UTILIZING THE FISH QUALITY AND GROWTH OF AQUATIC WEEDS AS A BIOMARKERS FOR WATER POLLUTION IN LAKE NUBIA, SUDAN

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ABSTRACT

The increasing levels of inorganic pollutants essentially heavy metals in natural waters became a problem of great importance, where their main sources are industrial and domestic wastes as well as agricultural runoff. Toxic metals can move from aquatic ecosystems by various processes and through biological chain, to accumulate by hundreds times their concentration in water, then could reach human beings.

The present investigation was carried out in the northern part of Nubia Lake to quantify the presence of the heavy metals in water, sediment and fishes as well as the aquatic weeds infestations.

Water, sediment and fish samples, were collected from several regions at Nubia lake. The results of Fish samples analysis imply that fish accumulate Copper (Cu), Iron (Fe), Manganese (Mn), Zinc (Zn) and Lead (Pb) mainly in the liver and kidney, while the muscle tissues nearly accumulate the least quantities during December 2004 and January 2006.

These results may help in predicting the pollution status of the water and its impacts on sediments and fish quality. On the other hand, fish contamination with different heavy metals especially lead, zinc and iron through the accumulation process could be considered as a severe pollution problem which needs immediate action.

In addition, two landsate satellite images acquired in Aug. 2001 and Sep. 2004 was classified and percentages of infestation by ditch bank weeds and submerged weeds were evaluated for the studied area. The results indicated that the most predominate emerged weeds infested the reach between km 357 (El-Gandle section) and km 487 (El-Dakka section) is the polygoun decipieus and can sustain up to 4 m water depth. High infestations by ditch bank weeds can be attributed to the high fluctuation of water levels.

INTRODUCTION

In 1959, the construction of a rock- filled dam started on the River Nile, 17 km south of Aswan, 900 km from Cairo, which created one of the largest man- made lakes in Africa- the High Dam Lake. The lake extends from the dam itself in the north to the cataract at Dal, Sudan in the south.

The whole reservoir extends about 496 km, 292 km for Lake Nasser and 204 km for Lake Nubia.

Generally, the aquatic environment with its water quality is considered the main factor controlling the state of health and disease in both man and animal. Trace metals such as copper, zinc, Iron and manganese play a biochemical role in the life processes of some if not all-aquatic organism as fish. Therefore, their presence in trace amounts in the aquatic environment is essential. Most of these elements are essential to aquatic organisms in trace quantities, but at high concentrations they become toxic. Others, such as Lead have no known biological function but are toxic element. Generally, metals enter the Reservoir from a variety of sources, such as: i) the rocks and soils directly exposed to surface waters are the largest natural source; ii) dead and decomposing vegetation and animal matter; iii) wet and dry fallout of atmospheric particulate matter; iv) man's activities, including the discharge of various treated and untreated liquid wastes to the water body.

The aquatic weed infestations are traditionally estimated by visual inspection, or using aerial photographic-based method. However, use of these methods in large open areas like reservoir or complex shoreline have proven unreliable, labor intensive, too expensive, and can take months to complete. Recently such success has been achieved in mapping aquatic weeds distribution using global remote sensing, positioning system "(GPS) and geographic information system (GIS) technologies, Hosny 2003, used remote sensing and GIS to detect and map the aquatic weeds in Khor Kalabsha-Nasser Lake. Also, Hosny 2005 applied a new technology in aquatic weeds management in Khors EL-Alaky and Tushka, Nasser Lake. Bakry *et al.,* 2004, studied the effect of using grass carp fish to control the growth of aquatic weeds in the down stream of High Aswan Dam. As shown in Figure 1, the studied reach extends from El-Dakka section (487 km upstream the High Aswan Dam) to Sarra section (325 km upstream the High Aswan Dam).

The specific objectives of this research are; i) assessing the level of heavy metals in water, sediment and fish; ii) understanding the role of sediments in the transport, transformation and distribution of heavy metals in aquatic environment; and iii) evaluating the status of aquatic weeds growth as a bioindcators for water pollution in Lake Nubia.

MATERIALS AND METHODS

Five sites were chosen (4 sites from Lake Nubia and one site in the down stream of HAD) according to the variety of water quality along lake Nubia, during December 2004 and January 2006.

For classifying the level of heavy metal, fish samples were obtained from fish pens located in the vicinity of the sampling stations, or from fishermen. The fish samples were packed in ice during transport to the laboratory and stored in a freezer at – 15˚C. In the laboratory, amounts of gills, muscle, liver, and kidney, were prepared to determine Cu, Pb, Fe, Mn and Zn by atomic absorption (Perkin Elmer model 2380) according to APHA (1995). Water samples were also collected from the surface using a modified Schindler sampler. Three- Liter samples each from the surface at 0.5 m depth. After that, samples were stored, preserved and analyzed according to APHA (1995). Sediment samples were recovered with a ponar grab sampler and placed in polyethylene bags. The sediment samples were then oven dried at 105° C, ground to less than 200 mesh, and digested using nitric acid, hydrogen peroxide and hydro fluoric acid.

For evaluating the hazard of aquatic weeds, two landsate (TM7) satellite images dated in 19/8/2001 and 28/9/2004 with 30 m ground resolution were analyzed. Each image covers the northern part of Nubia Lake inside the Sudanese side with a total area of 180 km x 180 km. The studied area lies approximately between latitudes 22°-23° and longitude 31°-32°. Throughout the site investigation conducted in Dec. 2004, about 14 sites of aquatic weeds communities were selected as shown in Figure 1 and their coordinates (latitude/longitude) were recorded (See Table 1) using the global positioning system (GPS). Based on these sites, a supervised classification process was performed using the maximum likelihood classification algorithms method. The images were also subjected to unsupervised classification process and band ratio technique. With the aid of Arc View GIS software, the final classified images were imported and many layers introduced and overlaid on the classified images in order to produce the weedy maps of the study area. The final classified images, which are presented in Figures 2 and 3, show the areas and locations of the aquatic weed infestations and terrestrial vegetation zones.

RESULTS AND DISCUSSION

Status of Aquatic Weeds

The site investigation conducted in Dec. 2004 revealed that the studied reach was widely infested only by emerged weeds and mostly free of submerged or floating weeds. The most predominate emerged weeds infested the reach between km 357 (El-Gandle section) and km 487 (El-Dakka section) is the *polygoun decipieus* and can sustain up to 4 m water depth. The second type of ditch bank weed is *Tawarix milotica* and other types such as *Hyoscyawus muticus* and *Amberoria maritima* were also shown. The slightly infestation by submerged weeds can be attributed to the high suspended material (turbidity) and the limitation of eutrophication process which can

be used as an important indicators for water quality. The chemical analysis of water indicates that there is no eutrophication problem in the water lake which is considered one of the main reasons for not accelerate the rate of growing the submerged weeds.
Utilizing the final classified images by using the geographical information system (ArcView version 3.2), the percentages of ditch bank weeds and submerged weeds are 10.39% and 0.81% respectively in August 2001. While in sept. 2004, the ditch bank weeds and submerged weeds are 18% and 0.31% respectively as shown in Table (2). The intensive growth of ditch bank weeds as calculated in sep. 2004, could increase the water losses by evapotranspiration and harm the cross section by activating the process of sediment accumulation and consequently reducing the capacity of water way.

Accumulation of heavy metals in different organs

Chemicals discharged into an aquatic system are distributed within the soluble phase, the suspended or bottom sediments, and in biota (Connell, 1987). This complex process is governed not only by the physico-chemical properties of the chemicals, but also by hydrological, weathering and geological factors (Gesamp, 1987), with trace metals, only a small proportion remains in the soluble fraction, while the major fraction is removed and becomes associated with the suspended or bottom sediments (Luoma, 1988). According to De Gregori *et.al.* (1994), it is well known that heavy metals have a great ecological significance due to their toxicity and accumulative behavior playing a prominent role in aquatic ecosystems. They occur in all compartments in aquatic environment with tendency to accumulate in organism from different trophic levels of aquatic weeds. A long this pathway, toxic heavy metal becomes a potential hazard for man, aquatic birds and mammals.

The result of metal concentrations of varies organs belongs to five locations within Aswan High Dam Reservoir are presented in Tables from (3) to (7). The data appear as averaged over the number of samples (n) analyzed. The individual variation from the mean is also indicated as ± SD for each reported value. The data in Tables from (3) to (7) indicated a high degree of randomness toward trace metal distribution in the muscle and other organs of various fish to different location, that was used as metal biological marker in toxicological studies in which it was substantiated with the sensitivity to toxic effect (Patin, 1984). A high degree of significant between all studied heavy metals in different organs, location and fish type as presented in Table (8). The statistical analyzed according to computer software SAS (1996).

Kalfakakon and Akrida-Demertai (2000) reported that Fe, Cu, Mn, Zn and Pb exhibited bioaccumulation from water to fish. They demonstrate that metal concentrations in fish are higher in water, which indicates the bioaccumulation. Unfortunately, there are no data available on the concentrations of trace elements in fishes from Aswan High Dam Reservoir, inside Sudan and the Down stream of HAD. However, Rashed (2001a, b) studied Co, Cr, Cu, Fe, Mn, Ni, Sr, Pb, Cd and Zn in different tissues of fish (*Tilapia nilotica)* from Nasser Lake to assess both the water pollution with these metals and the lethal level of these metals in fish. Fish samples were collected from two Khors in Nasser Lake (khor Kalabsha and khor El-Ramel).

The fish tissues includes muscle, gill, stomach, intestine, liver, veritable column and scales. The fish ages were 1, 1.5, 2, 2.5 and 3 years. This study resulted in that fish scales exhibited the highest concentrations of Cd, Pb, Co, Cr, Ni and Sr (0.088, 0.95, 0.29, 0.30, 0.25 and 3.21 µg/g dry weight respectively). Whole fish contain the higher concentrations of the studied metals compared to the previous study by Awadallah *et al.* (1985), in the same fish from Nasser lake and this mean the increase in metal pollution in lake water as the results of man activities.

In the present study, liver and kidney of all fish accumulated the highest concentration of trace element compared to other investigated tissues. This high accumulation in both liver and kidney tissue organs may be attributed to the high movement of metals from different tissues to the liver for detoxification and then to the kidney for subsequent excretion. This assumption has been described by a number of authors as Heath (1987), Roesijadi and Robinson (1994) and Salah El Deen, (1999) on fish. Also, the other studied tissues (gills and muscle) showed a general tend of metal accumulation. On the other hand, U.S. food and Drug Administration "action level" for human consumption (Federal Register, 1974) stated that higher allowable concentrations of copper, lead, iron, manganese and zinc in edible tissue should not exceed 60, 0.5, 0, 18 and 40 µg/g tissue respectively. Although the muscle tissues nearly accumulate the least quantities of heavy metal, a high concentration of Fe, and Pb have been founded in muscles in most fish of all location during 2004 and 2006 which may be as the result of increasing pollution loads of the lake from agricultural wastes, which include chemical pesticide and fertilizers. Sudan has a great deal of commitment to agriculture, with the consequential application of pesticides, which started in the 1930's. D.D.T was used in the Gezira scheme in the mid- forties until 1982, after which it was replaced by organophosphates & carbamates, in 2004 neo-nicotinoids were introduced, over 500 compounds are imported as pesticides. Unfortunately the poorer smaller farmers (10%) often do not conform to the rules of application of pesticides, causing a number of pollution incidents. Also increased urbanization particularly in Khartoum and wad Medani has also resulted in further pollution of the Nile especially from sewage as only a relatively small proportion of the towns have public sewage systems, the rest have individual cesspits. The treated effluent from the sewage works is used for irrigation, but in the rainy season most of this water goes directly into the river (Nile basin report 2005 & El-Sebae, 1989).

Trace metals in water samples

Trace metal analyses were performed for Cu, Fe, Mn, Zn and Pb. Table (9) shows the levels of tested heavy metal concentrations in water samples collected during winter 2004 and 2006 for some location in AHDR.

Cu concentration in some location of AHDR varies between 0.01 and 0.22 mg/l during 2004 and rang from 0.05 to 0.11 during 2006. The observed Zn concentrations in the AHDR locations ranged from N.D. to 0.03 mg/l during 2004 and range from 0.03 to 0.06 mg/l during 2006.

The present study revealed an elevation of Pb and Fe concentrations in water samples collected in most locations which the Pb concentration rang from non detectable to 0.41 mg/l and rang from non detectable to 0.36 mg/l during 2004 and 2006 respectively. Twort *et.al.* (1974) reported that the WHO " international standards" (1971) a tentative limit of 0.1 mg lead/ l in water, the WHO " European standards" (1970), suggested that a maximum Pb concentration in water is 0.3 mg/ l and under normal running condition the concentration of lead in water should be less than 0.05 mg/liter. Wardrope and Graham (1982) stated that the WHO and European communities recommended Pb level for water 0.1 mg/l. WHO (1984) stated that the natural Pb content of lake and river water world wide has been estimated to be 1-10 µg/l. The Egyptian Standards of the environmental laws no. 48/1982 and 4/1994 state that the maximum Pb concentration in water is 0.05 mg/l. The comparison between the present results and the previous recommended international standards indicated a higher concentration recorded in some locations as Atery, Okma and Gomaye sites during 2004 and 2006.

Manganese concentrations observed in AHDR from 0.078 to 0.6 mg/l and from 0.03 to 0.18 mg/l during 2004 and 2006 respectively. Manganese values were close to the allowable limits during 2004 and 2006 except the location of down stream HAD during winter 2004. The high manganese concentration may be due to the release of manganese from suspended matter deposited on the sediment surface.

The iron concentrations in all locations were high than the Egyptian standards of the environmental laws no. 48/1982 and 4/1994 (1.0 mg/l) except Down stream of HAD location during 2004 and 2006, which could be attributed to that Fe was librated from sediments as sulphides. Thus, several mechanisms are responsible for the remobilization of this metal e.g. desorption, dissolution, mineralization, legend exchange and enzymatic hydrolysis. These processes are affected by environmental factors such as PH, temperature, turbulence and depend on the dynamic equilibrium between the concentration of Fe in the interstitial water and the sediment (Elewa 1976, Bostrom *et.al*. 1982 & Grobler *et.al*. 1987) and may be from the agricultural chemical products, the industrial waste, and the household waste, cause degradation in the quality of water in the irrigation canals, in particular when they are dumped during a period of low water flow (winter).

Trace metals in sediment samples

The trace metals analyses of Cu, Fe, Mn, Zn and Pb were found to be highest in all locations as shown in table (9), While Cu and Pb were found low concentrations in most sediment locations. The increase in mean metals concentration in analyzed sediment samples followed the order: Mn › Fe › Zn › Pb › Cu.

Although the trace metals have become accumulated in high concentrations in some location sediments, the levels of metals concentration were still lower than the permissible limit (GESAMP, 1982) during the time of sample collection during 2004 and 2006 except lead concentration during 2004 and 2006 but the concentration of Cu, Mn, Zn and Pb in location of down stream HAD, were higher than the permissible limits of unpolluted sediment (GESAMP, 1982) during 2006.

In fact, these metals can be released by numerous process due to anthropogenic influences, remobilization of trace metals from suspended material and sediments. These metals are potentially hazardous not only for the aquatic eco- system, but also for the drinking water supply. Remobilization is mainly caused by four types of chemical changes in water (Forstner & Wittmann, 1979) as follow:

a. Elevated salt concentrations, where by the alkali and alkaline earth cations can complete with the metal ions sorbed on to solid particles,
b. Changes in the redox conditions, usually in conjunction with a decrease in the oxygen potential due to advanced eutrophication,
c. Lowering of PH which leads to a dissolution of carbonates and hydroxides, as well as to increase adsorption of metal cations due to competition with H + ions, and
d. Increased use of natural and synthetic complexing agents, which can form soluble metal complexes sometimes of high stability with heavy metals that are otherwise adsorbed to solid particles.

CONCLUSION

It could be concluded from this study that Aswan High Dam Reservoir, which is the main source in Egypt, is slightly polluted with iron and lead in some locations mainly at most location study. A programme should be developed for monitoring the heavy metals in aquatic and fish environments of the AHDR at different seasons. Moreover, increasing public awareness and the need to immediate action are also required. The findings of this study are summarized as follows:

1- The average level of the studied metals in the reservoir water is below the Egyptian standards of the environmental laws no. 48/1982 and 4/1994 except iron and lead during winter 2004 and 2006.
2- The high metals concentrations in sediments relative to that in water, demonstrate the importance of the suspended matter as a transport pathway for metals.
3- Trace metals have become accumulated in high concentrations in sediments indicating the existence of localized pollution contamination. Various processes of remobilization and move up the biological chain can release trace metals and reaching the human beings resulting in producing chronic and acute ailments.
4- The data presented in this work highlighted the accumulation and distribution pattern of some heavy metals in fish tissue particularly when used for human consumption after fishing from Lake. Fish accumulate Cu, Fe, Mn, Zn and Pb mainly in the liver, kidney then followed by other tissue organs where the muscle tissue nearly accumulates the least quantities.

5- Increase in heavy metal may be also resulting from continued use of pesticides on cotton fields in the Gezera project in central Sudan.
6- The most predominate emerged weeds infested the reach between km 357 (El-Gandle section) and km 487 (El-Dakka section) is the *polygoun decipieus* and can sustain up to 4 m water depth. High infestations by ditch bank weeds can be attributed to the high fluctuation of water levels. These intensive weeds increase the water losses by evapotranspiration and harm the cross section by activating the process of sediment accumulation and consequently reducing the capacity of water way. Therefore, inspections monitoring, and management the aquatic weeds in that reach with the status of water quality should be considered annually to assess the decision maker in management the limited water resources of Egypt.

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Table (1): Coordinates (latitude/longitude) for Lake Nubia

Site no.	Site name	Coordinates
1	West Akma	21° 11´ 35 N 30° 40 09 E
2	East Akma	21° 11´ 25 N 30° 40 11 E
3	West El Daka	21° 03´ 01 N 38° 38 48 E
4	East El Daka	21° 02´ 50 N 30° 38 50 E
5	East second El Gandel	21° 47´ 50 N 31° 13 49 E
6	West second El Gandel	21° 50´ 26 N 31° 13 11 E
7	East Abdel Kader	21° 49´ 27 N 31° 19 49 E
8	West Abdel Kader	21° 52´ 00 N 31° 12 56 E
9	East Doghaim	21° 52´ 27 N 31° 19 48 E
10	West Doghaim	21° 54´ 10 N 31° 16 12 E
11	East Dabarosa	21° 56´ 16 N 31° 21 58 E
12	West Dabarosa	21° 56´ 35 N 31° 21 07 E
13	East Okasha	21° 00´ 05 N 30° 41 07 E
14	West Okasha	21° 06´ 53 N 30° 41 07 E

Table (2): The aquatic weed infestation area in Lake Nubia

Parameters		19 August 2001	28 September 2004
Water level U/S HAD	(m)	177.52	174.55
Water surface area	(km^2)	641.93	622.92
Ditch bank weeds	(Km^2)	66.74	111.96
	%	10.39	18
Submerged weeds	(Km^2)	5.029	1.9
	%	0.81	0.31

Locations	English name of fish	Mean wt of fish (gm)	2004 (Mean ± SD)				Mean wt of fish (gm)	2006 (Mean ± SD)			
			Liver	Kidney	Muscle	Gills		Liver	Kidney	Muscle	Gills
El Gandel	*Schilbe niloticus*	111.25± 12.374	12.308± 2.557	11.525± 3.522	0.325± 0.104	2.105± 0.461	92.75± 24.395	26.665± 8.959	20.941± 1.938	1.186± 0.186	2.852± 0.482
	Labeo niloticus	311.5± 12.021	2.525± 0.575	3.353± 0.376	N.D.	2.374± 0.359	185.000± 21.213	12.525± 1.379	5.328± 1.126	0.356± 0.078	3.401± 0.438
	Hydrocynus vittatus	152± 5.657	8.031± 0.269	8.927± 0.289	2.183± 0.267	3.993± 1.107	-	-	-	-	-
Akma	*Alestes dentex.* (L.)	251.5± 12.021	1.550± 0.214	0.591± 0.136	N.D.	1.988± 0.153	260.000± 56.569	6.385± 0.870	0.490± 0.156	N.D.	1.062± 0.100
Atery	*Labeo niloticus*	646.5± 47.376	4.977± 0.134	6.809± 0.438	N.D.	3.823± 0.148	385.500± 91.217	8.800± 1.612	8.122± 0.832	0.295± 0.092	4.093± 0.196
	Oreochromis niloticus	450± 42.426	2.079± 0.122	2.480± 0.423	0.341± 0.07	1.684± 0.176	280.000± 28.284	15.430± 5.812	2.736± 0.276	0.295± 0.037	2.091± 0.187
Gomaye	*Oreochromis aurens* (Steind.)	772.5± 10.607	23.049± 1.610	42.734± 4.151	0.600± 0.029	3.122± 0.211	675.000± 106.066	35.800± 1.556	54.605± 6.088	1.341± 0.551	6.282± 1.288
	Bagrus docmak (Forssk)	655.5± 6.364	13.593± 0.961	2.987± 0.301	0.669± 0.099	1.345± 0.319	407.500± 67.175	18.760± 1.527	3.871± 0.112	0.964± 0.180	2.315± 0.305
Down stream HAD	*Tilapia zilli*	71.5± 0.707	2.674± 0.629	370.49± 21.312	3.457± 0.484	6.153± 0.327	-	-	-	-	-
	Oreochromis nilotica	59.5± 0.707	67.199± 0.151	3.135± 1.084	5.759± 1.265	55.631± 1.114	50.000± 14.142	28.270± 3.776	3.119± 0.294	6.332± 1.129	3.418± 0.400
	Hydrocynus vittatus	107± 1.414	6.781± 0.478	13.105± 2.852	2.792± 0.739	12.245± 0.472	125.000± 49.497	8.795± 1.195	20.659± 2.056	3.610± 0.552	8.197± 1.199
	Ctenopharyngodon idella Val.	96.95± 15.627	2.268± 0.421	1.575± 0.138	0.862± 0.088	4.007± 0.135	40.000± 14.142	1.590± 0.127	1.024± 0.043	N.D	2.877± 0.472
	Lates (Lates) niloticus (L.)	64.5± 0.707	7.983± 0.243	71.211± 0.016	N.D.	4.139± 0.339	50.000± 7.071	6.175± 0.530	25.446± 4.038	N.D	5.612± 0.424
	Synodontis schall (Bl. & SCHN.)	40.5± 0.707	1.635± 0.343	1.208± 0.131	3.161± 0.260	5.074± 0.372	-	-	-	-	-
	Bagrus docmak (Forssk)	235.5± 9.192	2.934± 0.076	1.755± 0.182	100.658± 2.179	293.602± 29.276	580.000± 113.137	1.955± 0.219	69.652± 7.495	47.144± 9.569	14.234± 3.785
	Alestes dentex. (L.)	137.3± 17.961	574.116± 34.259	83.195± 4.254	93.474± 16.502	15.841± 5.074	-	-	-	-	-

Table (3): Bioaccumulation of Copper (µg/g fresh tissue) of different organs in different fish

Table (4): Bioaccumulation of iron (µg/g fresh tissue) of different organs in different fish

Locations	English name of fish	Mean wt of fish (gm)	2004 (Mean ± SD)				Mean wt of fish (gm)	2006 (Mean ± SD)			
			Liver	Kidney	Muscle	Gills		Liver	Kidney	Muscle	Gills
El Gandel	*Schilbe niloticus*	111.25± 12.374	266.048± 12.285	200.567± 3.475	19.849± 2.078	71.749± 2.869	92.750± 24.395	175.605± 21.348	280.258± 13.784	8.925± 1.960	98.550± 4.497
	Labeo niloticus	311.5± 12.021	53.401± 2.390	60.710± 2.172	11.999± 2.303	74.419± 6.264	185.000± 21.213	83.915± 9.327	111.039± 13.160	3.441± 1.599	47.055± 9.537
	Hydrocynus vittatus	152± 5.657	124.931± 4.438	151.215± 8.791	10.519± 1.789	119.134± 2.512	-	-	-	-	-
Akma	*Alestes dentex.* (L.)	251.5± 12.021	374.789± 6.812	163.316± 2.239	21.669± 1.184	100.258± 0.999	260.000± 56.569	228.246± 17.330	206.145± 7.983	20.445± 2.639	165.935± 7.969
Atery	*Labeo niloticus*	646.5± 47.376	70.446± 1.718	84.511± 3.678	21.389± 1.979	124.868± 3.432	385.500± 91.217	53.641± 10.848	60.343± 15.005	26.606± 5.791	87.731± 3.959
	Oreochromis niloticus	450± 42.426	34.668± 4.371	120.358± 12.649	20.122± 0.919	94.033± 8.95	280.000± 28.284	59.877± 5.610	87.106± 4.801	10.668± 1.306	66.182± 7.426
Gomaye	*Oreochromis aurens* (Steind.)	772.5± 10.607	84.61± 4.151	129.228± 1.877	13.103± 1.853	43.924± 1.912	675.000± 106.066	112.151± 14.453	87.351± 4.836	N.D	41.971± 3.648
	Bagrus docmak (Forssk)	655.5± 6.364	51.809± 1.262	235.717± 5.891	12.856± 1.309	124.615± 2.411	407.500± 67.175	79.112± 17.425	166.401± 24.182	11.624± 1.291	81.466± 3.173
Down stream HAD	*Tilapia zilli*	71.5± 0.707	70.729± 2.769	840.164± 69.485	370.399± 25.881	111.458± 6.136	-	-	-	-	-
	Oreochromis nilotica	59.5± 0.707	240.400± 12.304	148.809± 12.836	72.368± 1.154	269.045± 1.605	50.000± 14.142	175.641± 7.453	159.714± 11.026	56.632± 9.788	92.106± 3.685
	Hydrocynus vittatus	107± 1.414	79.438± 2.143	50.086± 1.377	35.932± 3.440	259.231± 5.818	125.000± 49.497	95.426± 2.665	73.626± 9.496	29.641± 2.731	60.852± 14.059
	Ctenopharyngodon idella Val.	96.95± 15.627	60.258± 2.969	20.274± 0.511	23.534± 1.122	104.495± 13.55	40.000± 14.142	10.648± 1.617	6.616± 1.830	N.D	10.011± 2.703
	Lates (Lates) niloticus (L.)	64.5± 0.707	5.555± 0.532	34.291± 3.338	18.616± 1.508	120.915± 1.124	50.000± 7.071	17.778± 0.567	26.215± 4.660	8.902± 1.146	39.941± 3.379
	Synodontis schall (Bl. & SCHN.)	40.5± 0.707	94.393± 3.793	202.609± 2.403	74.099± 2.158	204.815± 4.871	-	-	-	-	-
	Bagrus docmak (Forssk)	235.5± 9.192	132.829± 5.419	76.635± 1.754	39.722± 6.174	241.374± 12.595	580.000± 113.137	25.454± 5.832	16.542± 1.584	9.656± 1.617	56.289± 4.117
	Alestes dentex. (L.)	137.3± 17.961	177.831± 2.138	354.549± 4.129	42.631± 0.059	150.524± 7.674	-	-	-	-	-

Table (5): Bioaccumulation of zinc (µg/g fresh tissue) of different organs in different fish

Locations	English name of fish	Mean wt of fish (gm)	2004 (Mean ± SD)				Mean wt of fish (gm)	2006 (Mean ± SD)			
			Liver	Kidney	Muscle	Gills		Liver	Kidney	Muscle	Gills
El Gandel	*Schilbe niloticus*	111.25± 12.374	28.672± 2.051	197.123± 0.298	19.016± 1.329	98.769± 0.069	92.750± 24.395	41.905± 11.830	80.475± 14.023	24.815± 3.230	54.305± 4.958
	Labeo niloticus	311.5± 12.021	34.424± 2.046	18.819± 1.541	9.907± 0.673	55.324± 3.384	185.000± 21.213	31.011± 5.075	57.658± 2.431	20.495± 2.003	42.249± 1.863
	Hydrocynus vittatus	152± 5.657	36.919± 2.602	132.906± 4.405	10.763± 1.096	64.76± 3.752	-	--	-	-	-
Akma	*Alestes dentex.* (L.)	251.5± 12.021	33.485±4.5 04	59.973± 2.915	21.065± 2.387	33.121± 2.193	260.000± 56.569	41.861± 2.632	39.361± 1.925	19.725± 0.913	23.463± 2.492
Atery	*Labeo niloticus*	646.5± 47.376	79.652± 1.585	28.633± 1.556	11.969± 1.162	30.151± 0.594	385.500± 91.217	59.000± 1.797	31.879± 1.897	8.626± 1.549	39.332± 2.884
	Oreochromis niloticus	450± 42.426	7.667± 0.786	27.989± 1.525	8.588± 0.646	37.699± 1.285	280.000± 28.284	20.976± 1.787	30.621± 2.701	11.153± 1.329	25.084± 3.045
Gomaye	*Oreochromis aurens* (Steind.)	772.5± 10.607	19.442± 1.032	35.389± 2.229	4.487± 0.798	12.575± 1.108	675.000± 106.066	28.617± 2.978	45.902± 2.306	4.966± 1.336	19.907± 0.163
	Bagrus docmak (Forssk)	655.5± 6.364	50.096± 3.531	18.816± 1.248	6.415± 0.601	11.863± 1.088	407.500± 67.175	42.174± 3.467	29.396± 3.005	7.972± 1.498	18.897± 1.847
Down stream HAD	*Tilapia zilli*	71.5± 0.707	20.585± 1.366	166.352± 4.838	44.071± 6.053	71.846± 0.148	-	-	-	-	-
	Oreochromis nilotica	59.5± 0.707	21.217± 0.769	13.341± 2.073	20.891± 0.266	65.726± 0.023	50.000± 14.142	25.010± 6.773	25.572± 1.698	19.019± 4.638	23.594± 4.530
	Hydrocynus vittatus	107± 1.414	77.113± 2.234	141.993± 21.397	25.874± 0.071	150.391± 1.893	125.000± 49.497	77.726± 3.543	106.417± 7.785	38.371± 2.317	46.604± 5.703
	Ctenopharyngodon idella Val.	96.95± 15.627	39.009± 1.963	16.489± 3.848	23.253± 2.133	30.487± 3.970	40.000± 14.142	29.647± 0.531	41.639± 1.516	27.904± 3.765	25.096± 3.429
	Lates (Lates) niloticus (L.)	64.5± 0.707	12.202± 1.826	13.054± 1.868	11.602± 3.602	55.771± 5.711	50.000± 7.071	16.266± 1.399	24.615± 1.549	16.811± 1.555	29.102± 2.573
	Synodontis schall (Bl. & SCHN.)	40.5± 0.707	32.697± 4.097	68.247± 2.611	17.873± 2.147	54.455± 5.833	-	-	-	-	-
	Bagrus docmak (Forssk)	235.5± 9.192	26.313± 1.563	26.953± 0.614	26.564± 3.958	42.245± 4.314	580.000± 113.137	34.126± 2.299	49.483± 3.151	27.966± 3.176	20.078± 1.650
	Alestes dentex. (L.)	137.3± 17.961	174.374± 3.075	310.612± 3.425	37.216± 0.315	197.259± 21.408	-	-	-	-	-

Table (6): Bioaccumulation of manganese (µg/g fresh tissue) of different organs in different fish

Locations	English name of fish	Mean wt of fish (gm)	2004 (Mean ± SD) Liver	Kidney	Muscle	Gills	Mean wt of fish (gm)	2006 (Mean ± SD) Liver	Kidney	Muscle	Gills
El Gandel	*Schilbe niloticus*	111.25± 12.374	6.017± 0.431	21.076± 0.589	6.062± 0.373	14.009± 1.752	92.750± 24.395	20.374± 1.206	37.997± 3.146	10.371± 1.188	14.761± 2.774
	Labeo niloticus	311.5± 12.021	10.569± 1.094	4.573± 0.651	0.03± 0.0028	16.907± 2.257	185.000± 21.213	14.351± 1.074	12.389± 1.163	0.290± 0.057	8.375± 1.205
	Hydrocynus vittatus	152± 5.657	16.172± 2.349	41.559± 2.897	8.018± 1.297	9.822± 1.162	-	-	-	-	-
Akma	*Alestes dentex.* (L.)	251.5± 12.021	19.779± 1.336	14.952± 1.204	2.407± 0.565	11.767± 0.332	260.000± 56.569	34.866± 3.330	27.370± 2.628	4.192± 1.442	19.587± 1.309
Atery	*Labeo niloticus*	646.5± 47.376	16.226± 2.409	6.519± 1.214	5.645± 1.037	24.305± 2.017	385.500± 91.217	9.160± 1.499	6.351± 0.508	3.355± 0.502	8.605± 0.842
	Oreochromis niloticus	450± 42.426	3.267± 0.531	20.383± 1.196	0.939± 0.291	14.562± 2.807	280.000± 28.284	17.359± 2.036	15.255± 1.365	0.945± 0.076	9.164± 1.480
Gomaye	*Oreochromis aurens* (Steind.)	772.5± 10.607	5.683± 0.642	16.62± 0.986	N.D	7.093± 0.393	675.000± 106.066	6.849± 0.354	10.622± 1.288	0.455± 0.107	5.111± 0.298
	Bagrus docmak (Forssk)	655.5± 6.364	1.065± 0.093	4.316± 0.315	0.197± 0.008	4.366± 0.550	407.500± 67.175	5.657± 1.505	5.921± 0.424	0.269± 0.082	2.614± 0.688
Down stream HAD	*Tilapia zilli*	71.5± 0.707	1.139± 0.291	7.982± 0.465	0.593± 0.057	32.475± 3.202	-	-	-	-	-
	Oreochromis nilotica	59.5± 0.707	37.584± 3.531	12.535± 1.078	6.458± 0.774	76.135± 3.185	50.000± 14.142	24.626± 2.680	17.006± 1.817	4.761± 0.793	16.486± 0.869
	Hydrocynus vittatus	107± 1.414	36.495± 4.297	61.097± 0.173	8.799± 1.053	12.583± 0.094	125.000± 49.497	28.400± 2.673	47.796± 3.117	3.910± 0.269	8.750± 1.061
	Ctenopharyngodon idella Val.	96.95± 15.627	1.771± 0.196	1.648± 0.670	1.059± 0.196	2.481± 1.995	40.000± 14.142	1.914± 0.129	0.890± 0.127	0.346± 0.065	0.986± 0.023
	Lates (Lates) niloticus (L.)	64.5± 0.707	0.399± 0.018	8.229± 0.407	3.324± 0.554	21.745± 1.312	50.000± 7.071	6.317± 1.720	8.261± 1.783	1.296± 0.416	4.650± 1.515
	Synodontis schall (BI. & SCHN.)	40.5± 0.707	4.097± 0.303	20.678± 3.065	5.103± 1.559	3.134± 0.957	-	-	-	-	-
	Bagrus docmak (Forssk)	235.5± 9.192	14.716± 0.103	5.297± 1.591	8.834± 0.355	11.795± 1.715	580.000± 113.137	19.421± 1.542	12.965± 1.788	3.151± 0.622	8.650± 1.203
	Alestes dentex. (L.)	137.3± 17.961	3.658± 0.989	66.951± 3.231	4.725± 0.499	81.561± 8.529	-	-	-	-	-

Table (7): Bioaccumulation of lead (µg/g fresh tissue) of different organs in different fish

Locations	English name of fish	Mean wt of fish (gm)	2004 (Mean ± SD) Liver	Kidney	Muscle	Gills	Mean wt of fish (gm)	2006 (Mean ± SD) Liver	Kidney	Muscle	Gills
El Gandel	*Schilbe niloticus*	111.25± 12.374	47.851± 2.121	136.235± 0.451	1.676± 0.201	89.808± 7.765	92.750± 24.395	53.024± 4.120	74.876± 6.584	2.662± 0.409	68.716± 2.539
	Labeo niloticus	311.5± 12.021	42.138± 2.600	54.550± 4.015	2.330± 0.117	55.622± 3.111	185.000± 21.213	47.496± 3.642	38.136± 3.429	1.841± 0.128	26.605± 4.391
	Hydrocynus vittatus	152± 5.657	63.130± 1.991	119.397± 2.278	5.385± 0.204	84.033± 2.097	-	-	-	-	-
Akma	*Alestes dentex*. (L.)	251.5± 12.021	65.725 ± 1.677	118.896± 1.570	5.375± 0.189	83.430± 1.245	260.000± 56.569	265.100± 6.505	309.256± 9.538	17.672± 2.900	85.317± 7.502
Atery	*Labeo niloticus*	646.5± 47.376	28.539 ± 1.358	32.676 ± 1.774	1.550 ± 0.084	39.019 ± 1.582	385.500± 91.217	43.961± 4.580	48.316± 3.683	2.051± 0.111	35.671± 4.385
	Oreochromis niloticus	450± 42.426	20.349 ± 1.672	98.407 ± 2.382	0.298 ± 0.029	44.052 ± 2.628	280.000± 28.284	25.137± 3.430	43.622± 4.383	0.387± 0.049	32.956± 3.770
Gomaye	*Oreochromis aurens* (Steind.)	772.5± 10.607	34.461 ± 2.318	82.744 ± 1.169	2.158 ± 0.060	15.662 ± 1.316	675.000± 106.066	33.910± 3.268	73.606± 3.374	1.991± 0.122	22.525± 2.821
	Bagrus docmak (Forssk)	655.5± 6.364	37.190 ± 2.571	28.151 ± 1.726	1.477 ± 0.083	25.243 ± 1.508	407.500± 67.175	31.965± 2.468	27.361± 2.460	1.497± 0.248	29.371± 1.627
Down stream HAD	*Tilapia zilli*	71.5± 0.707	40.772 ± 1.469	58.842 ± 1.316	0.782 ± 0.015	90.287 ± 1.715	-	-	-	-	-
	Oreochromis nilotica	59.5± 0.707	28.640 ± 0.406	57.189 ± 3.761	0.283 ± 0.0129	227.629± 31.872	50.000± 14.142	21.146± 2.226	29.456± 1.068	0.256± 0.033	65.726± 7.361
	Hydrocynus vittatus	107± 1.414	58.640 ± 0.406	57.189 ± 3.761	2.831 ± 0.129	250.629± 0.654	125.000± 49.497	58.902± 5.219	69.531± 1.075	0.822± 0.127	23.876± 4.743
	Ctenopharyngodon idella Val.	96.95± 15.627	34.291 ± 2.080	52.038± 1.877	0.516 ± 0.027	93.255 ± 5.686	40.000± 14.142	11.402± 1.598	9.326± 0.784	0.447± 0.177	10.160± 1.499
	Lates (Lates) niloticus (L.)	64.5± 0.707	49.393 ± 1.445	35.611 ± 1.470	2.991 ± 0.028	135.774± 2.635	50.000± 7.071	33.862± 5.163	42.061± 2.631	1.165± 0.293	23.855± 4.607
	Synodontis schall (BI. & SCHN.)	40.5± 0.707	70.755 ± 0.612	101..997± 2.848	5.206 ± 0.178	144.647± 4.034	-	-	-	-	-
	Bagrus docmak (Forssk)	235.5± 9.192	26.121 ± 1.798	43.33 ± 0.330	6.456 ± 0.027	67.345 ± 1.915	580.000± 113.137	13.621± 2.970	18.122± 2.263	2.405± 0.433	6.767± 1.082
	Alestes dentex. (L.)	137.3± 17.961	407.222± 1.599	387.295± 12.111	5.453 ± 0.350	141.759± 162.426	-	-	-	-	-

Table (8): Probability of all organs related to location and fish type

2004	Effect	Location	Fish type	2006	Effect	Location	Fish type
	DF	4	10		DF	4	10
	Probability				Probability		
Liver	Copper	< 0.0001	< 0.0001	**Liver**	Copper	0.0384	< 0.0001
	Iron	0.0008	0.0005		Iron	0.0201	< 0.0001
	Lead	< 0.0001	< 0.0001		Lead	< 0.0001	< 0.0001
	Manganese	< 0.0001	< 0.0001		Manganese	0.6760	0.1735
	Zinc	< 0.0001	< 0.0001		Zinc	< 0.0001	< 0.0001
Kidney	Copper	< 0.0001	< 0.0001	**Kidney**	Copper	< 0.0001	< 0.0001
	Iron	< 0.0001	< 0.0001		Iron	< 0.0001	< 0.0001
	Lead	< 0.0001	< 0.0001		Lead	< 0.0001	< 0.0001
	Manganese	< 0.0001	< 0.0001		Manganese	< 0.0001	< 0.0001
	Zinc	< 0.0001	< 0.0001		Zinc	< 0.0001	< 0.0001
Muscle	Copper	< 0.0001	< 0.0001	**Muscle**	Copper	0.0120	< 0.0001
	Iron	0.0023	< 0.0001		Iron	< 0.0001	< 0.0001
	Lead	0.0040	< 0.0001		Lead	< 0.0001	< 0.0001
	Manganese	0.0026	0.0003		Manganese	< 0.0001	< 0.0001
	Zinc	<0.0001	< 0.0001		Zinc	< 0.0001	< .0001
Gills	Copper	< 0.0001	< 0.0001	**Gills**	Copper	0.0003	< 0.0001
	Iron	0.0001	< 0.0001		Iron	< 0.0001	<0.0001
	Lead	< 0.0001	< 0.0001		Lead	< 0.0001	< 0.0001
	Manganese	< 0.0001	< 0.0001		Manganese	< 0.0001	< 0.0001
	Zinc	< 0.0001	< 0.0001		Zinc	< 0.0001	< 0.0001

Table (9): Heavy metal concentration in water (mg/l) and Sediment (µg/g dry weight) from different location in Aswan High Dam Reservoir

Year	Metal	Permissible limit	locations				
			El Gandel	Akma	Atery	Gomaye	Down stream HAD
Water Winter 2004	Copper	1.0	0.124	0.01	0.102	0.122	0.22
	Iron	1.0	2.72	2.15	2.10	1.90	0.25
	Manganese	0.5	0.078	0.153	0.215	0.11	0.6
	Zinc	1.0	0.002	0.030	N.D.	N.D.	0.008
	lead	0.05	N.D.	0.09	0.26	0.41	N.D.
Water Winter 2006	Copper	1.0	0.11	0.05	0.06	0.06	0.05
	Iron	1.0	0.8	2.1	1.6	2.0	0.7
	Manganese	0.5	0.03	0.18	0.15	0.11	0.06
	Zinc	1.0	0.06	0.03	0.05	0.04	0.04
	lead	0.05	0.01	0.09	0.17	0.36	N.D.
Sediment Winter 2004	Copper	33	6.8	7.4	5.2	38.3	60
	Iron	$41 * 10^3$	2.8	20.8	72	207	-
	Manganese	770	13.44	10.04	532.8	660	744
	Zinc	95	9.72	10.88	30.16	90.7	99
	lead	19	24	32	32	28	55
Sediment Winter 2006	Copper	33	8	8	12	8	-
	Iron	$41 * 10^3$	11.2	27.2	75	229	-
	Manganese	770	17	18.5	511	672	-
	Zinc	95	64	51	41	96	-
	lead	19	29	44	40	31	-

* Law of water: 48/1982.
** Law of unpolluted sediment: GESAMP, 1982

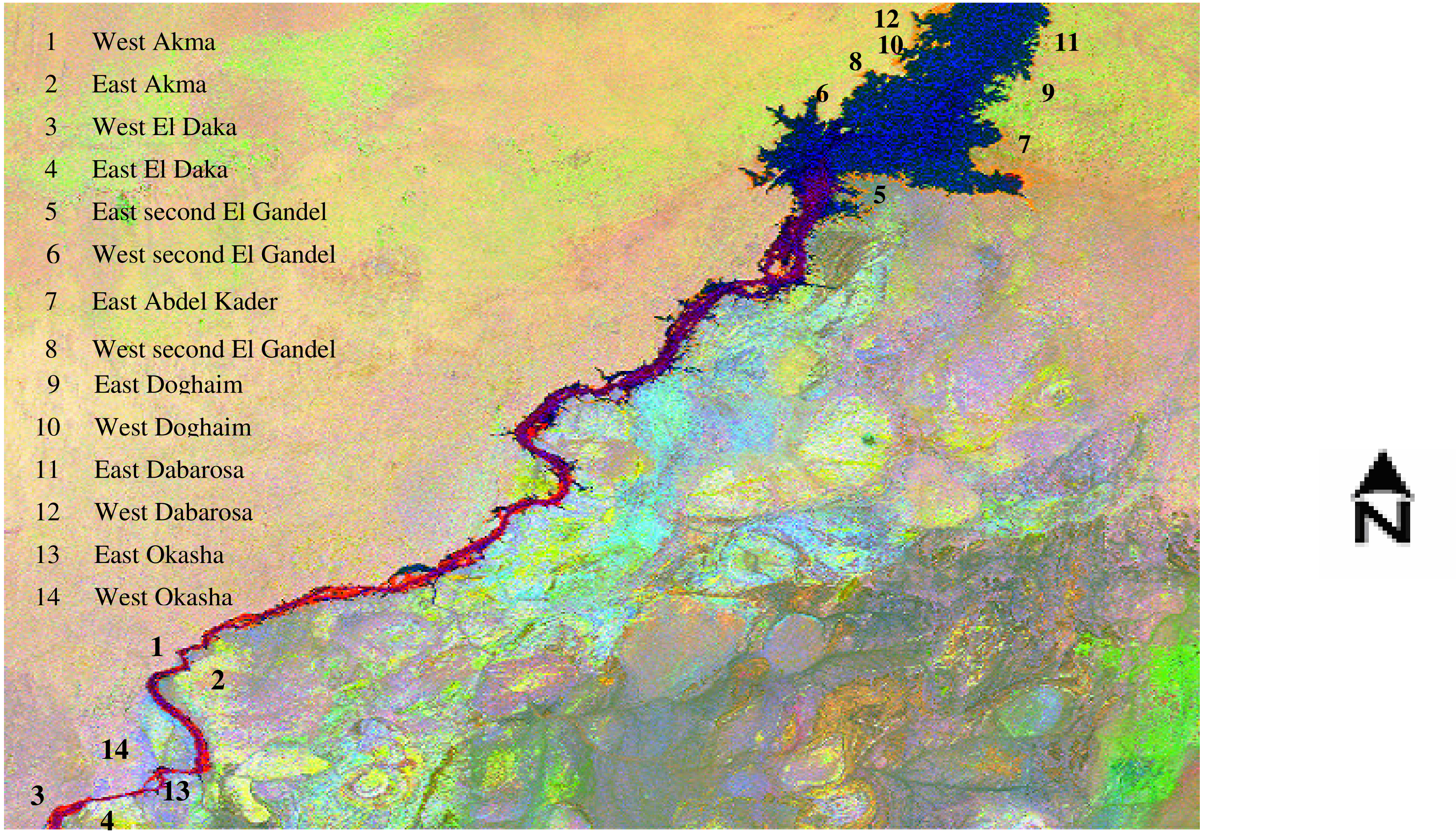

Figure (1): Location of the Selected Aquatic Weeds Communities

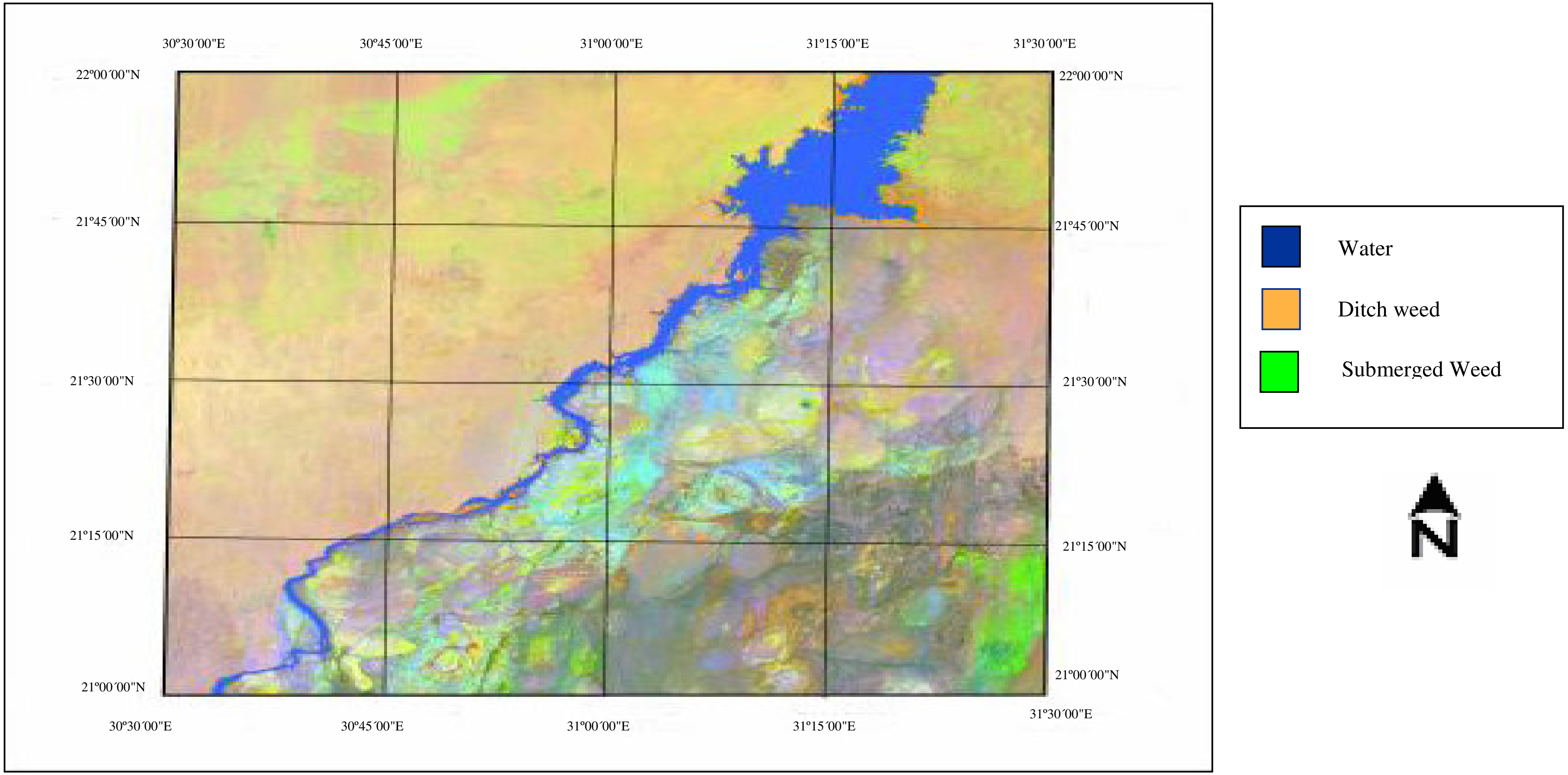

Figure (2): Status of Aquatic Weeds in Nubia Lake, Sudan. 19 Aug. 2001.

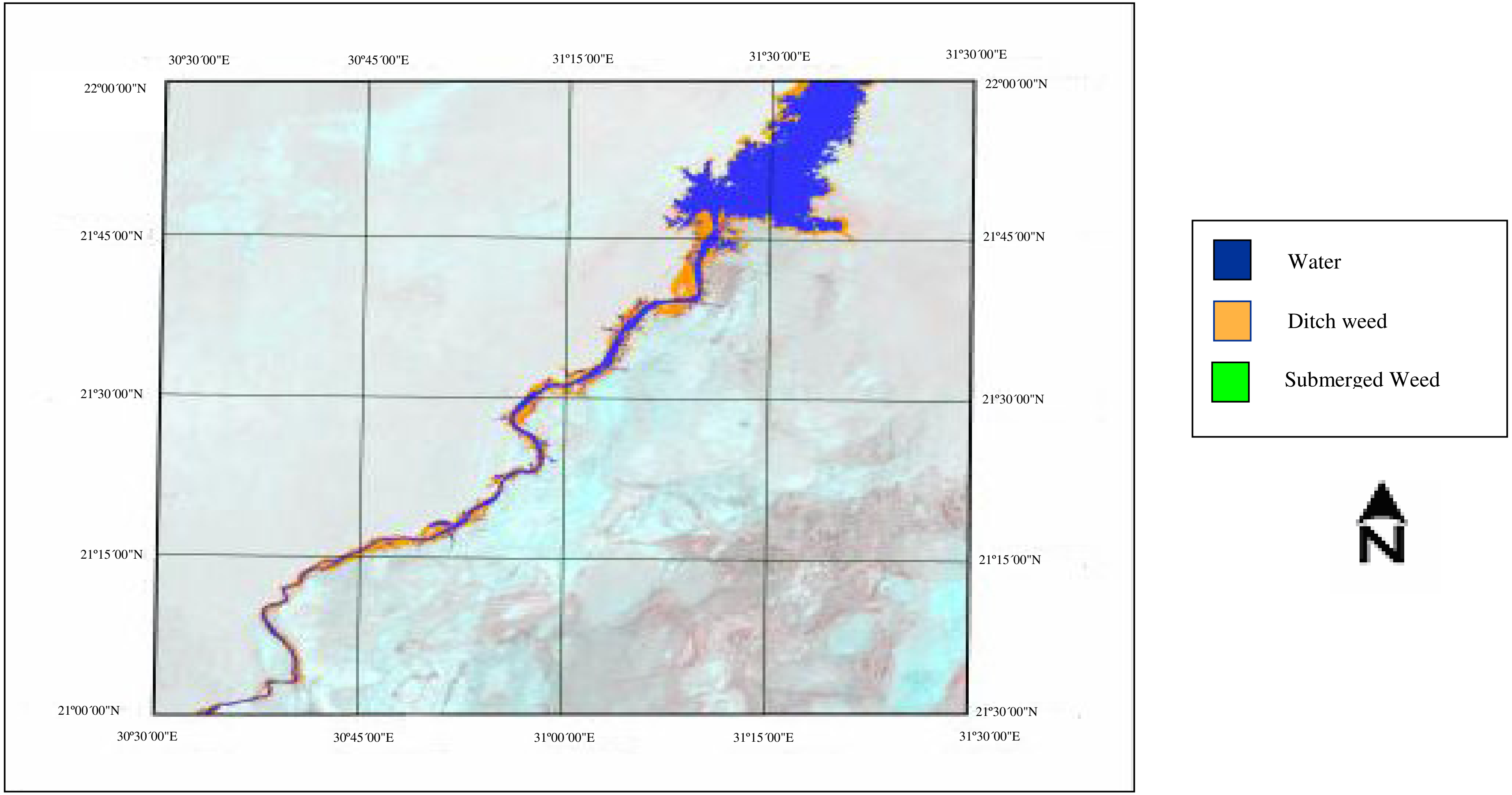

Figure (3): Status of Aquatic Weeds in Nubia Lake, Sudan 28 Sep. 2004