AACL BIOFLUX

Aquaculture, Aquarium, Conservation & Legislation
International Journal of the Bioflux Society

Utilization of desalinated brackish water residues for cultivation of the marine fish species, *Dicentrarchus labrax, Sparus aurata,* and *Sciaenops ocellatus*

[1,2]Mutaz A. Al-Qutob, [2]Ra'fat A. Qubaja, [2]Tharwat S. Nashashibi

[1]Department of Earth and Environmental Studies, Faculty of Science and Technology, Al Quds University, East Jerusalem, Palestinian Authority; [2]Aquatic and Aquaculture Research Laboratory, Al-Quds University, East Jerusalem, Palestinian Authority. Corresponding author: M. A. Al-Qutob, qutob@planet.edu

Abstract. The utilization of brackish water residues from desalination units for fish mariculture in Palestine could represent an environmental friendly alternative of disposing brine water which could have an adverse effect on wild life. In this study, three juvenile marine fish species (Gilt-head bream *S. aurata*, European sea bass *D. labrax*, and red drum *S. ocellatus*) with average weights of 0.7-4.9 g, were acclimated and reared in brine brackish water residues collected from Jericho desalination units with salinities of 6.5 ‰ and 11 ‰ diluted sea water as control for 3-7 months. Fish were fed 56 % rich protein diet. Brine brackish water contained high levels of Cl^{-1} (3369 mgL^{-1}), Na^{+1}(3735 mgL^{-1}), K^{+1}(300 mgL^{-1}), SO_4^{-2} (716 mgL^{-1}) with the divalent ions Mg^{+2} (57.3 mgL^{-1}) and Ca^{+2} (276 mgL^{-1}).The experimental well showed more than the maximum allowable concentration of Cr (14.49 μgL^{-1}), Ag (5.3 μgL^{-1}) and Mn (27.88 μgL^{-1}) for water quality of fisheries use. The sea bass with an average weight of 0.76 g (at a salinity of 6.5 ‰) showed an acceptable growth performance parameters and reached a percentage weight gain (% WG) of 6345.23 % and a survival rate of 77.5 % compared to control groups at 11 ‰ that reached at the same time a % WG of 6543.78 % and a survival rate of 82 % after 30 weeks. The red drum juveniles reached a % WG of 2661.6 % and 2673.92 % after 15 weeks at 6.5 ‰ and 11 ‰ respectively while sea bream reached a % WG of 241.63 % and 772.44 % after 15 weeks at 6.5 ‰ and 11 ‰ respectively. Survival rate was only 5 % at both salinities for the two species. In a further study sea bass fingerlings with an average weight of 20.5 g were reared in brackish water of 6.5 ‰ salinity for 7 weeks and were fed superior fish meal with fish oil. They received diets of 2.1 %, 3.0 %, and 4.0 % of body weight. Sea bass fingerlings which received diets of 2.1 %, had the highest FCE (0.82) and PER (1.46) with the lowest FCR (1.22). These results confirm that the most suitable fish for cultivation utilizing brackish water from Jericho desalination units with salinity of 6.5 ‰ is sea bass *D. labrax*, while the other two species need some modification to acclimatize to this water. Furthermore, the best food % for optimum growth of sea bass at this salinity is 2.1 % after 7 weeks. Brackish water from Jericho desalination units are suitable for cultivation of these species, but may need some modification as adding salts to fish diet or water and reducing toxicity of some high trace metals present by a suitable method.

Key Words: Brine brackish water, Jericho desalination units, fish mariculture, percentage weight gain, survival rate, food %.

Resumen. La utilización de las aguas residuales salobres producidas en plantas desalinizadoras para el cultivo de peces marinos en Palestina podría ser una alternativa respetuosa con el medio ambiente para la eliminación de la salmuera cuyo vertido podría causar un efecto negativo sobre la vida silvestre. En este estudio tres especies de peces marinos (dorada *S. aurata*, lubina europea *D. labrax* y corvinón ocelado *S. ocellatus*), con un peso medio de 0.7 -4.9 g, fueron aclimatados y criados durante 3-7 meses en aguas residuales salobres procedente de plantas desalinizadoras de Jericó con unas salinidades de 6.5 ‰, y como control en agua de mar diluida al 11 ‰. Los peces fueron alimentados con una dieta rica en un 56 % de proteínas. El agua salobre contenía unos altos niveles de Cl^{-1} (3369 mgL^{-1}), Na^{+1}(3735 mgL^{-1}), K^{+1}(300 mgL^{-1}) y SO_4^{-2} (716 mgL^{-1}) con iones divalentes de Mg^{+2} (57.3 mgL^{-1}) y Ca^{+2} (276 mgL^{-1}). La piscina experimental tenía agua con unas concentraciones de Cr (14.49 μgL^{-1}), Ag (5.3 μgL^{-1}) y Mn (27.88 μgL^{-1}) superiores al máximo permitido para su uso en la producción de peces. Las lubinas con un peso medio de 0.76 g en una salinidad de 6.5 ‰ mostraron parámetros de crecimiento aceptables después de 30 semanas, con un porcentaje de incremento de peso (% WG) del 6345.23 % y una tasa de supervivencia del 77.5 %, en comparación al grupo control de 11 ‰ que alcanzaron en el mismo tiempo un porcentaje de incremento de peso (% WG) del 6543.78 % y una tasa de supervivencia del 82%. Después de 15 semanas, los juveniles de corvinón ocelado alcanzaron un porcentaje de incremento de peso (% WG) de 2661.6 % y 2673.92 % en 6.5 ‰ y 11 ‰, respectivamente; mientras que la dorada

llegó a un porcentaje de incremento de peso de 241.63 % y 772.44 % en 6.5 ‰ y 11 ‰, respectivamente. La tasa de supervivencia fue de sólo 5 % en ambas salinidades para las dos especies. En un estudio posterior, los alevines de lubina con un peso medio de 20.5 g fueron criados en agua salobre con una salinidad de 6.5 ‰ y alimentados con harina y aceite de pescado durante 7 semanas. Fueron alimentados con dietas de 2.1 %, 3.0 % y 4.0 % de su peso corporal. Los alevines de lubina que recibieron dietas del 2.1 %, mostraron una mayor FCE, eficiencia de conversión de alimento, (0.82) y PER, tasa de eficiencia proteica, (1.46) y una menor FCR, tasa de conversión de alimento, (1.22). Estos resultados confirman que las lubinas *D. labrax* son los peces más adecuados para el cultivo en agua salobre con una salinidad de 6.5 ‰ procedente de plantas desalinizadoras de Jericó, mientras que las otras dos especies necesitan algunas modificaciones para aclimatarse a esta agua salobre. Además, el mejor % de comida para un crecimiento óptimo de la lubina a esta salinidad es de un 2.1 % después de 7 semanas. El agua procedente de las plantas desalinizadoras de Jericó es adecuada para cultivo de estas especies de peces, pero sería necesario incluir alguna modificación como la adición de sales a la dieta o al agua de mar y reducir la alta toxicidad de algunos metales pesados presentes mediante un método adecuado.
Palabras Clave: Aguas residuales salobres, plantas desalinizadoras, cultivo de peces marinos, % de incremento, tasa de supervivencia, % de comida.

Introduction. The new interest of aquaculture today is the natural resource management and the commercial production of high quality low fat food. Brackish water residue from desalination units is a new local resource that can be used for Mariculture in the inland west bank region of Palestine. Farming marine fishes in brackish water from desalination units in the Palestinian region could introduce a new cheap source for proteins in Palestine. In Palestine, brackish water is found naturally in the Jordan River Valley, West Bank and in different parts of the Gaza Strip. Apart from the brackish wells there are 297 springs and seeps in the West Bank, with 105 springs yielding more than 0.1 L sec^{-1}. The average annual flow is around 100 Million Cubic Meters (MCM). The amount of fresh water is 55 MCM, used mainly for irrigation. The rest (45 MCM) is brackish water (PASSIA 1999). Desalination water treatment facilities are used in Jericho and in the Jordan Valley region to produce fresh water from the brackish wells, which are used for different purposes. Desalination processes produce brine (or reject) stream, which has a higher level of dissolved salts than either the feed water or the product water, and must be disposed of in an environmentally acceptable manner (Spiegler & Laird 1980). Since previous investigations have shown the significant potential of the geothermal, brackish water for the successful culture of aquatic organisms (Appelbaum & Arockiaraj 2009a), the utilization of brackish water residues from desalination units for Mariculture in Palestine could provide large amount of unpolluted brackish water with lower cost which allows a high quality fish product compared to fresh water. On the other hand it represents an environmental friendly alternative of disposing this brine water which could have an adverse effect on wild life if it is disposed in the environment (Girard 2010).

The euryhaline marine fish such as sea bass (*Dicentrarchus labrax*), sea bream (*Sparus aurata*), and red drum (*Sciaenops ocellatus*) can live in a broad ranges of environmental salinities. The gilt-head bream (*S. aurata*), is capable of living in environments of different salinities ranging from 2 to 60 ‰ (Laiz-Carrion et al 2005). Appelbaum & Arockiaraj (2009a) reported cultivation of gilthead sea bream fingerlings with an average weight of 19 g in low salinity inland geothermal water of 2.5 ‰, 3.5 ‰ and 4.5 ‰ salinities for 56 days. Their study showed increasing of weight by 90 %, 121 %, 98 % respectively. The European sea bass (*D. labrax*), is eurythermic (5-28 °C) and euryhaline capable of living at 3 ‰ to full strength sea water; but the most suitable and favorable rearing water was reported to be low salinity brackish water rather than sea water (Klaoudatos & Conides 1996). Red drums are reported to be collected from waters with salinities between 0.14 – 50 ‰ (Simmons & Breuer 1962) and can be successfully acclimated to freshwater (Arnold et al 1977).

This study attempted to assess the potential use of brackish water residues with salinity of 6.5 ‰ from Jericho desalination units in the Palestinian Territories for cultivation of the marine fish species, *D. labrax*, *S. aurata*, and *S. ocellatus*. The study predicted which species are most suitable for this water, and determined the effect of brackish water residues on growth rate, survival, and mortality of these fish. Furthermore, the appropriate feeding percentage of fish reared in this brackish water waste has been determined.

Material and Method.

Experimental system. This study was carried out at the Aquaculture research laboratory, in Al-Quds University, Jerusalem, Palestine, from fall 2010 to fall 2011. Two warm water recirculation systems consisting of 36 aquaria of 45 L capacity were used for the study. The aquaria were housed indoor and were connected in each system in order to have the same conditions. The first system (A) consisted of 12 aquaria used as control filled by commercial sea salt dissolved in tap water at 11 ‰ salinity. The other system (B) consisted of 24 aquaria filled by brackish water residue of 6.5 ‰ salinity as experimental. Brackish water residue was brought to the aquaculture facilities in Al-Quds University from desalination units in Jericho by water tanks. Onsite measurements for physicochemical parameters and chemical analysis of water from the well and desalination units for the cations and anions as well as for trace elements were achieved using Ions Chromatography (IC) at the Center of Chemical and Biological Analysis, in Al-Quds University and inductive coupled plasma-mass spectrometry (Agilent 7500 ICP-MS) at the Aquaculture lab respectively (Tables 1, 2). All aquaria were kept on 80 cm high platform to facilitate better observation and easy maintenance. The flow rate of water was maintained at 0.5 L min^{-1}, oxygen saturation above 60 % and water temperature at 25 ± 1 ^oC. A constant photoperiod of 12 h light and 12 h dark was maintained throughout the experimental period. Daily, 5 % of the water was renewed from each aquarium in order to maintain optimum water quality and better hygiene. Total nitrogen ammonia was always less than 3 mgL^{-1}.

Table 1

Physicochemical parameters of well water and brackish water residue from desalination units

Sample	*Well water*	*Fresh water*	*Brackish water residue*
pH	7.3	6.1	7.6
Ec (ms cm^{-1})	4.08	0.2	12.95
TDS (g L^{-1})	2.04	0.1	6.5
TSS (mg L^{-1})	2	0	16
Turbidity (FAU)	5	4	30
TS (g L^{-1})	2.042	0.1	6.5
Na^{+1} (mg L^{-1})	899	43	3735
K^{+1} (mg L^{-1})	87.5	4.45	300
Mg^{+2} (mg L^{-1})	13.4	0.04	57.3
Ca^{+2} (mg L^{-1})	84.4	1.14	276
SO^{-4} (mg L^{-1})	159	1.95	716
Cl^{-1} (mg L^{-1})	776.3	29.4	3369
NO^{-3} (mg L^{-1})	14.7	0.43	-

Ec - Electrical conductivity, TDS - Total dissolved solids, TSS- Total suspended solids, TS- Total solids.

Table 2
Comparison of trace elements between our experiment and allowable concentrations for fisheries

Trace Elements (ppb) or x10^{-9}	*Sample 1*	*Sample 2*	*Sample 3*	*Average*	*WHO*[1]	*U.S. EPA*[2]
^{53}Cr	13.325	14	17.5	14.94	2-20	5.4
^{55}Mn	29.9	29.25	24.5	27.88	Ins. Data*	20
^{56}Fe	<0.35	<0.35	<0.35	<0.35	50	50
^{59}Co	<0.1	<0.1	<0.1	<0.1	10	Ins. data
^{60}Ni	<3.825	<3.825	<3.825	<3.825	15-25	Ins. data
^{63}Cu	<0.4	<0.4	<0.4	<0.4	1-4	2
^{66}Zn	<3.425	<3.425	<3.425	<3.425	10-30	170
^{88}Sr	390.2	754.8	720.4	621.8	Ins. data	Ins. data
^{95}Mo	0.925	1.425	0.975	1.11	Ins. data	20
^{107}Ag	5.975	2.7	7.25	5.31	Ins. data	2.3
^{111}Cd	<0.55	<0.55	<0.55	<0.55	0.2-1.8	12
^{137}Ba	44.25	36.175	33.75	38.06	Ins. data	500
^{202}Hg	<3.275	<3.275	<3.275	<3.275	0.1-0.5	0.1
^{205}Tl	0.125	0.125	0.1	0.12	Ins. data	50
^{208}Pb	<2.075	<2.075	<2.075	<2.075	1-7	8.6
^{209}Bi	<0.05	<0.05	<0.05	<0.05	Ins. data	Ins. data

*Sources: [1]Water Quality Assessments, 1996; U.S. EPA[2], Water Quality Criteria, 1996; Ins. data - Insufficient data.

Experiment 1: Utilization of brackish water residues from Jericho desalination units for cultivation of the marine fish species, D. labrax, S. aurata, and S. ocellatus. Randomly selected individuals of three marine fish species, *D. labrax*, *S. aurata*, and *S. ocellatus*, collected from commercial hatchery, with average weights of 0.7 – 4.9 g per fish were reared up in marine water of 11 ‰ (system A) as control and brackish water of 6 ‰ (system B) as experimental for 3-7 months. 20 fish were stocked in each aquarium, of the 6 aquaria chosen for marine water in system (A) and 12 aquaria were chosen for brackish water from system (B). These aquariums were divided to three different groups in each recirculating system, two aquariums for each species in system (A) and four aquariums for each species in system (B). Feeding started on the same day of stocking once daily, and the amount of diet was given as percentage of fish weight. Fish were weighted every week and counted in each aquarium during experimental period and the feeding dose for each aquarium was calculated. Individual fish in each aquarium was weighted to the nearest 0.01 g using a digital scale. The growth rate (GR) was determined using linear regression: $y_t = a + bx_t$, where y_t is the average total weight (g) of at time t; a is the average weight (g) of fish at the start of the experiment; b is growth rate (g/day) and x is the number of days at time t. The following growth parameters were also calculated:

Percentage weight gain (% WG) **=** $[(W_f - W_i) / W_i] \times 100$

Where W_f is the final weight of the fish and W_i is the initial weight of fish.

Specific growth rate (SGR) **=** (ln final weight - ln initial weight) x 100 / No. of days of experiment

Feed conversion ratio (FCR) **=** Feed fed / Gain in weight of fish

Feed conversion efficiency (FCE) **=** Gain in wet weight of fish / Feed fed

Protein Efficiency Ratio (PER) **=** Increment in body weight (g)/ Protein intake (g)

Commercial feed rich protein diet 56%, was used as the fish diet. Crumble starter feed, promoting fast growth and high survival, with a balanced amino acids profile was given for juvenile marine fish. Then pre-grower and grower feed, which is a highly qualified starter feed for young sea bream and sea bass based on LT fish meal. It contained superior fish meal and fish oil, replacing crumble due to small particle size, stability in the water and hardly pollutes. Components of starter feed: fish flour, krill flour, wheat, wheat gluten, fish oil, food coloring E 129, preservative E280, vitamins A (30,000 IU kg^{-1}), D3 (3,000 $IUkg^{-1}$), E (400 $IUkg^{-1}$), C stable (300 $IUkg^{-1}$). Energy (per kg) gross (20.4 MJ) (4.87 Mcal.), digestible energy (18.3 MJ) (4.37 Mcal). Components of pre-grower and grower feed: meat flour, fish flour, products and by-products of grains and oil seeds, fish oil, vitamins A (30,000 $IUkg^{-1}$), D3 (3,500 $IUkg^{-1}$), E (400 $IUkg^{-1}$), C stable (300 $IUkg^{-1}$), and minerals. Gross energy (per kg) (20.9 MJ) (4.99 Mcal.), digestible energy (18.3 MJ) (4.37 Mcal.).

Experiment 2: predicting an appropriate feeding percentage for the most suitable species farming. Sea bass (*D. labrax*) with an average body weight of 20 g were reared under three different feeding percentages of their body weight (2.1 %, 3.0 %, and 4.0 %) for seven weeks. They were collected from previously sea bass juveniles acclimatized at 6.5 ‰ for more than 4 months in experiment 1. Brackish water system (B) was divided to three different groups, five aquariums for each percentage and 4 randomly individuals were selected for each aquarium after recording initial weight. Diet was given to fish in each aquarium once daily and the experiment followed the same procedure and calculations done in experiment one.

Results and Discussion.

Average weight, survival rate and growth rate of sea bream (S. aurata). Fish development, growth and survival are influenced by various physiological factors among which water salinity is one important parameter. Salinity plays a key role in growth control, influencing growth rate, metabolic rate, feed intake and feed conversion.

In the present study, *S. aurata* fingerlings with an average weight of 4.3 g were acclimated and reared for 15 weeks in water of two different salinities: diluted sea water (11 ‰) as control and brackish water waste from desalination unit (6.5 ‰) as experimental. At 11 ‰ salinity the fish average weight was 18.79 g and survival rate 87.5 % in week 8. On the other hand at 6.5 ‰ average weight was 8.49 g with a survival rate of 19 % at the same time period (Figures 1, 2). After the 10th week survival rate dropped to 5 % in system B (6.5 ‰) and mortality was 100 % in both systems A and B at the 16th week (Figure 2).

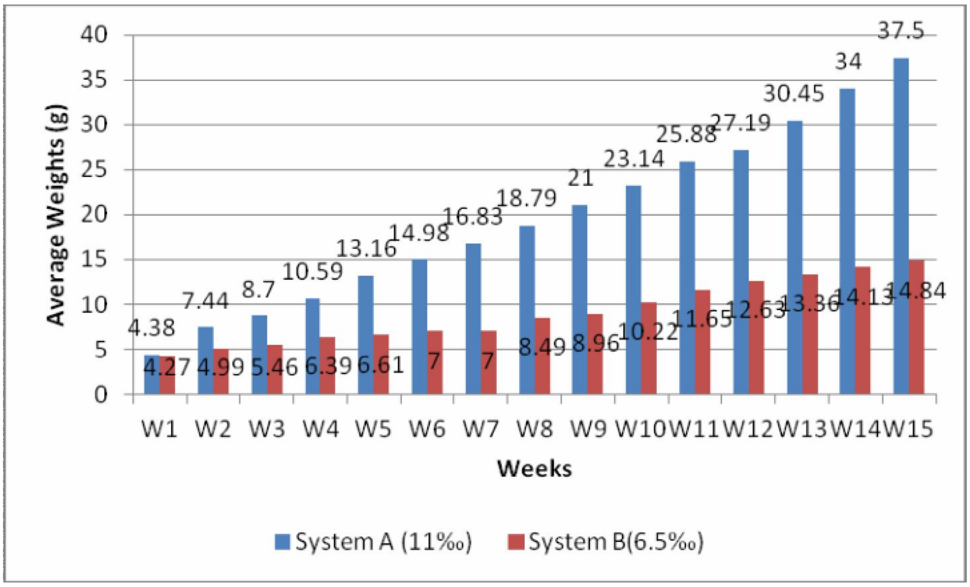

Figure 1. Weekly average weights of *S. aurata*, during experimental period.

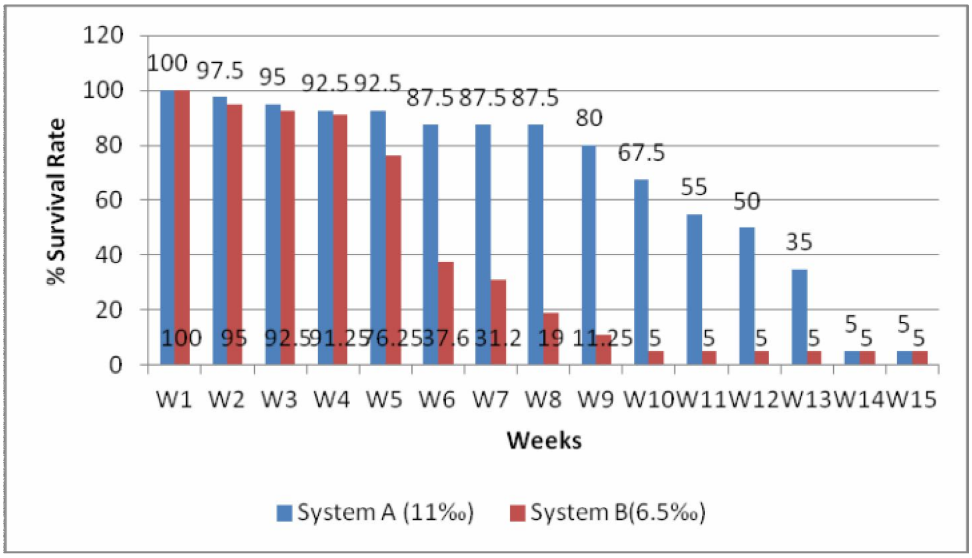

Figure 2. Percentage of survival rate of *S. aurata*, during experimental period.

S. aurata achieved a better growth rate during the 15 week experimental period at 11 ‰ (2.23) diluted sea water compared to 6.5 ‰ brackish waste water (0.77) (Figure 3).

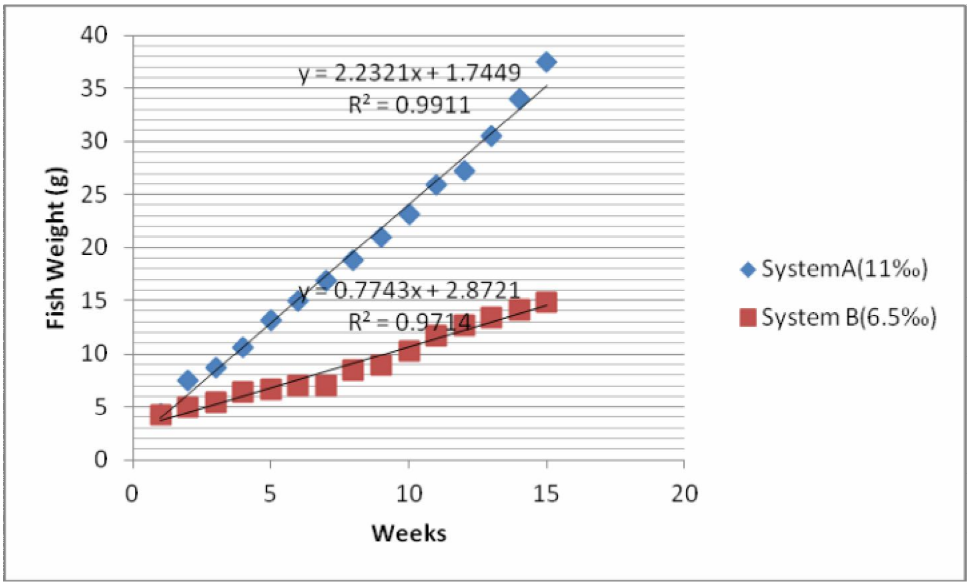

Figure 3. Comparative growth rate of *S. aurata* in system A (11 ‰) and B (6.5 ‰) during experimental period.

Previous studies on sea bream (Sangiao-Alvarellos et al 2003; Tandler et al 1995) have also shown higher survival and growth at 12 ‰ than at 6 ‰. In another study, gilthead sea bream fingerlings with an average weight of 19 g were acclimated and reared for 56 days in brackish water 4.5 ‰ from Dead Sea region showed (SGR) of 0.53 %/day and survival rate of 60 % (Appelbaum & Arockiaraj 2009a). Although a previous study indicated that gilthead sea bream grew faster and with a better survival rate when reared in low salinity brackish water (8 ‰) rather than in sea water at 38 ‰ (Klaoudatos & Conides 1996), it was demonstrated that their growth performance and survival in water of low salinity can be significantly improved by adding 12 % salt to their diet (Appelbaum & Arockiaraj 2009b). The chemical composition of our experimental brackish water residue showed high levels of Cl^{-1} (3369 mg L^{-1}), Na^{+1}(3735 mg L^{-1}), K^{+1} (300 mg L^{-1}) and SO_4^{-2} (716 mg L^{-1}) (Table 1) due to anthropogenic contamination of agriculture return flow and sewage effluents and dissolution of halite mineral within the lisan formation that could increase the Na/Cl ratios (Khayat et al 2005; Salameh 2002). Usually, fish adapted to low saline water show a passive outward flux of ions such as Na^{+1} and Cl^{-1} to the water via the gills, feces, and renal system, which must be compensated by the active uptake of ions from the water and/or from the diet (Schmidt-Nielsen 1997). Although, experimental brackish water residue contained high levels of monovalent ions, minerals absorbed from the water do not always meet the total metabolic requirements in fish. In addition, changes in oxygen consumption, and variations in the energy demands accompanied by osmoregulation (Sangiao-Alvarellos et al 2003; Conides & Glamuzina 2006), create a stressful condition. Thus, providing a sufficient amount of salt through feed is better and can spare energy that is used for osmoregulation, thereby reducing stress and allowing more energy for growth (Appelbaum & Arockiaraj 2009b). It is worth to mention that the iso-osmotic point for marine species is around 10 ‰, below which the reversion of the osmoregulatory mechanism occurs, so differences in survival ability are attributed to the ability of sea bream to conclude this reversion as quickly as possible and successfully (Brett 1979). On the other hand in low calcium aquatic environments, the ion pores of the surface membrane are sub maximally saturated with calcium which lowers the force or kinetic energy necessary to strip calcium from the pore. Thus, a rapid diffusion of sodium and potassium could occur moving from the fluid of highest concentration to the fluid of lowest concentration that is fast enough and cannot be compensate by active (energy dependent) uptake or elimination of ions. As a result, death would occur of altered circulatory volume or disrupted ion metabolism (Evans 1975). Ca^{+2} concentrations in experimental brackish water residue were only 276 mg L^{-1} (Table 1).

Furthermore, small fish are subjected to greater osmotic stress due to size (surface area) and higher metabolic rates (greater energy demands). In small fish, more extra cellular fluid is brought into close contact with the environment by way of body surfaces. Therefore, small fish lose relatively more ions to their environment as a result of diffusion across leaky permeability barriers which place a greater demand on energy dependent mechanisms of ion homeostasis. Stress can increase susceptibility to disease, retard growth and cause death (Stickney 1994).

Klaoudatos & Conides (1996) analyzed the influence of salinity (8 ‰, 18 ‰ and 28 ‰) on growth of fry sea bream (1.9 initial body weight) reporting high mortality rates (65 %) in fish acclimated to low salinity (8 ‰). However, in Carrión et al (2005), experiment; they have not observed any kind of mortality in the low salinity acclimated fish (20 g initial body weight). Differences in body size explained these discrepancies between both experiments. Humoral immunity of sea bream, was reported to be negatively affected after acclimatization to low salinity water (Cuesta et al 2005), leading either to mortality or reduced disease resistance. Previous mentioned facts could explain the lower survival rate in system B (6.5 ‰) compared to system A (11 ‰) in the first 8 weeks (Figure 2). Lower survival rate at the end of the experiment (Figure 2) could be attributed to technical factors such as filter failure, lack of maintenance, the addition of a large number of fish at the same time, over-feeding, over-enthusiastic cleaning of 'biological' filter media, and fish handling during stocking, resulting in stressed fish that release catecholamines, corticosteroids and possibly pituitary hormones, all of which can affect hydro mineral balance (Robertson 1984).

Sulfate SO_4^{-2} in brackish waste water reached (716 mgL^{-1}) (Table 1), which is significantly lower than seawater (SW) ~2592 mg L^{-1} SO_4^{-2}. SW contains ~1288 mg L^{-1} Mg^{2+}, ~400 mg L^{-1} Ca^{2+}, and ~390 mg L^{-1} K^{+1} as well as ~26300 mg L^{-1} NaCl. Usually excess sulfate SO_4^{-2} is excreted by the kidney in marine teleosts (Marshall & Grosell 2006). Studies reported that survival and growth of *S. ocellatus* was not affected by high sulfate concentrations (2000 mg L^{-1}) in 3 ‰ artificial seawater supplemented with either sodium sulfate or magnesium sulfate (Forsberg & Neill 1997). They also showed high survival rate, 85 % in a 5 ‰, high-sulfate (1723 mg L^{-1}), and high-calcium (427 mg L^{-1}) groundwater of West Texas (Forsberg et al 1996).

pH of the brackish water waste was 7.6 and it reached through the run of the experiment to 8.75 in system A (11 ‰) and to 9.08 in system B (6.5 ‰). The following water parameters were present during the run of the experiment in system A (11 ‰) and B (6.5 ‰) respectively, dissolved oxygen (DO) 6.63 mg L^{-1}, 6.52 mg L^{-1}, tempreture 25 ^oC, 24 ^oC, ammonia NH^{+4} 0-1.1 mg L^{-1}, and nitrate 0-5.3 mg L^{-1}. Sea bass and sea bream are able to maintain balanced acid/base concentrations and constant internal pH even when pH in ambient waters varies widely. They are able to cope with an acute rise in pH values by modulating ammonia excretion and osmoregulation. There is an increased risk of poor welfare at pH values below 6.5 and above 8.5 for both sea bass and sea bream and mortality can occur when fish are exposed abruptly to a pH below 4.5 and above 9.4, but this is unlikely to happen in normal practice (Eshchar et al 2006).

Heavy metals measured by (ICP-MS), in experimental well showed more than the maximum allowable concentration of chromium Cr (14.49 μgL^{-1}), silver Ag (5.3 μgL^{-1}) and Manganese Mn (27.88 μgL^{-1}) respectively for water quality of fisheries use (Table 2). For saltwater species in each 30 consecutive days the average concentration of Cr and Ag should not exceed 5.4 μgL^{-1} and 2.3 μgL^{-1} respectively (EPA 1996). Mn concentration < 20 µg L^{-1} present minimal risk to the saltwater species and protection of 95 % of species with 50 % confidence was derived at 0.3 mg L^{-1} Mn for the marine environment (Howe et al 2004; EPA 1996). Genotoxicity and mutagenicity were reported in *Oreochromis niloticus* at total Cr concentration of 10 µg L^{-1} (Matsumoto et al 2006). Khangarot et al (1999) reported immunosuppressive effects and susceptibility to bacterial (*Aeromonas hydrophila*) infection in cat fish, *Saccobran-chusfossilis* at subtoxic levels of Cr. Free silver ion is lethal to teleosts at nominal water concentrations of 1–5 µg L^{-1}. Adverse effects occurred on development of trout at concentrations as low as 0.17 µg L^{-1} (Davies et al 1978). In general, less toxicity of these metals to aquatic organisms is observed under conditions of low dissolved metal ion concentration and increasing water pH, hardness, salinity; (eg: the 96-h LC50 of silver at 25 ‰ salinity; seawater acclimatized rainbow trout adult was reported to be 401 μgL^{-1} while in soft, low-chloride water was 10.2 μgL^{-1} (Grosell et al 2000 ; Ferguson & Hogstrand 1998)), sulfides, and dissolved and particulate organic loadings; under static test conditions compared with flow-through regimens; and when animals were adequately nourished instead of being starved. In contrast, sensitivity to toxic effect is increased in the poorly nourished, young, and those exposed to low water hardness or salinity (Velma et al 2009). Calculated water hardness in our experiments was 925 mg L^{-1} (very hard water) and pH reached 8.75 and 9 in both systems which could have reduced their possible toxic effects. In contrast, young fish in our experiments were probably more sensitive to their harmful effect. Moreover, fish can accumulate heavy metals from water more than diet or sediment (Rashed 2001; Abdel-Baki et al 2011); thus further experiments on accumulation factor using this brine water is recommended, so as; these metals would not exceed the maximum limits approved by European Commission EC or WHO for fish consumption. In addition total removal of these heavy metals from experimental water is highly recommended.

Average weight, survival rate and growth rate of Sea bass D. labrax. In reference to (Figures 4, 5) there were no significant differences ($p > 0.05$) in the average weights or survival rates of sea bass (*D. labrax*) in both salinities (11 ‰ and 6.5 ‰). The final average body weights and survival rates after 30 weeks were (47.5 g, 82.5 %) and (51 g, 77.5 %) for 11 ‰ and 6.5 ‰ respectively. There was no significant difference ($p > 0.05$) in growth rate (GR) between both salinities, GRs were (1.51, 1.62) for 11 ‰ and 6.5 ‰ respectively.

Sea bass is capable to gradually acclimate to decreasing salinity values from 38 to 0 (Marino et al 1994). Eroldogan & Kumlu (2002) reported no mortality in juveniles sea bass transferred from SW to FW and better growth and growth indexes were observed in sea bass juveniles reared at 10 ‰ and 20 ‰ (near to the iso-osmotic threshold 11mg L^{-1} for the species) than at 30 ‰ and 40 ‰.

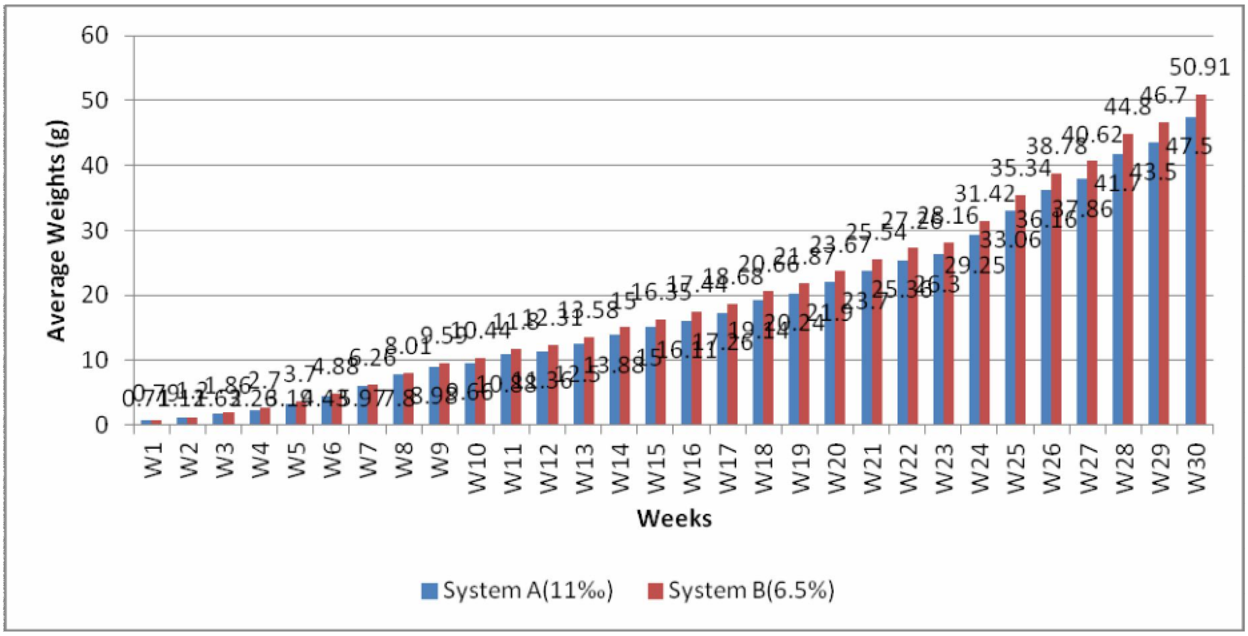

Figure 4. Weekly average weights of *D. labrax,* during experimental period.

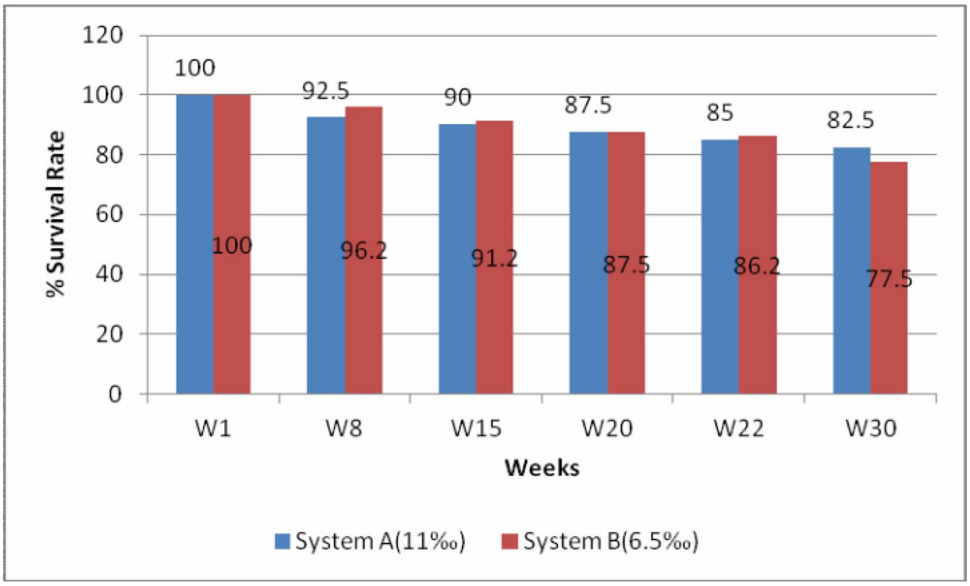

Figure 5. Percentage of survival rate of *D. labrax*, during experimental period.

Chatelier et al (2005) reported that adult sea bass exposed at constant temperature 14 °C, to acute reduction in water salinity down to freshwater (10, 5 and 0) did not show alterations in metabolic and cardiac performances, basically in relation to the strong capacity to keep constant plasma osmolarity levels. Furthermore, in Sea bass there is a strong acid-base regulation, allowing them to maintain constant blood pH level at any given blood CO_2 concentration (Marino et al 2006). No significant differences were shown in swimming behavior, feed intake, growth and feed conversion ratio inside a pH range between 6.0-8.5 (Marino et al 2006).

Average weight, survival rate and growth rate of red drum (S. ocellatus). In reference to Figure 6, there were no significant differences ($p > 0.05$) in the average weights of *S. ocellatus* in both salinities (11 ‰ and 6.5 ‰) at the end of 15 weeks. The average body weights were (34.29 g) and (34.94 g) for 11 ‰ and 6.5 ‰ respectively.

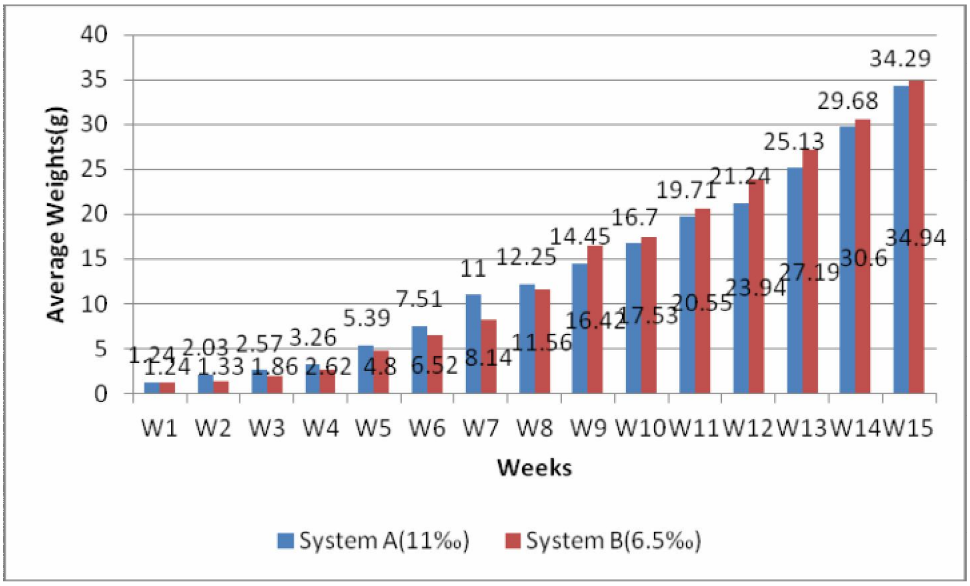

Figure 6. Average weights of *S. ocellatus* in the 15 weeks experimental period.

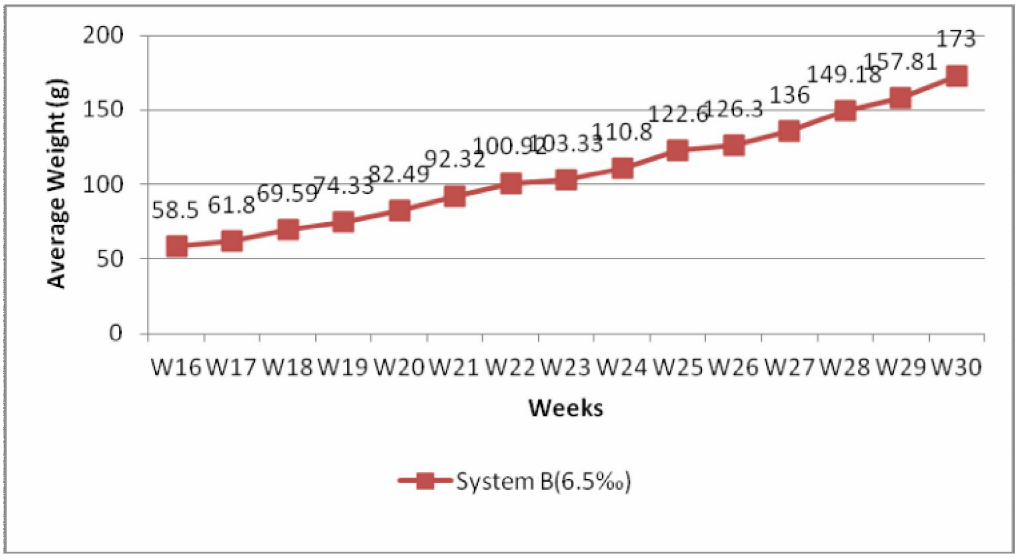

Figure 7. Average weights of *S. ocellatus* in system B (6.5 ‰) from 16-30 weeks.

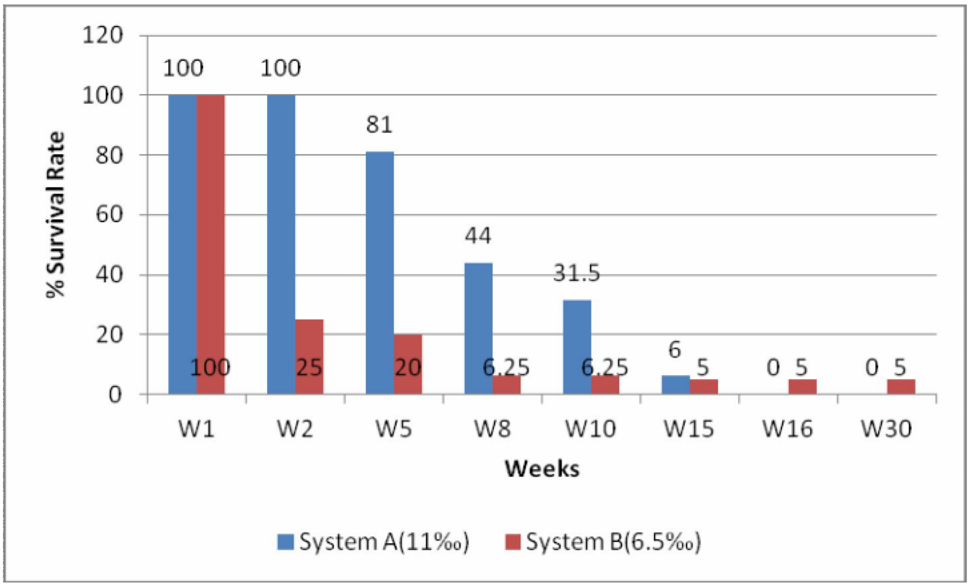

Figure 8. Percentage of survival rate of *S. ocellatus* during experimental period.

Survival rate was 44 % in system A (11 ‰) compared to 6.25 % in system B (6.5 ‰) at the end of 8 week. Survival rate dropped to 6 %, 5 % in system A (11 ‰) and B (6.5 ‰) respectively at the end of 15 week (Figure 8). From 16th to 30th week fish only survived in system B (6.5 ‰) to reach a final average weight of (173 g) and 5 % survival rate (Figure 7). There was no significant difference in growth rate (GR) between both salinities ($p > 0.05$), GRs were (2.31, 2.5) for 11 ‰ and 6.5 ‰ respectively. These results confirm that red drum showed good growth in both salinities, but bad survival rate when reared in 6.5 ‰ compared to individuals reared in sea water at salinity of 11 ‰. Forsberg et al (1996), in 30 day experiment with juvenile red drum (0.4–3.0 g), reported high survival 85 % in a 5 ‰ salinity, high-sulfate (1,723 mg L^{-1} SO_4^{-2}), and high-calcium (427 mg L^{-1} Ca^{+2}) groundwater. In a complementary bioassays of low-salinity (3 ‰) ground waters, calcium chloride ($CaCl_2$) addition to a 3 ‰ ground-water low in Ca^{+2} resulted in the greatest increase in survival (0–93 %), with increasing Ca^{+2} concentration from (36–336 mg L^{-1}) (Forsberg & Neill 1997). Fish in water containing less than 176 mg L^{-1} Ca^{+2} exhibited 100 % mortality. Highest survivals were observed in water containing 340-465 mg L^{-1} Ca^{+2} (Wurts & Stickney 1989). Our experimental water contained 276 mg l^{-1} Ca^{+2}, which was less than the required concentration for a high survival rate. This is one explanation of high mortality rate of red drum since beginning of experiment. Other causes are referred to the same reasons of high mortality rate of sea bream discussed earlier. In addition optimum level of 500 mg L^{-1} Cl^{-1} is preferred (Pursley & Wolters 1994). This study demonstrated that red drum can survive in brackish water from desalination units but growth and survival rate can be improved by adding optimal levels of Ca^{+2} and Cl^{-1} to their diet or water.

Growth performance parameters of S. aurata, D. labrax, and S. ocellatus. Growth performance within 30 weeks for, the *D. labrax* showed that they increased in weight by 6543.78 %, in diluted sea water system A (11 ‰) compared to 6345.23 % in experimental waste water system B (6.5 ‰). SGRs of 2.6 and 2.58 %/day, were obtained in 11 ‰ aquariums and 6.5 ‰ aquariums, respectively. FCR for brackish water from desalination units was 1.2 g feed/g gain, which was comparable to diluted sea water (1.19 g feed/g gain). In addition the PERs of fish in both experimental water and control water showed that they had comparable values (1.47, 1.5g gain/g protein intake) (Tables 3, 4). A previous study by Eid & Mohamed (2010), on sea bass (*D. labrax*) fingerlings with an average body weight of 1.2 g reared under salinity of 14 ‰ and temperature 25 ºC, which were fed diets containing 50 % crude protein at 3 % of body weight, for 24 weeks, reported net weight gain of 16.6 g, SGR (2.19 %), FCR (1.8), PER (1.11), FCE (0.55) and survival rate of 64 %.

On the other hand *S. aurata* increased in weight by 772.44 %, in diluted sea water system A (11 ‰) compared to 241.63 % in experimental waste water system B (6.5 ‰) within 15 weeks. Better SGR (2.31 %/day), FCR (1.24 g feed/g gain), FCE (0.81), and PER (1.44) were obtained in 11 ‰ system compared to 6.5 ‰ system (Tables 3, 4). As we discussed previously in term of survival *D. labrax* achieved better survival rates (82.5 %, 77.5 %) at both salinities compared to *S. aurata* (5 %). Sea water (11 ‰) acclimated *S. ocellatus* showed the same growth performance parameters with respect to brackish water (6.5 ‰) within 15 weeks. They increased in weight by 2673.92 % and 2661.6 % in system A (11 ‰) and B (6.5 ‰) respectively (Tables 3, 4). These results confirmed that *S. ocellatus* showed good growth performance at both salinities, but bad survival rate when reared in 6.5 ‰ compared to those reared in sea water at salinity of 11 ‰ (Figure 8).

Table 3

Growth performance parameters of *S. aurata*, *D. labrax*, and *S. ocellatus* in system A (11 ‰)

Experimental sets	*Net weight gain (g)*	*Percentage weight gain (% WG)*	*Growth rate GR (g\day)*	*Specific growth rate (%)*	*Total Feed Provided (g)*	*Food conversion efficiency (FCE)*	*FCR*	*Protein intake (g)*	*Protein Levels (%)*	*Protein efficiency ratio*
A (*S. aurata)*	33.16	772.44	2.23	2.36	40.87	0.81	1.24	22.89	69.59	1.44
A (*D. labrax)*	46.78	6543.78	1.51	2.6	55.82	0.83	1.19	31.26	66.82	1.5
A (*S. ocellatus)*	33.05	2673.92	2.31	3.65	26.75	1.24	0.81	14.98	45.34	2.21

Table 4

Growth performance parameters of *S. aurata*, *D. labrax*, and *S. ocellatus* in system B (6.5 ‰)

Experimental sets	*Net weight gain (g)*	*Percentage weight gain (% WG)*	*Growth rate GR (g\day)*	*Specific growth rate (%)*	*Total Feed Provided (g)*	*Food conversion efficiency (FCE)*	*FCR*	*Protein intake (g)*	*Protein Levels (%)*	*Protein efficiency ratio*
B (*S. aurata)*	10.56	241.63	0.77	1.33	26.34	0.4	2.49	14.75	150.54	0.70
B (*D. labrax)*	50.12	6345.23	1.62	2.58	60.56	0.82	1.20	33.92	67.70	1.47
B (*S. ocellatus)*	33.7	2661.6	2.5	3.17	29	1.16	0.86	13.34	46	2.52

Experiment 2: predicting an appropriate feeding percentage for D. labrax. Accurate formulation of food requirement to best growth rate of fish in marine fish aquaculture should meet but do not exceed nutritional requirements, the precise formulation should lower feed costs for commercial aquaculture of sea bass in Palestine. Finding the suitable nutritional requirements amounts of this species will reduce nitrogen losses to the environment. Sea bass juvenile (20.6 g in weight) were acclimatized at brackish water from desalination unit (6.5 ‰) and were fed by three percentages of food (2.1 %, 3 %, 4 % of the body weight) with commercial food 56 % protein for 7 weeks.

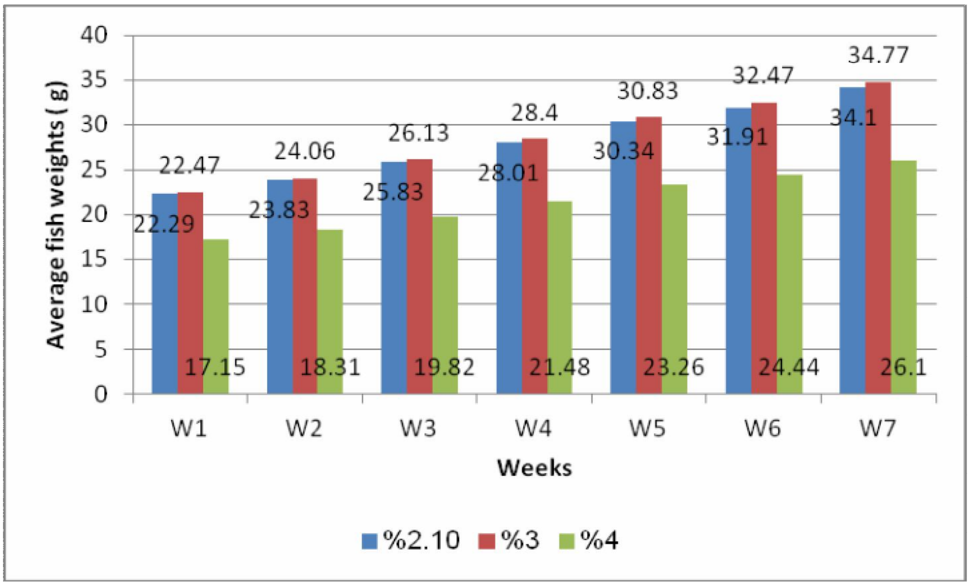

Figure 9. Weekly average weights of sea bass *D. labrax* fed by 2.1 %, 3%, 4% of their body weight during 7 weeks experimental period.

In reference to Figure 9, the highest average weight was achieved by fish fed 3 % of their body weight (34.77 g), followed by 2.1 % (34.1 g) and 4 % (26.1 g). Fish increase in (% WGs) were 54.6 %, 53 %, 52 % at 3 %, 2.1 %, and 4 % levels respectively.

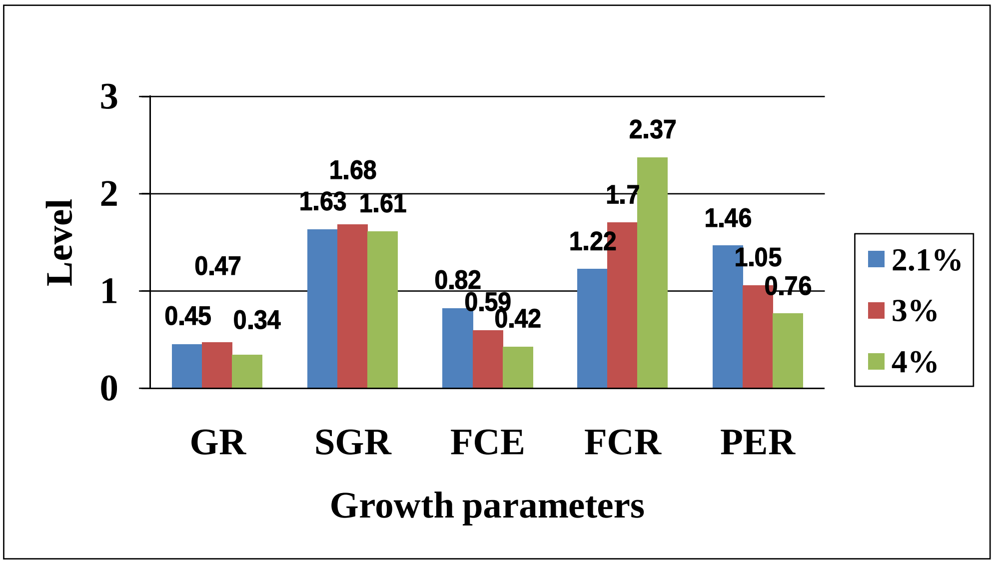

Figure 10. GR, SGR, FCE, FCR and PER for *D. labrax* fed by 2.1 %, 3.0 % and 4.0 % of their body weight during 7 weeks experimental period.

The highest growth rate, however, being achieved in the fish groups fed the 3 %, followed by those fed the 2.1 %, and finally the 4 %, which produced the lowest growth rate. Significantly, the highest (SGR) was also observed in the groups fed the 3 % (Figure 10). On the other hand, the highest (FCE) and (PER) were achieved in fish groups fed the 2.1 % (Figure 10). Food conversion efficiency decreased with increasing percentage of food. This result confirms that the best food % for optimum growth of sea bass seems to be 2.1 % and it is significantly different from other percentages of food. The FCR (1.2) was lower for fingerlings sea bass fed a diet containing 2.1 % of body mass than the rest of experimental groups (Figure 10). The FCR values were compared favorably to FCR observed in other studies with marine fish which were fed a diet containing 50% protein and 18% fat (Conides & Glamuzina 2006; Williams et al 2003). Furthermore, many studies demonstrated the result of a protein sparing effect of lipid (Boujard et al 2004; Olive-Teles 2000; Olive-Teles & Gancolves 2001). This action uses fat to provide energy and allows protein to be saved for muscle tissue and could explain the higher PER in fingerlings fed a diet containing 2.1 % of body mass than the rest of experimental groups.

Conclusions. This is the first time to our knowledge when where tested the growth rate of marine fish in brine waste brackish water from desalination units in Palestine. The results showed that the most suitable fish for cultivation utilizing brackish water from desalination units with salinity of 6.5 ‰ is sea bass (*D. labrax*), while the other two species need some modification to acclimatize to this water. The sea bass with an average weight of 0.76 g showed acceptable growth performance parameters and reached a % WG of 6345.23 % and a survival rate of 77.5 % compared to control groups at 11 ‰ that reached at the same time a % WG of 6543.78 % and a survival rate of 82 % after 30 weeks. On the other hand sea bream (*S. aurata*) and red drum (*S. ocellatus)* showed lower % WG and higher mortality rates. The red drum juveniles reached a % WG of 2661.6 % after 15 weeks but survival rate was only 5 % at 6.5 ‰, this could be contributed to several factors including osmolarity changes and rate of fish adaptation, toxic effect of some high trace metals in our experimental water and optimal requirement of some necessary anions like chloride and calcium needed for optimal growth. The requirements for maximum weight gain determined in this study, when expressed as a dietary concentration, were similar to those determined for sea bass. However, the expression of requirements in manipulating formulations and feeding strategies is to meet economical purposes. Sea bass fingerlings which received diets of 2.1 %, had the highest FCE and PER. This confirms that the best food % for optimum growth of sea bass is 2.1 % after 7 weeks. In summary, brackish water from desalination units could be suitable for marine fish cultivation, but may need some modification as adding salts to fish diet or water and reducing toxicity of some high trace metals present by a suitable method.

References

Abdel-Baki A. S., Dkhil M. A., Al-Quraishy S., 2011 Bioaccumulation of some heavy metals in tilapia fish relevant to their concentration in water and sediment of, Wadi Hanifah, Saudi Arabia. Afr J Biotechnol 10(13):2541-2547.

Appelbaum S., Arockiaraj A. J., 2009a Cultivation of gilthead sea bream (*Sparus aurata* Linnaeus, 1758) in low salinity inland brackish geothermal water. AACL Bioflux 2(2):197-203.

Appelbaum S., Arockiaraj A. J., 2009b Salt incorporated diets for enhancing growth performance and survival in gilthead sea bream *Sparus aurata L.* juveniles reared in low saline brackish water. Sci Mar 73(S1):213-217.

Arnold C. R., Bailey W. H., Williams T. D., Johnson A., Lasswell J. L., 1977 Laboratory spawning and larval rearing of red drum and southern flounder. Proc. Annu. Conf. Southeast Assoc. Fish Wild Agencies 31:437–440.

Boujard T., Gelineau A., Coves D., Corraze G., Dutto G., Gasset E., Kaushike S., 2004 Regulation of feed intake, growth, nutrient and energy utilization in European sea bass (*Dicentrarchus labrax)* fed high fat diets. Aquaculture 231:529-545.

Brett J. R., 1979 Environmental factors and growth. In: Fish Physiology, Vol. III, Hoar W. S. & Randall D. J.(ed), pp. 599 – 675. Academic Press, New York.

Chatelier A., McKenzie D. J., Claireaux G., 2005 Effects of changes in water salinity upon exercise and cardiac performance in the European sea bass (*Dicentrarchus labrax*). Mar Biol 147(4):855-862.

Conides A. J., Glamuzina B., 2006 Laboratory simulation of the effects of environmental salinity on acclimation, feeding and growth of wild-caught juveniles of European sea bass *Dicentrarchus labrax* and gilthead sea bream, *Sparus aurata*. Aquaculture 256:235-245.

Cuesta A., Laiz-Carrión R., Martín del Río M. P., Meseguer J., Mancera J. M., Ángeles Esteban M., 2005 Salinity influences the humoral immune parameters of gilthead seabream (*Sparus aurata L.*). Fish Shellfish Immunol 18:255-261.

Davies P., Goettl J., Sinley J., 1978 Toxicity of silver to rainbow trout. Water Res 12:113–117.

Eid A., Mohamed K., 2010 Effect of dietary lipid levels on growth performance of Sea bass (*Dicentrarchus labrax*) fingerlings. Aquaculture 225:191-206.

EPA, 1996 Water quality criteria documents for the protection of aquatic ife in ambient water. Washington, DC, US Environmental Protection Agency (820B96001), National Service Center for Environmental Publications (NSCEP) 1-114.

Eroldoğan O., Kumlu M., 2002 Growth performance, body traits and fillet composition of the european seabass (*Dicentrarchus labrax)* reared in various salinities and fresh water. Turk J Vet Anim Sci 26:993-1001.

Eshchar M., Lahav O., Mozes N., Peduel A., Ron B., 2006 Intensive fish culture at high ammonium and low pH. Aquaculture 255:301-313.

Evans D. H., 1975 Ionic exchange mechanisms in fish gills. Comp Biochem Physiol 51(A):491-495.

Ferguson E., Hogstrand C., 1998 Acute silver toxicity to seawater-acclimated rainbow trout: Influence of salinity on toxicity and silver speciation. Environ Toxicol Chem 17(4):589–593.

Forsberg J. A., Dorsett P. W., Neill W. H., 1996 Survival and growth of red drum, *Sciaenops ocellatus,* in saline ground waters of West Texas, USA. J World Aquac Soc 27:462-474.

Forsberg J. A., Neill W. H., 1997 Saline groundwater as an aquaculture medium: Physiological studies on the red drum, *Sciaenops ocellatus.* Environ Biol Fishes 49:119-128.

Girard J. E., 2010 Principles of environmental chemistry, 2nd Edition. Jones & Bartlett (ed), pp. 687, LLC.

Grosell M., Hogstrand C., Wood C., Hansen H., 2000 A nose-to-nose comparison of the physiological effects of exposure to ionic silver versus silver chloride in the European eel (Anguilla anguilla) and the rainbow trout (Oncorhynchus mykiss). Aquat Toxicol 48(2–3):327–342.

Howe P. D., Malcolm H. M., Dobson S., 2004 Manganese and its compounds: environmental aspects. (Concise international chemical assessment document; 63). WHO, Geneva.

Khangarot B. S., Rathore R. S., Tripathi D. M., 1999 Effects of chromium on humoral and cell-mediated immune responses and host resistance to disease in a fresh water cat fish, *Saccobranchus fossilis* (Bloch). Ecotoxicol Environ Saf 43:11-20.

Khayat S., Hötzl H., Geyer S., Ali W., 2005 Hydrochemical investigation of water from the Pleistocene wells and springs, Jericho area, Palestine. Hydrogeol J 14:198–202.

Klaoudatos S. D., Conides A. J., 1996 Growth, food conversion, maintenance and long-term survival of gilthead sea bream, *Sparus auratus L.*, juveniles after abrupt transfer to low salinity. Aquacult Res 27:795–774.

Laiz-Carrión R., Sangiao-Alvarellosb S., Guzmána J., Martín del Ríoa M., Soengas J. L., Mancera J. M., 2005 Growth performance of gilthead sea bream *Sparus aurata* different osmotic conditions: Implications for osmoregulation and energy metabolism. Aquaculture 250:849–861.

Marino G., Cataldi E., Pucci P. I., Bronzi P., Cataudella S., 1994 Acclimation trials of wild and hatchery sea bass (*Dicentrarchus labrax)* fry at different salinities. J Appl Ichthyiol 10:57-63.

Marino G., Di Marco P., Petochi T., Priori A., Finoia M. G., 2006 Blood gas and acid-base status in seabass *Dicentrarchus labrax* exposed to environmental hypercapnia. AQUA 2006. European Aquaculture Society Congress. Abstracts, p. 572. Florence, Italy.

Marshall W. S., Grosell M., 2006 Ion transport, osmoregulation and acid-base balance. In The Physiology of Fishes, Evans D. H. & Claiborne J. B. (ed), pp. 177-230. Boca Raton, FL: CRC Press.

Matsumoto S. T., Mantovani M. S., Malaguttii M. A., Dias A., Fonseca I. C., Marin-Morales M. A., 2006 Genotoxicity and mutagenicity of water contaminated with tannery effluents, as evaluated by the micronucleus test and comet assay using the fish *Oreochromis niloticus* and chromosome aberrations in onion root-tips. Genet Mol Biol 29(1):148-158.

Olive-Teles A., Gancolves P., 2001 Partial replacement of fishmeal by brewers east (*S. cerevisae*) in diets for sea bass (*D. labrax*) juveniles. Aquaculture 202:(3-4)269-78.

Olive-Teles A., 2000 Recent advances in European sea bass and gilthead sea bream nutrition. Aquaculture International 8:477-492.

PASSIA (Palestinian Academic Society for the Study of International Affairs), 1999 Water crisis in Palestine - Scenarios for Solutions. Jerusalem.

Pursley M. G., Wolters W. R., 1994 Effect of total water hardness and chloride on survival, growth, and feed conversion of juvenile red drum, *Sciaenops ocellatus*. J World Aquac Soc 25:448–453.

Rashed M. N., 2001 Monitoring of environmental heavy metals in fish from Nasser lake. Environmental International 27:27-33.

Robertson L., 1984 Plasma cortisol, glucose and osmolality stress responses in cultured red drum (*Sciaenops ocellatus*) elicited by handling and transportation and modulation of these responses via anesthetics. Master's thesis, University of Texas at Austin, 101 pp.

Salameh E., 2002 Sources of water salinities in the Jordan Valley area, Jordan. Acta Hydrochim Hydrobiol 29:329-362.

Sangiao-Alvarellos S., Laiz-Carrion R., Guzman J. M., Martin del Rio M. P., Miguez J. M., Mancera J. M., Soengas J. L., 2003 Acclimation of *S. aurata* to various salinities alters energy metabolism of osmoregulatory and non-osmoregulatoy organs. Am J Physiol Regul Integr Comp Physiol 285:897–907.

Schmidt-Nielsen K., 1997 Water and osmotic regulation. In: Animal physiology adaptation and environment, 5th ed., Schmidt-Nielsen K. (ed.), pp. 301–354, Cambridge University Press.

Simmons E. G., Breuer J. P., 1962 A study of redfish, *Sciaenops ocellata* Linnaeus, and black drum, *Pogonias cromis* Linnaeus. Publ Inst Mar Sci Univ Tex 8:184-211.

Spiegler K. S., Laird A. D., 1980 Principles of desalination, 2nd edition, Academic Press, New York.

Stickney R. R., 1994 Principles of aquaculture. Willey J., and Sons (ed), pp.Vii-502, New York.

Tandler A., Anav F. A., Choshniak I., 1995 The effect of salinity on growth rate, survival and swim bladder inflation in gilthead sea bream, *Sparus aurata*, larvae. Aquaculture 135:343-353.

Velma V., Vutukuru S. S., Tchounwou P. B., 2009 Ecotoxicology of hexavalent chromium in freshwater fish: A critical review. Rev Environ Health 24(2):129–145.

WHO, 1996 Water Quality Assessments - A guide to use of biota, sediments and water in environmental monitoring. 2nd edition, Chapman D. (ed), pp. 651, F & FN Spon.

Williams K. C., Barlow C. G., Rodgers L., Hockings I., Agcopra C., Ruscoe I., 2003 Asian seabass *Lates calcarifer* well when fed pelleted diets high in protein and lipid. Aquaculture 225:191-206.

Wurts W. A., Stickney R. R., 1989 Responses of red drum (*Sciaenops ocellatus*) to calcium and magnesium concentrations in fresh and salt water. Aquaculture 76(1-2):21-35.

Received: 18 December 2012. Accepted: 13 January 2013. Published online: 19 January 2013.
Authors:
Mutaz Ali Al-Qutob, Al-Quds University, Faculty of Science and Technology, Department of Earth and Environmental Studies, Israel, Jerusalem, P. O. Box 19164, e-mail: qutob@planet.edu
Ra'fat Abdul-Hamied Qubaja, Al-Quds University, Aquatic and Aquaculture Laboratory, Israel, Jerusalem, P. O. Box 19164, e-mail: mitorafat@yahoo.com
Tharwat Salah Nashashibi, Al-Quds University, Aquatic and Aquaculture Laboratory, Israel, Jerusalem, P. O. Box 19164, e-mail: tharwatnash33@hotmail.com

How to cite this article:
Al-Qutob M. A., Qubaja R. A., Nashashibi T. S., 2013 Utilization of desalinated brackish water residues for cultivation of the marine fish species, *Dicentrarchus labrax, Sparus aurata,* and *Sciaenops ocellatus.* AACL Bioflux 6(3):162-179.