# Effect of Light and Music on Growth Performance and Survival Rate of Goldfish (*Carassius auratus*)

**Imanpoor M. R.; Enayat Gholampour T*; Zolfaghari M.**

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**Abstract**

Environmental enrichment is one of the methods for improving fish growth performance. In the present trial, the effects of both light color and music on growth performance and survival of goldfish (*Carassius auratus*) (initial mean weight: 4.15±0.08 g) were investigated for 2 months. Two light color treatments (red light and white light) and three music treatments ($M_0$: without music, $M_{30}$:30 minutes music and $M_{60}$:60 minutes music) were considered. At the end of the rearing stage, growth performance including weight gain (WG), specific growth rate (SGR), daily growth rate (DGR) and food conversion rate (FCR) and also survival rate (SR) were surveyed. Results indicated that the effect of music and interaction effect of light by music were not significant (P>0.05) on growth performance parameters, whereas light significantly (P<0.05) affected FCR and SGR. According to these results, goldfish showed a better growth in white light than red light (P<0.05) while music treatments did not influence growth performance differentially (P>0.05). Using music in the rearing environment had no positive or negative effect on goldfish growth, revealing that goldfish can distinguish music from other environmental stressful sounds.

**Keywords**:*Carassius auratus*, Environmental enrichment, Light color, Music, Growth indices, Survival rate

Faculty member, Dept. of fisheries, Gorgan university of Agricultural Sciences and Natural Resources.
Corresponding author's email: T_enayat2007@yahoo.com

## Introduction

Hearing in fishes has been studied in numerous ways since the early 20th century. Fish live in an environment that is a specifically good conductor of sound, and the myriad extant species counting 25,000 in the class Actinopterygii (bony fishes) (Nelson, 1984) have evolved diverse mechanisms for acoustic stimuli transmittance. Also, under intensive culture, fish are often subjected to stressful situations that negatively affect growth (Rowland et al., 2006), reproduction (Campbell et al., 1994) and immune response (Vazzana et al., 2002).

Rearing conditions in aquaculture tanks can produce more sound levels within the frequency range of fish hearing ability that is 20–50 dB higher than the limit; encountering in their natural habitats (Bart et al., 2001; Cited in: Smith, 2004). Water is an essential requirement for fish farming, so any proper-prepared plan for aquaculture must describe the quality and quantity of water available for this purpose (Summerfelt, 2000; Cited in: Moogouei et al., 2010).

Many researchers in Iran (Akbary et al., 2010; Bo Zhang, 2010; Moogouei et al., 2010) have studied the effects of environmental changes on growth, survival and spatial distribution in many species.

Sound is an important means of communication in aquatic environments because it can be distributed rapidly (five times faster than in air) over great distances and it is not attenuated as quickly as other signals such as light or chemicals (Hawkins and Myrberg, 1983; Cited in: Smith et al., 2004b). Thus, it is not surprising that fishes and marine mammals make considerable use of sound for communication, for detection of both predators and prey as well as for learning about their environment (Fay and Popper, 2000). Several research studies have been published on noise-induced stress responses, sound perception and auditory sensitivities in goldfish (Smith et al., 2004b; Fay, 1995; Friedrich and Wysocki, 2009).

There seems to be a synergistic effect between food availability and light that improves the trophic activity of larvae (Boeuf and Le Bail, 1999; Cited in: Pedro Canavate et al., 2006), also this factor plays an important role in the growth and survival of larval fish (Batty, 1987 Cited in: Puvanendran and Brown, 2002). Light regimes that permit rapid initiation of successful feeding should facilitate survival of larvae through early developmental bottlenecks, e.g. the switch from endogenous to exogenous food sources. Light intensity was also reported to affect swimming activity and feeding (Almaza´n-Rueda et al., 2004), cannibalism (Kestemont et al., 2003), skin color (Rotllant et al., 2003), physiological hormones (Boeuf and Le Bail, 1989), metabolism (Appelbaum and Kamler, 2000) and initiation of ecdysis (Waddy and Aiken, 1991).

Generally, the whole concept falls in the section of ‘‘environmental enrichment’’ that has been defined as an improvement in the biological functioning of captive animals resulting from modifications to their environment (Newberry, 1995). Fish auditory sense is based on detection of sound pressure and involves the combined function of otolith organs, lateral line and swim bladder (Fay and Popper, 2000; Popper et al., 2003). Fish are able to detect, respond to and even produce a wide range of sounds and more importantly to discriminate between sounds of different frequencies and magnitudes, to determine the direction of a sound source (sound source localization) and to detect a biologically relevant sound in the presence of other signals (Popper et al., 2003 Cited in: Popoutsoglou et al., 2007).

We chose goldfish as a model hearing specialist because of their known hearing sensitivity and the available literature database about hearing in this species (Fay, 1998, Cited in: Popoutsoglou et al., 2007). Goldfish are otophysan fishes, which possess weberian ossicles (modified cervical vertebrae that abut the ear (Smith et al., 2004b). These bones acoustically couple movement of the swim bladder imposed by impinging sound pressure waves to the inner ear, leading to enhanced hearing sensitivity that includes a broadened frequency range of hearing and lower auditory thresholds when compared with fishes without such specializations. Furthermore, goldfish are known to perceive acoustic dimensions equivalent to what humans perceive as pitch and timbre (Fay, 1995, Cited in: Chase, 2001). The main objective of the present investigation was to evaluate music and light color effects on goldfish (*Carassius auratus*) growth performance and survival rate. In addition, in order to investigate the possibility of using musical auditory stimuli in aquaculture facilities, the experiment was carried out under two different light conditions (red and white lights) since it still remains unclear whether or not rearing in different light is stressful for goldfish.

## Materials and methods

### *Fish acclimation and rearing conditions*

The Goldfish (*Carassius auratus*) were provided by a commercial supplier in Gorgan. This trial was carried out in the rearing room of Natural Resource and Agricultural of Gorgan, Iran. The goldfish were placed in holding tanks (Volume: 100 L, temperature: 26.1±0.4°C, pH: 7.8 ± 0.1, salinity: 0.1 g/l and dissolved oxygen: 7.6 ± 0.03 mg/l) and acclimated for 2 weeks prior to the experiment, showing a normal feeding pattern during this period. To begin this experiment, goldfish (n=540) were captured from a holding tank and both mean weight (4.15±0.05 g) and mean length (9.5±0.2 cm) were measured. Then fish samples were placed in 18 tanks (Volume: 70 lit water capacity, height 70×width 30×length 40Cm) (30 goldfish/tank) with two treatments of light (red light and white light) and three treatments of music (($M_0$: without music, $M_{30}$:30 minutes music and $M_{60}$:60 minutes music). The treatments were replicated three times in separate aquariums. Continuous aeration was provided to maintain dissolved oxygen near saturation level. A 200W immersion heater was installed in each aquarium to control water temperature. The whole sample was divided into six groups (one control and five experimental groups); each consisting of 3 aquariums. The treatment for control group consisted of white light and no music which is the usual condition of fish in the natural environment. The experimental group consisted of five sub-groups: (1) white color and 30 min music, (2) white color with 60 min music, (3) red color with no music, (4) red color with 30 min music and (5) red color with 60 min music. The fish were reared under experimental treatments for 60 days.Initial mean weights did not differ significantly (P>0.05) among treatments. No food was offered from 24 hr before the first biometric.

Water physiological characteristics were monitored twice daily (before the first meal and 30 min after the last meal) and water quality was maintained as followed: temperature, 26.4±0.7°C; pH, 7.7 ± 0.1; salinity, 0.1 g/l and dissolved oxygen 7.5 ± 0.05 mg/l.

The goldfish were adequately fed, by hand, a commercial pelleted diet (Biomar, made in France) twice daily at 8:00 am and 4:00 pm when there was no music (4% of body weight).

The fish were individually weighed every two weeks (days 1, 15, 30, 45 and 60) throughout the experimental period. Fish were anesthetized at weighing to decrease the stress caused by handling, without any subsequent effect on food intake. The body weight gain (WG, g) was calculated as the increase in weight of goldfish at the end of experimental period, WG=Wf−Wi, where Wf and Wi are the final and initial body weights, respectively (Luz et al., 2008). Daily growth rate was calculated with (Wf-Wi) ×100/ (days × Wi) formula (Luz et al., 2008). The specific growth rate (SGR, %/day) was measured according to the formula (lnWf−lnWi) ×100/Δt; where Δt is the time interval (in days) between Wi and Wf measurements (Watanabe et al., 1993). The food conversion ratio (FCR) was assessed as food consumption/weight gain (Luz et al., 2008).

Fish mortality was checked every day. No mortality occurred during the experimental period.

*Light*

To provide recommended light conditions, wooden boxes with black covers were used. In order to provide red and white light colors, red and white mercury lamps (40 W) were used. One lamp was applied on top of each aquarium and the height of each lamp was adjusted in a way so that the intensity of light would be 300 LX on the surface of water. The intensity of light was measured by luxmeter (Model: Lutron Lx-101, Tiwan).

The time for each group (red light and white light) was set as 12L: 12D (from 7 am to 7 pm) which was controlled by a timer. The equipments for light transmission were tested daily.

*Music*

In this research, the design and construction of equipments required for playing music and transmitting sound under water was based on the method explained by Papoutsoglou et al. (2007). In our study, the music treatments consisted of 1: no music at all (control group, M0), 2: music was played for 30 minutes (M30), and 3: music was played for 60 minutes (M60). The music was played 4 times a day at 9:00, 11:00, 13:00 and 15:00. The equipments for sound transmittance were controlled daily. The piece of selected music was from part of the lute violin (Mon amour of Clude mishel) performed by Iran symphonic orchestra (2005). The time period of the selected music was 6 min and 30 seconds and the piece was repeated during the exposure time. Then the selected music was modified by Jet audio software so that frequencies lower than 100 Hz and higher than 1000 Hz were deleted. Therefore the frequencies which were of interest to be reproduced ranged from 100 Hz to 1000 Hz. Two VCD players which were equipped by a timer controller system (timer, model 026, Nourfrocslsterom Company, made by Germany) were used to play and control the time period of music. Each VCD player containing the CD of the treatment was attached to a speaker (10 cm wide, 100W) by means of a cable and then the speaker was placed under the water in the corner of aquarium (except for the control tanks). An amplifier (80 W, Pars Sound, Iran) was utilized after the output of the VCD player to boost and control the sound intensity. The intensity of sound was set as 30 decibel which was measured by a hydrophone. The speakers and hydrophone were made by Gorgan Company. The equipments were set in the tank in a way that did not inhibit the swimming of the fishes (Fig. 1). The related equipments were controlled every day.

*Data analysis and statistical methods*

Using a factorial design of 3*2, three music conditions ($M_0$, $M_{30}$ and $M_{60}$) and two lights (red and white) were randomly arranged to three replicate tanks. Prior to statistical analysis, all data were tested for normality by the Kolmogornov-Smirnov test. The homogeneity of variances among the different groups was tested using the Levene test. Data were analyzed by a two-way analysis of variance (ANOVA) followed by a Duncan test. All statistical analyses were performed using SPSS15.0 statistical package. The probability level of $P<0.05$ was considered statistically significant. All data in tables and texts are untransformed means ± S.E. (the standard Error).

## Results

In this research, there were no significant differences ($P>0.05$) in initial mean weight (4.15±0.05 g) among treatments (Table 1).

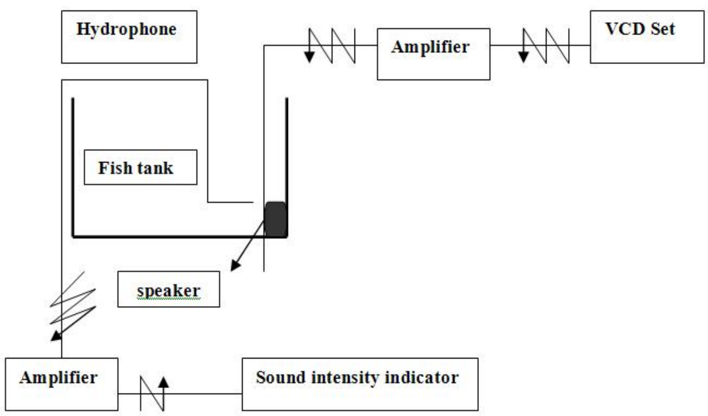


**Figure 1: Schematic diagram of music transmission in goldfish tank and hydrophone output recording.**

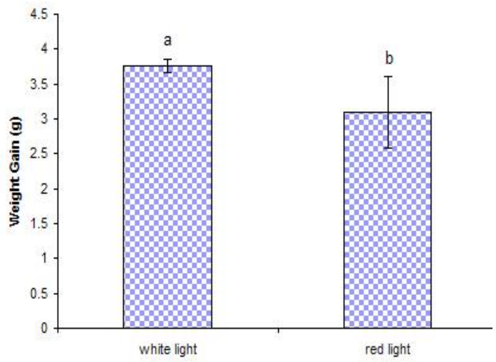


**Figure 2: Weight gain of goldfish in red and white light**

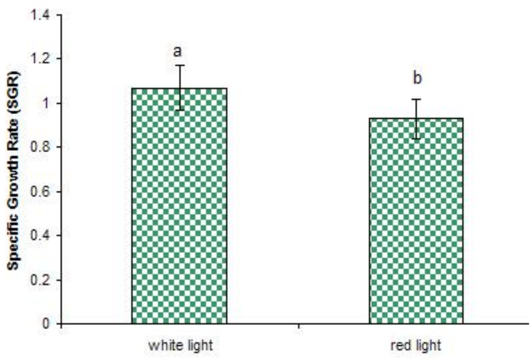


**Figure 3: Specific growth rate of goldfish in red and white light**

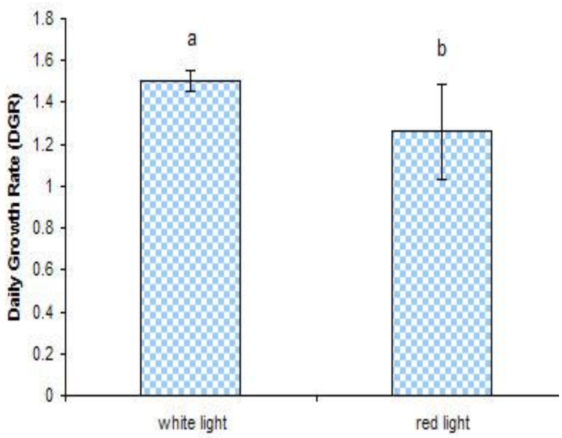


**Figure 4: Daily growth rate of goldfish in red light and white light**

**Table 1: Growth performance parameters (mean± S.E) in goldfish reared under white light, red light, no music (C), 30 min (M30) and 60 min (M60) music transmission for 60 days**

| | White light | | | Red light | | | TWO-way ANOVA | | |
|---|---|---|---|---|---|---|---|---|---|
| | C | M30 | M60 | C | M30 | M60 | Lighting | Music | LM |
| **IW** | 4.16±0.02[a] | 4.2±0.05[a] | 4.14±0.04[a] | 4.08±0.09[a] | 4.17±0.14[a] | 4.15±0.05[a] | NS | NS | NS |
| **WG** | 3.76±0.10[a] | 3.57±0.19[a] | 3.98±0.18[a] | 3.09±0.51[b] | 3.23±0.04[b] | 3.41±0.10[b] | * | NS | NS |
| **DGR** | 1.50±0.05[a] | 1.41±0.08[a] | 1.60±0.05[a] | 1.26±0.23[b] | 1.30±0.05[b] | 1.37±0.04[b] | * | NS | NS |
| **SGR** | 1.07±0.02[a] | 1.02±0.04[a] | 1.12±0.02[a] | 0.93±0.13[b] | 0.95±0.03[b] | 1.00±0.02[b] | * | NS | NS |
| **SR** | 95.55±1.92[a] | 96.66±3.33[a] | 95.55±7.69[a] | 94.44±6.93[a] | 97.77±1.92[a] | 6.66±5.77[a] | NS | NS | NS |
| **FCR** | 2.25±0.05[b] | 2.36±0.11[b] | 2.16±0.06[b] | 2.61±0.31[a] | 2.55±0.04[a] | 2.43±0.06[a] | NS | NS | NS |

Significant treatment effects and the interactions are shown as letters; means with the same letters are not significantly different ($P>0.05$, two-way ANOVA); *: $P<0.05$

**NS**: non significant; **IW**: initial weight; **WG**: weight gain; **DGR**: daily growth rate; **SGR**: specific growth rate; **SR**: survival rate; **FCR**: food conversion rate. All data are given as means ± S.E., LM: Lighting ×Music

The results obtained of this trial indicated that weight gain (WG), specific growth rate (SGR) and daily growth rate (DGR) were affected significantly by light (P<0.05), but the effect of music and interaction of light by music were not significant (P>0.05) on weight gain (WG), specific growth rate (SGR) and daily growth rate (DGR) (Table 1). Survival and food conversion rates (FCR) were not affected significantly by light effect, music and interaction effect of light by music (P>0.05) (Table 1).

Regarding the findings of mean comparison of weight gain (WG) (Fig. 2), specific growth rate (SGR) (Fig. 3) and daily growth rate (DGR) (Fig. 4), it was observed that these parameters were significantly (P<0.05) higher at white light than red light.

**Discussion**

The results obtained in the present study, demonstrated that effect of music was not significant on growth performance in goldfish. Control fish reared without music (M0) and with white light and fish samples in treatments of M30 and M60 showed similar growth indices (WG, SGR and DGR) (P>0.05).

The findings in our research were in agreement with the results of Papoutsoglou et al., (2007), who reported that growth performance was not significantly affected by music in common carp (*Cyprinus carpio*). In any case, the results of our study were in consistence with the findings of Papoutsoglou et al., (2008), who investigated combined effects of music and light intensity in *Sparus aurata*. Additionally, they found that music had a positive effect on fish growth performance. High levels of ambient sound may prevent fish from hearing biologically important sounds and alter fish normal behavior (Popper, 2003). Considering not enough and certain information for the effect of music and light on fishes, there is low contrasting suggestions. Among music transmission effects, it has been reported that cows were more willing to approach the automatic milking system (Uetake et al., 1997; Cited in: Papoutsoglou et al., 2007), broiler chicks were less fearful and grew better (Gvaryahu et al., 1989; Cited in: Papoutsoglou et al., 2007), but few studies have been conducted to assess the music on fish growth. Smith et al., (2004) express that extra sounds in the environment cause stress in fish and so detrimentally affect growth. In the present study, if fish could not distinguish music from other extra sounds and rather identify it as a disturbing sound, it would encounter chronic stress during the experimental period and growth would be less than the control group. With regard to the fact that no significant difference was observed among the treatments of M0, M30 and M60 in terms of growth performance, it is concluded that the goldfish is able to distinguish and identify rhythmic sounds. This is in agreement with the findings of Davis (1992) and Verheijen and Flight (1997).

In the research by Chase (2001) subjects were koi, which are members of the carp family and close relatives of the goldfish. Neither goldfish nor koi are known to communicate by making sounds (Fay, 1995; Cited in: Chase,2001), but both are classified as otophysans, a group that has bony structures (the Weberian ossicles) coupling the swim bladder to the inner ears, in which there are hair cells with a specialized orientation pattern.

In the present research, the results of growth function obtained from light color treatments indicated that growth indices (WG, SGR and DGR) of goldfish have a better performance in white light than in red light. The effect of light color on growth performance has been proved which is different based on type of species and stage of life in fish. Fish are capable of color vision (Cheng and Flamarique, 2004) and the effects of light spectrum on several aspects of fish physiology have been investigated.

The main role in this process is played by the eyes and pineal organ, because only they can detect colors (Ekstrom and Meissl, 1997). For instance, the results of experiments by Ruchin (2004) demonstrated that different species of fish can have different response to light quality. Thus Crucian carp developed better by green light, Rotan by blue and green and Guppy by blue light. Also, in their study, by red light the growth rate in all species decreased. The response in different species of fish to the light environment appears to be governed by changes in energy metabolism and hormone disproportion.

Most species of fish have well developed color sight, and are therefore very sensitive to colored light. In our study, results indicated that rearing goldfish in white light had favorable effects on fish growth performance. While in other researches, the survival rate of Haddock larvae (*Mellanogrammus aeglefinus*) is higher with blue and green light (Downing, 2002). The growth rate of Silver carp larvae (*Hypophthalmichthys molitrix*) and young carp (*Cyprinus carpio*) increased with green light (Ruchin et al., 2002).

Thus, the results obtained by Ruchin (2004) demonstrate that there are differences in response to different colored zones in various species of fish. Some species such as carp, crucian carp and silver carp grow well with blue and green light (Ruchin et al., 2002), the growth rate of other species (guppy, whitefish) increases with blue light (Radenko and Terent'ev, 1998; Cited in: Ruchin, 2005) and others (rotan) grow equally well with both green and blue light.

Villamizar et al., (2011) showed that larvae (European sea bass and sole larvae) were significantly affected by light characteristics. For example, the larvae achieved the best performance, and showed fastest development and lowest degree of deformity under a light/dark cycle using blue light, conditions which were closest to their natural aquatic environment. On the other hand, Migaud et al., (2009) achieved maximum survival rates of Cod (*Gadus morhua*) larvae in red light than white, green and blue light (Migaud et al. 2009; Cited in: Villamizar et al., 2011).

Karakatsouli et al., (2007) observed that rainbow trout (*Oncorhynchus mykiss*) reared under red light had a better food intake and growth than blue light. Also, they found that red light can affect the growth indices and survival rate of fish, such as rainbow trout. One of the reasons which were mentioned for this phenomenon is the existence of oil droplets in the eyes of such fish. These oil droplet filter spectrums have a low wavelength and let high wavelengths pass by. Therefore fish culture in red light causes the food to contrast better with the environment and ease the process of feeding. In addition, fishes like goldfish lack this oil droplet in their eyes (Bowmaker, 2008). Therefore, red light does not play any role in feeding facilitation of goldfish.

Therefore, white light in comparison with red light, having wavelengths similar to natural light, caused less stress in the fish breed in artificial environments which finally results in a better development. Also, it is suggested that further investigations on intensity and duration of music and light, in relation to other rearing environment (tanks, water quality, etc.) and fish (species, life stage, feeding, rearing density, etc.) origin factors affecting farmed fish quality and welfare, would contribute to a very promising outcome in improving our understanding of fish physiology.

Based on the results in the present study, it was found that music did not affect fish growth, therefore goldfish could able to distinguish music from other environmental stressful sounds, and music did not enumerate unfavorable potential and stressful aspects for goldfish. In hence, we can say that studying music which effects fish physiology status should be considered as a novel experimental field. According to the results obtained in the present trial, red light is not a fit option to environmental enrichment in goldfish.

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# تاثیر رنگ نور و موسیقی بر عملکرد رشد و نرخ بازماندگی ماهی قرمز (*Carassius auratus*)

محمد رضا ایمانپور، طیبه عنایت غلامپور*، مهدی ذوالفقاری

## چکیده

غنی سازی محیطی از روشهای جدید در بهبود عملکرد رشد ماهی است. در تحقیق حاضر، اثر رنگ نور و موسیقی بر عملکرد رشد و نرخ بازماندگی ماهی قرمز (*Carassius auratus*) (میانگین وزن اولیه: ۰/۰۸±۴/۱۵ گرم) به مدت ۲ ماه مورد ارزیابی قرار گرفت. دو تیمار نور (رنگ سفید و رنگ قرمز) و سه تیمار موسیقی (M۰: بدون موسیقی، M۳۰: ۳۰ دقیقه پخش موسیقی و M۶۰: ۶۰ دقیقه پخش موسیقی) در نظر گرفته شد. در پایان دوره پرورش، عملکرد رشد بچه ماهیان شامل وزن اکتسابی (WG)، نرخ رشد ویژه (SGR)، نرخ رشد روزانه (DGR) و ضریب تبدیل غذایی (FCR) و همچنین نرخ بازماندگی (SR) مورد بررسی قرار گرفت. نتایج نشان داد که تاثیر موسیقی و نیز اثر متقابل نور و موسیقی بر عملکرد رشد بچه ماهیان معنی دار نبود (P>۰/۰۵) در حالیکه تاثیر نور بر نرخ رشد ویژه و ضریب تبدیل غذایی بچه ماهیان معنی دار گزارش گردید (P<۰/۰۵). بر طبق نتایج بدست آمده در تحقیق حاضر، بچه ماهیان قرمز در نور سفید نسبت به نور قرمز رشد بهتری را نشان دادند (P<۰/۰۵) در حالیکه تیمارهای موسیقی بر عملکرد رشد تاثیر معنی داری نداشتند (P>۰/۰۵). کاربرد موسیقی در محیط پرورش بچه ماهیان قرمز هیچگونه تاثیر مثبت یا منفی بر رشد آنها نداشت که این امر بیان کننده این است که ماهی قرمز قادر به تشخیص موسیقی از سایر صداهای استرس زای محیطی می باشد.

**واژگان کلیدی**: ماهی قرمز، غنی سازی محیطی، رنگ نور، موسیقی، شاخص های رشد، نرخ بقاء

۱- دانشکده شیلات- دانشگاه علوم کشاورزی و منابع طبیعی گرگان.

۲-دانشگاه علوم کشاورزی و منابع طبیعی گرگان. دانشکده شیلات

*پست الکترونیکی نویسنده مسئول: T_enayat2007@yahoo.com