Impact of Grass Carp Stocking Densityon Vegetation Managementin AswanReservoir - Egypt (case study)

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Abstract: Stocking grass carp *Ctenopharyngodonidella* Val. is a commonly applied technique used to management nuisance aquatic vegetation spread in reservoirs. Factors that influence the degree of aquatic vegetation control are stocking density, regional climate, abundance and species composition of the aquatic plant community, and relative feeding preferences of grass carpto the plant species. In Aswan Reservoir there are several islands, the shorelines are infested by submerged weeds. The infested areas were one of the main resources of submerged weeds which were often removed by fisher's activities and finally accumulated upstream the power stations (1) and (2). The study evaluated high-density grass carp stocking in a reservoir for control of C*eratophyllumdemersum, Vallisneriaspirlis L.* and *Naiasarmatalindb.* and the associated effects on water quality. The significant differences were detected before and after grass carp stocking for temperature, pH, secchi depth, or dissolved oxygen, ammonia, nitrite, nitrate, phosphate sulphate, copper and iron concentrations during the months from November 1998 to October 2011. The results demonstrate that intensive grass carp stocking can control an invasive aquatic plant and reveal associated changes in water quality. The results of this study, the effectiveness and ecological impacts of utilizing grass carp for aquatic plant control will help managers in developing aquatic plant management plans.

[Salwa M. Abou El Ella. **Impact of Grass Carp Stocking Densityon Vegetation Management in Aswan Reservoir - Egypt (case study)**. *J Am Sci* 2013;9(12): 324-332]. (ISSN: 1545-1003). http://www.jofamericanscience.org. 44

Key word: Grass carp, biological control, submerged weed, reservoir.

1. Introduction

The establishment of Aswan High Dam in the southern part of the River Nile in Egypt has many side effects. The aquatic macrophyte vegetation is growing so rapidly and densely that it represents an acute problem.The problems created by the hydrophytes are many such as, constituting a health hazard by providing mosquitoes larvae with an ideal breeding place, causing oxygen depletion, interfering with navigation, obstructing drainage and flow of water in irrigation canals, decreasing phytoplankton production, polluting water supplies, increasing sedimentation by trapping silt particles and causing loss of water through evapotranspiration (Ibrahim and Yasser, 2007).

The existence of submerged aquatic weeds led to breakdown the operation of hydroelectric Aswan power stations (1) and (2) for several hours daily, which was not economically feasible. The ideal aquatic plant management tool should provide cost effective control with long-term impact, a high level of selectivity, and if possible have minimal or no negative side effects. Fish used for aquatic weed control include several species of tilapia (*Tilapia spp*.), silver dollars (*Metynnisroosevelti Eig.* and *Mylossomaargenteum E. Ahl*.), common carp (*Cyprinuscarpio* L.), silver carp (*Hypophthalmichthysmolitrix* Val.), and the grass carp (*Ctenopharyngodonidella* Val.) (Shell 1962, Yeo 1967, NAS 1976). Of these fish, only the grass carp is able to consume large quantities of aquatic macrophytes (Van Dyke *et al.,* 1984). Under suitable conditions, adult grass carp will eat more than its own weight of plant material on a daily basis (Cross, 1969).

So for controlling the submerged weeds in the studied reach (the reach between Aswan Reservoir and High Dam), herbivorous grass carp fingerlings were applied annually in the last twelve years from year 1999 to year 2012.Stocking grass carp is an important biological management technique for nuisance aquatic plant growth. Grass carp were introduced to Egypt for aquatic macrophyte control in 1982 on an experimental scale .The attractiveness of this biological weed control increased since chemical aquatic weed control was banned 1991.

In 1991, the Ministry of Water Resources and Irrigation (MWRI) adopted a policy to introduce biological weed control with grass carp in the wider canals (bed-width >6 m), which are operated under continuous flow. This decision was also based on the fact that this method has less negative environmental side effects compared to other weed control methods, it is relatively cheap and it is a source of protein.

High-density grass carp stocking is a potential management technique for controlling target plant species that are food sources not preferred by grass carp (Fowler and Robson, 1978; Pine and Anderson, 1991; Catarino*et al.,*1997). However, achieving control of aquatic vegetation not preferentially consumed by grass carp with intensive stocking could result in elimination of all aquatic vegetation in the system (Shireman *et al.,*1985; Kohler and Courtenay, 1986; Allen and Wattendorf, 1987; Bain, 1993; Cassani, 1995). So about one million and half of fish weighing 10 grams each, were stocked in the reservoir every year

The research aims to assess the aquatic weed management in reservoir region. This study attempts to investigate the efficiency of this fish in reducing the submerged aquatic weed infestations within the reach between Aswan Reservoir and High Dam, without causing any negative environmental side effects on the water by comparing such variables before stocking the fish in year 1998 and after twelve years from stocking the fish in year 2011.

Description of the Study Area

High Aswan Dam was constructed on Nile River 7.00 km upstream Old Aswan Reservoir. High Aswan Dam is considered one of the largest dams on River Nile and is operated under High Aswan Dam Authority in Aswan city. High Aswan Dam was constructed in order to satisfy, agriculture, domestic and industrial needs and to increase crop production and hydroelectric energy. A huge reservoir was established upstream High Aswan Dam where, the lake is 500 km length, average width 12 km and with maximum capacity of 162 billion m^3. Old Aswan Reservoir was designed to release the required discharge daily from hydropower plants (1), (2) as shown in figure (1). The existence of aquatic weeds led to close the hydropower plants for several hours daily. The water in the reservoir was stored all over the night hours and released during the day from the power plants. The water level was fluctuated in the reservoir between 2 and 3 meters.

In Aswan Reservoir there are several islands as shown in figure (1), the shorelines are infested by submerged weeds. The infested areas were one of the main resources of submerged weeds which were often removed by fishermen activities and finally accumulated upstream the power stations (1) and (2).

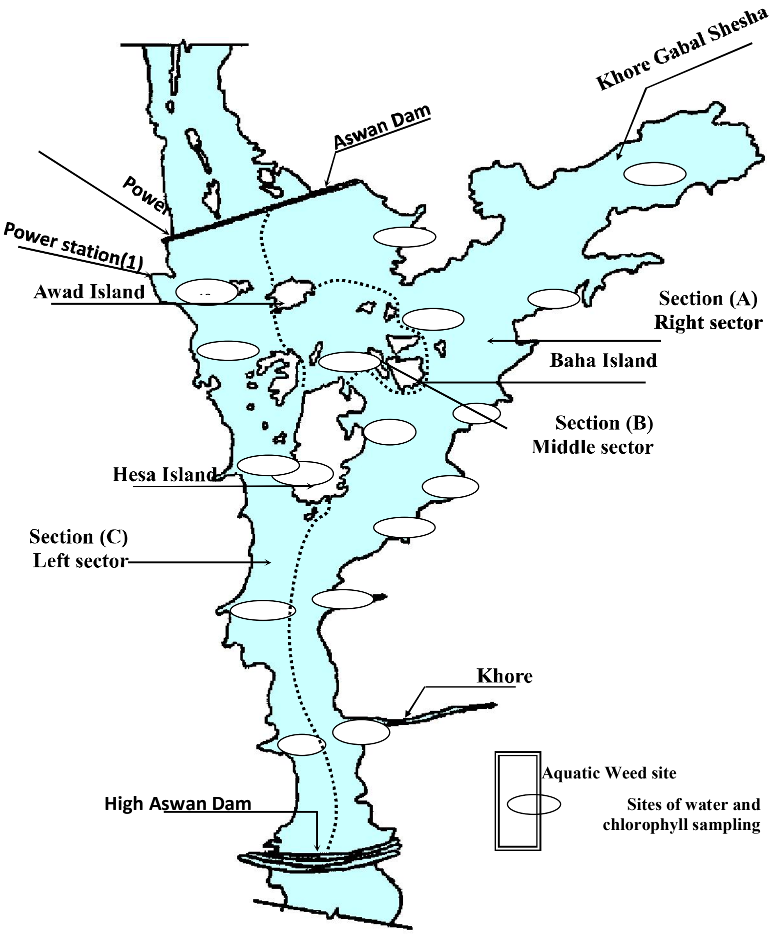

Figure (1): Schematic map showing the study area and Aquatic weed, water and chlorophyllsamples sites.

2.Materialsand Methods

To determine grass carp efficiency as a control agent of submerged aquatic weeds, inthe reach between Aswan Reservoir and High Dam, extensive field measurements were carried out to determine the hydraulic characteristics of the reservoir.

In order to monitor the aquatic weed infestation, a method was applied depending on calculating the observed infected submerged aquatic weed area by sign several points using GPS, however, it was hard to calculate the aquatic weed infestation by sight vision in huge area.

Vegetation infestation

To calculate the percentage of aquatic submerged weed infestation, the reservoir's area was divided into 3 zones (Fig. 1): Section (A) (the right bank) with an area 3380330 m^2, Section (B) (the middle area) with an area 781100 m^2 and Section (C) (the left bank) with an area 5519050 m^2. Seventeenlocations along the reservoir were detectedto determine the infestation percent of submerged weeds as shown in figure (1) and table (1).Then, the spots of weed infestations were estimated in order to compute the infested areas during years from1998 to year 2011.

Table (1): Aquatic weed and water quality locations

Location no.	Location name
1	Right sector- KhoreAgrnia
2	Right sector- small khore
3	Left sector- the creeping sand dunes
4	Right sector- beach area
5	Right sector- small khore
6	Right sector- beach area
7	Left sector- the creeping sand dunes
8	Right sector- beach area- in front of the station of GabalShesha drinking water
9	Right sector- east land of Hesa island
10	Right sector- in front of Philae temple
11	Right sector- Mount Shisha khore
12	Right sector- nearby tourist Mursi
13	Left sector- in front of power station of Aswan (1)
14	Left sector- beach area
15	Left sector- west zone of Hasha island
16	Left sector- contrast part to the west mainland of Hasha island
17	Middle sector- centrist islands- in front of Awad island

Water Quality Sampling

For investigation of physical and chemical variables in the study area, watersampling was done using a four-liter polyvinyl-chloride (van Dorn) sampling bottle. Surface samples and measurements were collected from seventeen locations in the right,middle and left sector areas (Figure 1) in October 2011 and compare the results with the results obtained through years from 1998 to 2011. Water transparency was detected with a 20 cm diameter Secchi Disc. Water temperature, pH and dissolved oxygen (DO) measured simultaneously in situ using an Oxygen temperature probe (mod. YSI, 51B). Electrical conductivity (EC) measured with Conductivity-Temperature Bridge (YSI Conductivity, salinity, and temperature meter, model 33). An approximation values of total dissolved solids (TDS) were calculated by multiplying the respective EC value with a factor as discussed in Chattopadhyay, (1998).

Surface samples for ammonia, nitrite, nitrate, phosphate, sulfate, copper and ironwere filtered immediately under low pressure through a 0.45-µ glass fiber filter to remove suspended solids. Surface samples were placed on ice immediately following collection or collection and filtration and maintained at less than 4^o C until analyzed. Samples were analyzed according to the standard method (APHA, 1992).

Phytoplankton biomass represented as Chlorophyll *a* (Chl*a*). A defined volume of water sample filtered on glass microfiber filter (GF/F) using filtration unit (Sartorius). Chl*a* extracted in 90% acetone overnight at 4 ºC (Parsons *et al*., 1984), prepared and measured with spectrophotometer (Kontron 930, UV & Vis). Trichromatic equation (SCOR/UNESCO, 1991) was applied to calculate Chl a concentration.

Water quality variable were monitored by the channel Maintenance Research Institute (CMRI, 2011) during the months from November 1998 to October 2011. The location monitored for the research provided a comparison of water quality parameters before (1998) and after (from 1999 to 2011) grass carp stocking.

Data analysis

The comparison between data collected during 2011 and 1998 were performed using t test in Statistical Analysis Software of PHARM/Pcs – version 4, (Tallarida and Murray ,1986). All statistical comparisons were considered significant at a probability of less than 0.01($P< 0.01$).

Pearson Correlation Coefficient analysis was done between parameters in water in different years. The products of the correlation coefficient (r) were evaluated as follows:

- 0–0.3: No correlation;
- 0.3–0.5: Low correlation;
- 0.5–0.7: Medium correlation;
- 0.7–0.9: High correlation;
- 0.9–1.0: Very high correlation

3.Results

Aquatic weed infestation

Only three submerged aquatic plant were

encountered in the sampling for this research; they were *Ceratophyllumdemersum, Vallisneriaspirlis L., Naiasarmatalindb.*The present study showed that *Ceratophyllumdemersum* was a dominant submerged weed species.

In year 1998, the percentage of calculated submerged weed infestation was 29181 m^2, 12822 m^2 and 5300 m^2at Right, Middle and Leftsections respectively with a total 0.5 % infestation along the whole reservoir (Figure2). To control the submerged weed infestation along the whole reservoir, the reservoir was stocked with grass carpfingerlings in years from 1999 to 2011 (with the range between one million and one and half million fingerlings). As a result, the total percentage of the calculated aquatic weed infestations along the whole reservoir sharply decreased from 0.5 % in year 1998 to 0.2, 0.09, 0.09 , 0.05, 0.035, 0.057, 0.07, 0.066, 0.07 , 0.36 and 0.26 % in years from 1999, to 2011 respectively (Figure 2).

The results of this investigation showed that the maximum aquatic weed infestation area was 18000 m^2 at location no 1 and the least was 72 m^2 at location no 3 duringyear 1998.

During the period between the years 1999 to 2007, the infestation area decreases in some location and increased in the others. Themaximum aquatic weed infestation area was 75000 m^2 at location no 1 in year 1999 and then disappear in other years tell 2011 as shown in table (2). Aquatic weeds increased in all locations in year 2010 then decrease in some location during 2011.

From the results, the total percentage of the aquatic weeds infestations along the whole reservoir sharply decreased from 0.5 % in year 1998 to 0.07 % in year 2007 and then increased to 0.36 % in 2010 and decreased to 0.26 % in year 2011.

Table (2): Aquatic Weed infestation along different location in Aswan reservoir from 1998 to 2011

Location No.	November 1998	November 1999	November 2000	September 2001	September 2002	September 2003	November 2004	September 2005	September 2006	October 2007	October 2010	October 2011
1	18000	75000	-	-	-	-	-	-	-	-	-	-
2	-	50	5	-	-	-	-	-	-	-	500	500
3	72	800	-	-	-	-	-	-	-	-	800	700
4	-	-	-	-	-	-	-	-	-	-	200	100
5	2250	1500	80	150	-	-	-	-	-	-	1200	1000
6	194	90	-	-	150	200	-	-	-	-	700	900
7	89	119	150	150	450	250	200	400	500	400	1300	1900
8	98	400	500	650	900	500	350	800	850	650	350	450
9	7528	1700	2500	1100	600	700	250	2700	2300	2100	1500	1200
10	-	750	-	250	-	-	2500	900	1100	1900	20000	15500
11	950	450	200	350	400	320	500	1100	750	1000	950	650
12	-	150	-	-	300	140	150	200	250	150	-	50
13	-	75	20	10	-	-	-	-	200	100	300	50
14	150	150	120	-	-	-	-	-	-	-	250	100
15	1250	750	500	350	-	-	-	-	-	-	200	250
16	4000	600	250	200	200	150	100	-	150	100	250	750
17	5822	4515	4200	5000	2000	1100	1500	700	450	350	1150	950
Total	**50402**	**19599**	**8525**	**8210**	**5000**	**3360**	**5550**	**6900**	**6650**	**6750**	**29650**	**25050**
Percentage	**0.52%**	**0.20%**	**0.09%**	**0.09%**	**0.05%**	**0.04%**	**0.06%**	**0.07%**	**0.07%**	**0.07 %**	**0.36 %**	**0.26 %**

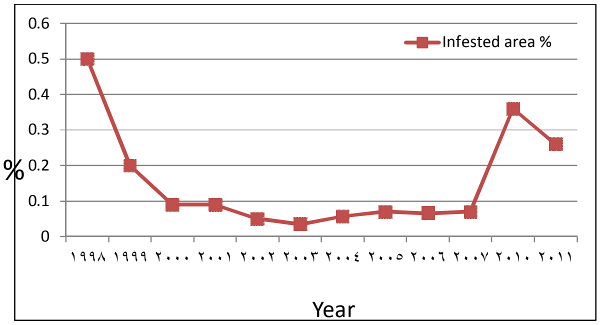

Figure (2): Percentage of infesting submerged weeds (%) during different years

Water quality

The significant differences were detected before and after grass carp stocking for pH, transparency, dissolved oxygen, ammonia, nitrite, nitrate, phosphate, sulphate, copper and iron concentrations (figures from 3 to 13).There was a significant increase in chlorophyll a concentrations from 2009, 2010and 2011, but this change did not coincide temporally with grass carp stocking.No consistent or ecologically significant changes between seasons in physical water quality parameters were detected during the years following grass carp stocking.

Variation in dissolved oxygen concentrations were observed over the entire Reservoir of the study area. A relatively high degree of variability in secchi depth readings was found during the twelve years following grass carp stocking.

Some interesting changes were observed in chemical parameters, with elevated concentrations of phosphate, nitrate, andnitrite throughout the first year after the grass carp were stocked.

Nitrite was increase more than 50% from the existing data in year 1998. Mean nitrate concentrations were varied during the yearfrom1999 to 2011; No significant differences were detected in mean phosphate concentrations except the year 2007 which decrease than those in after following grass carp stocking. No significant differences were detected in mean chlorophyll a concentrations; maximum detected concentrations were disparate, 5.1 mg/L during October2010 versus 2.16 mg/L during November 2009 and 3.4 mg/l during October 2011. Slightly elevated levels of Iron were observed during the last two years of 2010 and 2011, relative to those of the previous year. Stable copper and ammonia concentrations.

The output of Pearson correlation coefficient (r) analysis on combinations ofdifferent parameter pairs (Table 3) which are present together in water showed medium + ve correlation (r = 0.5-0.7) between several parameter pairs ($SO_4$and DO; TDS and NH_4; Cu and NO_2; NO_3 and Cu) and high + ve correlation (r = 0.7-0.9) between two parameter pairs (NH_4 and TDS; Fe and NO_3) (Table 2).

The results presented in table (4) showed that the concentrations of all parameters in water were high significant differences between the year 1998 and 2011 before and after using the grass carp but all data within the permissible limit of law 1948.

4.Discussion

In the present study, monitoring of the submerged weeds revealed that, the dominate weed species was *Ceratophyllumdemersum*. These data showed that the weeds infestation is not uniform all over Aswan reservoir which agrees with result obtained by Bakry *et al.,* 2004 and Hossam*et al.,* 2005.

The analysis of infestation data of aquatic weeds of infestation the aquatic weed data indicated that control was achieved shortly after grass carp stocking. One factor that may have influenced the degree of control is the timing of the stocking. Grass carp were stocked in the early autumn season, one month prior to the initiation of the *Ceratophyllumdemersum* growing season in Aswan Reservoir. In this case, the plant biomass of a major infestation did not require depletion to achieve reasonable control; rather, grass carp could consume less abundant vegetation as it grew. Grass carp presence at the initiation of the *Ceratophyllumdemersum* growing season may be a key factor contributing to the level of control seen. Also, *Ceratophyllumdemersum*new growth may be more palatable to grass carp facilitating early and continued control as the growing season progressed (Prowse 1971; Leslie *et al.,*1994). This factor (i.e., timing) may be of equal importance as density of grass carp for controlling *Ceratophyllumdemersum*.

The percentage of the aquatic weed infestation along the reservoir indicated a lack of plant biomass and continued vegetation control from 1999 to 2007. The second factor is the continue evaluation of aquatic weed infestation to determine the density of grass carp required. There is no evaluation in the years 2008 and 2009, so the total percentage of the observed aquatic weed infestations along the whole reservoir increased from 0.07 % to 0.36% in the year 2010 due to the grass carp stocking was very low comparing with aquatic weed infestation, then decrease to 0.26 % in 2011 due to the reservoir was injected with the grass carp in year2011 with one and half million instead of one million fingerlings.

Of the significant changes detected in the water quality parameters of reservoir area after grass carp stocking, only those for nutrient and chlorophyll *a* concentrations pose ecological significance. The elevation in Chorophyll*a* during the year2010 after grass carp were stocked could be indicative of a shift in nutrient availability to the phytoplankton community resulting from grass carp excreta or re-suspension of sediments (Boyd 1971; Shireman *et al*., 1985).

Elevated nitrate and sometimes phosphate levels were observed at beginning of the summer of 2004 and through the year of 2009, 2010, 2011 and a relatively increase in chlorophyll *a* concentrations during the 2009, 2010 and 2011. Chlorophyll *a* serves as an index of primary production (Brylinsky and Mann, 1971). In addition, there was an elevation in iron concentration observed in the last two years. In the reservoir with extensive littoral areas, aquatic macrophytes can comprise a significant portion of the primary production as they sequester nutrients and alter photic conditions early in the growing season in competition with phytoplankton communities (Boyd, 1971). Aquatic macrophytes also have added competitive advantages over phytoplankton by accessing nutrients in the substrate as well as stabilizing those substrates preventing nutrient recycling to the water (Bachmann *et al.,*2004). However, attributing this increase in phytoplankton production to the loss of littoral vegetation is not clear.

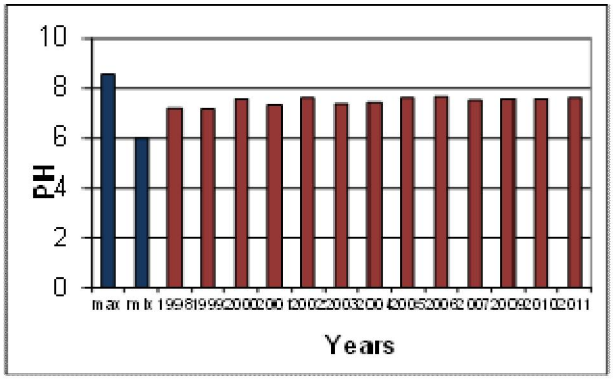

Figure (3):pH value during the years from 1998 to 2011

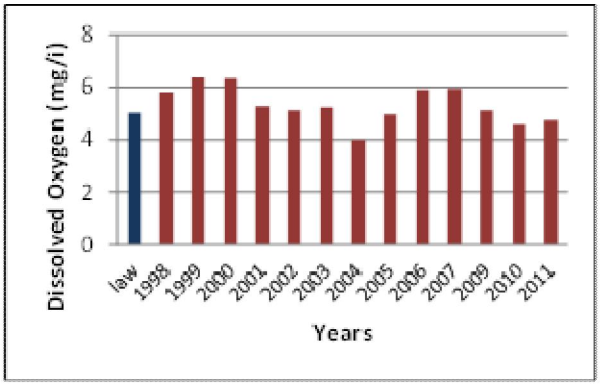

Figure (4): Dissolved oxygen (mg/l) during the years from 1998 to 2011

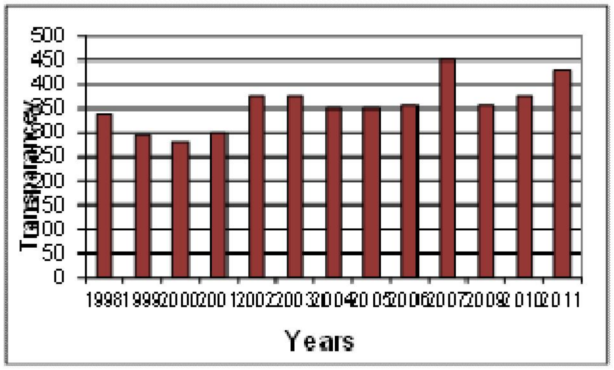

Figure (5): Transparency (cm) during the years from 1998 to 2011

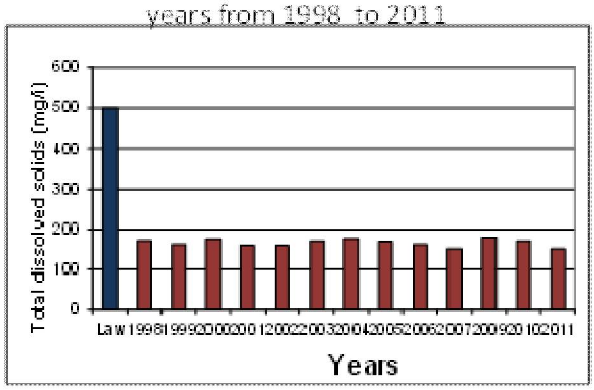

Figure (6):Total dissolved solids (mg/l) during the years from 1998 to 2011

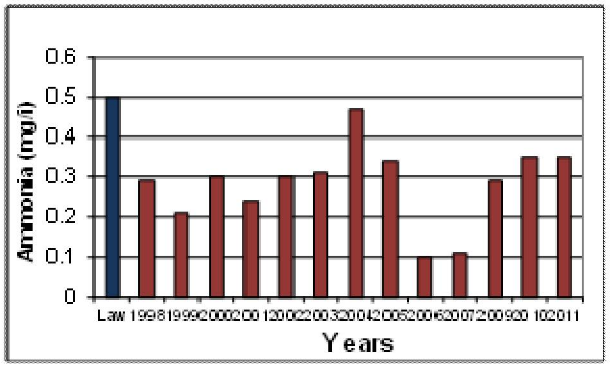

Figure (7): Ammonia concentration (mg/l) during the years from 1998 to 2011

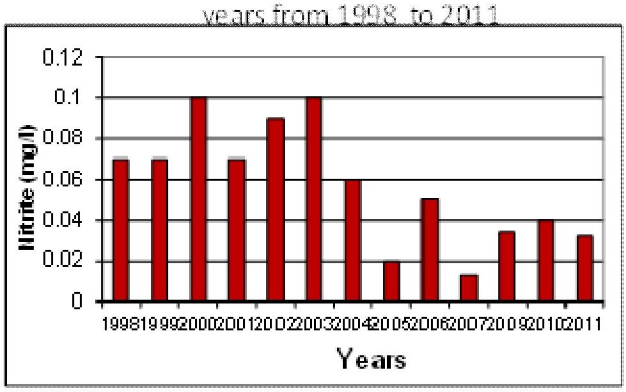

Figure (8):Nitrite concentration (mg/l) during the years from 1998 to 2011

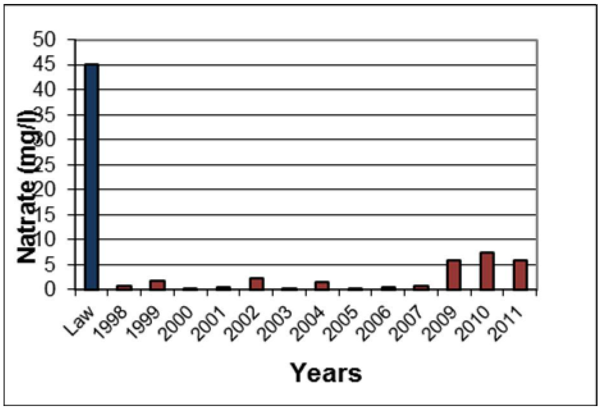

Figure (9):Nitrate concentration (mg/l) during the years from 1998 to 2011

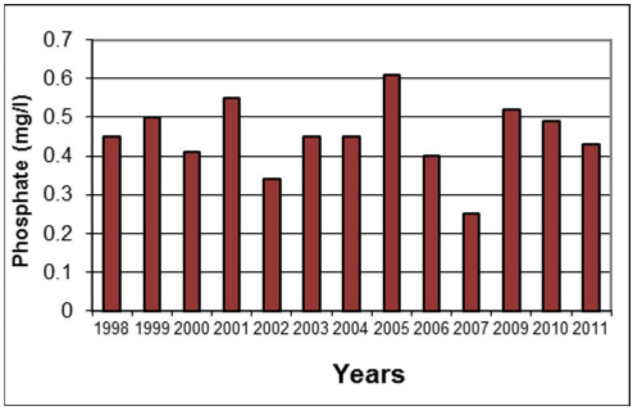

Figure (10): Phosphate concentration (mg/l) during the years from 1998 to 2011

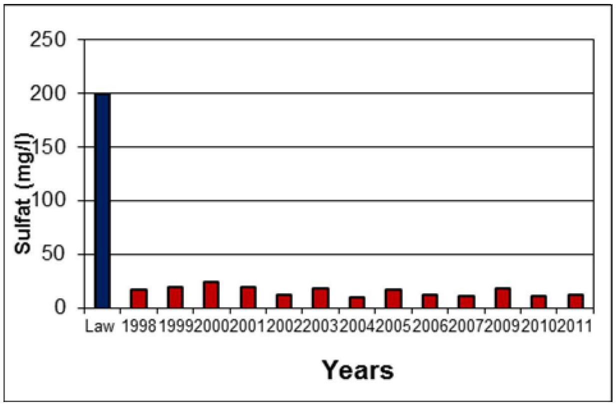

Figure (11): Sulfate concentration (mg/l) during the years from 1998 to 2011

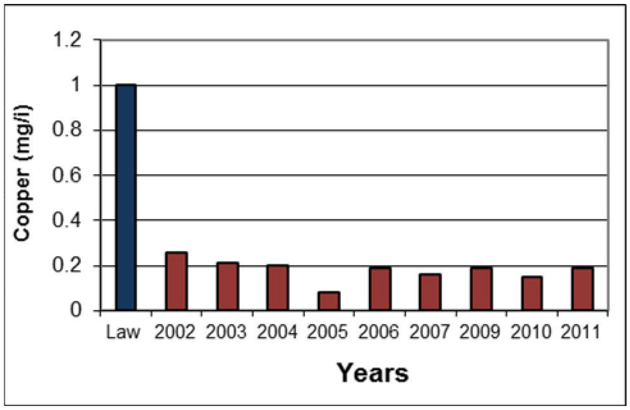

Figure (12):Copper concentration (mg/l) during the years from 1998 to 2011

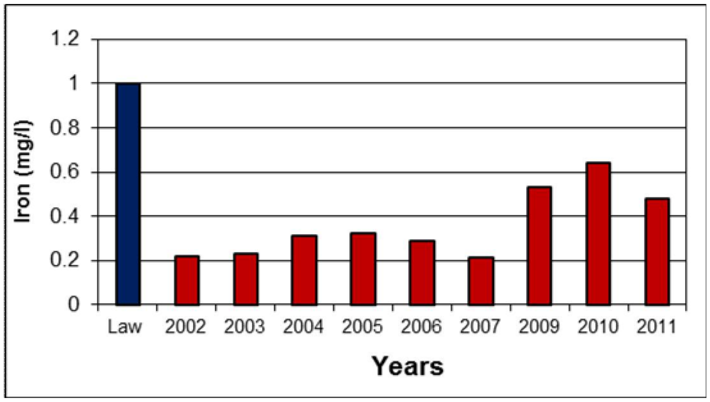

Figure (13): Iron concentration (mg/l) during the years from 1998 to 2011

In conclusion, the results of this study and other studies addressing the effectiveness and ecological impacts of utilizing grass carp for aquatic plant control will aid managers in developing aquatic plant management plans. Relating the effectiveness and potential ecological impacts of various control techniques is crucial in this process.

Table(3): Correlation coefficient matrix between parameter pairs in water

		DO	PH	EC	TDS	Transparency	NH_4	NO_2	NO_3	PO_4	SO_4	Cu	Fe
DO	Pearson Correlation N		-0.278 13	-0.361 13	-0.401 13	-0.335 13	-0.756 13	-0.060 13	-0.467 13	-0.282 13	0.539* 13	0.001 9	-0.443 9
PH	Pearson Correlation N	-0.278 13		0.034 13	0.042 13	0.418 13	0.000 13	0.191 13	0.313 13	-0.204 13	-0.362 13	-0.187 9	0.250 9
EC	Pearson Correlation N	-0.361 13	0.034 13		0.996** 13	-0.342 13	0.693* 13	-0.249 13	0.312 13	0.493 13	0.278 13	-0.049 9	0.552* 9
TDS	Pearson Correlation N	-0.401 13	0.042 13	0.996** 13		-0.281 13	0.716** 13	-0.266 13	0.352 13	0.495 13	0.243 13	-0.064 9	0.579* 9
Trans parency	Pearson Correlation N	-0.335 13	0.418 13	-0.342 13	-0.281 13		-0.086 13	0.041 13	0.334 13	-0.526 13	-0.723 13	0.043 9	-0.097 9
NH_4	Pearson Correlation N	-0.756 13	0.000 13	0.693 13	0.716 13	-0.086 13		0.072 13	0.324 13	0.402 13	-0.052 13	0.011 9	0.340 9
NO_2	Pearson Correlation N	-0.060 13	0.191 13	-0.249 13	-0.266 13	0.041 13	0.072 13		-0.027 13	-0.350 13	-0.172 13	0.644* 9	-0.357 9
NO_3	Pearson Correlation N	-0.467 13	0.313 13	0.312 13	0.352 13	0.334 13	0.324 13	-0.027 13		0.130 13	-0.324 13	0.044 9	0.922** 9
PO_4	Pearson Correlation N	-0.282 13	-0.204 13	0.493 13	0.495 13	-0.526 13	0.402 13	-0.350 13	0.130 13		0.402 13	-0.538 9	0.495 9
SO_4	Pearson Correlation N	0.539* 13	-0.362 13	0.278 13	0.243 13	-0.723 13	-0.052 13	-0.172 13	-0.324 13	0.402 13		-0.170 9	0.004 9
Cu	Pearson Correlation N	0.001 9	-0.187 9	-0.049 9	-0.064 9	0.043 9	0.011 9	0.644* 9	0.044 9	-0.538 9	-0.170 9		-0.253 9
Fe	Pearson Correlation N	-0.443 9	0.250 9	0.552 9	0.579 9	-0.097 9	0.340 9	-0.357 9	0.922** 9	0.495 9	0.004 9	-0.253 9	

* Medium Correlation (r = 0.5 - 0.7), ** High Correlation (r = 0.7 - 0.9)

Table (4): Comparison between parameters of water quality during the years 1998 and 2011

Sample statistics	**pH**		**Transparency**		**EC**		**Ammonia**		**Nitrite**	
	1998	2011	1998	2011	1998	2011	1998	2011	1998	2011
Mean ± SEM	7.425± 0.024	7.750± 0.045	306.83± 2.07	450.83± 25.57	176.33± 1.047	255.44± 8.57	0.239± 0.008	0.348± 0.014	0.094± 0.006	0.031± 0.003
t-test (Two tailed)	6.947		5.471		8.748		7.068		8.844	
Significance level	*P*< 0.01		*P*< 0.01		*P*< 0.01		*P*< 0.01		*P*< 0.01	
Sample statistics	**Nitrate**		**Phosphate**		**Sulfate**		**Copper**		**Iron**	
	1998	2011	1998	2011	1998	2011	1998	2011	1998	2011
Mean ± SEM	1.44± 0.037	6.58± 0.514	0.231± 0.006	0.44± 0.031	27.417± 0.214	13± 0.896	0.123± 0.003	0.213± 0.013	0.191± 0.006	0.486± 0.026
t-test (Two tailed)	9.627		6.816		17.115		7.068		10.681	
Significance level	*P*< 0.01		*P*< 0.01		*P*< 0.01		*P*< 0.01		*P*< 0.01	

* (N= 12)

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11/12/2013