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Research Article

Impacts of Water Quality, Fishing Mortality and Food Availability on the Striped Piggy *Pomadasysstridens* Production in Bitter Lakes, Egypt

Abstract

Pollution, fishing effort and food availability are the main factors affecting the fish production from natural resources. Bitter lakes are one of the important lakes in Egypt that produce a number of commercial species with mean annual fish production of 5000 ton. Recently a dramatic decline in this production is recorded and we try to find the main reasons for this. Water quality of the Bitter lakes and trace elements in the water and fish tissues were investigated during 2013. Five different sampling sites covering the whole course of the Bitter lakes were selected and pH, water temperature and salinity were measured. The cations Ca, Mg, Na, and K concentrations in sample water as well as the heavy metals Cu, Cr, Mn, Pb, and Cd in water and its residues in the tissues of *Pomadasysstridens* were determined. The crustacean communities as one of the main food items for *P. stridens* were studied in the chosen five sites. Density and diversity of marine crustaceans depend not only on the state of pollution but also on the type of substrates and different predators. The distribution of the crustaceans in the Bitter lakes varied widely within the different stations and seasons. A production model was applied to estimate some target reference points for the rational exploitation of *P. stridens* in Bitter lakes. The obtained results revealed that, the production depleting of this species is due to the overfishing and pollution that affect the food availability and the estimated precautionary target reference points advised the reduction of fishing effort by about 40-55% as well as the treatment of pollution resources along the lakes.

Introduction

The aquatic environment with its water quality as well as the over exploitation due to the excessive fishing effort are considered the main factors affecting quality and quantity of fish production either in natural habitats or culture ponds [1,2]. Quality of water may be changed due to different types of chemicals, biological and physical pollutants originating from different industrial and agricultural sources [3]. Pollution of the aquatic environment by inorganic and organic chemicals is a major factor posing serious threat to the survival of aquatic organisms including fish. While, the heavy metals in water considered as the most dangerous source of water pollution [4]. Fish that often exposed to highly polluted water, show different disabilities, ranging from biochemical changes in single cells to changes in the whole organism [5,6]. The toxic effects of heavymetals on fish are multi-directional and manifested by numerous change in the physiological and chemical process oftheir body system. Accumulation of metals in various organs of fish may cause structural lesions and functional disturbances [7].

Description of the study area

Bitter lakes (30°20′ N, 32°23′ E) are the largest water bodies along the Suez Canal, containing about 85% of the system's water. The Great and little Bitter lakes [Figure 1], separated by narrows, are saline lakes situated between the north and south parts of the Suez Canal [8]. The Bitter lakes have a surface area of about 250 km². The Bitter Lakes have an important role as a part of very important waterway; Suez Canal, and as a valuable fishing and tourism area in Egypt. Bitter lakes suffer from various sources of pollution, including domestic sewage from the surrounding human settlements, thermal pollution from Abu–Sultan electric power station's cooling water, as well as industrial and agricultural wastes from Ismailia City via the Malaria Drain, which also collects agricultural wastes from the cultivated lands on the west bank of the Great Bitter lake [8]. These activities affect the lakes boundaries and their water quality as well as their fish production.

The grunts, family Haemulidae, consists of 18 genera (133 species), including the population of the striped piggy
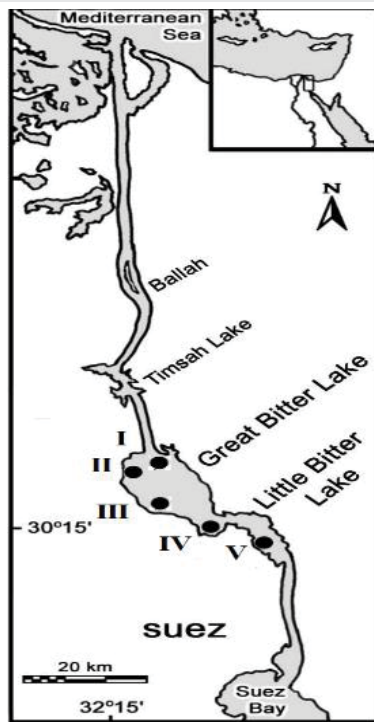
Figure 1: Map of the study area.

Pomadasysstridens [9]. The striped piggy is a marine reef-associated species inhabiting the coastal waters of the Indian Ocean; off Red Sea, off South Africa, and off western India and also in Mediterranean Sea as a lessepsian migrant [10]. The striped piggy species is common in the Bitter lakes contributing 4% of the total catch of the lakes. It feeds on zoobenthos especially benthic crustaceans and fishes which are highly sensitive to pollution [11], and their distributions are strongly influenced by the physico-chemical parameters [12].

Extensive research programs have been carried out to investigate the aquatic environment of Bitter lakes [8,13-18].On the other hand, the studies on the fishery status of different fish stocks inhabiting the lakes are very scarce [19-21]. Different aspects of biological parameters of *P. stridens* have been studied by different authors; Pauly et al. [22], in Philippines waters, Fischer et al. [23], in Mozambique water, Ben-Tuvia and McKay [24], in north-eastern Atlantic and the Mediterranean, Hashemi and Taghavimotlagh [25], in Persian Gulf, Iran.

Since the Bitter lakes represent a most important, vital and strategic region in Suez Canal, which is characterized by highly intensive rate of development, the present work aimed to investigate some physical and chemical parameters of Bitter lakes and to evaluate the pollutants levels including the accumulation of some heavy metals (Cu, Cr, Mn, Pb, and Cd) in the water and the organs of *Pomadasysstridens* as one of the commercial fish species in the lakes. The study aimed also at the estimation of population parameters of this species to evaluate the impact of fishing mortality on its production as well as the investigation of crustacean communities as one of the main food items for it. The results from this study are expected to provide highly important information about how to manage and develop the fisheries of the region and to improve its water quality.

Materials and Methods

Water quality and metals study

Sampling: Water and fish samples were collected bimonthlyfrom five stations (Defersoir I- Fayed II- Fanarah III – Kabrit IV – Shandorah V) at Bitter lakes during 2013 [Figure 1]. Water samples were collected using Nansen bottles at 30 cmdepth, and then stored in acid-washed polyethylenebottles for analysis. All the precautions recommended by Kremling [26] to minimize risks of sample contaminationwere followed during collection and treatmentof samples. Fish samples were dissected and the organs muscles, skin, gills and liver were taken. Each organ was weighed and placed in polyethylene bags according to FAO [27] and UNEP [28], labeled and frozen in deep freezer at a very low freezer temperature (below -20°C). until the time of analysis. Composite samples for small fish samples were taken.

Procedures: At the sampling time, surface water temperature was measured using standard (0-100ºC) thermometer, pH was measured on the board using a pocket pH meter (Orion 210), while salinity was determined using an inductive salinometer (SCT meters) from yellow springs Instrument Co. model 33.Na, Ca, Mg and K were determined directly after dilution of seawater samples with deionized water by using AAS according to standard methods committee [29].

Solvent extraction was utilized using ammonium pyrrolidinedi-thiocarbamate (APDC) and methyl isobutylketone (MIBK). Watersamples were pre-concentrated with APDC – MIBK extraction procedure according to the standard methods [29]. Heavy metals in the obtained solution were measured using the flame Atomic Absorption Spectrophotometer. The preparation of samples of fish to determine concentration of heavy metals was carried out according to FAO [30], and analyzed by flame atomic absorption spectrophotometer. The measurements were performed using Perkin Elmer A Analyst 100 Atomic Absorption Spectrophotometer. The obtained data wereexpressed as µg/g wet weight. Bioaccumulation factor (BAF) was determined according to [31], as: (BAF) = Cm / Cwater, where Cm – metal content in the organs (mg kg^{-1}).

Macrobenthic invertebrates study

During the present study five stations were chosen to represent different benthic environments and different conditions in the Bitter lakes and coincide with the water sampling stations. Sub tidal samples were collected from these stations by Van Veen grab with an opening area equal to 0.0288 m² of seabed. All samples were gently washed using seawater by 0.75 mm mesh sieve to remove excess sediments, and the remaining portion was fixed in 10% formalin in seawater. Organisms were isolated and identified to species level by Stereo and compound microscopes.

Pomadasys stridens fisheries studies

Sampling: Monthly random samples of P. stridens were collected from the local fishermen at Bitter lakes during the period from January 2013 to January 2014. The total length to the nearest millimeter, total weight to the nearest 0.1 g and sex were recorded for each specimen.

Methods: The growth parameters of the von Bertalanffy [32], growth model (K, L∞ and t_o) were estimated based on the length frequency distribution by using ELEFANI software [33]. The fitting of the best growth curve was based on the ELEFAN I program [34], which allows the fitted curve through the maximum number of peaks of the length-frequency distribution. With the help of the best growth curve, growth constant (K) and asymptotic length (L∞) were estimated.

The length weight relationship was calculated using the power equation W=aL^b, where (a) is constant proportionality and (b) is regression coefficient which were estimated by the least squares regression method.

Total mortality coefficient "Z" is estimated using two different methods; the first is based on the analysis of age composition data (semi-logarithmic regression method of Ricker) [35] and the second is based on the analysis of length composition data (cumulated catch curve method of Jones and Van Zalinge) [36].

Natural mortality coefficient "M" was estimated using the formula suggested by Ursin [37] and Taylor [38], while the fishing mortality coefficient "F" was computed as F = Z – M. The exploitation rate "E" was calculated using the formula of Gulland [39], as E = F/Z.

Impact of fishing mortality on the striped piggy production

To study the impact of fishing mortality on the production of *P. stridens*, the yield per recruit model of Beverton and Holt (1957) [40] was applied. The formula suggested by Gulland [41] is as follows:

$$Y/R = F\ e^{-K\ (Tc-Tr)}\ W\infty\ [(1/Z) - (3S/Z+K) + (3S^2/Z+2K) - (S^3/Z+3K)]$$

Where S = e– K (Tc – to), K is the von Bertalanffy growth parameter, Tc is theage at first capture, Tr is the age at recruitment, to is the age at which the length is nil, W∞ is the asymptotic weight, F is the fishing mortality coefficient, M is the natural mortality coefficient and Z is the total mortality coefficient.

Results and Discussion

Physical and chemical parameters

The physical and chemical parameters with their means and SD for water samples in the selected five sites are given in (Table 1). The average water temperature during the study period varied from a minimum of 22.51°C at station V to a maximum of 24.48°C at station I, which receives cooling water

from the Abu-Sultan electric power station near it. As fish is a cold blooded animal, its body temperature changes according to that of environment affecting its metabolism and physiology and ultimately affecting the production [42]. The average salinity of little Bitter lake was higher than that of Great Bitter lake, with a maximum of 43.96 at station V and a minimum of 43.21 at station I. salinity is a major driving factor that affects the density and growth of aquatic organism's population [43]. The mean pH values of the Bitter lakes ranged from 8.06 at station V to 8.24 at station I. The lowest pH values appeared in site V, where the lake subjected to the increase of sewage wastewater. According to [44], the relatively lowest pH of some sites can be attributed to the discharge of effluents which loaded with a large amount of organic acids.

The mean concentration of calcium for the whole water column ranged from 0.40 g/L at station I to 0.48 g/L at station V. The minimum concentration of magnesium is 1.35 g/L found at station I, while the maximum concentration was 1.49 g/L found at station III. The minimum and maximum concentrations of sodium in surface water were 10.69 g/L at station I, and 12.43 g/L at station V. For potassium, the minimum concentration (0.48 g/L) was recorded at station I, while the maximum concentration (0.56 g/L) was at station V. The high electrolytes content were found at stations V. These can be attributed to the high rate of evaporation, leaching and dissolution of rocks and evaporate deposits at the bottom particularly ultra-basic rocks containing electrolytes ores and station I near the lower salinity at Timsah lake [13,45].

Heavy metals in water

The average concentrations of heavy metals in the different stations of the Bitter lakes (Table 1), (Figure 2), showed annual variations in water samples. The concentrations had the order: Pb> Cu > Cr >Mn> Cd. Station V had the higher concentration (0.342, 1.924 and 0.142 µg/L) of Cr, Pb and Cd, respectively. This is may be attributed to the huge amounts of raw sewage, agricultural and industrial wastewater discharged into the south of Bitter lakes from Shandorah dumping drain [1]. Station I had elevated concentrations (0.862 and 0.163 µg/L) of Cu, Mn respectively. Where, it receives a huge amount of industrial pollutant from Abo Sultan power station, agriculture and domestic wastes, as well as the discharges from ships and fishing boats passing or waiting transit through Suez Canal, which contain antifouling paint [46]. The other three stations had lower levels of studied metals because they lie slightly away from the sources of pollution and its effects

Heavy metals in fish

The mean values of the five trace metals (µg g⁻¹wet weight) evaluated in pooled liver, gills, muscle and skin of *P. stridens* collected from Bitter lakes are shown in (Table 2). The distribution of the trace metals varied as follows: Cu and Cd: liver > gill > skin > muscle; Cr: skin > gill > liver > muscle; Mn: gill > skin > liver > muscle; and Pb: gill > liver > skin > muscle. The heavy metal residues in the tissues of *P. stridens* exhibited different patterns of accumulation and distribution among the selected tissues. It was evident from our study that,

Table 1: Some physical and chemical parameters with mean and SD of Bitter lakes water during 2013.

Station Parameter	Defersoir	Fayed	Fanarah	Kabrite	Shandorah
Temperature, ºC	24.08 − 24.70 24.48 ± 0.350	24.02 − 24.64 24.33 ± 0.312	23.66 − 24.21 23.94 ± 0.281	23.16 − 23.36 23.26 ± 0.101	22.38 − 22.61 22.51 ± 0.122
Salinity, ‰	42.77 − 43.69 43.21± 0.460	43.62 − 43.48 43.36 ± 0.100	43.62 − 43.76 43.71 ± 0.071	43.36 − 44.34 43.83 ± 0.493	43.67 − 44.33 43.961 ± 0.33
pH (Unit)	8.221 − 8.270 8.242 ± 0.021	8.170 − 8.191 8.180 ± 0.011	8.121 − 8.131 8.120 ± 0.011	8.061 − 8.092 8.071 ± 0.011	8.091 − 8.120 8.100 ± 0.022
Ca (g/L)	0.373 − 0.432 0.401 ± 0.031	0.440 − 0.480 0.460 ± 0.021	0.451 − 0.551 0.502 ± 0.051	0.442 − 0.462 0.451 ± 0.011	0.450 − 0.510 0.480 ± 0.031
Mg (g/L)	1.320− 1.391 1.353 ± 0.041	1.430 − 1.490 1.460 ± 0.020	1.481 − 1.492 1.491 ± 0.010	1.390 − 1.530 1.450 ± 0.091	1.431 − 1.491 1.461 ± 0.031
Na (g/L)	10.68 − 10.70 10.69 ± 0.011	11.73 − 12.19 11.96 ± 0.230	12.69 − 13.17 12.93 ± 0.241	11.98 − 12.97 12.47 ± 0.486	12.15 − 12.71 12.43 ± 0.281
K (g/L)	0.480 − 0.491 0.480 ± 0.005	0.492 − 0.563 0.521 ± 0.030	0.522 − 0.541 0.533 ± 0.010	0.550 − 0.566 0.552 ± 0.005	0.520 − 0.601 0.564 ± 0.040
Cu (µg /L)	0.850 − 0.873 0.863 ± 0.110	0.669 − 0.692 0.681 ± 0.011	0.721 − 0.725 0.723 ± 0.002	0.533 − 0.556 0.544 ± 0.012	0.610 − 0.636 0.623 ± 0.013
Cr (µg /L)	0.231 − 0.281 0.256 ± 0.025	0.283 − 0.392 0.337 ± 0.054	0.250 − 0.263 0.257 ± 0.007	0.178 − 0.347 0.263 ± 0.084	0.331 − 0.351 0.342 ± 0.010
Mn (µg /L)	0.160 − 0.167 0.163 ±0.003	0.130 − 0.145 0.139 ± 0.007	0.108 − 0.130 0.119 ±0.011	0.079 − 0.114 0.108 ±0.018	0.073 − 0.098 0.086 ± 0.012
Pb (µg /L)	1.582 − 2.114 1.848 ± 0.260	1.603 − 1.976 1.789 ± 0.186	1.448 − 1.670 1.559 ± 0.111	1.652 − 1.777 1.715± 0.062	1.880 − 1.968 1.924 ± 0.044
Cd (µg /L)	0.097 − 0.112 0.104 ± 0.007	0.024 − 0.068 0.046 ± 0.022	0.059 − 0.097 0.078 ± 0.070	0.050 − 0.071 0.060 ± 0.010	0.130 − 0.152 0.142 ± 0.011

liver was the site of maximum accumulation for the elements followed by gills while muscle was the overall site of least metal accumulation. In addition, the liver is the principal organ responsible for the detoxification, transportation, and storage of toxic substances and it is an active site of pathological effects induced by contamination. The gills perform the function of respiration and are directly in contact with water and pollutants that may be present in water. Thus, the concentrations of trace metals in gills reflect the concentration of trace metals in the waters where the fish lives [47]. The low accumulation of metals in muscle may be due to lack of binding affinity of these metals with the proteins of muscle. This is particularly important because muscles contribute the greatest mass of the flesh that is consumed as food [44]. Except muscles, lead concentration in all organs of studied fish, exceed the permissible limits of WHO, (2 µg/g) according to a report [48]. This shows that these fish could be at risk and who eat it.

Thestudy of bioaccumulation factor (BAF) in aquatic organism>s tissues useful to explain the best organism have the ability of heavy metals bioaccumulation in environment and help to use this organisms as clam in environmental monitoring programs [49].

From the results of bioaccumulation factor obtained in (Table 3) and (Figure 3), it was observed that, it follows the order: Mn> Cd > Cr > Cu >Pb and those metals were accumulated in soft tissue of *P. stridens* by bioaccumulation factor (BAF) as (0.881, 1.131, 4.190, 0.255, 2.465) x 10^3 than concentration in water respectively.

According to Abou-El-Ezz and Abdel-Razeq [50], the concentration of these metals in muscles was much higher ten times in some cases than that found in the surrounding water. This result provide good evidence of metals accumulation in aquatic organisms more than water that help use this organisms as bio-indicators and as a good environmental tools to study of aquatic pollution [51].

Finally, the high level of bioaccumulation factor of Mn, Cd and Cr shows that they were good bio-indicator to monitor pollution in the Bitter lakes for the fish species. Although, we did not investigate the role of adsorption, precipitation of metal ions and influence of interference in this work these will be considered in our next work.

Fishery study

Growth parameters: The present study estimated the asymptotic total length of the combined sexes of *P. stridens* from the Bitter lakes as 23.15 cm TL while the value of K was 0.51 per year and the age at length zero t_o was -0.29 year. Results indicated that this species have short life and high growth rate especially for young stages. Also, the negative t_o value means
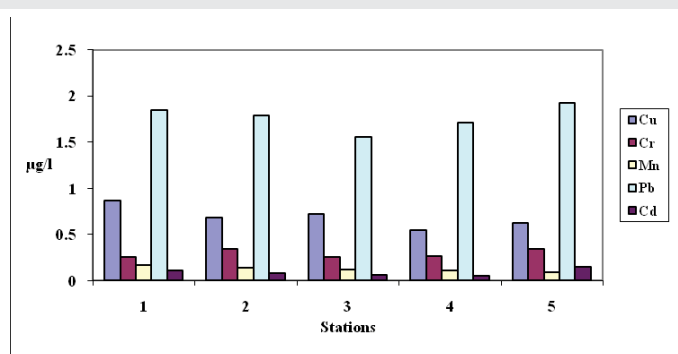

Figure 2: Level of heavy metals (μg/L) in water at different stations along Bitter Lake.

that the juveniles grew more quickly than the predicted growth curve for adults [52].

Length-Weight relationship: The length-weight relationship in fish is of great importance in fishery assessments [53]. Length and weigh relationship in conjunction with age data can give information on the stock composite, age at maturity, life span, mortality, growth and production. Length-weight relationship of *P. stridens* in the Bitter lakes was fitted for data of the all individuals combined (Figure 4). The total length varied from 7 to 19.9 cm while the total weight ranged between 4.9 and 121 g and the resultant equation was: $W = 0.0143 L^{2.9794}$.

Isometric growth was observed for striped piggy in Bitter lakes as the value of b was not significantly different from 3 (95% Confidence Interval = 2.9236 - 3.0353). The same finding was recorded in Hashemi and Taghavimotlagh [25], where they gave b = 3.04 and the growth pattern was isometric in the Persian Gulf. The value of b for Philippines waters was estimated as 3 for both sexes [22]. The variation of b in the different regions could be due to the seasonal fluctuations in environmental parameters, physiological conditions of the fish at the time of collection, sex, gonad development and nutritive conditions in the environment of fish [54].

Mortality Coefficients: The obtained results (Figure 5) indicate that the estimated values of total mortality coefficient Z from the two different methods are very close to each other with a geometric mean of 1.28/year. The mean value of natural mortality coefficient M was computed as 0.40/year and accordingly the fishing mortality coefficient F was estimated as 0.88 yearly. The exploitation ratio of striped piggy in Bitter lakes was found to be very high (0.69/year) compared to the optimum values given by Gulland [39] and Pauly [33] indicating the high level of exploitation.

Optimum length, Length at first capture and length at maturity: The estimated optimum length L_{opt} for striped piggy in the Bitter lakes was 18.35 cm TL, while the length at first capture L_c was 10.75 cm and the length at first maturity L_m was 15.11 cm. It was found that up to 95% of the striped piggy catch was under the optimum size and up to 85% was not reaching its sexual maturity (Figure 6).

Feeding habits: Analysis of full stomachs revealed that the striped piggy is a carnivorous species, fed mainly on crustaceans (62.12%), mollusks (20.31%) small fishes (11.31%), pollychaets (1.26%), while the detritus and digested food constituted 5%.

Impact of fishing mortality: The model of Beverton and Holt [40], which was based on the estimation of the yield per

Table 2: Heavy metals concentration (μ g /g) with mean and SD of different organs of Pomadasysstridens collected from Bitter lakes during 2013.

| Heavy metal	Organs			
	Muscles	Skin	Gills	Liver
Cu	0.518 − 0.6930.605 ± 0.016	1.281 − 2.6841.877± 0.24	1.896 − 1.9861.923 ± 0.021	3.621 − 5.3824.482 ± 0.024
Cr	0.334 − 0.4350.329 ±0.02	1.262 − 1.789 1.461 ± 0.15	1.074 − 1.5081.231 ± 0. 56	0.773 − 0.7950.784 ± 0.02
Mn	0.495 − 0.5320.507 ± 0.06	14.25 − 19.6516.95 ± 4.11	16.86 − 20.5018.68 ± 2.89	12.36 − 12.9612.47 ± 4.36
Pb	0.336 − 0.5660.451 ± 0.03	3.282 − 5.3564.360 ± 0.51	6.376 − 7.8436.961 ± 0.18	5.754 − 7.2416.497 ± 0.41
Cd	0.200 − 0.2250.212 ± 0.16	0.487 − 1.1610.808 ± 0.12	0.635 − 1.1790.863 ± 0.11	0.866 − 1.5481.207 ± 0.12

recruit under a particular set of fishing mortality coefficients, was applied. The input parameters used in Beverton and Holt model are as follows:

$L\infty$ = 23.15 cm, $W\infty$ = 166.3 g, K = 0.51 yr^{-1}, M = 0.4 yr^{-1}, F = variable, Tr = 0.42 yr

T_c = variable, t_o= – 0.29 yr and Z = 1.28 yr^{-1}

**Table 3:** Bioaccumulation factor x 103 (BAF) for metals in Pomadysisstridens's tissues.

Heavy metal	Organs			
	Muscles	Skin	Gills	Liver
Cu	0.881	2.732	2.799	6.525
Cr	1.131	5.024	4.233	2.696
Mn	4.190	140.1	154.3	103.1
Pb	0.255	2.467	3.939	3.676
Cd	2.465	9.395	10.03	14.03
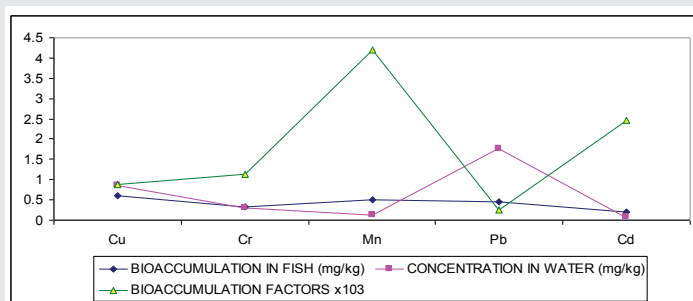
Figure 3: Heavy metal concentrations in water, bioaccumulation in fish muscles and bioaccumulation factors.
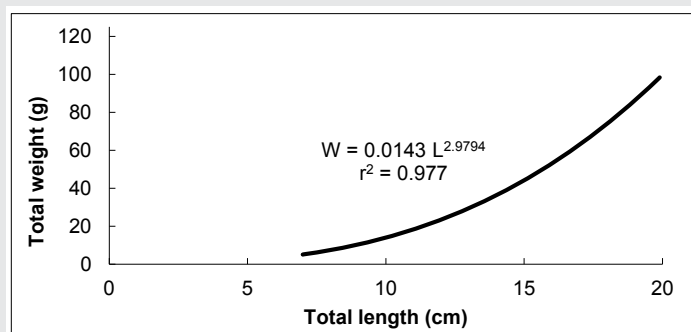
Figure 4: Length weight relationship of striped piggy from Bitter lakes.
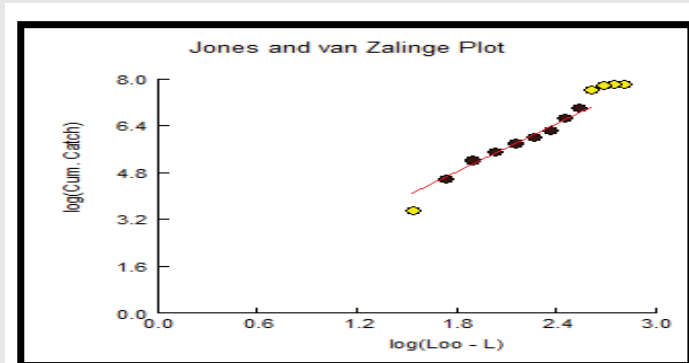
Figure 5: Cumulated catch curve of striped piggy from Bitter lakes.

The estimated yield per recruit of *P. stridens* in the Bitter lakes (Figure 7), indicates that, the yield per recruit was zero when the fishing mortality was zero, then the yield per recruit increases rapidly as the fishing mortality increases and reaches its maximum value at fishing mortality coefficient of 0.7 after which the yield per recruit decreases with further increase of fishing mortality. The results indicate also that, at the present level of fishing mortality coefficient (F= 0.88), age at first capture (T_c = 0.92 year) and natural mortality coefficient (M= 0.40), the yield per recruit was estimated to be 24.16 g. This means that, the present level of fishing mortality is higher than that which gives the maximum yield per recruit and to obtain the maximum yield per recruit, the fishing mortality coefficient must be reduced from 0.88 to 0.7 (21%).

To show the impact of mesh size on the striped piggy production, the yield per recruit was estimated using two different T_c values (0.5 and 1.5 year). The results (Figure 7), indicated that the Y/R increases with the increase of mesh sizes

Pomadasys stridens food availability

Distribution of macrobenthic invertebrates in the Bitter lakes: *Pomadasys stridens* feed on crustaceans, mollusks, small fishes & polychaetes. And show variation in relation to different size groups, seasons and environmental biota [55]. The annual changes of macrobenthic invertebrate community in Bitter lakes from (summer, 2013 to spring, 2014) comprised 36 species affiliating to 6 phyla. Polychaeta (15 species and 6689 animals / m²), Mollusca (10 species and 132244 animals/m²), Crustacea (6 species and 5767 animals / m²), Echinodermata (3species and 623 animals / m²), Cephalochordata (one species and 1736 animals / m²) and Pripulida (one species and 35 animals / m²). Figure 8 shows the seasonal variation of crustaceans where it recorded only 6 species and 5767 animals/m². This low density of crustaceans is mainly due to high pollution of the Bitter lakes.

Descriptive analysis and spatial variation: The distribution of the crustaceans in the Bitter lakes varied widely within the different stations (Figure 9). The highest crustacean species number and density was recorded at stations II and III (4 and 3 species, respectively) and (1146 and 1145 animals / m², respectively).The highest density at station II was attributed to *Balanus* sp. Which constituting 15% of the total crustaceans at the Bitter lakes with an annual average of 868 animals / m². Stations I and IV come in the second degree where the density and species numberwere2 and 1 species for each and 277 and 35 animals / m², respectively. As a result of pollution, the crustaceans at station V were totally missing throughout this investigation.

Seasonal variation: The distribution of the crustaceans in the Bitter lakes varied widely within the different seasons (Figure 10). Autumn and winter seasons encompassed the highest density (1979 and 3164 animals/m², respectively) and the highest number of species (4 species for each, respectively) as well. Otherwise summer and spring recorded the lowest population density (174 and 450 animals / m², respectively) and the lowest number of species (3 and 4 species, respectively).
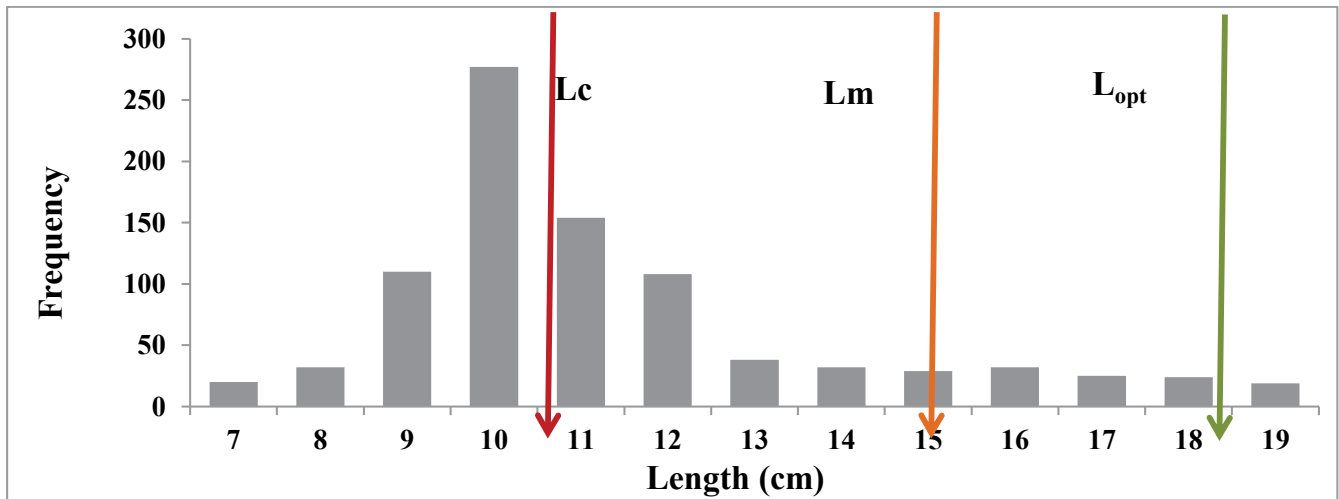
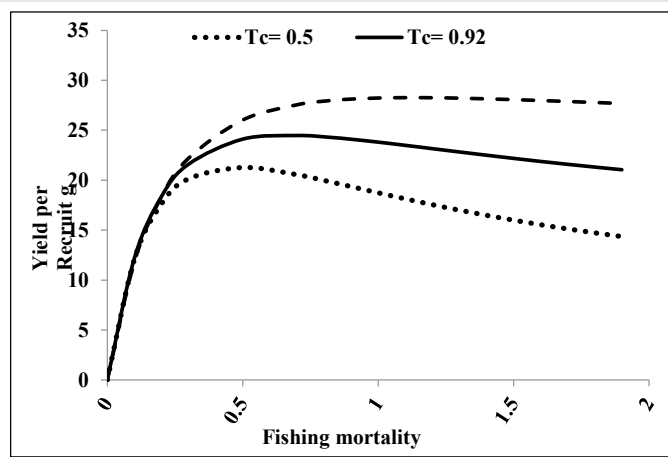**Figure 6:** Critical lengths of striped piggy from Bitter lakes.

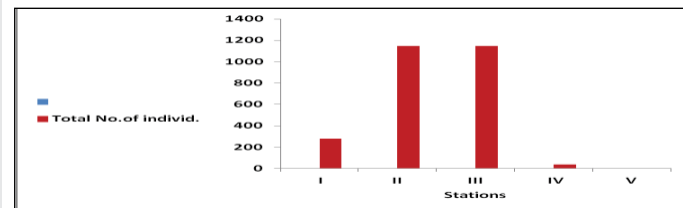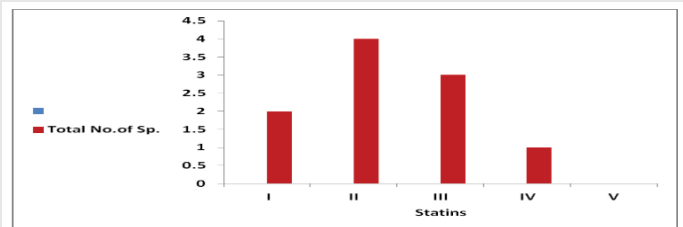**Figure 7:** Yield per recruit analysis of P. stridens from Bitter lakes.

Figure 9: Spatial variation of crustacean community (animals /m²) at the different stations in Bitter lakes
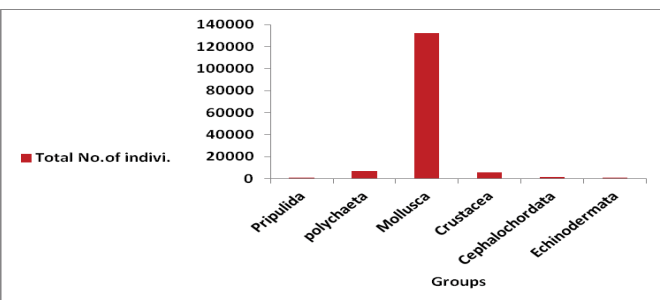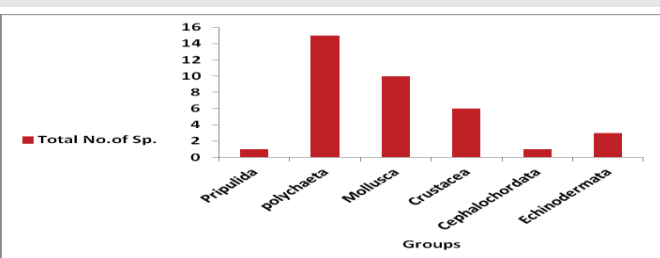

Figure 8: Population density of benthic fauna (animals / m²) from Bitter lakes.

Conclusion and Recommandations

It could be concluded that both of pollution and excessive fishing mortality are responsible for the severe reduction in the fish production from Bitter lakes. Pollution affected the water and fish quality and alters the physical and chemical characters of its aquatic environment. Also, pollution leads to the decreasing the natural main food of the species where crustaceans are very sensitive to pollution. While the high fishing effort causes both growth and recruitment overfishing where all large sized specimens are disappeared from the fishery and the striped piggy catch decreased to less than its half value. So it recommended that preventing all kinds of pollutants to keep the quality of water, reducing the fishing effort by at least 40% of its current level, banning all kinds of illegal fishing methods and reviewing the fisheries and environmental laws.
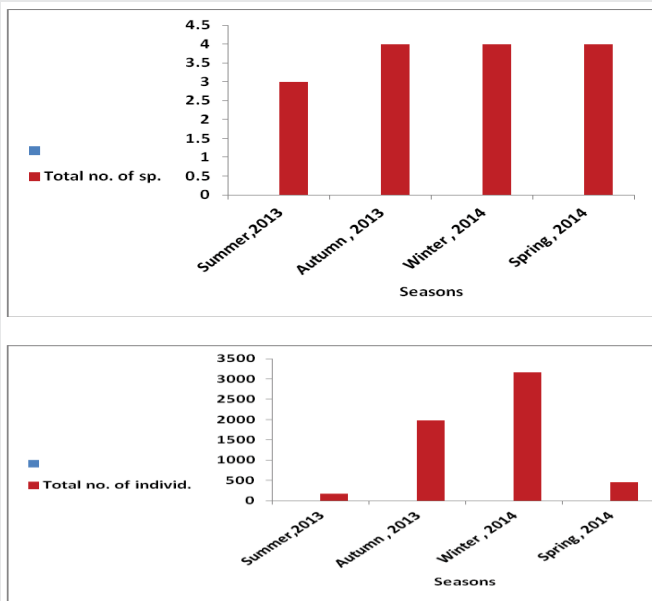
Figure 10: Seasonal average of crustacean community (animals /m²) in Bitter lakes.

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