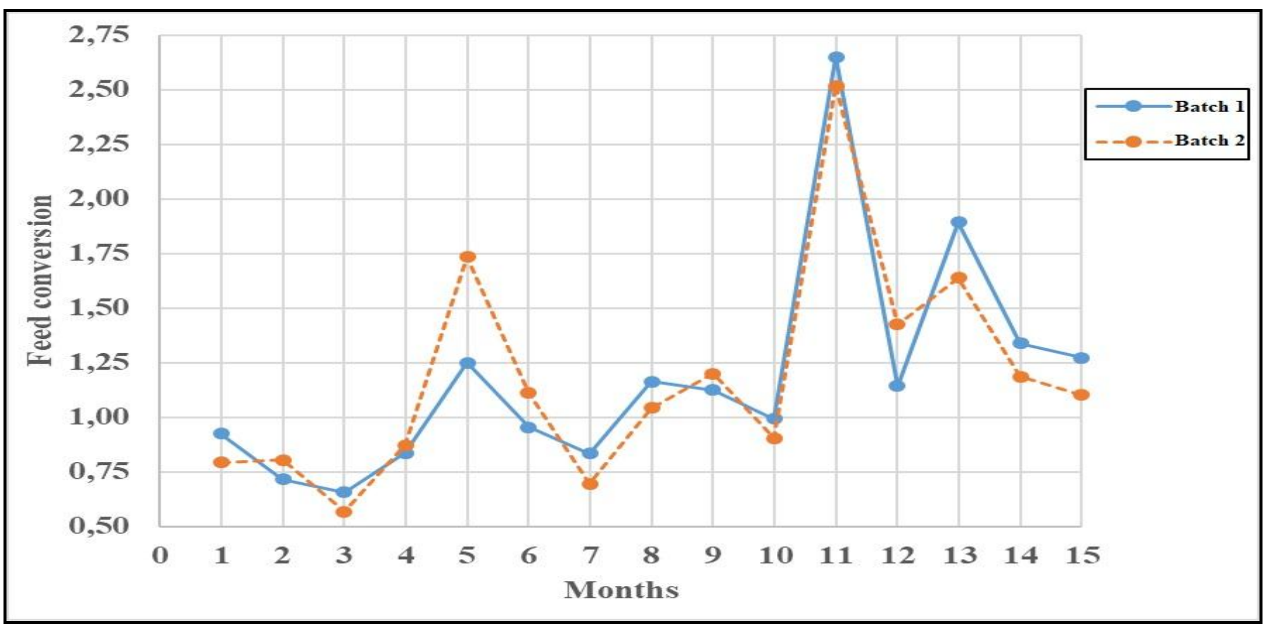

Fig. 4. A histogram showing monthly changes in feed conversion ratio for the two batches of gilthead sea bream reared in fish cage practice (between March 2018 and July 2019)

The recorded feed conversion ratio values during the rearing period are presented in Table (7), revealing a successful use of the feed administrated.

Table 7. Feed conversion ratio values recorded for the two batches of gilthead sea bream

	Pre-on-growing phase	**On-growing phase**	**Farming cycle**
Batch1	0.78 ± 0.11^{a}	1.32 ± 0.49^{b}	1.18 ± 0.31^{c}
Batch 2	0.76 ± 0.13^{a}	1.34 ± 0.52^{b}	1.19 ± 0.34^{c}

The values in the same column for each phase having a different exponent differ significantly with (Student's t- test, p value < 0.05).

Table (7) shows that, the recorded values of the feed conversion ratio are consistent with the values mentioned in the technical sheet for the feed used during the rearing cycle. Thus, the conversion rate of batches 1 and 2 can be marked significant and very encouraging for fish farming at Dakhla Bay, being around 1.18 for batch 1 and 1.19 for batch 2. This finding confirms that an outstanding performance is achieved when growth is strong and the conversion rate is low.

For feed consumption and the conversion ratio in the two batches as well as the feed rations, it can be seen that the recorded values are identical to those identified by the food manufacturer, and which do not have to be very costly for cage- farming to remain a profitable activity. Hence, it is worth noting that the conversion ratio values obtained during the rearing cycle are very low and do not exceed 1.18 for batch 1 and 1.19 for batch 2. Identically, the feed rations' values fluctuated during the rearing period between 1.5% and 3%. These recorded values at Dakhla fish farming system are consistent with the hypothesis **of Brett and Groves (1979), Hernandez *et al*. (2007)** and **Dutil *et al*. (2008)**, who confirmed that water temperature has a direct influence on growth rate and feed conversion ratio. It must be emphasized that high feed conversion ratios could be due to two major problems arising from a shortage of semi-moist fish feed, on the one hand, and its low cohesion **(Guerbej, 1995),** on the other hand.

4. Condition factor

Table (8) shows that, the relationship between the total fish weight of gilthead sea bream of batches 1 and 2 and the total length can be expressed as: $TBW_1 = 0.039\ TBL^{2.892}$ (n =315, R^2 = 0.91) and $TBW_2 = 0.0035\ TBL^{2.935}$ (n =318, R^2 = 0.90), respectively. The final equation of the length- weight relationship of the two gilthead sea bream batches has an allometry coefficient close to 3, which represents isometric growth.

Table 8. Length-weight relationship of both batches(1&2) of gilthead sea bream reared in floating cages at Dakhla Bay

Batch	Length (L) in cm and Weight (W) in g	a ± I.C	b ± I.C	R^2	N
1	$W = a.L^b$	0.039 ± 0.005	2.892 ± 0.101	0.91	315
	Ln W = ln a + b.ln L	Ln W = 2.892 ln L – 3.39			
2	$W = a.L^b$	0.035 ± 0.011	2.935 ± 0.117	0.90	318
	Ln W = ln a + b.ln L	Ln W = 2.935 ln L – 3.534			

Cabello (2000) pointed out that, if the values of the condition factor ranged between 1.5 and 1.6, then the fish reared in captivity would receive an adequate feedstuff ration. If the values were higher, fish would be reared under exceptional conditions, and if values were less than 1.5, fish would be regarded underfed. Table (9) illustrates the condition factor of batches 1 and 2, with values of 2.33 and 2.21, respectively. No statistically significant differences were recorded between the two gilthead sea bream batches (Student's t- test, p value < 0.05).

Table 9. Condition factor of the two batches of gilthead sea bream reared in floating cages in Dakhla Bay

	Condition Factor ± Standard deviation
Batch 1	2.33 ± 0.51 [a]
Batch 2	2.21 ± 0.68 [a]

Values are reported as mean ± SE, n = 365 (for each batch). The values of the same column in each phase having a different exponent are significantly different with (Student's t- test, p value > 0.05).

5. Survival rate

Over the course of the two breeding phases, the mortality rate of the fingerlings from the two batches was taken daily. The results obtained during the study period showed that the recorded survival rate was very high and exceeded 90%, i.e. 91% for batch 1 and 90% for batch 2. Furthermore, the few mortality cases enumerated during the experiment did not seem to be closely linked to attacks by pathogens or to sudden changes in the physico-chemical parameters of seawater. They were mostly stress-related, occurring during the operations incuding the release of fingerlings into water, net change, transfer of the cages, transfer of the fingerlings to the growing cages, cleaning of the net, adding to the fish handling during sampling operations. There were also cases of cannibalism among juvenile fish, the latter was confirmed by dead fish specimen found floating on the surface of the sea, whose body was deprived of the head because of attacks perpetrated by other bigger fish. Fig. (9) provides a summary of cumulative mortalities of the two farmed gilthead sea bream batches during the pre-on-growing and on-growing phases.

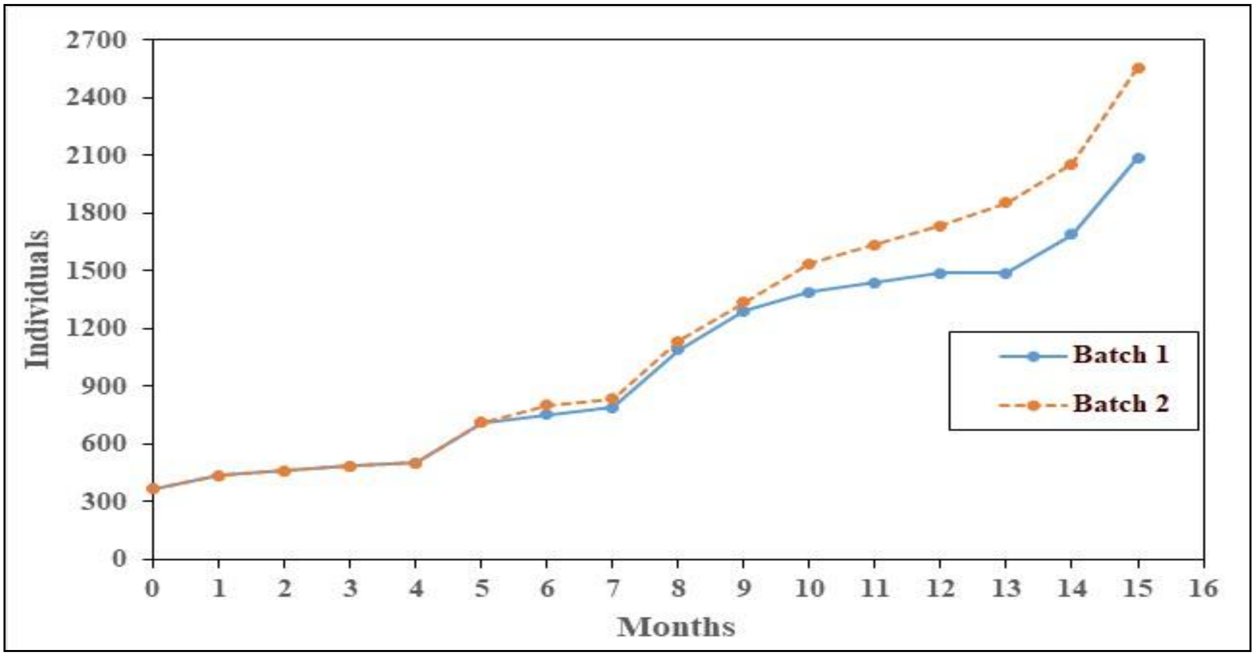

Fig. 8. A historgam showing cumulative mortality for the two gilthead sea bream batches.

With respect to Fig. (9), the following findings can be highlighted:

- High mortality was observed for the two fish batches soon after the fingerlings were released into water.
- During the pre-ongrowing period (i.e. the first four months of rearing), general mortality was very low which was probably due to the successful adjustment of the fingerlings to the conditions of Dakhla Bay.
- However, during the ongrowing period, elevated mortality rate was noticed in the later months of the breeding cycle. This occurrence is quite normal in relation to the frequency of fish handling operations (fish transfer, net change, sampling, etc.).
- Overall, mortality rates during the rearing cycle of batches 1 and 2 were at a rate of 9.2% and 11.4%, respectively. From a technical and economic perspective, these are very low and very encouraging rates;

The recorded survival rate for each batch indicates that the current experiments have been carried out in line with the required hygiene and environmental standards. As a matter of fact, the aquafarm did not experience any outbreak of diseases, and the survival rate exceeded 90% for both batches. This could be attributed to the following:

- Total absence of sources of pollution, such as rivers, human-based activities (industry, agriculture, cattle farming, shipping, etc.), which might cause a particular risk of pathogen proliferation and impact the quality of water, which is a key factor and the lifeblood of fish farming **(Izzabaha *et al*,. 2020)**.

- The best adaptation of fish to the physico-chemical parameters of the water of Dakhla Bay, which is consistent with the optimal range needed for the survival and the growth of the gilthead sea bream.
- Absence of abrupt temperature changes that are responsible for triggering fish stress and can have adverse effects on immune defences (**FAO, 2012**).
- The oxygen levels recorded were always above 3 mg/l, this value is considered optimal in the study of **Dosdat (1984)**.
- The minimum temperature recorded during the study period is 16.2°C > 15°C, which according to **Domenech (1997)** is a temperature that can hasten the onset of diseases.

6. Comparison growth rate of gilthead sea bream growth with other fish farming locations

Analysis of Fig. (10) shows that during the pre-on-growing phase (the first four months), average weight changes are almost identical in all locations, with a slight but very remarkable upward trend in average weight of sea bream reared in Tunisia, followed by fish aquaculture at the INRH farm in Dakhla. The performance of the last two has witnessed an improvement, compared to those recorded in other countries, especially in Algeria (the lowest average weight – value ratio in four months of rearing).

During the on-growing season in Dakhla aquafarm, the growth rate of sea bream showed a remarkable growth performance in all locations, both in terms of gained average weight and the duration of the rearing period. With regard to curves, it seems that the best combination of rearing time and gained average weight was recorded in Dakhla for reared sea bream, where fish grow faster compared to other rearing locations (i.e. Tunisia, Greece, Maroste– Nador, Turkey, Spain and Algeria). In the various farming locations, sea bream weight rose from 3.7g to 520g after 15 months rearing in Dakhla . On the other hand, the lowest value was recorded in Nador with an average weight of about 300g after 22 months. Therefore, it was observed that sea bream growth in Dakhla has increased exponentially, exceeding by far and large the results of the Mediterranean basin.

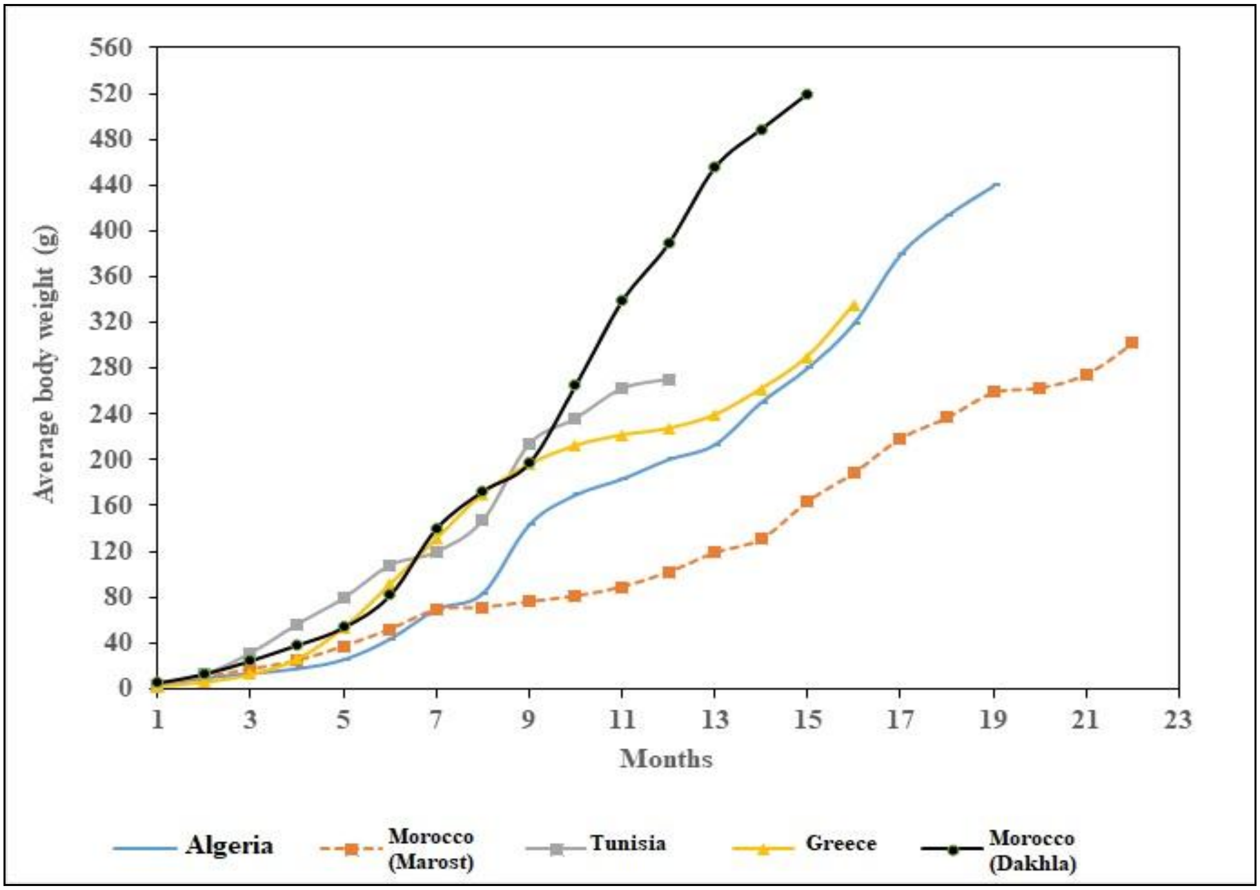

Fig. 9. A histogram showing the comparison of growth rate of gilthead sea bream farmed in Dakhla Bay (current study) with other breeding locations, Greece **(Petridis *et al, 1996)***, Tunisia **(Boussaidia, 2017)**, Marost : Progress report by the maroste company in Nador Lagoon north of Morocco**,** Algeria **(Hamdi *et al*, 2011)**

This current review targeted, for the 1st time, the exploration of the zootechnical performance of sea bream (*Sparus aurata*) farming in floating cages in Dakhla Bay. Given the physico- chemical characteristics of Dakhla Bay water (i.e. Temperature, dissolved oxygen, pH and salinity), it is clear that they fit within the optimal range for sea bream rearing, and in favour of setting up a fish farming activity, targeting sea bream rearing, in particular. The results obtained during the trial period clearly show the substantial adaptability of sea bream to the prevailing conditions of the bay while recording the optimum growth performances. Thus, the tough resistance of floating cages demonstrates the adaptability of this type of structure to the hydrodynamic characteristics of Dakhla Bay.

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