Egyptian Journal of Aquatic Biology & Fisheries
Zoology Department, Faculty of Science,
Ain Shams University, Cairo, Egypt.
ISSN 1110 – 6131
Vol. 28(2): 717 – 734 (2024)
www.ejabf.journals.ekb.eg

The Effectiveness of Coded Wire-Tagging and Release Methods as an Approach for Increasing the Stocking of Grey Mullet (*Mugil cephalus*) in an Egyptian Enclosed Wadi El-Rayan Lake

Mohamed A. Essa[1], Amr M. Helal[1, *], Nevine M. Abou Shabana[1], Basem S. Abdelaty[1], Mohamed A. Elokaby[1], Mohamed El Hammamy[1], Mohamed Baroma[1], Ahmad M. Aboseif[1], Marwa M. Zaher[1], Mohamed Ashour[1, *], Kevan L. Main[2], H. Lee Blankenship[3], Kenneth M. Leber[2], Ashraf M.A.-S. Goda[1]

[1]National Institute of Oceanography and Fisheries (NIOF), Egypt
[2]Mote Marine Laboratory, Sarasota, FL, USA
[3]Northwest Marine Technology, Olympia, WA, USA

[*]**Corresponding Authors: amr_helal@yahoo.com, microalgae_egypt@yahoo.com**

ARTICLE INFO

Article History:
Received: Feb. 7, 2024
Accepted: March 19, 2024
Online: April 14, 2024

Keywords:
Grey mullet,
Mugil cephalus,
Coded-wire tag,
Stock enhancement

ABSTRACT

Determining appropriate methods to release fish into confined water bodies such as lakes necessitates an awareness of the potential impact on local fish and the ecosystem in general, as well as a cost-benefit analysis. The purpose of this study was to apply various release strategies boosting the survival rate (%) of grey mullet (*Mugil cephalus*) fingerlings in the lower part of Wadi El-Rayan Lake (WRL) located in Al-Fayoum Governorate, Egypt. This study involved two experiments. The first experiment involved nursing and rearing grey mullet fingerlings in net enclosures (NE-CWT) and an earthen pond for 40 days before releasing them into the WRL. In the second experiment, three groups were studied before being released into the WRL: the first group underwent a nursing experiment (nursing for 40 days for acclimatization), the second group underwent grow out rearing for 334 days, and the third group (control group, continued) was released directly into the WRL, without extended rearing, acclimatization, or CWT recovery. During the first experiment, the growth performance, feed utilization, and survival rates of *M. cephalus* fingerlings were recorded. Throughout the second experiment, the fishermen collected monthly samples from the WRL to monitor the growth and survival rates of *M. cephalus*. The data revealed that fish temporarily held in NE-CWT had significantly higher ($P < 0.05$) final body weight, total weight gain, specific growth rate, and survival rate. Growth trends were similar for the fish temporarily held in EP-CWT. These findings emphasized the significance of short-term rearing and acclimation prior to release for improving the performance parameters of mullet seed compared to direct release into the lake. The study results can be used to increase the effectiveness of future grey mullet (*M. cephalus*) stockings in the Egyptian lakes. Transferring the results to fishermen’s associations in Egypt will provide these groups more time to evaluate and improve the stock enhancement technologies.

INTRODUCTION

Egyptian aquaculture stands as the largest producer of fish in Africa and the Mediterranean basin. With the continuous growth of the population and the increasing cost of food imports, the Egyptian aquaculture industry is striving to establish itself as a leader in sustaining food supplies not only for the local population but also for the region and beyond **(Mabrouk *et al.*, 2022; Sharawy *et al.*, 2022)**. In Egypt's fish production, grey mullet *Mugil cephalus* holds the second position after the Nile tilapia **(FAO, 2022)**. Among the prominent species in Egypt and many Mediterranean countries is the grey mullet. The current production of mullets heavily relies on inland fisheries in lakes, where the main source of mullet seed is wild fry **(GAFRD, 2020)**. On the other hand, mullet aquaculture production relies heavily on the capture of wild fry along the Mediterranean coast. Despite advancements in fish hatchery technologies, mullet farming still heavily relies on the capture of wild fingerlings from coastal waters and their subsequent stocking in lakes and ponds **(Saleh, 2008)**. Therefore, the wild populations of mullet are yearly experiencing a significant decline **(El Basuini *et al.*, 2022; FAO, 2022)**. While captive rearing of fry has improved for many species, rearing mullet fry remains a significant obstacle to commercial production **(Oz *et al.*, 2022)**.

Notably, Egypt's natural fisheries contributed 400,000 tons of mullet production, while lake production reached 183,000 tons. However, this dependency on wild larvae poses limitations to aquaculture production due to their seasonal and unpredictable nature, and this may also impact local capture fisheries negatively **(Patil *et al.*, 2022)**. To address these challenges, restrictions have been imposed on the catch of wild mullet fry in Egypt, and programs have been developed to enhance stock enhancement in lakes **(Goulding & Kamel, 2013; Soltan, 2013; Soliman, 2017)**. The introduction of exotic species and the translocation of native species from one drainage system to another throughout the same country are widely accepted methods for enhancing natural waters worldwide **(Pofuk *et al.*, 2017; Abbas *et al.*, 2020; Abo-Taleb *et al.*, 2020; Alprol *et al.*, 2021)**. Stocking fry in closed lakes holds importance for several reasons. It aids in maintaining a healthy ecosystem by restoring or enhancing fish populations that may have been depleted due to overfishing or other factors. Stocking fry supports local fishermen, boosting their economic well-being, while also providing recreational opportunities for anglers and outdoor enthusiasts. This, in turn, can stimulate local economies and promote tourism in the area **(Baird, 2022; Orth, 2023)**.

Mullet stocking is a common practice in many parts of the world, particularly in areas where mullet is a popular food fish. However, the suitability of mullet stocking in lakes depends on various factors, such as water quality, temperature, and habitat availability. Producing market-size mullet begins with the stocking of fry or juveniles into a rearing environment that assures rapid growth and survival to allow harvest in the shortest possible time. After hatching, the wild mullet larvae begin to swim near the Mediterranean Sea coast where they usually arrive in mass after 2 months **(Meseda & Samira, 2006)**. At this point, they would have reached a size of 25mm. On the coast, they form small schools and begin to move toward the estuaries. The capture of wild mullet fry for stocking is commonly done as they enter the estuary using seine nets, deep nets, among others **(Saleh, 2008)**. Restrictions were imposed on the catch of wild mullet fry in

Egypt, and programs were encouraged to stock hatchery-reared mullet to stock the lakes in Egypt. Although there have been advances in captive rearing for many marine finfish species, hatchery production remains the main challenge hindering the commercial production of captive-bred mullet **(Oz *et al.*, 2022)**.

Coded wire tag (CWT) has been extensively used in fisheries research to study the movement and behavior of fish in aquatic environments. Aquatic animal species from at least 37 families have been tagged with CWT **(Vander Haegen *et al.*, 2011)**. These families include shrimp **(Kneib & Huggler, 2001)**, crabs **(Davis *et al.*, 2004)**, crayfish **(de Graaf, 2007)** amphibian larvae **(Martin, 2011)**, and lobster **(McMahan *et al.*, 2012)**. The technique involves inserting a small piece of magnetic stainless-steel wire, measuring 0.25mm in diameter and 1.1mm in length into the body of the fish. The CWT is detected using a handheld magnetometer or a stationary antenna, which can track the fish's movement and behavior over time **(Lahoz-Monfort & Magrath, 2021)**. **Brennan *et al.* (2005)** provided valuable insights into the movement and behavior of fish, such as their migratory patterns, habitat preferences, and feeding behavior. Overall, CWTs are a useful tool for fisheries research and management that allows scientists to study the behavior and survival of fish in their natural environments **(Jepsen *et al.*, 2010)**.

Wadi El-Rayan Lakes (WRLs) in Al-Fayoum Governorate are economically significant due to their shallow depths, good water circulation, and high fertility since they are regarded as a natural breeding ground and nursery for a variety of economically important fish species **(Goher *et al.*, 2019)**. The Al-Rayyan Valley has a vast limestone depression with a drop of 43m below sea level on average. The area, which encompasses roughly 1759km^2, was established as a natural reserve by Prime Minister Decision No. 943 of 1989, as revised by resolution No. 2954 of 1997 **(Kleijn & Dijkema, 1988)**. Yearly, the valley gets approximately 250 million cubic meters of agricultural effluent into WRLs. Wadi El-Rayan Lakes get agricultural drainage water from the Wadi drain and have different physical and chemical qualities **(Shama *et al.*, 2011)**. Water level and quality declines endanger the economic assets (fishing, agriculture, and tourism) that support local communities **(Goher *et al.*, 2019; Metwally *et al.*, 2020)**. Temperature is a significant factor in aquatic ecosystem health since it affects the pace of chemical processes and the metabolic rate of organisms **(Abu Salem *et al.*, 2017; Mansour *et al.*, 2022)**. It varies within a normal range of 17.80ºC in winter to 32.40ºC in summer with large temporal changes. The fisheries production of WRLs **(GAFRD, 2020)** has increased from 1313 tons in 2005 to 6750 tons in 2020. The main fish species captured was tilapia spp. (1436 tones), mullet spp. (851 tones), grass carp (776 tones), barges (422 tones), and the Nile perch (379 tones). Therefore, the objective of this study was carried out to investigate the suitability of the effectiveness of tagging *M. cephalus* fingerlings, cultured in the lower portion of Wadi El- Rayan Lake (WRL), using coded wire tags (CWTs) approach as a sustainable advanced nursing technique to improve and optimize the stock enhancement of grey mullet *Mugil cephalus* fingerlings in WRL.

MATERIALS AND METHODS

1. Selection and characterization of the growing location

After surveying the natural water body for grey mullet stock enhancement of several sites in Egypt's Governorates, as well as based on the previously published works **(El Bayomi, 2006; Ali *et al.*, 2007; Shama *et al.*, 2011; Mohamed *et al.*, 2015; Abd Ellah, 2016; Abu Salem *et al.*, 2017; CMFRI, 2017; Goher *et al.*, 2019; Helal *et al.*, 2020; Abd Ellah & Haque, 2022)**, the lower portion of Wadi El-Rayan Lakes (WRL) in the Al-Fayoum Governorate were selected to study the CWT in the current for grey mullet growing study. The WRLs (Fig. 1) are a part of the Al-Fayoum depression, which is located in the Western Desert approximately 80km southwest of Cairo. Water began to flow into the Al-Rayyan valley in 1973 through a 9km open channel and an 8km tunnel, delivering 31% of the Al-Fayoum depression's drainage water **(Hereher, 2015)**, forming two anthropogenic lakes (Fig. 1), one in the north (upper lake) and one in the south (lower lake) **(El-Shabrawy, 2007)**. The lakes in Rayan Valley have an annual flow of $200 \times 10^{-9} m^3$/ year. The upper lake's salinity ranges from 1,400 to 1,500ppm, whereas the bottom lake's salinity ranges from 4,500 to 6,100ppm. After Lake Nasser in southern Egypt, the continuous discharge of drainage water into the depression formed Egypt's second-largest man-made water body. El-Rayan lakes exhibit dynamic behavior in proportion to the volume of drainage water discharged into the depression, as well as water losses due to evaporation and seepage into the Earth **(El-Shabrawy & Dumont, 2009)**.

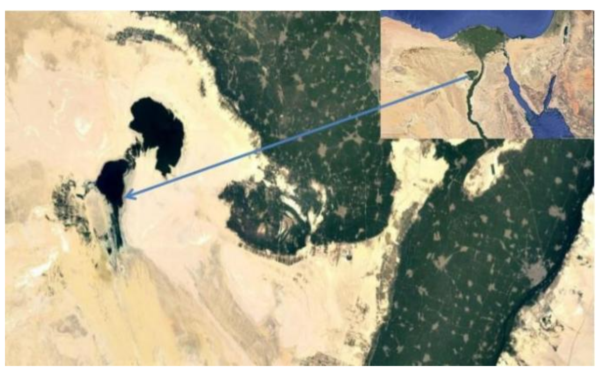


Fig. 1. Wadi El-Rayan Lakes (29.13, 30.40)

Al-Fayoum Depression is a confined basin surrounded by hills in the south and a cliff in the north, with an active irrigation system. Bahr Yusuf and Bahr Hassan Wasif are the main irrigation canals. These channels are regularly separated to supply clean water to the entire El-Rayan Valley **(Mohamed *et al*., 2015)**. The significance of the El-Rayan Valley extends beyond the country's borders since these artificial lakes are regarded as a haven for migratory birds from the northern hemisphere. The El-Rayan Valley was designated a nature reserve in 1989 and is overseen by the Ministry of Environmental Affairs. The International Union for Conservation of Nature recognized the El-Rayan

Valley as one of Egypt's Important Plant Areas in 2011, and it joined the Ramsar Convention as a biodiversity wetland region in 2012 **(Afefe, 2020)**.

2. Fry capturing, nursing, and feeding program

A one-acre pond in the Edku area (40km east of Alexandria) was used as a nursing unit for growing *M. cephalus* fry according to **Bakeer (2006)**, using a method of fertilization with organic and inorganic fertilizers. Five ponds with a total area of 400m^3 each have been used as nursing ponds. The nursery ponds were kept dry, and 15-days before the arrival of mullet fry collected from the Mediterranean Sea, the nursing ponds were disinfected with quicklime (150kg/ acre) to eliminate any pathogens (bacterial, viral, or parasitic). After two days, 800kg of dry chicken manure was added to each pond in the form of piles dispersed across the pond. The following day, filtered water was fed into the ponds through a tiny mesh (0.7mm) to cover only the top of the pillars, and the ponds were filled to a depth of 1m before being left for a day. During this time, chemical fertilizers (60kg/ fed triple superphosphate and 40kg/ fed urea) were introduced to the pond water. The ponds were left for three days to completely dissolve the organic manure. The water turned green, and the turbidity ranged between 28 and 35cm, indicating that the amount of plankton in the water was sufficient to meet the nutritional needs of mullet fry and that the environmental conditions of the pond water ponds had improved enough to accept young mullet. The pH was always kept stable on the alkaline side at 7.6 to 8.0. Thirty-two thousand mullet fry, with an initial body weight of 3.3± 0.34g, were stocked at a rate of 2400 fish/ pond in the five nursery ponds. For six days a week, the fry were fed rice bran at a rate of 15% of their biomass, which was lowered to 10% of their biomass after one month. Fry were kept in the nursery ponds for two months until their average body weight reached 7- 9g (temperatures ranged between 20 and 24°C). The grey mullet fingerlings were tagged at the end of the nursing period.

3. General tagging procedure

Grey mullet *Mugil cephalus* fingerlings were anaesthetized for 1- 4 minutes in 30ppm clove oil. For each tank, the weights and lengths of anesthetized fish were recorded and tagged (Fig. 2) as follows: CWTs were injected free-hand using Mark IV tagging devices (Northwest Marine Technology, Anacortes, WA, USA, (Figure 3a). A needle guard was employed to control the depth of needle penetration, and the presence of tags was confirmed using a magnetic field detector (both from Northwest Marine Technology Shaw Island, WA, USA). The CWTs were inserted posteriorly into the anterior epaxial nose tissue or “nape” (Fig. 3b) tissue. Immediately after the tag was inserted and scanned for retention, fish were placed in recovery water. Tag codes were recorded, and the number of fish per code was determined (Fig. 4).

Fig. 2. Photographs showing how to tag grey mullet *Mugil cephalus* fingerlings

A b

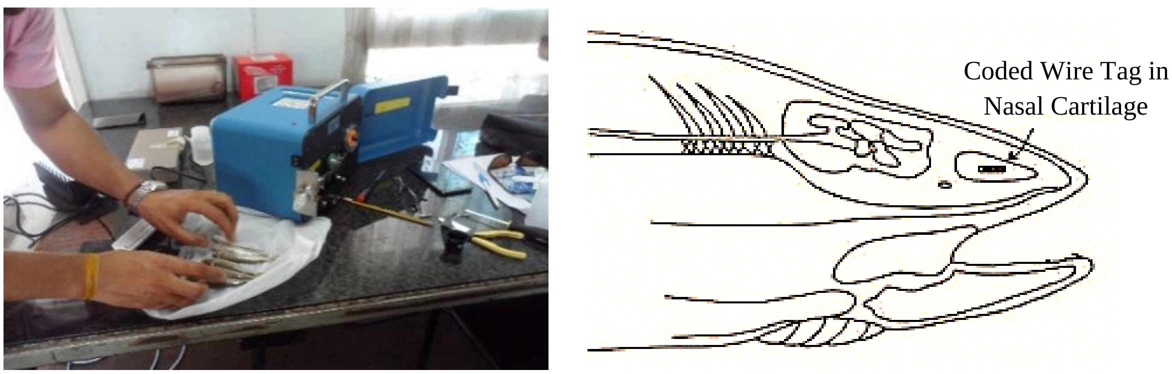


Fig. 3. (a): CWTs were injected free-hand with Mark IV tagging machines; (b): showing the location where the tag is placed in mullet

Fig. 4. Grey mullet nursing ponds and net enclosures

4. Approaches for acclimating tagged, wild fry before release

Two release strategies were evaluated using CWTs, involving 40 days of extended nursery and acclimation of grey mullet fingerlings in net enclosures and small earthen pond (Fig. 5) before release into WRL. A third tagged group (experimental control group) was tagged and released directly into WRL after two days. The recovery of the tags from fingerlings was conducted after 40 days (Fig. 6).

Fig. 5. Photos showing direct release of grey mullet fingerlings after the tagging with CWTs

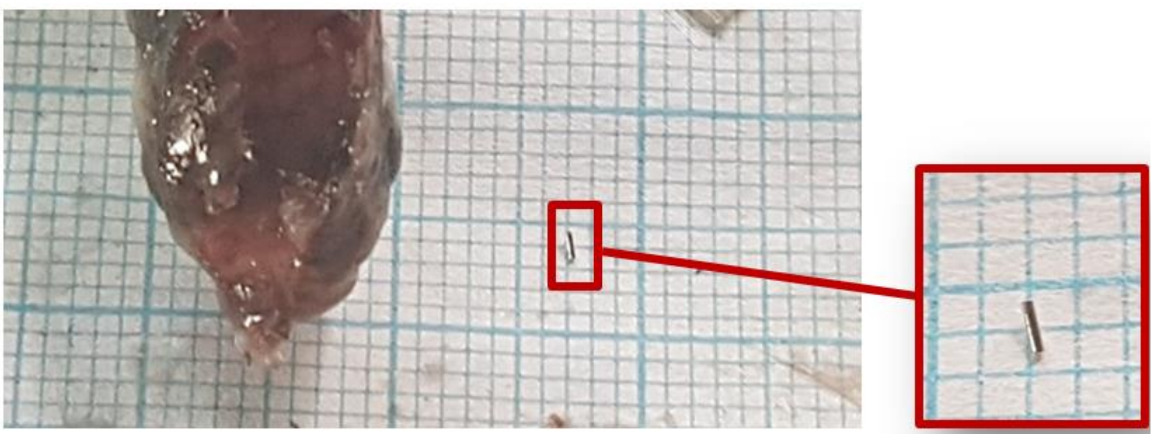


Fig. 6. Recovering the tags from grey mullet fingerlings after 40 days

5. Experimental design and fish rearing facility

This study was designed with two experiments to evaluate the effectiveness of tagging grey mullet fingerlings cultured in the lower portion of WRL, using the coded wire tags (CWT) approach as a sustainable advanced nursing technique to improve and optimize stock enhancement of grey mullet. The first experiment involves nursing and rearing grey mullet fingerlings in net enclosures (NE-CWT) and an earthen pond for 40 days before releasing them into the WRL. In the second experiment, three groups were studied before being released into the WRL: the first group involved a nursing experiment (nursing for 40 days for acclimatization), the second group involved a grow out rearing for 334 days, and the third group (control group, continued) was released directly into the WRL without extended rearing, acclimatization, or CWT recovery.

Treatment group: Thirty-two thousand grey mullet fingerlings, with initial body weights of 8.66± 0.84 and 7.34± 0.91g, were tagged and reared in three earthen ponds (400m^3 each) and three net enclosures (50m^3 each) for 39 days, respectively, before being released into WRL to investigate the effect of short-term nursing and acclimation before release in WRL. The fish were fed rice bran at a rate of 3% daily for six days a week during this entire period. Water quality was also examined to ensure that it was suitable for mullet growth and survival. The water temperature ranged from 24 to 27°C, the dissolved oxygen in the water was not less than 5.12mg L^{-1}, and the ammonia concentration did not exceed 0.31mg L^{-1}. The water had a salinity of 1.05ppt and a pH that was always on the alkaline side (7.90- 8.76). These parameters have consistently remained within internationally permissible ranges. The growth performance and survival rate (%) of mullet fingerlings were determined at the end of the rearing period. The sample for validating the successful CWT was determined, as well as the number of fish per code. Control group: A third group of thirty-two thousand grey mullets, with an initial body weight of 7.5± 0.8g, were tagged and then released two days after tagging directly into the WRL. During the first experiment, growth performance, feed utilization, and survival rates of *M. cephalus* fingerlings were recorded. Throughout the second experiment, and after the release of the tagged mullet into the WRL, the fishermen collected monthly samples from the WRL to monitor the growth and survival rates of *M. cephalus* over 334 days.

6. Water quality parameters

In WRL, the water quality indicators of water temperature, pH, dissolved oxygen (DO_2), and total ammonia nitrogen (TAN) were weekly measured. Temperature and pH were measured by a portable pH Meter (HI 8424) (HANNA Instrument). DO_2 was measured by a HI-9142 (HANNA Instrument). Salinity was measured using a YSI EcoSense EC300 conductivity/ salinity meter. TAN was monitored using a YSI 9300 photometer and YSI Professional Plus. Using the data of pH, temperature, salinity, and total ammonia nitrogen (TAN), the concentration of un-ionized ammonia-N was calculated as a percentage of TAN according to the following software:
(https://floridadep.gov/waste/district-business-support/documents/un-ionized-ammoniacalculator).

7. Growth performance indicators

Growth performance parameters of total weight gain (g fish^{-1}), average daily gain (ADG, g fish^{-1}), specific growth rate (SGR, % days^{-1}), condition factor (K), survival rate (%), and recovered CWT (%) were calculated using the methods of **Aboseif *et al.* (2022)**, as follows:

$$\text{Total Weight gain (TWG/ g)} = \text{Final body weight (FW)} - \text{Initial body weight (IW)} \quad (1)$$

$$\text{Average daily gain, ADG (g/ fish/day)} = \frac{\text{FW(g)} - \text{IW(g)}}{\text{trial duration (days)}} \quad (2)$$

$$\text{Specific growth rate (SGR) (\%/ day)} = \frac{\ln\ (\text{FW}) - \ln\ (\text{IW})}{\text{trial duration (days)}} \times 100 \quad (3)$$

$$\text{Condition factor (K)} = \frac{\text{Total fish weight (g)}}{\text{Total fish lingth (cm)} - 3} \times 100 \quad (4)$$

Survival rate (SR, %) = No. of surviving fish/total No. of fish at the beginning ×100 (5)

Recovered percentages are plotted relative to the beginning day of observations during that season.

8. Statistical analysis

Data were processed using a one-way analysis of variance (ANOVA), followed by Duncan's post hoc test which was used to rank the means. $P < 0.05$ was regarded as statistically significant. All statistics were processed using the SPSS package (version 23.0).

RESULTS AND DISCUSSION

The water quality parameters of WRL are detailed in Table (1). The results revealed that the temperature, salinity, pH, ammonia, and DO levels were within the acceptable limits for mullet fish production as mentioned by **Boyd and Tucker (2012)**.

Table 1. Physicochemical parameters recorded in WRL

Parameter*	**Value**
pH	8.18 ± 0.05
Temperature (˚C)	26.8 ± 2.0
Salinity (ppt)	21.5 ± 3.25
DO (mg L^{-1})	5.56 ± 3.33
BOD (mg L^{-1})	5.05 ± 2.06
(NH_4 mg L^{-1})	0.8 ± 1.17
NO_2 (mg L^{-1})	0.08 ± 0.01
NO_3 (mg L^{-1})	0.19 ± 0.03
PO_4 (µg L^{-1})	76.66 ± 0.66

*Data are presented in (Mean ±SD)

For more than a century, Egypt has used wild-caught mullet seed for the annual replenishment of inland lakes and the aquaculture sector. The impact of wild seed fisheries on mullet wild stocks has received little attention. The Fisheries Law No. 124/1983 governs wild fry collecting in Egypt. It is illegal to fish, collect, handle, or transport wild fish fry without an official permit from the **GAFRD (2020)**. As a result, when farmers are unable to obtain official permission to cover the required amount of mullet seed, they turn to illegal sources of seed supply. Unlicensed fishermen use seine nets, light boats, and small trucks to infiltrate coastal areas or the borders of drainage canals. The fry are caught, carried in buckets filled with seawater, and maintained for a few hours in hapas or collection tanks on the seashore. Illegally harvested fry are brought early in the morning via country roads to the secret shop, where they are sold by the thousands. At this point, the fry are either sold to clients or loaded onto transport trucks for sale in fish farms. Seed stocks are also trucked to separate nursery units or nurseries on fattening farms for fingerling production. The quantity of mullet fry collected through this black-market distribution is incalculable and uncontrolled. These illegal market transactions are estimated to be substantial, and the number of illegally caught fish may surpass those collected through regular channels. In developed nations, stocking programmers should ideally be limited to small quantities of larger fish to support native species or recover endangered species. Pre-conditioning and acclimatizing stocked fish to the conditions of the receiving water bodies may improve their chances of survival **(Cucherousset *et al.*, 2012)**. Table (2) illustrates the growth performance and characteristics of the 'Treatment group' grey mullet that were CWT after the extended rearing and acclimation in earthen ponds or net enclosures for 40 days. The data revealed that fish nursing in net enclosures had the highest significant differences (*P*< 0.05) in their final body weight (g fish^{-1}), weight gain (TWG, g fish^{-1}), specific growth rate (SGR, % days^{-1}), and survival (SR, %). Furthermore, these fish had an excellent condition coefficient (1.16), indicating that the aquatic and feeding environment provides sufficient stimulation for fish growth and survival (%) as well as good health conditions.

Table 2. Growth performance and characteristics of the grey mullet *M. cephalus* tagged with magnetic wire codes, as well as the control group evaluated after the nursing methods period

	First experiment (40 days)		
Item	Control group*	Earthen ponds	Net enclosures
Number of tagged fish	~32,000	~32,000	~20,000
Initial length (cm fish^{-1})	8.50±0.12	7.30 ± 1.11	8.12 ± 1.21
Final length (cm fish^{-1})	-	11.50 ± 1.45 ^{b}	12.25 ± 1.36^{a}
Initial weight (g fish^{-1})	7.50 ±0.8	8.66 ± 0.84	7.34 ± 0.91
Final weight (g fish^{-1})	-	16.30 ± 1.37 ^{b}	21.30 ± 1.52^{a}
weight gain (WG) (g fish^{-1})	-	7.64 ± 1.35 ^{b}	13.96 ± 1.47^{a}
Average daily gain (g/fish/day)	-	0.19	0.35
Specific growth rate (SGR, % days^{-1})	-	1.58± 0.42 ^{b}	2.66± 0.39 ^{a}
Condition factor (K)	-	1.07 ± 0.05	1.16 ± 0.08
Number of stocked fish	-	16,000 ± 0.00	16,000 ± 0.00
Number of fish after nursing	-	11,500 ± 23.18	13,000 ± 18.23
Successful fish tagging (%)	-	94.33 ± 0.52 ^{b}	97.42 ± 0.50^{a}
Survival rate (%)	-	71.88 ± 2.50 ^{b}	81.75 ± 2.25^{a}

* This group was not recaptured until the end of the experiment. Means in the same column bearing different superscripts differ significantly at *P*< 0.05 level. Values are means ± SD.

There were no CWT recoveries from the monthly samples by fishermen for the CWT 'Control group' released two days after tagging directly into WRL. Fish temporarily reared in ponds had the highest significant survival differences (*P*< 0.05) in recovered CWT percentage (Fig. 7). The remarkably high survival rate (81.25%) of these mullets is very compelling. These findings emphasize the significance of short-term rearing and acclimation in improving the performance parameters of mullet seed as compared to direct release after tagging in the lake (Table 2).

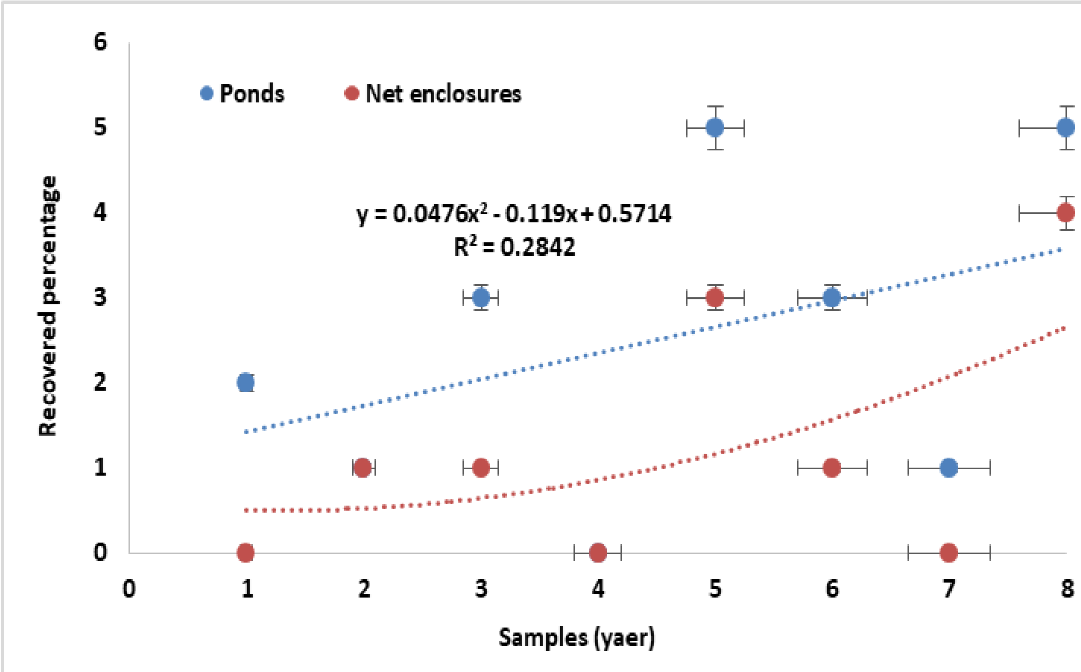


Fig. 7. Mean recovered (%) by season for gray mullet stocked into lower Lake of Wadi El-Rayan in Al-Fayoum. Recovered percentages are plotted relative to the beginning day of observations within that season

Table (3) shows the results of the growth performance and production performance characteristics of grey mullet fingerlings 334 days after restocking in Wadi El-Rayan lakes. Fish nursed in net enclosures before restocking in Wadi El-Rayan Lakes had the highest ($P < 0.05$) FBW, TWG, ADG, SGR, and K by 2020, the overall number of fry collected from the Mediterranean had reduced from 83.2 million in 1985 to 46.68 million **(GAFRD, 2020)**.

The majority of the collected fry (75% of the total number of fry collected) was utilized for aquaculture, with the remainder used for stock enhancement for inland lakes. The use of wild fry was previously linked to substantial seed mortality as a result of trauma caused by rough handling during collection and delivery. For wild mullet seed-based aquaculture, the fry normally acclimatizes to the pond conditions upon arrival. Dead and weak larvae are usually removed, and the number of larvae held in each pond is recorded. Due to poor acclimatization, most fish farms have a significant percentage of fry mortality. In the present study, the stock enhancement results showed that improvement in the outcome of grey mullet stocking in Wadi El-Rayan Lakes in the Al-Fayoum Governorate could be obtained by holding the mullet fry for 39 days before releasing them into the WRL. The improved survival rates after re-stocking were likely a result of treatments performed during the 39-day nursed period to (1) obtain a more optimum size-at-release (SAR) of the grey mullet fingerlings and (2) acclimate the fingerlings to the specific release-site in the LWRL.

Table 3. Growth and production performance parameters of grey mullet fingerlings evaluated 334 days after restocking in LWRL

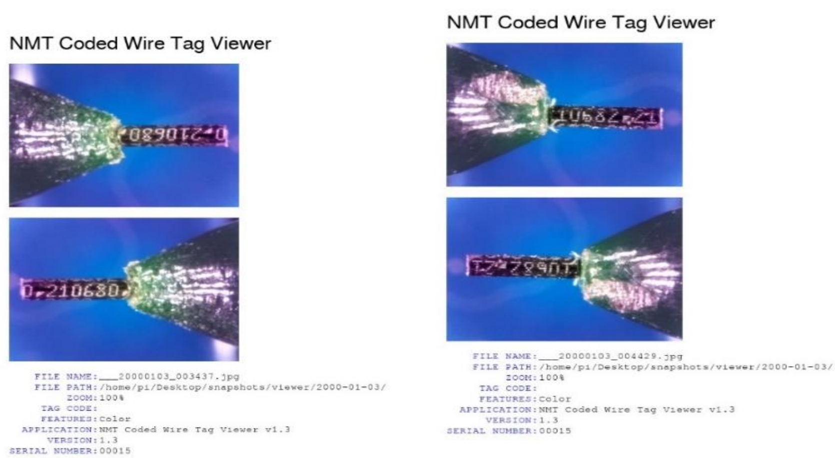
	Second experiment (334 days)		
	Control group	**Earthen ponds**	**Net enclosures**
Final length (cm fish^{-1})	24.2 ± 0.97^{c}	30.1 ± 2.28^{b}	33.24 ± 3.06^{a}
Final weight (g fish^{-1})	164.82±1.13^{c}	257.11 ± 3.25^{b}	350.72 ± 3.05^{a}
daily gain (g fish^{-1})	0.42 ±1.26^{c}	0.75± 0.06^{b}	1.02±0.10^{a}
Weight gain (g fish^{-1})	157.32±1.13^{c}	248.45 ± 3.22^{b}	343.38± 3.03^{a}
Average daily gain (g/fish/day)	0.47	0.74	1.03
Specific growth rate (SGR, % days^{-1})	0.93±1.10 ^{c}	1.02±0.06^{b}	1.16± 0.04^{a}
Recovered CWT (%)	4.00 ^{c}	13.00^{a}	9.00^{b}
Condition factor (K)	1.16 ^{c}	0.94^{b}	0.95^{a}

Means in the same column bearing different superscripts differ significantly at $P< 0.05$ level. Values are means ± standard error.

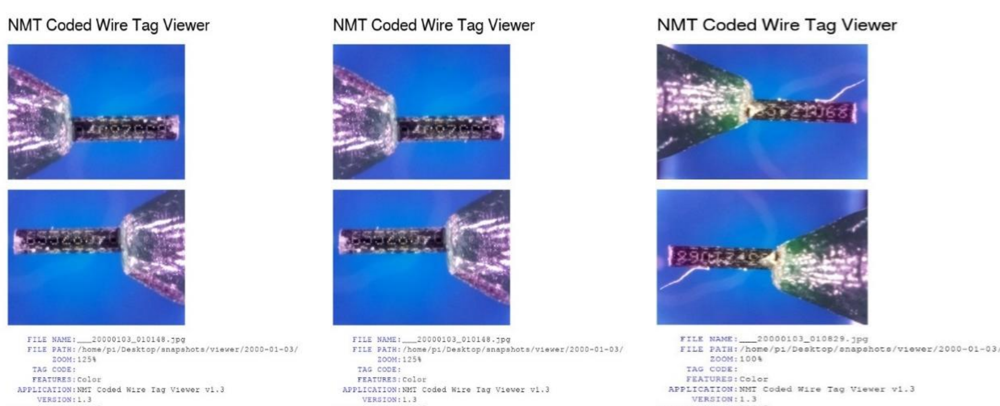
Over 334 days, the CWT fish were recovered from the fishermen's catch (Fig. 8), then the tags were extracted from the mullet head and decoded in the laboratory (Fig. 9). Given the absence of CWT recoveries from the control group (unacclimated) of fish released directly into WLR after tagging, it is likely that the current government plans to increase Egyptian lake fish production by releasing millions of small, wild mullet spp. collected from natural resources each year will be unsuccessful, or at the very least inefficient.

Fig. 8. Identifying the coded-wire tags on grey mullet fingerlings samples from fishermen catch by tagging viewer in WRL

Fig. 9. The extraction and identification (CWT) number of tagging in the laboratory



Ponds



Net enclosures

Fig. 10. The identified CWT number of some tagging from grey mullet fingerlings samples either earthen ponds or net enclosures

This study suggests that the majority of these fish may be lost due to their inability to adapt to new habitat conditions, particularly if the fry are extremely young. According to **(Kleijn & Dijkema, 1988)**, over four months, the mortality rate of fry in nursery farm ponds surpassed 35%. Regarding the restocking of wild fry in inland lakes, **Saleh (1991)** observed that mortality rates of up to 96% of transferred fry might occur within the first seven days if the fry were instantly transported to the lakes or farm without a gradual (6-8 hours) acclimatization. According to a study by **Runge *et al.* (2008)**, selecting the most successful release strategy and establishing a protocol for time and technique of release, is key to the survival of stocked fish. Fish must be stocked at a period when they can quickly acclimatize to their new environment and so learn to feed on natural food. Regarding species-specific considerations, different fish species have different size-related shifts in feeding behavior and habitat use. Some species, switch from feeding on plankton to larger prey as they mature, while others might migrate from shallow to deeper waters. When deciding the appropriate size of fish for release, several considerations must be taken into account, including information on their expected impact on local fish and the ecosystem in general, as well as a cost-benefit analysis. The impact of the size or age of fish released is particularly apparent in species that undergo size-related or ontogenetic changes in feeding behavior or habitat utilization. As shown in this study, preliminary pilot-scale release experiments are critical for determining effective release strategies, such as size-at-release, release habitat, and timing of releases at the sites intended for stock enhancement **(Leber *et al.*, 2016)**.

Stocking initiatives in developed nations should ideally be limited to small numbers of fish to help native species or restore endangered species. Improving supplied fish survival by pre-conditioning and acclimating fish to the conditions of the receiving water body may boost their chances of survival. Acclimatization is required for the fish to adjust to their surroundings, according to this study's results. Acclimatization, however, must be accompanied by a release strategy that minimizes stress on the provided fish. Allowing for acclimatization before release should result in significant decreases in post-release mortality. Concerning the precise length of acclimatization required to maximize survival, we found that confining fish in ponds, cages, or enclosures for seven weeks before being released, significantly enhanced survival rates, boosted growth rates, and improved recapture rates, all of which are desirable characteristics of effective stocking. This should be a fruitful topic for future research to optimize the time allotted for acclimatization.

Holding the fish before releasing them decreases the stress produced by bringing the fish to the release location. Fish that have been transplanted from still to moving water and from a farm or the wild should be exposed to running water conditions for an extended period before release. This strengthens the fish's muscles, allowing it to swim for longer periods. The present results indicated that an acclimatization period before release can be used to improve the effectiveness of future stockings of grey mullets in WRL. The results obtained from the pilot release-recapture experiments of grey mullet fingerlings in WRL will be used in other Egyptian lakes to improve the effectiveness of restocking in the future. There is a need to transfer these results to fishermen's associations, which will continue the improvement of mullet stock enhancement over a longer time frame.

CONCLUSION

Based on the current findings, it is possible to conclude that using various CWT-tagged strategies to release grey mullets (*Mugil cephalus*) fingerlings in enclosed Egyptian lakes, especially the lower part of Wadi El Rayan Lake (WRL) in Fayoum Governorate, Egypt, is critical for increasing survival rates (%) and improving stocking rates. The following is a future view for employing different approaches with coded wire tags (CWTs) to release fingerlings of *M. cephalus* into closed Egyptian lakes to increase the survival rate of stocked fish:

1. Progressive release of a small number of fish over time, allowing the fish to adjust to their new environment while lowering the risk of predation and resource competition.
2. The appropriate time to release, when the water temperature in confined Egyptian lakes drops. It is better to release grey mullet fingerlings in the early morning or late afternoon since this reduces stress for the fish and increases their chances of survival for longer periods of time.

REFERENCES

Abbas, E.M.; Ali, F.S.; Desouky, M.G.; Ashour, M.; El-Shafei, A.; Maaty, M.M. and Sharawy, Z.Z. (2020). Novel Comprehensive Molecular and Ecological Study Introducing Coastal Mud Shrimp (*Solenocera Crassicornis*) Recorded at the Gulf of Suez, Egypt. Journal of Marine Science and Engineering. 9: 9. https://dx.doi.org/10.3390/jmse9010009

Abd Ellah, R.G. and Haque, M.N. (2022). The degradation scenario of man-made lakes from satellite observations: A case of Wadi El-Rayan lakes, Egypt. The Egyptian Journal of Aquatic Research. 48: 99-106. https://doi.org/10. 1016/j. ejar.2022.03.003

Abd Ellah, R.G.E. (2016). Bathymetric Study of Wadi El-Rayan Lakes, Egypt. Lakes, Reservoirs and Ponds. 10: 110-125

Abo-Taleb, H.A.; Ashour, M.; El-Shafei, A.; Alataway, A. and Maaty, M.M. (2020). Biodiversity of Calanoida Copepoda in Different Habitats of the North-Western Red Sea (Hurghada Shelf). Water. 12: 656. https://doi:10.3390/w12030656

Abu Salem, H.S.; Abu Khatita, A.; Abdeen, M.M.; Mohamed, E.A. and El Kammar, A.M. (2017). Geo-environmental evaluation of Wadi El Raiyan Lakes, Egypt, using remote sensing and trace element techniques. Arabian J. Geosciences. 10, 244 https://doi.org/10.1007/s12517-017-2991-3

Afefe, A.A. (2020). Composition and changes in the spontaneous flora of the Wadi El Rayan Ramsar site, Fayoum, Egypt, in the last 20 years. Limnological Review. 20: 109-121. https://doi.org/10.2478/limre-2020-0012

Ali, M.; Abdel-Tawab, A.; Ali, A. and Soliman, G. (2007). Monitoring of Water Quality and Some Pollutants of Man-Made Lake (Wadi El-Rayan First Lake, Egypt). Egyptian Journal of Aquatic Biology and Fisheries. 11: 1235-1251

Alprol, A.E.; Heneash, A.M.M.; Ashour, M.; Abualnaja, K.M.; Alhashmialameer, D.; Mansour, A.T.; Sharawy, Z.Z.; Abu-Saied, M.A. and Abomohra, A.E. (2021). Potential Applications of Arthrospira platensis Lipid-Free Biomass in Bioremediation of Organic Dye from Industrial Textile Effluents and Its Influence on Marine Rotifer (Brachionus plicatilis). Materials (Basel). 14, 4446. https://doi.org/10.3390/ma14164446

Baird, C. (2022). Catching the released: conservation and aquaculture's shared colonial lineages in Newfoundland and Labrador. MSc Theses.

Bakeer, M. (2006). Performance of grey mullet (Mugil cephalus L.) reared in monoculture in the new desert areas. Journal of Arabian Aquaculture Society. 1: 44-56

Boyd, C.E. and Tucker, C.S. (2012). Pond aquaculture water quality management. Springer Science & Business Media, Springer Science & Business Media.

Brennan, N.P.; Leber, K.M.; Blankenship, H.L.; Ransier, J.M. and Debruler Jr.R. (2005). An evaluation of coded wire and elastomer tag performance in juvenile common snook under field and laboratory conditions. North American Journal of Fisheries Management. 25: 437-445. https://doi.org/10.1577/M04-003.1

Cmfri, K., (2017). ICAR-Central Marine Fisheries Research Institute-Platinum Jubilee Logo.

Cucherousset, J.; Bouletreau, S.; Martino, A.; Roussel, J.M. and Santoul, F. (2012). Using stable isotope analyses to determine the ecological effects of non-native fishes. Fisheries Management and Ecology. 19: 111-119. https://doi.org/10.1111/j.1365-2400.2011.00824.x

Davis, J.L.; Young-Williams, A.C.; Hines, A.H. and Zmora, O. (2004). Comparing two types of internal tags in juvenile blue crabs. Fisheries Research. 67: 265-274. https://doi.org/10.1016/j.fishres.2003.11.005

De Graaf, M. (2007). Tag retention, survival and growth of marron Cherax tenuimanus (Crustacea: Decapoda) marked with coded micro wire tags. Marine and Freshwater Research. 58: 1044-1047 https://doi.org/10.1071/MF07136

El-Shabrawy, G. (2007). Community structure and abundance of macrobenthos in Wadi El-Rayan Lakes (El-Fayoum, Egypt). Afr J Biol Sci. 3: 113-125

El-Shabrawy, G.M. and Dumont, H.J. (2009). The Fayum depression and its lakes, The Nile: origin, environments, limnology and human use. Springer.

El Basuini, M.F.; Teiba, I.I.; Shahin, S.A.; Mourad, M.M.; Zaki, M.A.; Labib, E.M.; Azra, M.N.; Sewilam, H.; El-Dakroury, M. and Dawood, M.A. (2022). Dietary Guduchi (*Tinospora cordifolia*) enhanced the growth performance, antioxidative capacity, immune response and ameliorated stress-related markers induced by hypoxia stress in Nile tilapia (*Oreochromis niloticus*). Fish & shellfish immunology. 120: 337-344. https://doi.org/10.1016/j.fsi.2021.12.002

El Bayomi, G. (2006). Area of Wadi El Raiyan lakes a geomorphological study. J Appl Sci Res. 2: 1304-1313

Fao, E. (2022). The state of world fisheries and aquaculture. Towards blue transformation.

GAFRD, (2020). General Authority for Fish Resources Development. Statistical analysis of total aquaculture production in Egypt, Ministry of Agriculture, Cairo, Egypt.

Goher, M.E.; Mahdy, E.-S.M.; Abdo, M.H.; El Dars, F.M.; Korium, M.A. and Elsherif, A.A. (2019). Water quality status and pollution indices of Wadi El-Rayan lakes, El-Fayoum, Egypt. Sustainable Water Resources Management. 5: 387–400. https://doi.org/10.1007/s40899-017-0162-z

Goulding, I. and Kamel, M. (2013). Institutional, policy and regulatory framework for sustainable development of the Egyptian aquaculture sector. WorldFish, WorldFish, pp.

Helal, A.M.; Abdelaty, B.S.; Elokaby, M.A.; Mustafa, M.M.; Hosny, S. and Heneash, A.M. (2020). Ecosystem management of al-nozha airport farm lake, Egypt utilizing TSI model. Inter J Fish Aqua Study. 8: 137-145

Hereher, M.E. (2015). Assessing the dynamics of El-Rayan lakes, Egypt, using remote sensing techniques. Arabian J. of Geosciences. 8: 1931-1938

Jepsen, N.; Klenke, R.; Sonnesen, P. and Bregnballe, T. (2010). The use of coded wire tags to estimate cormorant predation on fish stocks in an estuary. Marine and Freshwater Research. 61: 320-329 https://doi.org/10.1071/MF09038

Kleijn, L. and Dijkema, R. (1988). Final report Release of Mullet Fry project in Fayoum Governorate, Egypt.

Kneib, R. and Huggler, M. (2001). Tag placement, mark retention, survival and growth of juvenile white shrimp (*Litopenaeus setiferus* Perez Farfante, 1969) injected with coded wire tags. Journal of Experimental Marine Biology and Ecology. 266: 109-120. https://doi.org/10.1016/S0022-0981(01)00347-1

Lahoz-Monfort, J.J. and Magrath, M.J. (2021). A comprehensive overview of technologies for species and habitat monitoring and conservation. BioScience. 71: 1038-1062. https://doi.org/10.1093/biosci/biab073

Leber, K.M.; Lee, C.-S.; Brennan, N.P.; Arce, S.M.; Tamaru, C.S.; Blankenship, H.L. and Nishimoto, R.T. (2016). Stock enhancement of Mugilidae in Hawaii (USA).

Mabrouk, M.M.; Ashour, M.; Labena, A.; Zaki, M.A.A.; Abdelhamid, A.F.; Gewaily, M.S.; Dawood, M.A.O.; Abualnaja, K.M. and Ayoub, H.F. (2022). Nanoparticles of *Arthrospira platensi*s improves growth, antioxidative and immunological responses of Nile tilapia (*Oreochromis niloticus*) and its resistance to *Aeromonas hydrophila*. Aquaculture Research. 53: 125-135. https://doi.org/10.1111/are.15558

Mansour, A.T.; Alprol, A.E.; Abualnaja, K.M.; El-Beltagi, H.S.; Ramadan, K.M.A. and Ashour, M. (2022). The Using of Nanoparticles of Microalgae in Remediation of Toxic Dye from Industrial Wastewater: Kinetic and Isotherm Studies. Materials (Basel). 15: 3922. https://doi.org/10.3390/ma15113922

Martin, R.A. (2011). Evaluating a novel technique for individual identification of anuran tadpoles using coded wire tags. Herpetological Conservation and Biology 6: 155-160

Mcmahan, M.D.; Cowan, D.F.; Sherwood, G.D.; Grabowski, J.H. and Chen, Y. (2012). Evaluation of coded microwire tag retention in juvenile American lobster, Homarus americanus. Journal of Crustacean Biology. 32: 497-502

Meseda, M. and Samira, S.A., (2006). Spawning induction in the Mediterranean grey mullet Mugil cephalus and larval developmental stages. African Journal of Biotechnology. 5: 1836-1845. https://doi.org/10.5897/AJB06.036

Metwally, A.S.; El-Naggar, H.A.; El-Damhougy, K.A.; Bashar, M.A.E.; Ashour, M. and Abo-Taleb, H.A.H. (2020). GC-MS analysis of bioactive components in six different crude extracts from the Soft Coral (*Sinularia maxim*) collected from Ras Mohamed, Aqaba Gulf, Red Sea, Egypt. Egyptian Journal of Aquatic Biology & Fisheries. 24: 425 –434. https://doi.org/10.21608/EJABF.2020.114293

Mohamed, E.A.; El-Kammar, A.M.; Yehia, M.M. and Salem, H.S.A. (2015). Hydrogeochemical evolution of inland lakes' water: A study of major element geochemistry in the Wadi El Raiyan depression, Egypt. Journal of advanced research. 6: 1031-1044. https://doi.org/10.1016/j.jare.2014.12.008

Orth, D.J. (2023). Recreational Fishing and Keep Fish Wet. Fish, Fishing, and Conservation.

Oz, I.; Gajbhiye, D.S.; Columbus-Shenkar, Y.Y.; David, L. and Golan, M. (2022). Non-uniform metamorphosis underlies different development trajectories in hatchery-reared flathead grey mullet (*Mugil cephalus*). Frontiers in Marine Science. 9: 967984. https://doi.org/10.3389/fmars.2022.967984

Patil, P.; Kailasm, M.; Sukumaran, K.; Thomas, D. and Hussain, T. (2022). Present status of grey mullet Mugil cephalus farming. Recent Advances In Hatchery Seed Production And Farming of Milkfish. 70

Pofuk, M.; Zanella, D. and Piria, M. (2017). An overview of the translocated native and non-native fish species in Croatia: pathways, impacts and management. Management of biological invasions. 8: 425-435. https://doi.org/10.3391/mbi.2017.8.3.16

Runge, J.P.; Peterson, J.T. and Martin, C.R. (2008). Survival and dispersal of hatchery-raised rainbow trout in a river basin undergoing urbanization. North American Journal of Fisheries Management. 28: 745-757. https://doi.org/10.1577/M07-130.1

Saleh, M. (1991). Rearing of Mugilidae. A study on low salinity tolerance by thinlip grey mullet.

Saleh, M. (2008). Capture-based aquaculture of mullets in Egypt. Capture-based aquaculture. Global overview. FAO fisheries technical paper. 508: 109-126

Shama, S.; Goher, M.; Abdo, M.; Kaial, S. and Ahmed, A. (2011). Physico-chemical characteristics and heavy metal contents in water of Wadi El-Rayan Lakes, western desert, Egypt. Egyptian Journal of Aquatic Biology and Fisheries. 15: 225-240. https://doi.org/10.21608/EJABF.2011.2088

Sharawy, Z.Z.; Ashour, M.; Labena, A.; Alsaqufi, A.S.; Mansour, A.T. and Abbas, E.M (2022). Effects of dietary *Arthrospira platensis* nanoparticles on growth performance, feed utilization, and growth-related gene expression of Pacific white shrimp, *Litopenaeus vannamei*. Aquaculture. 551: 737905. https://doi.org/10.1016/j.aquaculture.2022.737905

Soliman, N.F. (2017). Aquaculture in Egypt under changing climate. Alexandria Research Center for Adaptation to Climate Change (ARCA): Alexandria, Egypt.

Soltan, M.A.H. (2013). Intensification of fish production in Egypt. Cairo, Egypt: Technica l.

Vander H.G.; Blankenship, H. and Knutzen, D. (2011). Advances in coded wire tag technology: meeting changing fish management objectives, Advances in fish tagging and marking technology. American Fisheries Society, Symposium, pp. 127-140.