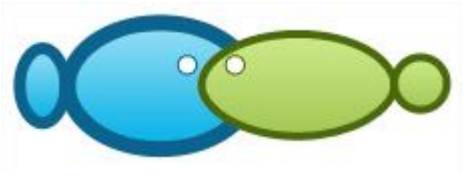

A comparative study on the effects of seawater and underground saltwater on water quality, growth, feed utilization, fish biomass, digestive system development, and blood health in gilthead seabream, *Sparus aurata*

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Abstract. A study was performed to evaluate the effects of different water sources on *Sparus aurata* farms' success level. Fish (11.0 g) were reared in (T1) concrete tanks using seawater, (T2) concrete tanks using underground saltwater, and (T3) fish cages using saltwater lake at the same stocking density. Fish were fed a pelleted diet (45/15 protein/lipid) for 240 days. Growth, survival, feed utilization, HSI, VSI, digestive system development, and blood health were evaluated. The results of water quality parameters showed significant ($p < 0.05$) variations of salinity, dissolved oxygen, NO_3, total nitrogen, PO_4, total phosphorus, and chlorophyll-*a* among treatments. The growth performance, survival, feed utilization indices, VSI, HIS, and blood parameters exhibited the best values in T1 where *S. aurata* reared in seawater, followed by T2, and the worst results were detected in T3. Growth performance at T1 increased by 18.4 and 56.1% compared with T2, and T3, respectively. An improvement with 5% and 15.9% of FCR was detected at T1 compared with T2 and T3, respectively. Blood parameters (Hb, RBCs, WBCs, PCV) significantly ($p < 0.05$) increased at T2 and T3 compared with T1, while glucose readings were significantly ($p < 0.05$) increased at T1 compared with T2 and T3. Also, serum parameters (TP, cholesterol, triglyceride, urea, ALT, and AST) were significantly ($p < 0.05$) decreased at T1 compared with T2 and T3. A reduction with 25.4% and 31.8% of AST was detected at T1 compared with T2 and T3, respectively. These findings indicate that rearing *S. aurata* using seawater is better than underground saltwater and saltwater lake.

Key Words: feed utilization, growth, hematological parameters, HSI, *Sparus aurata,* VSI, water sources.

Introduction. As a member belonging to the family Sparidae, gilthead seabream/or sea bream (*Sparus aurata*) is prevalent in the Mediterranean and Black Seas and found over the eastern Atlantic coasts from the United Kingdom to Senegal. They have a wide range of salinity to live, so they are caught in both marine and brackish water zones like littoral lagoons and estuarine places (Borrego et al 2017). For the Mediterranean basin countries, *S. aurata* is an important species in both capture and aquaculture (Prestinicola et al 2013). Traditionally, its cultivation was carried out on a small scale, depending on the capture of wild juveniles to be reared in the lagoons, but for the time being, it is intensively cultured using net pens, particularly in the southern coastal waters of Europe (Laiz-Carrion et al 2005). *S. aurata* is a major contributor to aquaculture in Mediterranean countries. The global output has increased steadily from about 96,000 tonnes (T) in 2003 to account for 228,576 T in 2018, with a US$ 1.08 billion value. Turkey and Greece are the largest producers, and together they account for 72% of global production, then Egypt comes in third, with an amount of 29.994 T (FishstatJ 2018).

The successful artificial breeding of sea bream is dating back to1981-82 in Italy. Since then, the hatchery production and rearing of these economic species are among the booming stages of the aquaculture business (Zaki et al 2007). *S. aurata* rapidly

demonstrated high adaptability to the intensive breeding conditions in both cages and ponds, and its annual production took an upward trend until reaching the peak in 2018. Various ways can be used to cultivate sea bream, such as seaboard ponds and lagoons, through extensive and semi-intensive and intensive techniques. The intensive grow-out usually follows other phases of culture such as reproduction, larvae rearing, and pre-fattening. Intensive pre-fattening and grow-out stages can be performed in ground facilities with rectangular concrete tanks of varying sizes (200-3000 m^3) depending on fish size and production requirements. Furthermore, grow-out can occur in marine cages, either in protected or semi-exposed sites (floating cages) or open sites (semi-submerged or submerged cages) (Cardinal et al 2010; Azab et al 2015; Bakiu et al 2019).

For Egypt, aquaculture ranked 10th worldwide in 2016 with a share of 1.7 percent, which represents 1,371,000 ton of the global production (FAO 2018). Regarding the African continent, the Egyptian aquaculture sector is the largest of all. The involvement of all African States in the global aquaculture production reached 2.5% with a value of 1,982 million T in 2016; of this share, 0.68% returns to Egypt (FAO 2018). A significant development in the Egyptian aquaculture sector has occurred over the past four decades due to the rapid expansion that extends far beyond traditional fishing activities. However, the status of the mariculture sector is still weak so far, where the proportion of mariculture products of aquaculture in 2014 accounted for 38,032 T, representing 3.74% from the overall aquaculture production and 2.79% of the gross harvest from aquaculture and fisheries (GAFRD 2015; GAIN Report 2016).

S. aurata is one of the most important species produced in Egyptian fish farms and the catch from capture fisheries. According to GAFRD (2016), aquaculture contributed 80% of the total output of fish in Egypt. After tilapia, carp, mullet, and catfish, seabream tops the most important cultured species in production and value. In 2016, it contributed about 27,579 metric T of the total output fish, of which 26,663 metric T came from aquaculture, while the rest is divided into 344 and 572 of the Mediterranean Sea and lakes, respectively (GAFRD 2016). In Egypt, *S. aurata* is cultured in sea cages along the northern coast of the Mediterranean and Northern lakes such as Lake Mariout and Bardawil. Moreover, farms where they are raised, are concentrated along the Northern coast alongside the extension of the Suez Canal, whether they are private or tracking with mega government projects such as the fish farming project in Canal Zone, Galion project in Kafr El-Sheikh, and fish farming project in Port Said (GAIN Report 2016; Shaalan et al 2018).

According to the water quality standards, semi-intensive and intensive systems are applied, whether in cages, earthen ponds, and concrete ponds. As *S. aurata* can be grown in a wide range of salinity, various ways are practiced, depending on the available water sources (Altan 2020). The present trial investigates water source influence used on the growth rates, feed efficiency, fish yield, blood health, gastrointestinal development in *S. aurata*, reared under marine lake water, underground saltwater, and seawater.

Material and Method

Experimental site and fish. This study was carried out at a private fish farm concerning *S. aurata* fish cages, Wadi Maruit mariculture area, Alexandria, and the Marine Fish Hatchery (K21) involving *S. aurata* ponds, Alexandria, Egypt, during a period of 240 days, from 1st August 2020 to 1st April 2021. Apparent healthy 27,000 *S. aurata* juveniles with an average initial body weight of 11.0±0.25 g $fish^{-1}$ and an average total length of 5.8±0.3 cm were used in this experiment. Fingerlings were acclimatized for 14 days in the fish production units. Fish juveniles were stocked at a 3000 juvenile $cage^{-1}$ or tank with ten fish m^{-3}. Each tank was supported with continuous artificial aeration with a paddle wheel (1.5 kw).

Experimental design. This experiment was designed to evaluate three methods of farming *S. aurata* using different water sources in Egypt. The three experimental groups were as follows:

T1: *S. aurata* juvenile (11±0.25 g) reared in three cement fish tanks, each 300 m^3 water volume (diameter 16 m x 1.5 m depth), the water source is seawater with salinity varying between 36 and 37 ppt;
T2: *S. aurata* juvenile (11±0.25 g) reared in three cement fish tanks, each 300 m^3 water volume (diameter 16 m x 1.5 m depth), the water source is underground saltwater with salinity varying between 36 and 38 ppt;
T3: *S. aurata* juvenile (11±0.25 g) reared in three fish cages, each 300 m^3 water volume (10 x 20 x 1.5 m), the water source is a marine lake (wadi Mariut Lake) with salinity varying between 10 and 18 ppt.

In T3, water comes out continuously from the ground with continuous running water. In T1 and T2, the daily water change rate was 25% per day.

Feeding protocol. Fish were fed on the extruded diets containing 45/15% protein/fat ratio produced by ALLER AQUA FEED (https://www.aller-aqua.com/), three times daily (8.00, 12.00, 16.00, hrs.) according to the recommended feeding level from the producing company. Feed proximate analyses were 45, 15, 2.8, 7.2, 22%, and 20.9 MJ for crude protein, crude fat, fibre, ash, NFE, and gross energy. The daily feeding rates were adjusted according to fish live body weights every two weeks. Pellet diameter was 1.5-, 2-, and 3-mm during experimental months 1-2, 3-5, 6-8, respectively.

Measured parameters

Water quality parameters. Water quality parameters were measured three times during the beginning, middle, and end of the experimental period, including salinity, water temperature, pH, dissolved oxygen, and ammonia.

Growth performance parameters and survival percentage. Periodical samples (Figure 1) of fish were taken every 15 days to estimate the growth performance in weight and length. Final body weight (FW), weight gain (WG), average daily gain (ADG), specific growth rate (SGR), survival %, length, length gain, and condition factor were conducted according to the following equations:

$$\text{Weight gain (g fish}^{-1}\text{)}: WG = W_t - W_0$$

where: W_0 = the initial mean weight of fish in grams;
W_t = the final mean weight of fish in grams.

$$\text{Average daily gain (g fish}^{-1}\text{ day}^{-1}\text{)}: ADG = W_t - W_0/n$$

where: n = duration period.

$$\text{Specific growth rate (\% day}^{-1}\text{)}: SGR = 100 \times [(\ln W_t - \ln W_0)/\text{days}]$$

where: ln = natural logarithm.

$$\text{Length gain (cm)} = L_t - L_0$$

where: L_0 = initial mean length of fish in cm;
L_t = final mean length of fish in cm.

$$\text{Condition factor} = 100 \times (\text{BW (g)}/L^3\text{ (cm)}$$

$$\text{Survival (\%)} = 100 \times (\text{final number of fish/initial number of fish})$$

Feed and nutrient utilization parameters.
Feed intake (g/fish): The amount of feed given or supplied during the experimental period/fish (g).
Feed conversion ratio (FCR) = feed intake (g)/weight gain (g).
Protein efficiency ratio (PER) = gain/protein intake.
Protein productive value (PPV %) =100 × gained protein /protein fed.
Energy retention (ER %) = 100 × gained energy/energy fed.

The protein efficiency ratio, protein productive value, and energy retention were made according to Nose & Arai (1973).

Fish and feed analytical methods. At the beginning and the end of each experiment, fish and feed samples were taken to determine the proximate analyses of diets and fish body, including moisture, protein, lipid, and ash contents. One sample of fish larvae on the day of stocking was taken randomly for body chemical analysis. Whole fish body moisture, crude protein, and crude fat contents on a dry matter basis were determined according to AOAC (2000).

The gross energy (GE) content of the diets was estimated according to the following equation:

Feed gross energy (GE) (kcal/100g DM) = (protein content x 5.64) + (lipid content x 9.44) + (carbohydrate (NFE) content x 4.11) (NRC 1993).

Biometric indices. At the end of this experiment, four fish (Figure 1) from each treatment were sacrificed to obtain their final biological records, including liver and viscera weights to determine hepatosomatic (HSI) and viscerosomatic (VSI) indices, as follows:

Hepatosomatic index, HSI = 100 * [liver weight (g)/total body weight (g)] according to Schreck & Moyle (1990);

Viscerosomatic index, (VSI) = 100 * [total weigh of all viscera (g)/total body weight of the fish before removal of the viscera (g)]

Blood sampling. The blood samples were collected from the caudal vertebral vein (Figure 1). Hemoglobin concentration was determined using the cyanomet hemoglobin method Drabkin's solution, according to Stoskopf (1993). The cyanomet hemoglobin method converts all hemoglobin derivatives to methemoglobin using ferricyanide and cyanide ion. Methemoglobin is a stable red compound and can be measured calorimetrically. The erythrocytes (RBC_S) and leukocytes (WBC_S) were counted according to the method described by Stoskopf (1993) using a hemocytometer and Natt-Herrik solution. According to Dacie & Lewis (1991), the microhematocrit method was used to estimate the PCV%. Thin blood films were obtained, air-dried, fixed with methanol for 3-5 min. They were stained with Gimsa stain for 8-10 min. Then they were rinsed with distilled water and left to dry. The white blood cells were counted among one hundred blood smears, according to Stoskopf (1993).

Blood serum biochemical analysis. Glucose level (mg/100 mL) was determined using glucose enzymatic PAP (Trinder 1969) kits obtained from Bio-Merieux (France). According to Doumas et al (1981), serum total proteins were determined at the wavelength of 540 nm. Serum albumin was estimated colorimetrically at wavelength 550 nm according to Dumas & Biggs (1972). Cholesterol (CHL) and triglyceride (TG) were determined with GPO-PAP and CHOD-PAP (commercial clinical kit) methods, respectively, according to Fynn-Aikins et al (1992). Activities of aspartate aminotransferase (AST) and alanine aminotransferase (ALT) were determined colorimetrically at the wavelength 540 nm (Reitman & Frankel 1957). Urea (mg dL^{-1}) was quantitatively estimated according to the method of Henry (1964).

Statistical analysis. Mean values and standard error of the mean (mean±SEM) for each parameter were first calculated. The results were subjected to statistical analysis, one-way analysis of variance (ANOVA), using SPSS software program, Version 22, to test the effect of treatments on water quality, survival, growth performance, feed utilization, digestive system development, and blood analyses. Differences between means were compared using Duncan according to Steel & Torrie (1980) using SPSS (version 22).

To seabream cages

Seabream samples

Seabream sample for morphometric measurements

Taking blood and dissection samples

Dissection samples

Digestive morphometric measurements

Figure 1. Field photos of the experimental team during visiting fish cages and taking seabream samples, blood samples, and morphometric measurements.

Results. The results of water quality parameters showed significant ($p < 0.05$) variations of salinity, dissolved oxygen, NO_3, total nitrogen, PO_4, total phosphorus, and chlorophyll-*a* among treatments. Measured parameters of salinity, dissolved oxygen, PO_4, total phosphorus, and chlorophyll-*a* showed no significant differences ($p > 0.05$) between T1 and T2.

Table 1

Water quality parameters in gilthead seabream, *Sparus aurata* rearing units with different water sources over 240 days trial period. Data are means (3 readings) ±SEM

Parameters	*Treatments*		
	T1	*T2*	*T3*
Salinity (ppt)	36.2±0.17^{a}	37.6±0.26^{a}	14.0±2.31^{b}
Temperature (^{o}C)	24.15±0.89	24.35±1.24	22.65±3.55
DO_2	6.45±0.26	6.35±0.21	7.95±1.88
pH	8.11±0.02	8.01±0.06	8.03±0.16
NH_3 (mg L^{-1})	0.055±0.01	0.080±0.02	0.050±0.02
NO_2 (mg L^{-1})	0.050±0.01	0.070±0.01	0.065±0.03
NO_3 (mg L^{-1})	0.305±0.04^{b}	0.570±0.11^{a}	1.095±0.26^{a}
Total nitrogen (mg L^{-1})	0.505±0.07^{b}	0.820±0.17^{a}	1.300±0.31^{a}
PO_4 (mg L^{-1})	0.090±0.02^{b}	0.165±0.04^{ab}	0.305±0.07^{a}
Total phosphorus (mg L^{-1})	0.19±0.02^{b}	0.51±0.06^{b}	1.36±0.35^{a}
Chlorophyll-*a* (µg L^{-1})	4.5±2.02^{b}	19.5±4.33^{b}	101.0±31.18^{a}

The values with a different superscript in the same column differ significantly ($p < 0.05$). Where, T1 - seabream (SB) reared in seawater tanks; T2 - SB reared in underground saltwater tanks; T3 - SB reared in a saltwater (underground) lake in fish cages.

The growth results and feed utilization of *S. aurata* fingerlings with an average initial body weight of 11.0±0.25 g fish^{-1} and an average total length of 5.8±0.3 cm, raised for eight months, under three water sources revealed significant differences as shown in Table 2. Concerning to growth parameters, the highest values were recorded for fish raised in T1, where the FW was 89.11 g, WG was 78.11 g, SGR was 0.872, ADG was 0.33, and survival rate was 99.83%. On the other hand, the lowest values of FW (57.07), WG (46.07), SGR (0.685), ADG (0.19), and survival rate (82.33) were recorded for fish raised in cages with salty groundwater in the lake. For the whole fish biomass per unit, the highest fish biomass value of 889.7 g m^{-3} was recorded for fish reared in seawater tanks, while the lowest value of 470.37 g m^{-3} was recorded for caged fish. The growth indicators of fish raised in underground saltwater tanks changed within the other two groups' growth values with a significant difference ($p < 0.05$) compared with the seawater tanks fish and cages fish.

Table 2

Growth performance, biomass, survival rate, and feed utilization of gilthead seabream, *Sparus aurata* reared under different water sources over 240 days. Data are means±SEM

Parameters	*Treatments*		
	T1	*T2*	*T3*
FW (g)	89.11±1.24^{a}	75.23±2.87^{b}	57.07±2.51^{c}
Gain (g)	78.11±1.33^{a}	64.23±2.99^{b}	46.07±2.42^{c}
ADG (g fish^{-1} day^{-1})	0.33±0.01^{a}	0.27±0.01^{b}	0.19±0.01^{c}
SGR (% day^{-1})	0.872±0.011^{a}	0.801±0.021^{b}	0.685±0.016^{c}
Survival (%)	99.83±0.10^{a}	97.50±0.29^{b}	82.33±1.45^{c}
Fish biomass (g m^{-3})	889.7±13.2^{a}	733.7±30.1^{b}	470.3±26.8^{c}
FCR (g)	1.74±0.01^{c}	1.83±0.01^{b}	2.07±0.03^{a}
PER (g)	1.27±0.01^{a}	1.21±0.01^{b}	1.07±0.01^{c}
PPV (%)	23.51±0.12^{a}	21.02±0.26^{b}	16.49±0.17^{c}
Energy gain (Kcal)	132.15±2.62^{a}	108.26±4.85^{b}	72.32±2.96^{c}
Energy utilization (%)	19.32±0.08^{a}	18.29±0.12^{b}	15.08±0.c

The values with a different superscript in the same column differ significantly ($p < 0.05$). Where, T1 - seabream (SB) reared in seawater tanks; T2 - SB reared in underground saltwater tanks; T3 - SB reared in a saltwater (underground) lake in fish cages.

Regarding the feed utilization of *S. aurata* juveniles, the recorded results showed a significant difference in FCR between the tested treatments. The best FCR was obtained with fish reared in seawater tanks (1.74), followed by fish raised in underground

saltwater tanks (1.83), while the worst FCR value was recorded for fish raised in cages (2.07). The PER, PPV, energy gain, and energy utilization values changed significantly between treatments. The highest PER, PPV, energy gain and energy utilization values were recorded for fish grown in seawater tanks and came 1.27, 23.51, 132.15, 19.32, respectively. The significantly worst PER, PPV, energy gain, and energy utilization values ($p < 0.05$) were recorded for the cage fish with the underground saltwater and represented 1.07, 16.49, 72.32, 15.08, respectively.

Morphological digestive system parameters. The effects of the water source on *S. aurata* raised in the three experiments are shown in Table 3. The presented data manifest the significant impact of water source VSI, HIS, intestine length/total length, and gut length/intestine length in the three fish groups. The highest VSI was recorded for fish raised in underground saltwater tanks and fish reared in seawater tanks, respectively, with no significant differences. The HSI indicators recorded significant differences between the three groups of fish. The highest value was 1.87 with fish reared in seawater tanks, while the lowest was 1.17 with fish raised in cages. The intestine length/total length ratio was differentiated significantly in favor of fish reared in seawater tanks with a mean value of 147.1. In contrast, the percentage of gut length/intestine length showed significant differences between the three groups. The highest value was 24.2 with fish raised in cages, while the lowest was 11.8 with fish grown in underground saltwater tanks.

Table 3

Morphological digestive system parameters of gilthead seabream, *Sparus aurata* reared under different water sources over 240 days. Data are means (3 readings) ±SEM

Morphological parameters, %	*Treatments*		
	T1	*T2*	*T3*
VSI	7.18 ± 0.01^{a}	7.25 ± 0.13^{a}	5.86 ± 0.31^{b}
HSI	1.87 ± 0.01^{a}	1.59 ± 0.05^{b}	1.17 ± 0.06^{c}
Intestine length/total length	147.1 ± 0.5^{a}	105.2 ± 2.5^{b}	107.7 ± 2.3^{b}
Gut length/intestine length	16.8 ± 0.08^{b}	11.8 ± 0.6^{c}	24.2 ± 0.9^{a}

The values with a different superscript in the same column differ significantly ($p < 0.05$). Where, T1 - seabream (SB) reared in seawater tanks; T2 - SB reared in underground saltwater tanks; T3 - SB reared in a saltwater (underground) lake in fish cages.

Blood and serum analyses. Table 4 showed the blood and serum biochemical analyses of *Sparus aurata* reared at different water sources.

Table 4

Blood and serum analyses of gilthead seabream, *Sparus aurata* reared under different water sources over 240 days. Data are means (2 readings) ±SEM

Parameters	*Treatments*		
	T1	*T2*	*T3*
Hemoglobin (Hb) (g dL^{-1})	5.28 ± 0.02^{c}	6.90 ± 0.03^{b}	7.29 ± 0.01^{a}
Red blood cells (RBCs) ($x10^{6}$ µ L^{-1})	2.46 ± 0.02^{c}	3.60 ± 0.04^{b}	4.70 ± 0.03^{a}
White blood cells (WBCs) ($x10^{3}$ µ L^{-1})	47.49 ± 0.15^{c}	55.38 ± 0.06^{b}	61.46 ± 0.14^{a}
Hematocrit (PCV) (%)	22.19 ± 0.05^{c}	23.18 ± 0.07^{b}	25.35 ± 0.09^{a}
Glucose (mg dL^{-1})	77 ± 5^{a}	39 ± 2^{c}	45.5 ± 4^{b}
Total protein (mg dL^{-1})	3.22 ± 0.03^{c}	4.04 ± 0.03^{b}	5.16 ± 0.04^{a}
Cholesterol (mg dL^{-1})	246.8 ± 0.63^{c}	250.8 ± 0.44^{b}	255.76 ± 0.75^{a}
Triglyceride (mg dL^{-1})	275.5 ± 1.5^{c}	293.5 ± 0.5^{a}	286.0 ± 2.0^{b}
ALT (U L^{-1})	41.19 ± 0.03^{c}	44.84 ± 0.08^{b}	45.16 ± 0.02^{a}
AST (U L^{-1})	42.36 ± 0.10^{c}	56.79 ± 0.08^{b}	62.10 ± 0.04^{a}
Urea (mg dL^{-1})	4.35 ± 0.03^{c}	4.90 ± 0.03^{b}	5.33 ± 0.02^{a}

The values with a different superscript in the same column differ significantly ($p < 0.05$). Where, T1 - seabream (SB) reared in seawater tanks; T2 - SB reared in underground saltwater tanks; T3 - SB reared in a saltwater (underground) lake in fish cages.

Overall, significant ($p \leq 0.05$) effects of three water sources were detected on blood and serum biochemical parameters of *S. aurata*. Hemoglobin, RBCs, WBCs, hematocrit, total protein, cholesterol, triglyceride, urea, ALT, and AST level exhibited significantly ($p \leq 0.05$) reduced values in *S. aurata* reared in tanks using seawater compared with increased values in tanks and cages using underground saltwater. Glucose values significantly ($p \leq 0.05$) increased in *S. aurata* reared in tanks using seawater compared to decreased values in *S. aurata* reared in tanks and cages using underground saltwater.

Discussion. It is well known that the water sources used in fish growing and their quality parameters are among the exogenous factors that have a strong effect on the aquatic species' growth (Altan 2020). The present study shows an attempt to investigate the influence of water sources on growth performances, blood characteristics, and gastrointestinal development in *S. aurata* fingerlings of single-origin (Marine Fish Hatchery (K21), raised under varying water sources and salinity. Water quality parameters recorded in the present study in T1 and T2 were within the recommended levels for *S. aurata* farms (Moretti et al 2005). In T3, it was significantly beyond the ideal levels in many parameters, especially salinity level. Excluding the influence of other water quality factors such as pH, water temperature, dissolved oxygen, and ammonia, the results can be interpreted as the low salinity is accompanied by a bad effect on the feed intake and energy required for osmoregulation, along with that the maintenance requirements were found to boost with lessening salinity (Conides & Branko 2006). Fish acclimated to low-salinity waters lose ions. This loss should be compensated for absorption from water or from the diet. Thus, the euryhaline fish reared at low salinity and fed diets that containing salts meet the osmotic requirements and contribute to providing energy that is required for osmoregulation showed good growth rates, as the backup energy can be diverted in favor of growth (Harpaz et al 2005; Appelbaum & Arockiaraj 2009). In Wadi Maruit lake, El-Ebiary et al (2015) recorded high levels of pollutants, such as sulfate (11.4-20.6 ppm), cadmium (1.2-1.4 ppm), copper (0.94-1.42 ppm), lead (0.63-0.99 ppm), and mercury (0.08-0.42 ppm) which had a negative effect on the growth and feed utilization of *S. aurata* reared in fish cages compared to other treatments.

Concerning growth results (FW, WG, SGR, ADG, and survival rate), the main finding of this study was the superiority of *S. aurata*, raised in seawater tanks with a salinity of 36-37 ppt in growth measures, compared to fish farmed in the other two groups of groundwater tanks with a salinity of 36-38 ppt, and groundwater with a salinity of 10-18 ppt, in cages inside the lake. This finding contrasts with Klaoudatos & Conides (1996), who stated that the faint salinity brackish water is the most proper and convenient growing water for the euryhaline aquatic species such as European sea bass (*Dicentrarchus labrax*) and brown spotted grouper (*Epinephelus chlorostigma*). Also, for *S. aurata*, they found that it grew faster recording a better survival rate with the low salinity brackish water of 8 ‰ compared to seawater of 38 ‰ . Additionally, the best SGR of 0.95 % day^{-1} was achieved by Sadek et al (2004) when they raised the *S. aurata* for 8 months in an extensive brackish water farming method with a salinity of 25 ppt. In this study, fingerlings of *S. aurata*, raised at low salinity (10-18 ppt) during an 8-month growth period, had the worst SGR, weight, and survival rate compared with fish reared at sea salinity (36-37 ppt). This differs somewhat from Azab et al (2015), who reported that *S. aurata* larvae that raised at low salinity (20 ‰) over a two-month growth period were roughly equal in length, weight, and survival rate with fish grown in high salinity (35 ‰). Given the growth rates of *S. aurata* reared using groundwater in tanks, the obtained results show the convergence between fish grown in seawater tanks and groundwater tanks. This reflects the interaction between the water source and the culture system used in fish farming.

The feed utilization parameters of *S. aurata* juveniles affected by the water source, where the best FCR, PER, and PPV were recorded for fish grown in seawater tanks, the values were close to those obtained by fish reared with underground water tanks. In contrast, these parameters with the groundwater cage fish were differentiated

with large values. In this trial, the best FCR (1.74) recorded with fish in seawater tanks was lower than that reported for *S. aurata* juveniles with an initial weight of 1.6 g, raised for 600 days at underground water salinity of 7 ‰. The same is recorded for the best SGR (0.872) and PER (1.27), as they were lower compared to the value of 0.906 and 1.40, respectively (Altan 2020). In the same context, El-Ebiary et al (2015) found that *S. aurata* reared in fish cages in Wadi Maruit at the same current density in the same area showed FCR values vary between 2.3 to 2.7 and PER values between 0.8 and 1.0. The previous results are similar to the present study. In a different context, the best FCR in this study was higher than that reported by Sadek et al (2004) at a salinity of 25 ppt, while the best PER value was lower. In the meantime, fish feeding maybe accounts for more than 45% of the total operating costs in Mediterranean intensive aquaculture (Martínez-Llorens et al 2009). Reducing the cost of feeding without reducing growth, fish quality, and welfare of cultured aquatic animals would significantly increase fish farms' profitability (Martínez-Llorens et al 2012).

Many studies have investigated the morphological, histological, and biochemical features of the digestive system of *S. aurata* regarding the digestive system characteristics. The morphological aspects of intestinal cells of the *S. aurata* fingerlings with a mean weight of 79 g, fed diets containing various lipid origins, were examined by Caballero et al (2003). Also, Elbal et al (2004) carried out studies on developing the digestive tract of *S. aurata* from hatching to 69 days, using light and electron microscopic. Moreover, *S. aurata* juveniles' digestive function with an initial body weight of 17.91 was tested with feeding frequency (Gilannejad et al 2021). In this experiment, the VSI was significantly differentiated for fish reared in underground saltwater tanks, while the HSI and intestine length/total length were differentiated considerably for those raised in seawater tanks; nevertheless, the gut length/intestine length was significantly increased in favor of fish grown in cages with underground saltwater inside the lake. This disparity in the gastrointestinal morphological parameters of *S. aurata* may be due to the effect of the environment in which the fish are raised, including the culture system influence and the water's physical and chemical properties. The difficulty of having similar studies on the impact of water sources hindered comparing these results with others. Still, Tina et al (2018) provided a reasonable explanation for the digestive system's histological and biochemical features in the cage-reared *S. aurata*.

Hematological parameters are commonly used as a physiological diagnostic tool in numerous aquaculture experiments to clinically evaluate, diagnose, predict and warn fish health status in response to abrupt changes related to water quality, nutrition, and disease (Michail 2020). As for the blood and serum analysis, hemoglobin levels recorded in the current study are higher than the values (4.55) recorded by Tort et al (2002) and less than the average values (9.197) calculated by Michail (2020) for *S. aurata*. The values of both RBCs and WBCs recorded in this experiment for treatment T1 were identical to those obtained by many researchers like Fazio et al (2013, 2015). Kanyılmaz & Tekellioğlu (2016) obtained similar RBCs values in *S. aurata* fed different zeolite levels, the same result obtained in T1. The increase in Hb, RBCs, and WBCs parameters in T2 and T3, especially T3 can be considered a negative indicator to some extent, as indicated by that scientist. In this context, Çelik (2006) reported an increase in WBCs value after a deterioration of hemostasis due to exposure to a stressful factor or an indicator of immunity weakening. In the present study, the blood glucose levels obtained in T1 are very similar to values obtained by Kanyılmaz & Tekellioğlu (2016), with values vary between 68.73-78. Also, the glucose levels are within the recorded values for *S. aurata* (Roncarati et al 2006; Peres et al 2013).

On the contrary, the results obtained for glucose in the treatments T2 and T3 were far from the reference results. In the current study, cholesterol and triglyceride values were within the referenced values recorded by Peres et al (2013) and Kanyılmaz & Tekellioğlu (2016) for *S. aurata.* The increase in cholesterol and triglycerides in T3 in the present study could somewhat result from the rise in lipid retention by fish fed wild fish coming into the fish cages. In the current study, urea, ALT, and AST concentrations are affected by water resources. The lower values of the previous parameters in T1 indicate better fish health.

Conversely, the higher values in T2 and T3 show the adverse effect of underground saltwater resources on *S. aurata* health and vitality. However, ALT and AST's recorded values in the current study are very far from those recorded by Kanyılmaz & Tekellioğlu (2016). Urea, ALT, and AST activities are related to the tissue damages in the liver, gut, and bile ducts (Roncarati et al 2006; Maita 2007; Peres et al 2013).

Conclusions. Juvenile gilthead seabream, *S. aurata*, can be cultivated with different acceptable degrees of success at salinities ranging between 10 and 38 ‰, using full-strength seawater (35-38 ppt) or underground saltwater (36-38 ppt) or underground brackish water (10-18 ppt). The best results were achieved using full-strength seawater followed by underground saltwater (36-38 ppt). The worst results were obtained when *S. aurata* was cultivated in fish cages using underground brackish water (10-18 ppt). This result indicates that *S. aurata* efficiently regulated their body physiology within a wide range of salinity levels (10-38 ppt) to achieve good performance. An improvement with 31.25%, 8.9%, 2.4%, 21.3%, 4.9%, 5%, 17.6%, 97.4%, 8.3%, and 25.4% free ammonia, SGR, survival, fish biomass, FCR, PER, HSI, glucose, ALT, and AST, respectively was achieved under full-strength seawater conditions compared with underground saltwater (36-38 ppt). Further experiments should be performed to accurately evaluate the effects of underground saltwater on other fish health parameters.

Acknowledgements. We are grateful for the close collaboration between the National Institute of Oceanography and Fisheries (NIOF) and Marine fish Hatchery K21, Alexandria, General Authority for Fish Resources and Development (GAFRD), performing this study. We thank the staff members of Marine fish Hatchery K21 for their participation and assistance during the field trips. Special thanks to Mr. Mohamed Saad for providing facilities and supports. The authors funded this study.

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Received: 12 April 2021. Accepted: 15 May 2021. Published online: 14 June 2021.
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How to cite this article:
Lotfy A. M., Elhetawy A. I. G., Habiba M. M., Abdel-Rahim M. M., 2021 A comparative study on the effects of seawater and underground saltwater on water quality, growth, feed utilization, fish biomass, digestive system development, and blood health in gilthead seabream, *Sparus aurata*. AACL Bioflux 14(3):1609-1621.