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Original research

Impact of Nile Crocodiles on Fish Production in Lake Nasser

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Abstract:

The problem of the present study is that no reasonable explanation of the inferring relationships of crocodile; fish, and environment variables in Lake Nasser. This research article aims to find out the mysterious interrelationship of Nile crocodile abundance and reduction fish production in Lake Nasser. Data needed to achieve a meaningful explanation of the interrelationship of Nile crocodiles with fish production in Lake Nasser consist of two sets; data on abundance of species at a series of sites, and data on environmental variables measured at the same sites. These two matrices of data were analysed using Principal Components Analysis (PCA) technique in order to identify patterns in data, and expressing the data in such a way as to highlight their similarities and differences. PCA technique is useful in data of high dimension such as records on Nile crocodiles and fish production of Lake Nasser, where patterns in data can be hard to find by means of graphical representation. The present study provides meaningful explanation of the relationships of crocodile, fish catch and environment variables in Lake Nasser. The findings of this research work will determine the real reasons for decreasing the fish catch in Lake Nasser. Eradication of the causes of decline in fish production will lead to increased revenue.

Keywords: *Crocodylus niloticus* - Catch per Unit Effort (CPUE) - Fishing Societies - IUCN - Fish Production.

1- INTRODUCTION

The problem to be addressed in this research is that no reasonable explanation of the inferring relationships of crocodile, fish and Lake Nasser environment, using the available community composition data and associated habitat measurements.

Identifying the interrelationship of Nile crocodile with fish production in Lake Nasser is important to improve fisheries and the conservation status of crocodiles and hence, bounce back the economic situation of Lake Nasser. Several attempts were conceded, however, none of them achieve an ecologically meaningful explanation for the structure of the Nile crocodile communities in Lake Nasser. Baha El Din (2006) stated that the number of breeding adults (sexual maturity is reached at about 10 years of age) is probably considerably fewer than 5000 animals.

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Regional report of submitted by Shirley and Salem (2008) to Crocodile Specialist Group of the Survival Commission of the IUCN (International Union of Conservation of Nature) pointed out the important traditional role played by the Nile crocodile (*Crocodylus niloticus*) in Egypt history. They reported two surveys that have been conducted for crocodiles in Lake Nasser. Ibrahim (1998) estimated the total population of in Lake Nasser being no more than 1000 crocodiles. Another survey was conducted by Salem and Asran (2006) who surveyed about 80% of Lake Nasser (both west and east banks from the High Dam at the North to Korosko at the South), and the population was estimated to be less than 2000 individuals. They stated that a project started in 2008 aimed to train a group of Egyptians to be capable of managing the Lake Nasser crocodile population. At that time, this group has no knowledge regarding specific technique for crocodile or for robust estimates of its population size.

Shirley *et al.* (2012) estimated the abundance of the Nile crocodile in Lake Nasser. Their raw encounter rate was 0.355 crocodiles per km. They classified Lake Nasser into three habitat types of relevance to crocodiles: (a) sandy beaches; (b) rocky cliffs; and (c) intermediate. When they accounted for observer effects and habitat, they estimated a surface population abundance of 2,581 (2,239-2,987, 95% credible intervals) crocodiles in Lake Nasser.

Data needed to achieve a meaningful explanation of the interrelationship of Nile crocodiles with fish production in Lake Nasser consist of two sets: data on the occurrence or abundance of a number of species at a series of sites, and data on a number of environmental variables measured at the same sites. These two matrices of data were analysed using Principal Components Analysis (PCA) technique. PCA is a way of identifying patterns in data, and expressing the data in such a way as to highlight their similarities and differences. It is useful in data of high dimension (ter Braak, 1983) such as records on Nile crocodiles and fish production of Lake Nasser, where patterns in data can be hard to find by means of graphical representation.

The state-of-art aspects of the present study are the way of handling the data collected by different organisations, and determining the structure of the Nile crocodile community attempting to find out the mysterious interrelationship of Nile crocodile abundance and fish production in Lake Nasser.

Previous studies only considered fish stock assessment. El-Haweet *et al*. (2008) indicated that shallow water zone along the whole Lake Nasser was dominated by *S. galilaeus* and *O. niloticus*. However, *T. zillii*, was only recorded in the southern part The deeper water zone was dominated by abundant of *H. forskalii* and *A. dentex* in the southern part, in addition to *L. niloticus* and by considerable amount of *O. niloticus* and *S. galilaeus* in the north part.

Limited studies were on the interrelationships between fish and other components of Lake Nasser ecosystem. Ali *et al*. (2010) studied the impact of aquatic plants on diversity and production of fish in Lake Nasser. They indicated that habitat complexity exerts a significant influence on ecological communities and in particular, composition and structure of submerged aquatic plants had a pronounced impact on fish production and diversity in Lake Nasser. The study indicated that: a) the littoral semi-pelagic zone is dominated by *Oreochromis niloticus;* and b) the lateral pelagic zone is taken over by *Latus niloticus* and *O. niloticus* in the northern sector and *Hydrocynus forskalii*, *Sarotherodon galilaeus* and *Tilapia zillii* in the southern sector. PCA biplot showed well separated consolidated three groups of submerged aquatic plant communities and pointed out fish species characterizing each of them. *Group I* contains species mainly from northern part of Lake Nasser (west bank Garf Hussein and Kalabsha), where compact structural submerged plants, *N. horrida* and *N. marina* (in shallow water zone) is favoured by tilapia (O. *niloticus*) and the sparse vegetation of *P. schweinfurthii* (in the deeper water zone) is dominated by the piscivorous tiger fish (*H. forskalii*) and Nile perch (*L. niloticus*). *Group II* comprises species from the middle part of the lake (east bank of Kurusku), where the compact submerged plant *M. spicatum* is preferred by uneconomic edible fish (*Clarias* spp., *Barbus* spp., *Mormyrus* spp., and *Synodontis* spp.). Group III embraces species largely from the southern part of the lake Tushka, where thick condensed submerged plant *M. spicatum* is favoured by small size fish species *T. zillii, S. galilaeus, B. bajad* and the uneconomic inedible fish *T. lineatus*.

2- MATERIALS AND METHODS

2.1- Study area

Lake Nasser is the second largest man-made lakes in the world after Bratsk Reservoir in Russia (Ali, 1992). The lake is some 479 km long and 16 km across at its widest point, which is near the Tropic of Cancer. It covers a total surface area of 5,250 km^2 and has a storage capacity of some 132 km^3 of water. It has a shore length of 7,844 km at 183 m above mean sea level (Muala *et al*., 2014).

2.2- Data Collection

The data were collected over adequate habitat range (1557 km) for fish, crocodiles and the Lake Nasser environment. This range of habitat includes representative sites from various shoreline habitats of Lake Nasser. Data on fish production and Nile crocodile in Lake Nasser in the years 2008 and 2009 were collected.

Data on Fish Production
Data on fish production and Fishing Societies of Lake Nasser were kindly provided by General Authority for Fish Resources Development and General Authority of Agricultural Projects, High Dam Lake Development Branch (HDLD). Shoreline of Lake Nasser is divided into five “Fishing Regions”. Each region represents a territory of a fishermen society.

Data on Nile Crocodiles
Information on numbers of adult Nile crocodile living in Lake Nasser was taken from the published literature (e.g. Shirley *et al.*, 2012 and CMU, 2014). In total, 15 locations were investigated by the CMU team members in the period from June 2008 to July 2009. According Fergusson (2010), adult individuals of Nile crocodiles are those >2.0 m length.

2.3- Data Analysis

Data on crocodile and their habitats were drawn up in the form of two matrices, one matrix of crocodile numbers × site and another matrix of environmental variables (habitat types) × site. Habitats comprised three dummy environmental variables ("sandy beach", "intermediate", and "rocky cliffs"). In order to relate the crocodile numbers to the habitat types recognised by Shirley *et al*. (2012), a Principal Components Analysis (PCA) was performed using XSTAT Programme (Addinsoft, 2019).

Two data matrices were constructed. A site-species matrix, where sites are the ‘Fishing Regions’ and species are represented by ‘number of adult crocodile’ (length > 2.0 m) observed in each ‘Fishing Region’ and another is a site-variables matrix, where the ‘shoreline length’ variable is considered for each “Fishing Region’. The two data matrices were analysed by the multivariate Principal Components Analysis (PCA) using XSTAT Programme (Addinsoft, 2019).

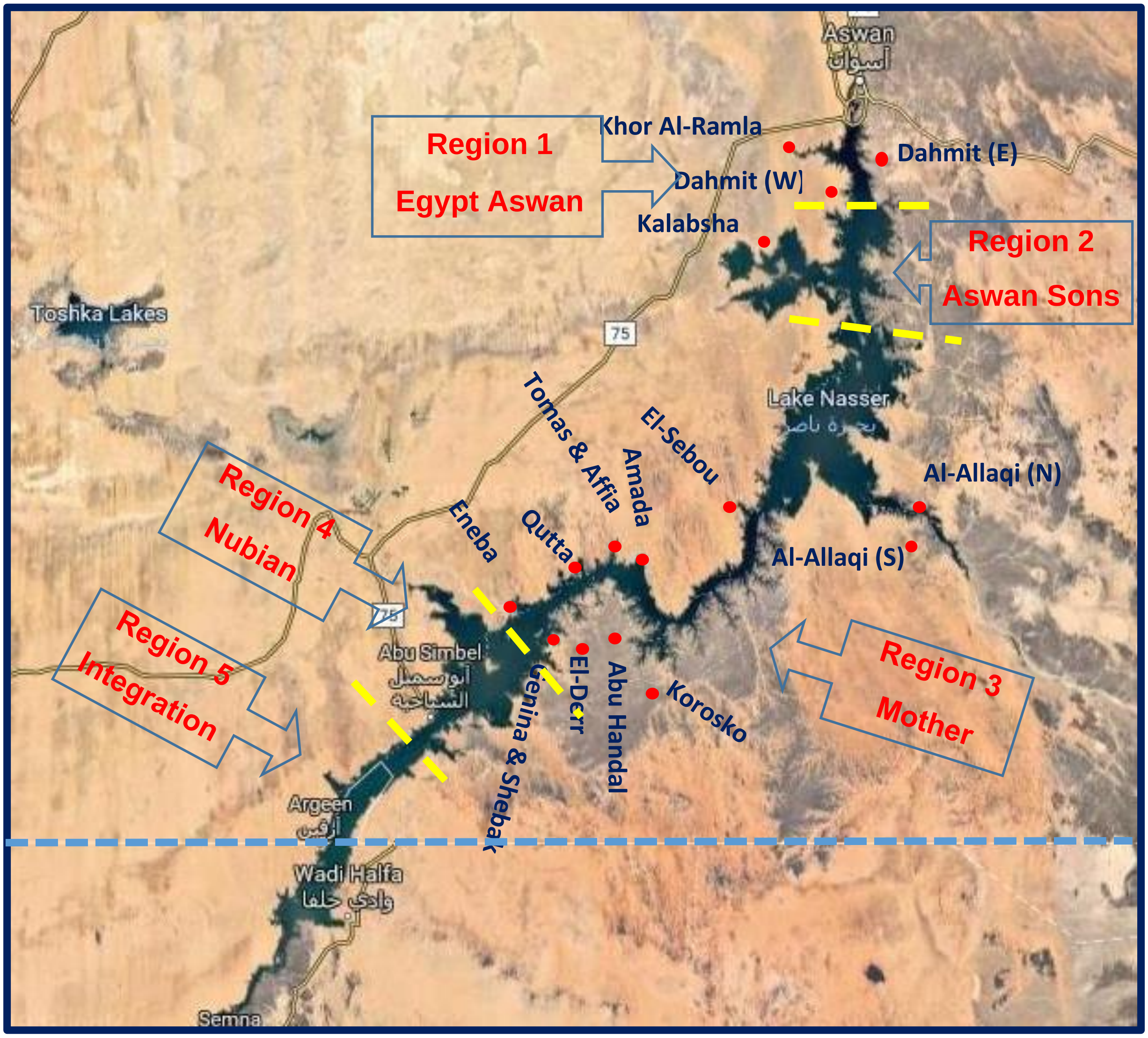

Fig. 1. Territories of the five fishermen societies (fishing regions) and locations visited for crocodile observation (Shirley *et al.*, 2012) in Lake Nasser.

XLSTAT provides a complete and flexible PCA feature to explore your data directly in Excel. XLSTAT transforms the complex ecological data one capture in the field into science. XLSTAT uses pioneering computing techniques allowing one to easily analyse and reformat the data within Excel. It is software that compiles basic and advanced tests and modelling tools, ordination methods, omics analysis tools and dose effect models used in ecology (Addinsoft, 2019).

Principal Components Analysis (PCA) produces a plot of site scores and species loadings are called a “PCA biplot”. PCA biplot displays both species composition and diversity. This type of biplot is termed a "distance biplot". The distance biplot is concluded to be among the most powerful analytical tools for species—composition data (ter Braak, 1983).

3- RESULTS AND DISCUSSION

Crocodile - Habitats Relationship

Table (1) shows number of crocodiles observed in each location visited by the Crocodile Management Unit in the period from June 2008 to July 2009. Crocodiles were most abundant in the intermediate habitats, lower numbers of adult crocodiles were observed in sandy beaches and rocky cliffs, respectively (Table 1). Lake Nasser shoreline can be divided into three major categories of habitats; gently slope sandy beaches, steep slope rocky cliffs, and rock shores with sandy batches. Table (1) shows that sandy shores are mainly located at the west bank of the lake. However, the east bank of the lake comprises locations characterising by rocky base and some with sandy batches in-between rocks.

Sandy beach habitats were those areas characterized by gently sloping shores composed predominantly of sand and loose rocky slate or gravel. Rocky cliff areas were those with sheer rock faces descending into the water with few or no haul-out sites. Intermediate habitats were those sites that have at least 25% beach habitat with the remainder composed of rocky shores ranging from gently sloping gravel banks to sheer rock faces.

PCA Biplot

The PCA ordination diagram elucidates the relationship between the numbers of adult crocodiles and habitats types in the 15 localities along shores of Lake Nasser (Fig. 2). PCA indicates that locations visited may be divided into three ecological meaningful groups (Fig. 2). Group I contains sites mainly from west bank. These locations are distinguished moderate numbers of adult crocodiles ranged between 2 at Qatta West Bank and 25 at Khor Al-Allaqi northern side (East Bank), and sandy beaches habitats. Group II comprises sites mostly from East Bank (Korosko, Abu Handel, and El Derr), except Dahmit is from the west bank, where adult crocodiles were the most abundant. Group III embraces sites largely from the East Bank, where rock cliffs are the prevailing habitats, where scarce individuals of adult crocodiles were observed.

Crocodile Abundant - Fish Catch Relationship

Data collected, in 2008, on territories of Fishermen Societies, total fish production in each fishing region, number of fishing boats of each society and correspondence number of adult Crocodile (>2.0 m) observed at 15 locations in Lake Nasser are organised and presented in Table (2). Also, catch per unit effort (CPUE) was calculated for each fishing region (Table 2). There are five fishermen societies working in Lake Nasser, namely: Company of Egypt- Aswan for Fishing and Fish Processing; Sons of Aswan Fishermen Society; Cooperative Society of Fishermen (Mother Society); Nubian Association of Fishermen; and Society of Integration for Fishermen. The Mother Society has the longest shoreline territory that extends for 800 km (from 'Mirwaw' at the North to 'Ibream' at the south), and has 1704 fishing boat; and the Society of Integration for Fishermen has the shortest fishing shore 66 km (From 'Or' the most South to the southern Egyptian – Sudanese borders) and 61 fishing boats (Table 2). In contrary, the highest annual catch per unit effort - CPUE (10.74 ton / boat / year) was recorded in the most southern part of the lake in the Society of Nubian Association of Fishermen (Region 4) and the lowest CPUE (1.32 ton / boat / year) was noticed in the Company of Egypt-Aswan for Fishing and Fish Processing (Region 1) at the North the closest to the High Dam (Table 2). Adult crocodiles were abundant at the northern part (Region 1) of the lake, where average number of crocodile was18.7 individuals and scarce at the southern part (Region 4), where mean number of crocodile per location was 3.75 individuals. No records were perceived for the Society of Integration for Fishermen at the most southern part of Lake Nasser (Table 2).

Table 1. Average numbers of adult crocodiles observed in each of the habitat types: 1= Sandy beaches, 2 = intermediate, 3 = rocky cliffs.

Distance South High Dam (km)	Crocodile Observation Locations	Habitat Type	No. of adult Crocodiles (> 2.0 m) Per observation location
20	Khor El-Ramla (West)	1	21
60	Khor Kalabsha (West)		15
115	Khor Al Allaqi North (East)		25
150	El Sebou (West)		7
200	Amada (West)		7
210	Tomas and Affia (West)		13
212	Khor Qutta (West)		2
230	Eneba (West)		3
40	Dahmit (West)	2	26
190	Khor Korosko (East)		48
195	Khor Abu Handel (East)		9
215	Khor El Derr (East)		9
45	Dahmit (East)	3	9
115	Khor Al Allaqi South (East)		14
235	Genena and Shebak (East)		1

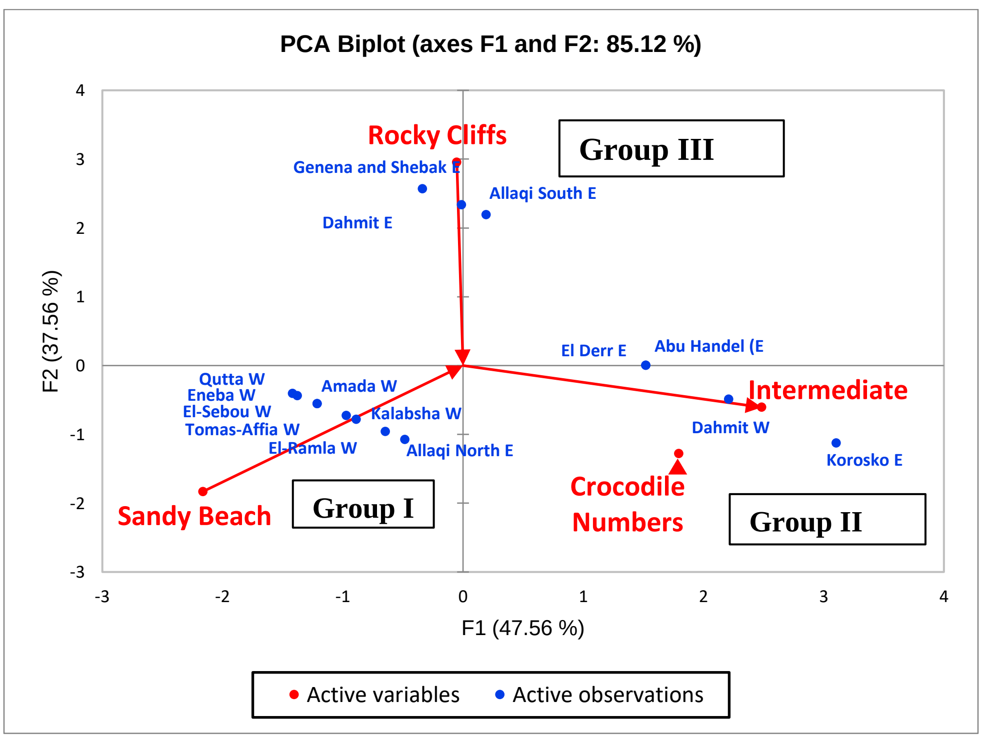

Fig. 2. Principal component analysis (PCA) ordination biplot of the relationship between adult crocodile (▲) and Habitat types: sandy beach; intermediate; and rocky cliffs (➔) reported in 15 locations along Lake Nasser (●).

Table (2). Territories of fishermen societies, total fish production, and Catch Per Unit Effort (CPUE) in each fishing regions (High Dam Lake Development Branch) and correspondence numbers of adult crocodile (>2.0 m) observed at 15 locations (Shirley *et al.*, 2012) in Lake Nasser (2008), between brackets average number of crocodiles per location.

Fishing Region	Fisher-men Society	Shore-line Length (km)	Total Fish Production in 2008 (Ton)	Number of fishing Boats	CPUE (Ton/Boat/Year)	Crocodile Observation Locations	No. of adult Crocodiles (> 2.0 m)	
							Per observation location	Per Fishing region
1	Company of Egypt-Aswan for Fishing and Fish Processing	187	249.31	189	1.32	Khor El-Ramla (West)	21	56 (18.7)
						Dahmit (West)	26	
						Dahmit (East)	9	
2	Sons of Aswan Fishermen Society	300	1752.87	621	2.82	Khor Kalabsha (West)	15	15 (15)
3	Cooperative Society of Fishermen (Mother Society)	800	6644.56	1704	3.90	Khor Al Allaqi North (East)	25	123 (17.6)
						Khor Al Allaqi South (East)	14	
						El Sebou (West)	7	
						Khor Korosko (East)	48	
						Khor Abu Handel (East)	9	
						Amada (West)	7	
						Tomas and Affia (West)	13	
4	Nubian Association of Fishermen	270	6176.15	575	10.74	Khor Qutta (West)	2	15 (3.75)
						Khor El Derr (East)	9	
						Eneba (West)	3	
						Genena and Shebak (East)	1	
5	Society of Integration for Fishermen	66	576.19	61	9.45	No Records		

PCA Biplot (Ordination Diagram)

The solution of Principal Correspondence Analysis (PCA) is displayed in an ordination diagram (biplot) with sites represented by points and the variables, number of adult Nile crocodiles, CPUE and length of the shoreline surveyed are represented by arrows. The arrows length shows the variability in those values across the displayed ordination space. The quantitative variables are shown by arrows indicating the direction, in which the value of variable increases (Fig. 3).

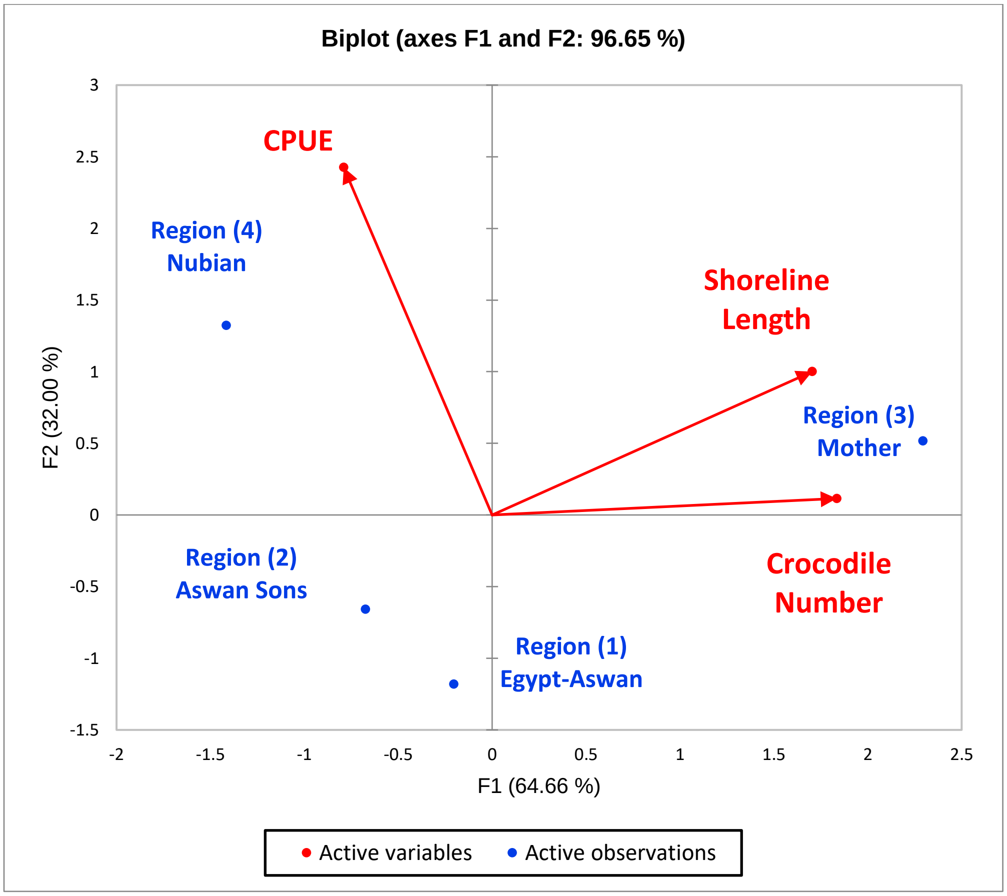

Fig. 3. Principal component analysis (PCA) ordination diagram (biplot) of fishing regions (•) and variables: catch per unit effort; Length of fishing regions; and numbers of adult crocodiles (➜).

The CPUE, the longest arrow, is the most influential variable that explains the variability between the four fishing regions. The position of a region's point along the variable's arrow indicates the value of each variable noticed in each region. A point closer to the head of the arrow usually has the highest value. For example, region (3) of the 'Mother Society' has the longest shores and the highest number of adult crocodiles, but has lower value of CPUE than region (4) of the 'Nubian Fishermen Society'.

Region (4) belonging to the Nubian Fishermen Society characterises by the highest CPUE. Region (1) has lowest values in the three variables; lower CPUE, lower number of crocodile, and shorter shores the other two regions (3) and (4). The acute angle between arrows of two variables indicates that they are high correlated (e.g. number of crocodiles and fishing shore length), however, those having wider angle between them are not correlated (e.g. number of crocodiles and CPUE).

Salem (2013) stated that the major conflict between man and crocodile is for living space. Crocodiles were most abundant in the intermediate habitats, lower numbers of adult crocodiles were observed in sandy beaches and rocky cliffs. Sandy banks are good fishing camps and village sites, which are also essential for crocodile ecology; therefore fishermen activities had a severe reverse influence on the success of crocodiles nesting and on the crocodiles themselves, in those habitats. On the other hand, intermediate habitats which are mixed habitats of rocky beaches with sandy areas. Unlike sandy beach habitat, intermediate habitat is unfavourable to human activities (e.g. agriculture, fishing, inhabitation, etc.). Shirley *et al*. (2012) noticed that intermediate habitat sites combine being more protected from environmental conditions (e.g., wind and waves) and of low human disturbance, which is in agree with the outcome of the present study.

In Lake Nasser, conflict between fisherman and crocodile becomes more frequent and severe over recent decade, as a result of human population growth and expansion of agricultural and industrial activities around the lake. Therefore, under these circumstances, the present study indicated that in Lake Nasser intermediate habitat is a ready alternative habitat for sandy beach habitats, which became highly disturbed.

In spite of strict security measures are applied to prevent fish smuggling from Lake Nasser; CPUE was the lowest in the Company of Egypt - Aswan for Fishing and Fish Processing (Region 1) at the North the closest to the High Dam. Fish from this region usually sneak out of the lake, which may explain the inaccurate fish catch and hence drop in the CPUE. One of the solutions suggested to avoid fish smuggling in Lake Nasser is binding the provision of boat licenses with the effort.

The highest annual catches per unit effort - CPUE were recorded in the southern part of the lake in the Society of Nubian Association of Fishermen (Region 4) and Society of Integration for Fishermen (Region 5). This may be due to environmental conditions that are favoured by fish and the weakened fish smuggling. This is in agree with ElKobtan *et al*. (2016), who stated that southern part of Lake Nasser (around Abu Simble) is of higher suspended sediments concentration, which made it a lacustrine environment supporting various living organisms and indicated the continuity of inverse relation with the suspended sediments concentration of the northward.

The highest CPUE at the Nubian Fishermen Society (Region 4) was in association with relatively lower number of adult crocodile observed. Ali *et al*. (2010) indicated that the pelagic zone of this region (for example at Tushka Station) characterised by dense submerged vegetation. Also, ElKobtan *et al*. (2016) pointed out that the grain size of the bottom sediments is smaller southward with the continuity of being suspended. Priyadarshana *et al*. (2001) demonstrated that high density of submerged aquatic plants can decrease predator efficiency by reducing visual contact with prey and hindering movement. In Region 4 crocodiles could not find their prey as a result of dense submerged vegetation and high suspended sediments.

ElKobtan et al. (2016) pointed out that increasing bottom sediments grain size northward makes the ready to coagulated and settle down. Also, Ali et al. (2010) stated that the northern sector of Lake Nasser, for example Kalabsha, submerged aquatic plants is of very open structure. In addition, these areas (e.g. Region 3) are characterising by high water transparency (Ali et al., 2010) and therefore, they are favoured by the visual predators such as the Nile crocodiles, which were of higher number in Region (3).

The present study provides reasonable explanations to the relationship between crocodile, fish and Lake Nasser environment. Nile crocodiles are the top predator in Lake Nasser that depends for feeding on visualising their prey. Crocodile feeding on fish are abundant and mainly found in northward locations that characterised by less sedimentation (i.e. poor in nutrients) with high water transparency, and very open submerged aquatic plants structure. However, southward locations characterised by high suspended sediments (i.e. rich in nutrients) and dense submerged aquatic plants that decrease predation efficiency of Nile crocodile by reducing visual contact with fish and hindering movement. Dense complex monotypic beds of weeds in shallow-water habitats decreases the risk of small fish becoming prey for crocodile (Dibble, 2014).

The present study allowed better understanding of the problem being examined. Nile crocodile is innocent of the charge of a lack of fish production. The main problem of decreasing fish catch is due to: (a) the lack of provisions to close the lake during tilapia spawning period negatively affects the fish stock; and (b) fishermen transport fish directly from the fishing sites and to get permission to move the fish out of the port, they reported much less weight than the actual weight to the port authority, and sneaking out underweight small fish that do not meet the fishing port specifications. These acts reduce the fish production, and in turn, lead to lower revenue.

4- CONCLUSION

The present study allowed better understanding of the problem being examined. Nile crocodile is innocent of the charge of a lack of fish production. The main problem of decreasing fish catch is due to: (a) the lack of provisions to close the lake during tilapia spawning period negatively affects the fish stock; and (b) fishermen transport fish directly from the fishing sites and to get permission to move the fish out of the port, they reported much less weight than the actual weight to the port authority, and sneaking out underweight small fish that do not meet the fishing port specifications. These acts reduce the fish production, and in turn, lead to lower revenue.

5- RECOMMONDATION

- Activation of the fishing law in terms of size of mesh (tilapia 2 pieces per kg)
- Transport fish from fishing sites to ports only by tanker vessels
- Compel all boats to the main ports
- Cancellation of the decision of the Governor of Aswan to load fish on cars without weight and without forming a committee
- Confiscation of all means of smuggling in favour of the state (motors - boats, tankers.
- Concentrate the work of police stations to be specialized police for Lake Nasser Protection
- The Ministry of Health and the Veterinary Medicine, Supply and Trade Authority are obliged to have representatives in the fishing port committee
- Re-examination of fishing ports and fish factory in Aswan
- The establishment of modern ports equipped to receive incoming fishing sites and reduce the period of fish transport
- Maintenance and operation of Egypt Aswan fish processing factory
- Cancelling the rental of the ice plant (line 1) and repair (line 2)

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