Effect of seasonality and initial stocking density on growth performances of gilthead seabream (*Sparus aurata*) cultured in offshore fish farm, in Dakhla Bay, Southern Morocco

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Abstract. Marine fish farming is an important activity to reduce fishing pressure on natural resources. This study sought to examine the effect of season of fingerlings introduction and initial stocking density on the growth performances of gilthead seabream (*Sparus aurata*) raised in offshore floating cages in Dakhla Bay The experiment was carried out at the offshore pilot farm of INRH located in Dakhla bay, for a period of 45 months. The total number of *S. aurata* fingerlings used during this study was 450,000, with an initial average weight of 3.95±0.47 g, and an initial mean length of 5.96±0.39 cm. The physicochemical parameters (temperature, dissolved oxygen, salinity and pH) recorded during the study period were within the optimal ranges for obtaining the expected growth and survival of gilthead seabream. Regarding the effect of rearing season on growth performance, no significant effect was observed ($p>0.05$). The harvest weight per fish for the entire rearing season reached over 500 g in 15 condition factor and survival rate values ranged from 1.12±0.21 to 1.09±0.19 (g day^{-1}), 1.08±0.15 to 1.05±0.12 (%), 1.33±0.09 to 1.31±0.05, 1.90±0.05 to 1.75±0.06 and 88.73±0.37 to 86.93±0.47 (%), respectively. A significant difference was observed between the initial stocking density 1: 25 fish m^{-3} and initial stocking density 2: 35 fish m^{-3} with regard to their influence on growth performance. The period of rearing, weight gain, specific growth rate and survival rate increased with a decrease in stocking density. The results indicate that low stocking density led to better growth and gross benefit compared to high stocking density in gilthead seabreams. The findings of the present study provide information in terms of the year-round growth performance, as the effect of rearing season and stocking density.

Key Words: rearing, seasonality, stocking density, cages, growth performance.

Introduction. Gilthead seabream (*Sparus aurata*), is one of the major aquaculture species with an annual production of over 281 thousand tons, representing around 51% of the total finfish marine aquaculture production in the Mediterranean area (FAO 2020a). The two biggest producers in Europe are Turkey and Greece, which produce 61,090 tons and 55,948 tons, respectively (FAO 2020b). The Aegean and the Mediterranean Seas are the main production areas for gilthead seabream (Dilara et al 2020). In Morocco, marine aquaculture production reached 1,133 tons only for the year 2021, mostly composed of table oyster production from two sites: Oualidia lagoon and Dakhla bay (ANDA 2018; DEPF 2018), both located on the Atlantic coast. Currently, only a single fish species represents the total output of the Moroccan fish farming (DPM 2021). The European sea bass (*Dicentrarchus labrax*) is reared in floating cages in M'diq Bay (in Mediterranean), accounting for 21% of marine aquaculture production in Morocco, with an estimated production of 244 tons in 2021 (DPM 2021).

Recently, the National Fisheries Research Institute initiated the first experimental fish farming trials on the southern Atlantic coast of Morocco in the bay of Dakhla. The trials aimed to evaluate the feasibility of developing fish farming activity in the area. Seabass and gilthead seabream were evaluated during the trial, and both species showed high growth performance, especially seabream (Gjije et al 2021; Izzabaha et al 2020).

The Dakhla Bay site in Southern 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; Gjije et al 2021; Izzabaha et al 2020; Saad et al 2022). The bay has an annual water temperature of 21°C (16.73–23.72°C), providing suitable water conditions for aquaculture of several fish species such as *D. labrax*, *S. aurata* and meagre (*Argyrosomus regius*). However, most studies on seabream culture in the Mediterranean have reported that the best growth can be achieved in water temperatures between 20 and 25°C, and a salinity range of 25–40‰ (Martinez-Llorens 2009). Feed intake and growth performance have been found to decline as the temperature increases over 28°C (Bonaldo et al 2010; Sanchez Lozano et al 2007; Sicuro et al 2010; Velazquez et al 2006a,b). This may explain why the gilthead seabream in the bay of Dakhla showed such promising growth results (Gjije et al 2021). It is an excellent indicator that the fish farming sector in the Kingdom of Morocco could be developed in this area.

To our knowledge, there have been numerous reports published on the growth of *S. aurata* in the Mediterranean Sea. However, to date, no reports are available on year-round growth performance or on the improvement and optimization of breeding conditions for gilthead seabream in the bay of Dakhla on the Atlantic coast. Therefore, the aim of this study was to evaluate the influence of seasonality and stocking density on the growth performance of *S. aurata* cultured in an offshore cage farm in the Dakhla Bay, Southern Morocco.

Material and Method

Animals and experimental design conditions. The study was conducted at an offshore cage system of the National Fisheries Research Institute (INRH) pilot fish farm located in Dakhla Bay, South Morocco (23°49’36.682” N 15°52’5.008” O) (Gjije et al 2021; Izzabaha et al 2020). The experiment used 450,000 *S. aurata* fingerlings, with an initial average weight of 3.95±0.47 g and initial mean length of 5.96±0.39 cm, from March 2018 to December 2021. Four cubic cages were used, each with dimensions of 5 m (length) x 5 m (width) x 4 m (depth), and 14 circular net-cages, of which nine cages of 12 m diameter and five cages of 25 m of diameter (Table 1). The cubic cages were mainly used for pre-growing periods, and the circular cages were used for on-growing periods until harvesting time.

Table 1

Trial site and cage characteristics

Parameters	*Pre-growing phase*	*On-growing Phase*
Distance from shore (km)	1.1	
Water depth (m)	12	
Type of cages (dimensions)	cubic cage (5X5X4 m^3)	circular cage (12 and 25 m of diameter)
Number of cages	4	9 (circular cage 12 m of diameter) 5 (circular cage 25 m of diameter)
Active volume of cage (m^3)	100	565 (circular cage 12 m diameter) 2210 (circular cage 25 m diameter)
Rearing net mesh (mm)	5 and 10	10, 15 and 20

Prior to each rearing cycle, the fingerlings were stocked firstly in a cubic cage and were subjected to a 3-days acclimatization during which they received anti-stress treatment enriched with vitamin C (4 g of vitamin kg^{-1} of food). Then, the fingerlings were introduced to 2 pre-on-growing cubic cages. After a 4-month pre-on-growing stage, the juveniles of *S. aurata* of an average weight of 40 g, were transferred to on-growing stage in a circular cage until harvesting time at a mean weight of 500 g (Table 2).

Table 2

Characteristics of the cage-cultured *Sparus aurata* in Dakhla bay from August 2018 to October 2020 (mean ± SE)

Study	*Effect of seasonality on growth performances*				*Effect of initial stocking density*	
No of repetition	2	2	2	2	2	2
No of fingerlings by lot (repetition)	25,000	25,000	25,000	25,000	55,300	77,500
Import date (month & year)	March 2018	September 2019	January 2020	July 2020	March 2018	November 2020
Season	Spring	Autumn	Winter	Summer	Spring	Autumn
Average weight (g) ± SE	3.67 ± 0.51	3.70 ± 0.48	3.68 ± 0.63	3.68 ± 0.53	3.81 ± 0.54	3.98 ± 0.39
Mean length (cm) ± SE	6.23 ± 0.53	6.03 ± 0.63	5.87 ± 0.41	5.99 ± 0.81	6.23 ± 0.53	6.13 ± 0.71
Pre-growing ISD (fish m^{-3})	250	250	250	250	250	250
On-growing ISD (fish m^{-3})	45	45	45	45	25	35
Coded cycle	C1-Spri	C3-Aut	C4-Win	C5-Sum	ISD 1	ISD 2

SE-standard error; C-cycle; Spri-spring; Aut-Autumn; Win-Winter; Sum-Summer; ISD-initial stock density.

Fish were randomly sampled monthly, the sampling operation consisted of pulling the net during the breeding, in order to concentrate the stock in a bag-like net, making it possible to get representative sample (individuals at the head and tail of the lot). Then, a sample of 300 fish was caught randomly in a seawater container in which an anesthetic (low-dose clove oil, 5 mL m^{-3} of seawater) was added to immobilize fish during the weighing and total length measurements (Chanseau et al 2002). After sampling, fish was put back into the cage. 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 were used to adjust both the stocking density and the feeding rate when losses were significant. The data collected through sampling were used to compute standard formulas growth, feed utilization, and biometric parameters, as previously described by several authors (Jobling et al 2003; Yigit et al 2006; Turchini et al 2011). The growth parameters referred to are shown in Table 3.

Table 3

Growth parameters used to express results of growth rates of *Sparus aurata*

Parameter (unit)	*Equation*
Survival rate (%)	SR = 100 x (Final number – Initial number) / Initial number
Biomass (t)	B = AW x Standing stock
Gained biomass (t)	GB = FB – IB
Stocking density (kg m^{-3})	D = B / available volume
Average weight increase (g)	GPM = AWF (g) – AWI (g)
Average daily weight increase (g day^{-1})	GPMQ = (AWF – AWI) / number of days
Feed conversion ratio	FCR=QA/ B
Specific growth rate (% day^{-1})	SGR = 100 x [ln (final weight) – ln (initial weight)] / trial duration (in days)
Condition factor	CF = AW x 100 L^{-3}

AW-average weight; QA-quantity of distributed feed; B-biomass; F-final; I-initial; L-fish length (cm); Pt-total fish weight (g).

Effect of seasonality on growth performance of S. aurata. To meet the required answers to the question, four production cycles (cycles 1, 3, 4, and 5) of fingerlings were performed starting at different seasons of the study. For duplicate objectives in each cycle, two cubic cages, and two circular floating cages of 12 m of diameter were used for pre-on-growing stage and for on-growing stage experiments respectively. A total number of 25,000 *S. aurata* fingerlings with an initial average weight of 3.95±0.47 g, and initial mean length of 5.96±0.39 cm, was brought from a French commercial hatchery, and were introduced to 2 pre-on-growing cubic cages at 4 different stages of the experiment (march 2018, September 2019, January 2020, and July 2020), corresponding to 4 different seasons of fingerling introduction into the pre-on-growing cages or treatments (spring (C1-Spr), autumn (C3-Aut), winter (C4-Win), and summer (C5-Sum)). In each cage, the initial stocking density was 250 fingerlings m^{-3} and the initial load was 0.98 kg m^{-3} (Table 2). After a four-month of pre-on-growing stage, the fish specimens were transferred to the on-growing circular cages of 12 m of diameter using an initial stocking density of 45 fishes m^{-3} and 1.8 kg m^{-3}, and reared until reaching a commercial size of 500 g (as shown in Table 2).

Influence of stocking density on growth performance of S. aurata. Fingerlings with the same features as in the previous experiment were stocked in the offshore pre-growing cubic cages at a density of 250 fish m^{-3} and reared until reaching the mean individual body weight of 40 g. Then, they were transferred to the on-growing circular cages of 25 m of diameter as two treatments in duplicate using two different initial stocking densities (ISD) (Table 2): ISD1 (25 fish m^{-3}, and 1.2 kg m^{-3}) and ISD2 (35 fish m^{-3}, and 1 kg m^{-3}).

Feeding. Throughout all the rearing cycles of all treatments, and according to growth stage, fishes were fed until satiation with six kinds of commercial feed (1.3, 1.5, 2, 4, 5 and 6 mm) consisting of extruded floating pellet with contents of crude protein and fat of 41–56% and 15–20%, respectively (Table 4). The fish were handfed and by using blowing feeders. Feeding rates used were 5% per day during the pre-ongrowing stage, and then 2% per day during the ongrowing stages.

Table 4

Size and composition feed used in the rearing cycle

Phase	*Pellet size (mm)*	*FW (g)*	*Characteristics*					
			Protein (%)	*Fat (%)*	*Vitamins*			
					A (UI kg^{-1})	*D3 (UI kg^{-1})*	*E (mg kg^{-1})*	*C (mg kg^{-1})*
Pre-growing	1.3	4-10	56	18	10,000	1,750	200	300
	1.5	10-15	56	18	10,000	1,750	200	300
	2	15-50	48	15	10,000	1,750	200	300
On-growing	4	50-300	42	20	10,000	1,750	200	150
	5	300-450	42	20	10,000	1,750	200	150
	6	>450	41	19	8,000	1,400	160	90

FW-fish weight; CP-crude protein.

Monitoring seawater quality. The environmental parameters of temperature (T), pH, dissolved oxygen (DO) and salinity were measured daily using an EXO2 YSI multi-parameter sensor (manufactured by the YSI company, located in USA) installed at a water depth of 3 m and connected to an on-farm data logger. Data transfer from the logger to the PC was scheduled on an hourly basis.

Statistical analyses. All analyses results were presented as mean values ± SE. Descriptive statistics and statistical analyses were conducted using IBM SPSS 24 statistical software (version 11.5). The normality and equality of variance of the data were analyzed by Shapiro–Wilk normality test and Levene's test, respectively. Differences in the results between seasonality and stocking density were tested using ANOVA, followed by multiple comparisons of the mean group using a Tukey test. Regression analyses were used to test the relationships between the variables.

Results

Physico-chemical seawater parameters. During the course of the study, various water variables such as temperature, oxygen levels, salinity and pH values were measured and presented in Figure 1. Water temperature ranged from 16.73±0.36°C in January 2020 and 23.72±0.22°C in September 2021, with an average of 20.99±1.64°C. The monthly average temperature (Figure 2) typically followed a similar pattern each year ($p>0.05$), with the highest temperatures recorded from June to September, and the lowest in January.

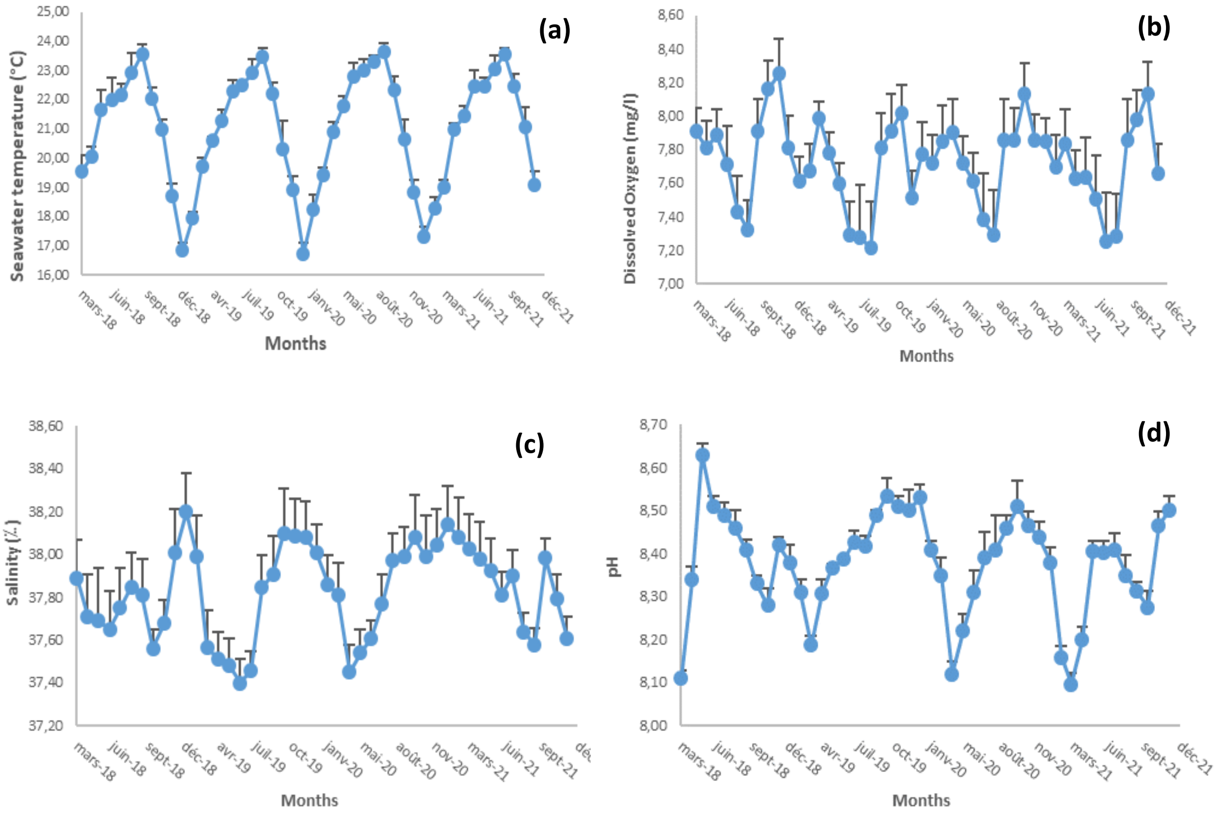


Figure 1. Monthly water parameters a: water temperature, b: oxygen, c:pH and d:salinity from March 2018 to December 2021.

The levels of dissolved oxygen, salinity and pH values varied from 8.63±0.21 to 7.28±0.31 mg L^{-1} (mean: 7.72±0.41 mg L^{-1}), 38.20±0.13 to 37.41±0.18‰ (mean: 37.82±0.33‰) and 8.63±0.05 to 8.09±0.07 (mean: 8.37±0.07), respectively.

Effect of seasonality on growth performance of S. aurata. At the beginning of the trial, all fingerlings imported for this experiment and reared in cages were homogeneous, in terms of body weight and length (3.95±0.47 g and 5.96±0.39 cm, respectively, $P<0.01$). The growth weight, average weight gain, specific growth rate (SGR) and feed conversion rate (FCR) of gilthead seabream across the four seasons are presented in Figure 3. The comparison of growth performance data between the four seasons for the different treatments is shown in Table 5.

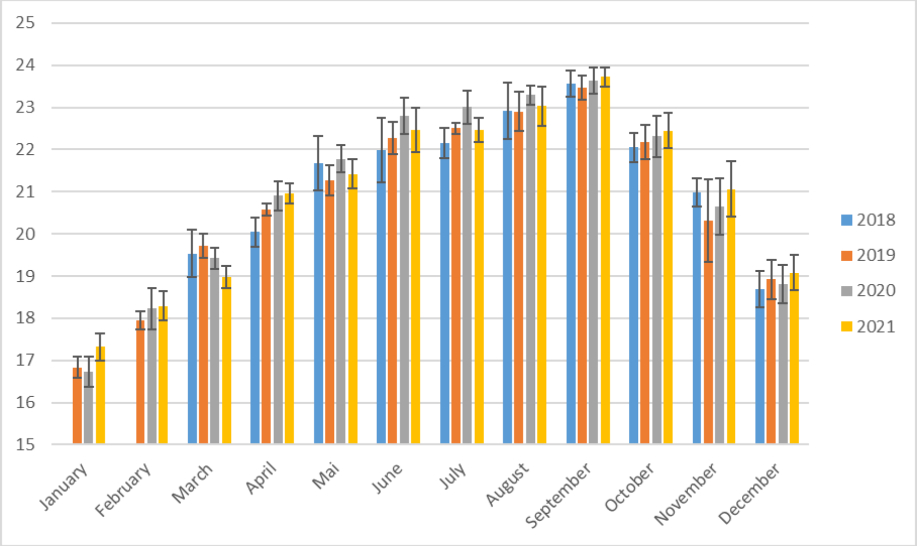
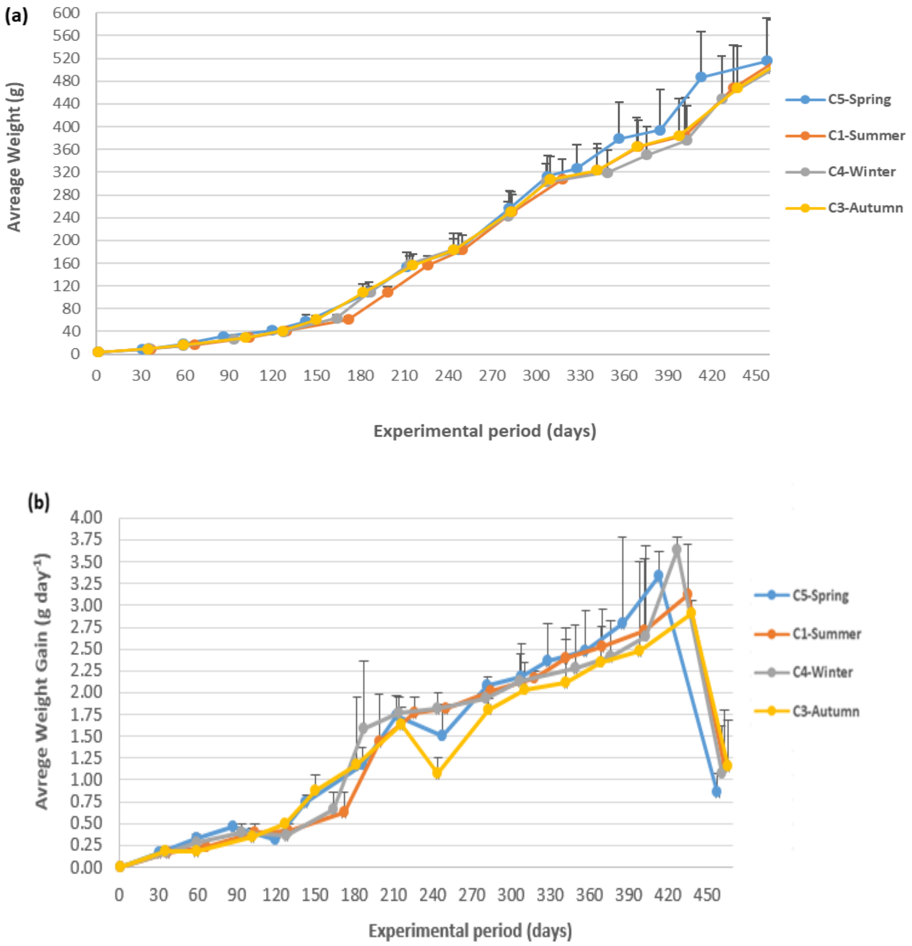


Figure 2. Changes in the monthly average temperature (°C) in Dakhla bay during the study period.



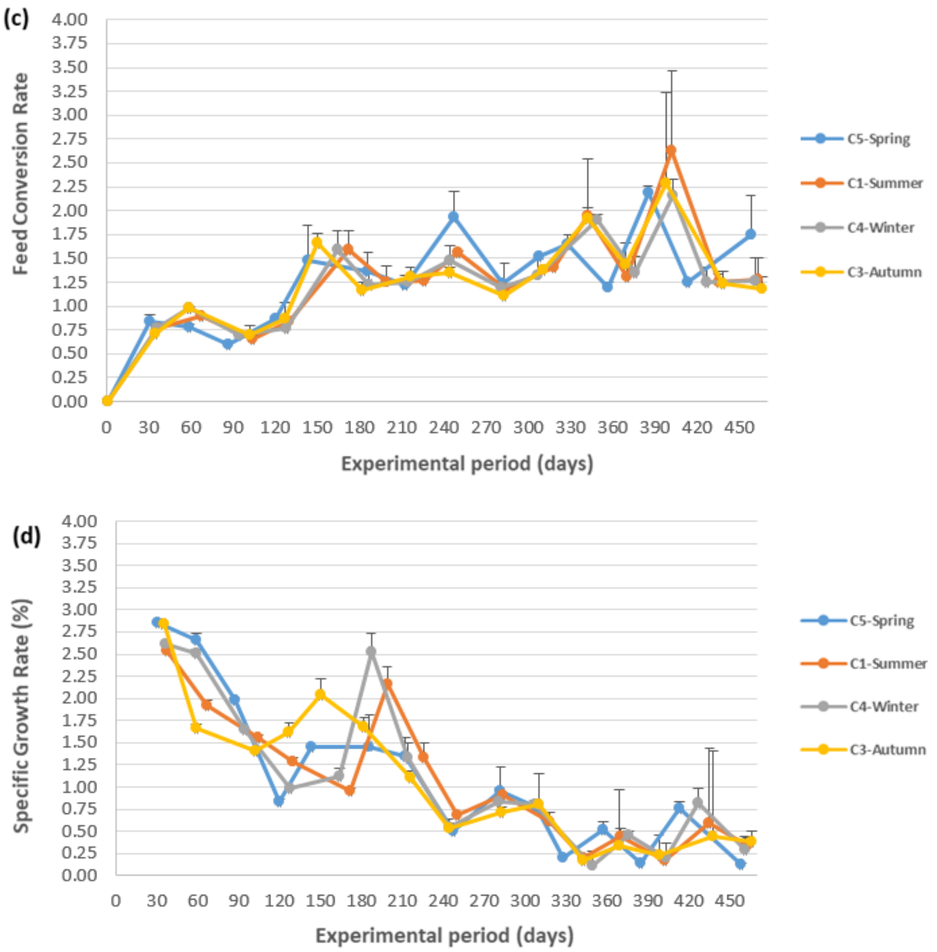


Figure 3. Comparison of the effect of fry import season on the evolution of growth performance: Average weight (a), Weight Gain per day (b), Feed conversion rate (c) and Specific growth rate (d), from March 2018 to December 2021. (C: cycle).

The values of average weight gains per day (WG), the specific growth rate (SGR), the feed conversion rate (FCR) and condition factor were similar and changed in the same way for all the treatments (P>0.05). They ranged between 1.12±0.21 to 1.09±0.19 (g day^{-1}), 1.08±0.15 to 1.05±0.12 (%), 1.33±0.09 to 1.31±0.05 and 1.90±0.05 to 1.75±0.06, respectively.

At harvest, all groups reached a final commercial weight of 458 to 515 g (p>0.05). However, the mortality rates were higher at the beginning of the rearing period following the transport of the juveniles to the cages. At subsequent stages, mortality was decreased, and no obvious disease syndromes were evident. The survival rate values observed for all groups were between a minimum of 86.93±0.47 % and a maximum of 88.73±0.37 % (Table 5).

Table 5

Seasonal comparisons of growth parameters of *Sparus aurata* reared in floating cage

Parameters	*Cycle-Season*				*P-value*
	Cycle 5-Spring	*Cycle 1-Summer*	*Cycle 4-Autumn*	*Cycle 3-Winter*	
Average initial weight (g) ± SE	3.67±0.51^{a}	3.68±0.53^{a}	3.70±0.48 ^{a}	3.68±0.63 ^{a}	0.171
Initial size (cm) ± SE	6.23±0.53^{b}	5.99±0.81^{b}	6.03±0.63 ^{b}	5.87±0.41 ^{b}	0.082
Period of rearing (day)	458^{c}	463^{c}	457 ^{c}	458 ^{c}	0.091
Average final weight (g) ± SE	516.15±86.79^{d}	513.91±84.22^{c}	506.66±88.83^{d}	511.59±88.53^{d}	0.063

Parameters	*Cycle-Season*				*P-value*
	Cycle 5-Spring	*Cycle 1-Summer*	*Cycle 4-Autumn*	*Cycle 3-Winter*	
Final size (cm) ± SE	29.99±6.09^{e}	30.75±2.84^{e}	30.19±3.15^{e}	31.09±4.01^{e}	0.089
Average Weight gain (g day^{-1}) ± SE	1.12±0.21^{f}	1.09±0.19^{f}	1.10±0.10^{f}	1.11±0.13^{f}	0.071
Feed conversion rate ± SE	1.33±0.15^{h}	1.33±0.09^{h}	1.32±0.11^{h}	1.31±0.05^{h}	0.091
Specific growth rate (% day^{-1}) ± SE	1.08±0.15^{j}	1.07±0.11^{j}	1.05±0.12^{j}	1.07±0.32^{j}	0.078
Condition factor ± SE	1.90±0.05^{k}	1.75±0.06^{k}	1.82±0.02^{k}	1.85±0.08^{k}	0.059
Final stocking density (kg m^{-3}) ± SE	20.27±0.67^{m}	19.99±0.81^{m}	19.22±0.21^{m}	19.88±0.41^{m}	0.101
survival rate (%) ± SE	88.73±0.37^{p}	87.91±0.41^{p}	86.93±0.47^{p}	87.83±0.53^{p}	0.089

Values in same rows marked with different letters are significantly different ($p<0.05$).

Influence of stocking density on the growth performance of S. aurata. At the end of this experiment, the growth parameters were compared for the two stocking densities ($p<0.05$), with ISD 1 (25 fish m^{-3}) having the highest performances (average weight gain, the specific growth rate, the feed conversion rate, the condition factor and the rearing period) throughout the experiment compared to those at ISD 2 (35 fish m^{-3}) (Table 6).

Table 6

Growth parameters of *Sparus aurata* reared in floating cage at two different stocking density (ISD 1: 25 fish m^{-3} and ISD 2: 35 fish m^{-3}), from March 2018 to December 2021

Parameters	*Initial stocking density*		*P-value*
	LSD-25	*MSD-35*	
Average initial weight (g) ± SE	40.53±3.11 ^{a}	40.78±2.86 ^{a}	0.123
Initial size (cm) ± SE	11.85±1.05 ^{a}	12.25±1.33 ^{a}	0.098
Period of rearing (day)	284 ^{a}	278 ^{b}	0.041
Average Final weight (g) ± SE	516.4±43.15 ^{a}	508.05±60.21 ^{a}	0.201
Final size (cm) ± SE	30.19±3.07 ^{a}	29.79±2.95 ^{a}	0.181
Average Weight gain (g day^{-1}) ± SE	1.68±0.61 ^{a}	1.67±0.62 ^{b}	0.038
Feed conversion rate ± SE	1.23±0.02 ^{a}	1.18±0.02 ^{b}	0.041
Specific growth rate (% day^{-1}) ± SE	0.89±0.05 ^{a}	0.95±0.07 ^{b}	0.035
Condition factor ± SE	2.33±0.48 ^{a}	2.09±0.61^{b}	0.021
Final stocking density (kg m^{-3}) ± SE	10.8±0.12 ^{a}	16.48±0.21 ^{b}	0.019
Survival rate (%) ± SE	97.14±0.15 ^{a}	96.76±0.25 ^{b}	0.023

Values in same rows marked with different letters are significantly different ($p<0.05$).

The rearing period was affected by density, with durations of 284 days in ISD 1 and 278 days at ISD2. The variation in weight, as shown by the standard errors (Figure 4), was elevated and increased with time. There was a significant difference ($P<0.05$) in final stocking density, condition factor and feed conversion rate. These values ranged from 10.8±0.12 to 16.48±0.21 ($p=0.019$), 2.33±0.48 to 2.09±0.61 ($p=0.021$) and 1.23±0.02 to 1.18±0.02 ($p=0.041$), respectively (Table 6).

For all densities, the specific growth rate changed significantly during the experiment, with the highest values obtained at the beginning of rearing (during the first 90 days) and the lowest ones between day 91 and the harvest day. The effect of density on SGR was significant ($p=0.035$). On other hand, the survival rates were 97.14±0.15 and 96.76±0.25 at densities of ISD 1 and ISD 2, respectively. The growth performance observed in this experiment increased with a decrease of the stocking density, but the feed conversion rate increased linearly with a decrease of the stocking density (Table 7).

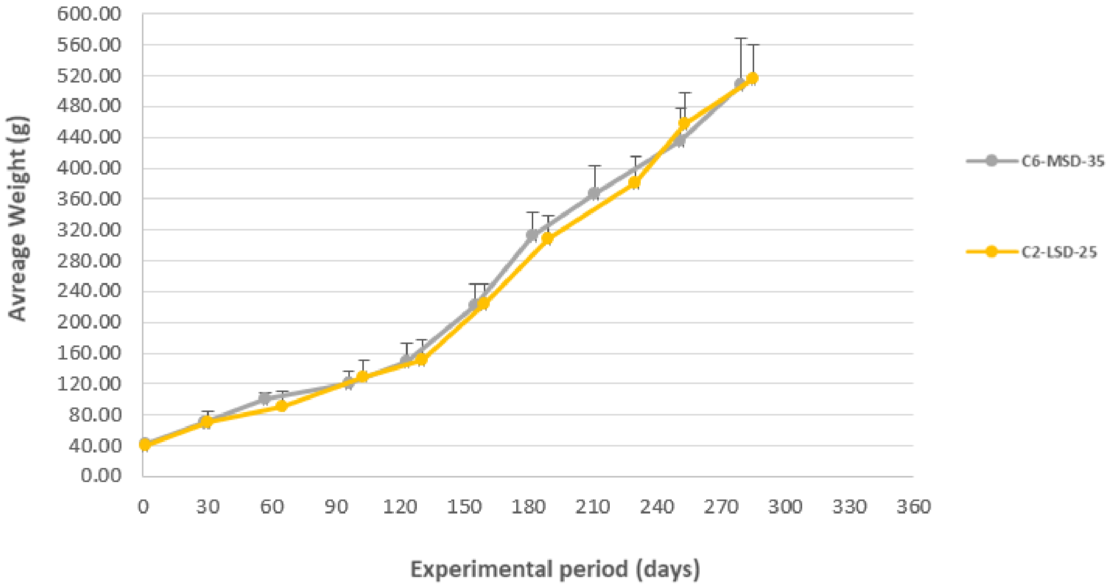


Figure 4. Comparison of the evolution of the average weight of *Sparus aurata* rearing in cages at two different stocking densities (ISD 1: 25 fish m^{-3} and ISD 2: 35 fish m^{-3}), from March 2018 to December 2021.

Table 7

Regression equations and coefficients (R2) of stocking density on growth performance

Main regression models	*R2*	*Adjusted R2*	*p-value*
WG=495.6 – 0.80 ISD	0.99	0.98	0.001
SGR=1.11 – 0.0075 ISD	0.70	0.69	0.041
CF=2.93 – 0.026 ISD	0.90	0.87	0.013
FCR=1.0158 + 0.0056 ISD	0.91	0.89	0.019

WG-weight gain; SGR-specific growth rate; CF-condition factor; FCR-feed conversion rate; ISD-stocking density.

Discussion. Previous trials already demonstrated, for the first time, that the growth of gilthead seabream is technically feasible and indicated the potential of Dakhla Bay for the development of marine fish farming (Gjije et al 2021; Izzabaha et al 2020). The present study is a logical continuation of previous work and is the first attempt to provide scientific data on the long-term and year-around growth performance for this species. The average daily temperature at the farm site ranged from 16.73±0.36°C to 23.72±0.22°C, with an average of 20.99±1.64°C and a temperature amplitude difference of around 7°C (Figure 1a). These temperatures fall within the optimal range for the growth of gilthead seabream (Person-Le Ruyet et al 2004). Notably, temperature amplitudes recorded in Dakhla Bay indicate more stable values around the mean than those in the Mediterranean, which range between 12.8 and 28°C in Nador (Morocco), 13.5 and 29°C in Tunisia, 18 and 27°C in Italy (Boussadia 2017; Vardar et al 2012; Llorente et al 2013). The optimal growth for *S. aurata* and sea bass occurs at temeratures around 24°C (Person-Le Ruyet et al 2004). Therefore, the time required to reach the harvest weight and the costs associated with fish farming vary across regions (Gasca-Leyva et al 2002). Llorente & Luna (2013) showed that the difference in water temperature between areas in the Mediterranean Sea is a significant source of competitive advantage for fish farms.

It is widely known that water temperature affects fish metabolism and many important physiological activities are highly dependent on environmental parameters (Rigos et al 2011; Vargas-Chacoff et al 2009). The optimum temperature range for *S. aurata* has been reported to be between 20°C and 25°C (Bonaldo et al 2010; Martinez-Llorens et al 2009; Sanchez-Lozano et al 2007; Sicuro et al 2010; Velazquez et al 2006a,b). Ibarz et al (2010) reported that at low temperatures (8–12°C), *S. aurata* may experience weight loss of 6.3–18%. Extreme water temperatures during the summer (27°C) exceed the optimal requirement levels of *S. aurata*, leading to sub-optimal levels of feed utilization, growth performance and fish survival rates (Jobling 1996). Based on the present study, we conclude that the average temperature of the Dakhla bay is optimal and positively meets the requirements of the gilthead seabream.

During the study period, the Dakhla Bay showed an annual average dissolved oxygen content of 7.72±0.41 mg L^{-1}, with measurements ranging from 8.25±0.21 and 7.28±0.31 mg L^{-1}. These values are within the recommended range for seabream cage farming possibly due to the high chlorophyll levels in the Bay, that have been reported by Gjije et al (2021); Saad et al (2022); Hilmi et al (2017); Berraho et al (2019) and Izzabaha et al (2020).

Salinity monitoring showed that this parameter remained almost constant during the study period (Figure 1c), with some fluctuations falling within the optimal range of 38.20±0.13 and 37.41±0.18‰, at the farming site. The recorded average salinity values correspond to the optimal range required for gilthead seabream growth, which typically falls between 30‰ and 39‰ (CNEO 1983).

The pH in the Dakhla bay varied from 8.63 to 7.28, with an annual average of 7.72±0.16 (Figure 1d). These pH values fall within the favorable range of 7.5 to 8.5 for fish farming (Hellin 1986), without reaching lethal levels.

Based on the recorded physicochemical parameters, such as temperature, salinity, pH and dissolved oxygen in Dakhla bay, it can be concluded that their values fall within the required ranges for *S. aurata* farming, and have been shown to be advantageous for growth performance (CNEO 1983; Hellin 1986). Furthermore, this study did not observe a significant effect of season on the growth performance in fish reared during different seasons. The four rearing cycles (summer, autumn, winter and spring) reached a harvest weight of more than 500 g in 15 months, with an average daily gain ranging between 1.12±0.21 and 1.09±0.19 g day^{-1}. This could be attributed to the thermal profile and the monthly thermal differences observed in Dakhla Bay during the study period.

The growth rate of fish is considered a crucial factor for fish farmers and is consistently a part of the rearing objectives, as stated by Sae-Lim et al (2012) and Besson et al (2016). A lower amplitude in temperature variability can reduce the periods during which fish are exposed to an extreme temperature of 27°C, (which leads to reduced growth) (Besson et al 2016). The body size also plays a crucial role in the effect of temperature on fish growth because at the optimal temperature for growth, food conversion decreases with an increase of the body size (Àrnason et al 2009). In most fish species, individual growth rates are mainly determined by temperature, as reported by Pauly (1980), Björnsson & Steinarsson (2001), Buckley et al (2004) and Britton et al (2010). Thus, understanding the implications of temperature on growth could lead to a better forecasting of the stock biomass (Baudron et al 2013).

It is interesting to note that the specific growth rates and feed conversion rates observed in the present study are higher than those reported by Şahin et al (1997) and Şahin et al (1999). This could be due to differences in the culture conditions, such as the water temperature and quality, feed composition and feeding management, among others. Additionally, it is worth mentioning that the present study was conducted over a longer period, of 15 months, compared to 6 months and 13 months in the studies of Şahin et al (1997) and Şahin et al (1999), respectively. This longer rearing period could have allowed for better growth performance and utilization of feed. Overall, the results of this study suggest that the farming of gilthead seabream in Dakhla Bay is highly favorable, with stable environmental conditions that promote good growth and feed conversion rates.

In the Aegean Sea, it has been reported that gilthead seabream can reach a final weight of 355–400 g during a 16 months rearing period, with mortality rates ranging from 5.20 to 18.10% and feed conversion ratios of 1.87–2.08 (Atalay 2011). In another study conducted in the Aegean Sea over a 390-days period, cage-farmed *S. aurata* weighting 71.4–78.9 g reached a final weight of 305.4–425.2 g, with feed conversion ratios of 2.37–2.04 (Vardar & Yıldırım 2012). Petridis & Rogdakis (1996) reported that *S. aurata* reached 335 g after 420 days of feeding in net cages in the Aegean Sea, and the average feed conversion ratio was of around 2.5. The differences in feed conversion ratios between these findings and our study could be attributed to the differences in fish weight, quality and type of diets, stocking density, fish welfare and culture conditions such as water temperature, oxygen, salinity or a combination of these factors.

During the study, no differences in the condition factor and survival rate were observed between seasons. The condition factor values ranged between 1.90±0.05 and 1.75±0.06, while the survival rate ranged between 88.73±0.37% and 86.93±0.47%. The high survival rate and the exceptional condition factor observed in this study could possibly be explained by the quality of feed, water temperature and high dissolved oxygen (Dosdat et al 1984; Doménech et al 1997). However, extreme water temperatures during the summer (27°C) exceeded the optimum levels required for the gilthead seabream culture, resulting in lower levels of feed utilization, growth performance and survival rate (Jobling et al 1996). Cabello (2000) pointed out that if the condition factor ranged between 1.5 and 1.6, then the fish reared in captivity would receive an adequate feed ration. Higher values would indicate that fish are reared under exceptional conditions, and if its values were less than 1.5, this would indicate underfed fish. Yıldız et al (2006) reported that the condition factor of cultured gilthead seabream ranged from 1.7 (fish weight of 307.7±5.1) to 2.3 (fish weight of 397.5±6.0) in the Aegean Sea, with an average water temperature of 15°C in winter, 18°C in spring and 27°C during the summer season. In contrast, a study conducted in the Black Sea reported an average condition factor of 1.61 for *S. aurata* (Şahin et al 1997).

In terms of the effect of initial stocking density on growth parameters of *S. aurata*, a significant difference was observed between initial stocking density 1 (ISD 1: 25 fish m^{-3}) and initial stocking density 2 (ISD 2: 35 fish m^{-3}). The results of this experiment clearly indicated that a decreased initial stocking density improved the growth parameters.

The growth rate observations in this experiment indicated that fish cultured at high densities (ISD 2) were characterized by a coefficient of variation of the order of 11.28%, compared to fish cultured at low initial stocking densities (ISD 2), whose coefficient of variation value was of 8.36%. This is probably one of the reasons justifying the low performance observed in fish in ISD 2 (35 fish m^{-3}) culture compared to fish in ISD 1 (25 fish m^{-3}). The decrease in growth rate associated with an increase in density of the farmed fish can cause a decrease in the average adult fish size (Ellis et al 2002; North et al 2006; Papoutsoglou et al 2006).

A high density can harm fish nutrition and ultimately their growth (Ellis et al 2002), even in the absence of aggressive interactions. Detecting and achieving food particles can be difficult when too many congeners block the sight and passage (Schram et al 2006). Dominant individuals prevent others from feeding, which generates variability in growth (Jobling 1995; North et al 2006). Variability in sizes often increases with density (Rubenstein 1981; Irwin et al 1999; Papoutsoglou et al 2006; Schram et al 2006) and it appears that the effect caused by the latter differs greatly from one individual to another (Kristiansen et al 2004). The increase in social interactions is often considered the main cause of the decline in growth of fish kept at high density (Wedemeyer 1997; Wendelaar-Bonga 1997; Sloman et al 2000).

This finding agrees with the growth reported for sea bass (Papoutsoglou et al 1998) and Arctic charr (Wallace et al 1988; Jorgensen et al 1993). High stocking decreased the growth in some fish species due to different factors such as decreased food consumption and social interactions (Wedemeyer 1997). Previous studies with stocking density of *S. aurata* reported that the growth decreased with an increase of the stocking density (Roncarati et al 2006). However, other studies with *S. aurata* showed that an increasing stocking density (at 45, 50 and 55 fish m^{-3}) didn’t affect the growth performance (Montero et al 1999; Yilmaz et al 2010).

Based on the study, the daily weight gains and average weight gain and the final size were similar in the ISD1-25 and ISD-2 groups. However, the study also highlighted the need for further research to better understand the effect of schooling intensity and feeding behavior on the studied specimens’ energy, in cage conditions. In terms of stocking density, the variation range was narrow and the density values were within the fish welfare densities.

Conclusions. *S. aurata* showed a good performance with high survival rates during all import season in the Bay Dakhla - Southern Morocco. Water temperature in Bay Dakhla was the main factor affecting positively the growth performance. On other hand, the results of the present study with *S. aurata* show that the stocking density of 25 fish m^{-3} cause an improved growth performance, while the period of rearing observed in this experiment for both densities was of only 11 months to reach 500 g (in average weight) at the harvest. Under high initial stocking density (ISD 2), competition between fish increases, which negatively affects the growth performance, including the heterogeneity of fish population at harvest, and this was confirmed by the coefficient of variation observed at end this experiment. The results of this study may encourage the development of fish farming on the Atlantic coast of Morocco, particularly for rearing gilthead seabream. This has the potential to contribute to the socio-economic development of the Dakhla Oued Eddahab region.

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