**Assessment of Fish Cages' Impacts on the Water Quality in Rosetta Branch of the Nile River Using Remote Sensing Technology**

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**Abstract**

In Egypt, the fish culture is an old activity that remained in the lowest general interest till the last 60 years where the increasing pressure on fish farming has received more attention. Production of fish in floating cages -legally and illegally- has been established in the Nile River because of its simple breeding technology which is economically feasible under the Egyptian socio-economic conditions.

With the high concern about environmental hazards that associated with increasing fish farming, this issue is profoundly investigated in the current manuscript to detect the environmental impact for such excessive fish culture on the surrounding ecosystem. The current research manuscript utilizes this Remote Sensing (RS) technology to assess, investigate, and identify the circumstances of the fish cages and their environmental impacts within Rosetta Branch.

Rosetta Branch of the Nile River, in Egypt, is the main source of freshwater for the western side of the Nile Delta. It is divided into 11 reaches detecting accurate fish cages' areas using RS images since most of the cages are illegal and owners hide them from monitoring campaigns by submersion. The results of the carried analysis showed the direct applicability and effectiveness of the utilization of the RS technology in identifying all fish cages characteristics as well as their environmental impacts based on the water quality of the fish farming area. In addition, this research opens a wide window for future RS environmental applications towards preserving the environment.

***Key words:*** Water quality, remote sensing, fish cages, Rosetta branch.

## 1. INTRODUCTION

In Egypt, fish farming in floating cages has been established in the river because it is simple technology, does not require additional water and economically feasible under Egyptian protein production conditions. In the Nile branches, there are many legal and illegal floating fish cages. The benefits of such culture include increases in farm productivity and profitability without any net increase in water consumption (Ali et Al, 2006). All possible information should be acquired through diverse measurements from the area of concern to allow the decision makers to identify problems coming from such activities and causing identified pollution.

The Law No. 124/1983 organizes fishing, fish farming and the aquaculture is the main legislative base for the fish production process in Egypt. It authorizes the General Authority for Fish Resources Development of the Ministry of Agriculture, as the responsible organization for the implementation of this law which prohibits the use of Nile water in fish farming yet there is no information about the legislation governing the use of feed (FAO, 2005).

### 1.1 Fish Cages and Water Quality

Generally, intensive fish farming produces considerable amounts of nutrient waste such as ammonia, nitrates and phosphorus. These wastes deteriorate the nature and decomposition of the water body. Also the fish heavily consume the dissolved oxygen leading to low oxygen content in the surrounding areas.

Wu, 1995 highlighted that the environmental impact of fish-farming depends very much on species, culture method, stocking density, feed type and hydrography of the site. Most of the phosphorus, carbon and nitrogen input into the fish culture system are through feed wastage, fish excretion and faeces production. The use of chemicals (therapeutants, vitamins and antifoulants) and the introduction of pathogens and new genetic strains have also raised environmental concerns. Carbon dioxide produced by fish respiration is unlikely to create adverse effect on the environment.

Unionized ammonia is actually toxic and its toxicity is dependant upon salinity, temperature and pH, while nitrate and nitrite are not significantly toxic to fish except in the context of promoting algal blooms. Beveridge, 1985 identified a noticeable decrease in Dissolved Oxygen DO and increases in Biological Oxygen Demand BOD, nutrients (Phosphorus P, organic and inorganic nitrogen N and total carbon C) in the water column around fish farms.

Ali et Al, 2006 showed that all the values of chemical parameters in the locations of floating fish cages in the Nile River were the highest when compared to the free-fish cages locations. Intensive fish culture significantly decrease the DO level (decreased to one third of locations before), increase NH3 (almost double the locations before), Total Nitrogen TN (an increase from double to four folds from locations before), BOD (an increase round triple the locations before) and COD (almost an increase double the locations before) as well as the Total Organic Carbon TOC in the surrounding area.

It is worth mentioning that Less than 3% of the high quality feed production is through licensed private sector factories while the rest is not under monitoring and lacks a quality control program (El-Gamal, 2011).

Fish Cages in Egypt are usually made of a rigid frame as shown in figure 1 and are usually covered with a mesh material through which water can readily flow but fish cannot escape. Most of the feed used is in mash form for poultry, cattle, sheep, fish, etc.

**Figure 1: Fish cages in Rosetta branch**

***The possible risk of fish cages:***

1. Toxic substances, either naturally present or added to the feed (components) before, during or after processing or regenerated within the feed by decomposition during its storage can be toxic and threatening to other organisms.
2. Aquaculture drainage water may contain residues of hormones, pesticides, herbicides, antibiotics or chemical compounds associated with fish treatments; can cause serious problems to the ecosystem and the human health.
3. In-adequate operation of the floating fish farm associated with over stocking of fish in the cages may cause severe negative impacts on the water and sediment quality.
4. Nutrients in the effluent waters from floating fish cages are primarily derived from feed waste (fines/dust and feed not eaten by fish), and excreted and faucal wastes. Usually, such nutrients are discharged in the form of $NH_4$. However, during the process of equilibrium if $NH_3$ exceeds to certain level, it can be toxic to the human and other organisms.

### 1.2 Study Area

Down streaming into the Mediterranean Sea, the Nile River is diverted into two major branches Damitta and Rosetta Branches. Rosetta Branch is 220 km in length and flows downstream Delta Barrage to the North ending with Idfina Barrage regulating the excess flow of the branch to be released to the Miditerranean Sea. It is considered as one of the major sources of freshwater for the western side of the Nile Delta where several municipal pump stations exsist on (Mahallet Abu Ali, Desouk, Fowwa and Mahmoudia 1& 2) to supply adjacent cities with potable water. Unfortunately the branch receives considerable discharges of drainage water that are significantly polluted with domestic and industrial pollutants. It is also used as a media for fish culture. Figure 2 shows the area where fish cages occur along Rosetta branch and this area is divided into eleven reaches as shown in the figure.

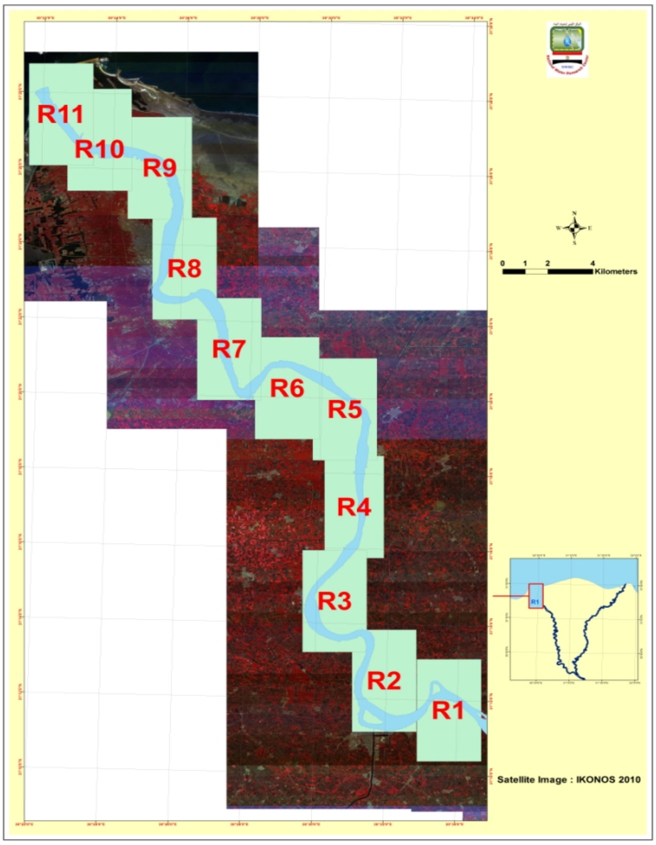


**Figure 2: The study area in Rosetta Branch**

### 1.3 Remote Sensing Images

IKONOS imagery is collected in four multi-spectral bands with ground sampling distance (GSD)/spatial resolution of 3.28m and a panchromatic band with a GSD)/spatial resolution of 0.82m. The analyzed images of years 2005, 2007 and 2010 are property of the "Using Remote Sensing to Improve Water Quality Monitoring and Modeling in the Nile Delta" project RS-WQME. Two RS models were applied using Model Maker; one to extract the Nile River water from the image and the other to extract the features that were delineated by screen digitizing such as islands, water hyacinth and fish cages.

## 2. THE NEED FOR THE RESEARCH

Detecting accurate areas of floating fish cages and the exact coordinates on reality is hard to achieve due to the fact that since most of the cages are illegal, owners focus on finding ways to hide them from monitoring campaigns by submersion. Most studies base their calculations on hypothetical assumptions, so it deemed essential to go beyond visual detection to a precise reliable method. Remote sensing images clearly and accurately identify location, areas and impact of floating fish cages.

## 3. ANALYSIS AND DISCUSSION

According to the historical data analysis, the total fish production has increased more than 4 folds from year 1998 to 2010. Rising from 306,900 metric tons in 1998 to 1,290,000 metric tons in 2010 where Egypt comes in the eleventh place in total fish production.

Tilapia and catfish are the most dominant species raised in fresh water. Tilapia is Egypt's most popular fish that has been pond farmed for thousands of years. The ancient Egyptians farmed tilapias along the Nile. Now a days Egypt ranks second worldwide in the production of tilapia fish from aquaculture where its production represents about 54% of the total fish production in Egypt in 2009. An increase of about 6% is expected to have happened in 2011 according to RS-WQME project outputs.

The fish production from aquaculture and fisheries has followed the same national path; the production has increased slightly more than two folds from year 2000 to 2009, comparatively that of Tilapia close to three folds as shown in figure 3.

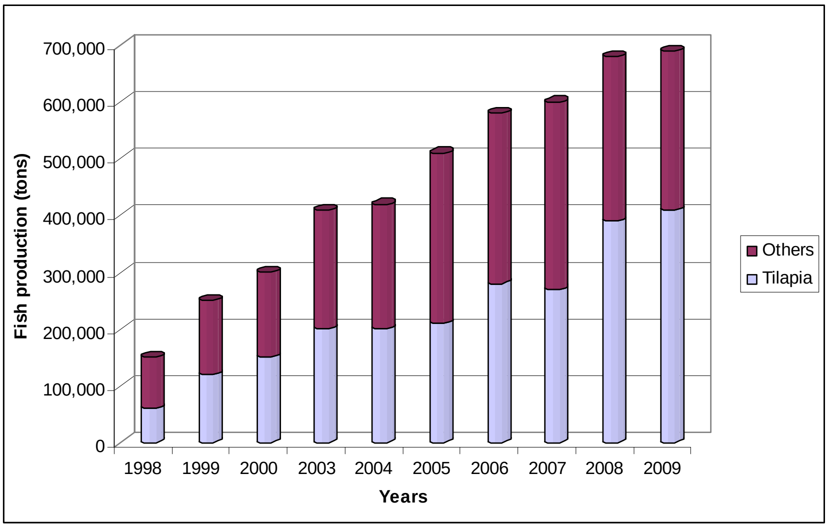


**Figure 3: Fish farming production**

### 3.1 Identification of Fish Cages

IKONOS satellite images reflecting the distribution of fish cages in the Rosetta Branch in years 2007 and 2010 are shown in figures 4 and 5. The images reflect the increase in fish farming by approximately 12.5%.


**Figure 4: The distribution of fish cages in the Rosetta Branch in 2007**

**Figure 5: The distribution of fish cages in the Rosetta Branch in 2010**

Table 1 presents the exact location of fish cages per identified reaches (longitude and latitude) with their associated areas. Figure 6 draws the distribution showing the vast increase in fish cages and the drops in farming (reaches R1, R2 and R3 in 2007).

**Table 1: Location and areas of fish cages along Rosetta branch reaches**

| Reach No. | Longitude | | Area ($Km^2$) | | |
|---|---|---|---|---|---|
| | From | To | 2005 | 2007 | 2010 |
| R1 | 31 10 00 | 31 13 00 | 0.183100 | 0.000000 | 0.065867 |
| R2 | 31 11 00 | 31 13 30 | 0.173300 | 0.000000 | 0.237760 |
| R3 | 31 13 30 | 31 16 00 | 0.053818 | 0.019117 | 0.202212 |
| R4 | 31 16 30 | 31 18 30 | 0.049701 | 0.023941 | 0.048425 |
| R5 | 31 18 30 | 31 21 30 | 0.049126 | 0.165648 | 0.204496 |
| R6 | 31 20 00 | 31 21 30 | 0.069193 | 0.308049 | 0.041563 |
| R7 | 31 21 00 | 31 22 30 | 0.124957 | 0.423802 | 0.000000 |
| R8 | 31 22 30 | 31 25 00 | 0.413246 | 0.426499 | 0.614685 |
| R9 | 31 25 00 | 31 27 30 | 0.112005 | 0.173521 | 0.546994 |
| R10 | 31 26 00 | 31 28 30 | 0.055762 | 0.095913 | 0.145835 |
| R11 | 31 26 30 | 31 28 30 | 0.000000 | 0.018366 | 0.009999 |
| Total | | | 1.284208 | 1.654856 | 1.842734 |

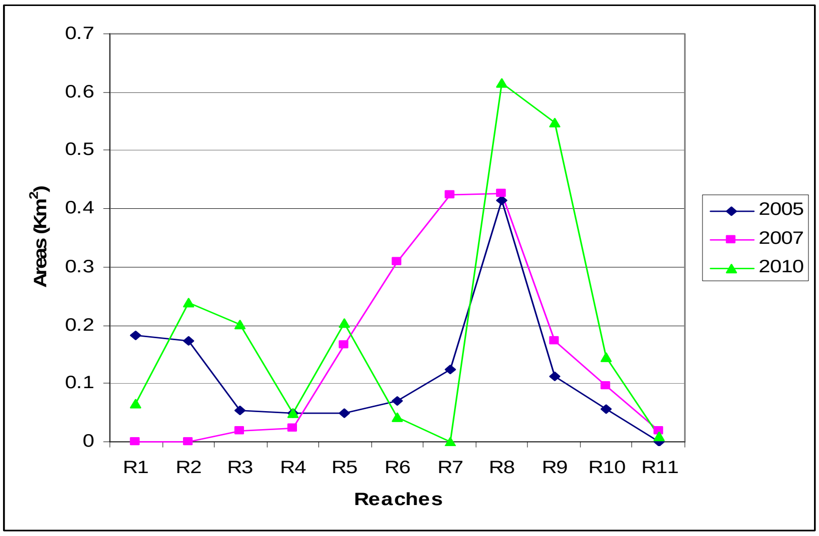


**Figure 6: Areas of fish cages along Rosetta branch reaches in years 2005, 2007 and 2010**

In 2007 the Minister of environmental protection issued a decree banning any placement of cages in fresh water and removing cages violating the Law, specifically before barrages (Edfina Barrages located at the end of reach R5). Accordingly fish cages in reaches R1 and R2 have been removed while those in R3 and R4 were reduced to 35% and 45% of the areas of year 2005; respectively. Soon after intensive monitoring campaigns were back in the routine follow up fish cages were back in place and even more intensively. A classification of the fish cages areas per reach is presented in figure 7 for year 2010. Reaches before Edfina Barrages where many drinking water intakes exist are mainly medium to low intensity while reaches with high intensity are found in the reaches close to the Mediterranean (R8 and R9) where no potable water intakes are placed. Also these reaches witness sea water intrusion that makes such water not usable for ordinary irrigation purposes.

### 3.2 Assessment of Water Quality

One of the greatest challenges faced by Egypt's water-resources decision makers is acquiring reliable integrated water quality information to guide the use and appropriate planning of fresh water. That challenge is being addressed by this research to draw the complete picture of water quality in Rosetta branch for better management or for the development of remediation plans for resolving contamination problems as well as compliance with permits of water-supply in the sites where drinking water uptakes exist.

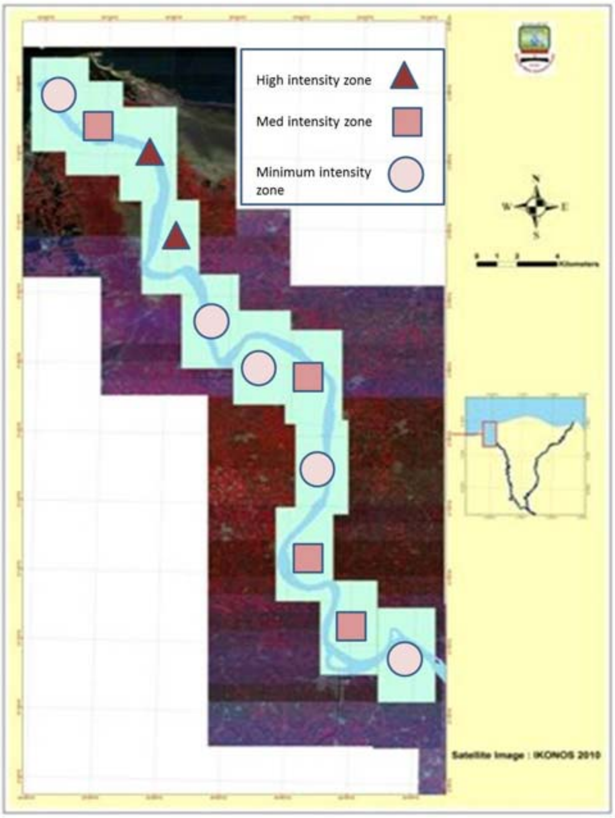


**Figure 7: Fish areas classification according to fish cages intensity 2010**

### 3.2.1. Fish cages impacts on water quality

Water samples were collected along axial transect of Rosetta branch twice a year for the National Water Quality Monitoring program NWQM (during winter and summer seasons) in order to examine the water quality variables. The data sets used are for the site NL44 at Km 1123 from High Aswan Dam before the area of fish cages and site NL46 at Km 1156.5 from High Aswan Dam. Site NL46 is just upstream Edfina Barrages in the area of fish cages as shown in figure 8.

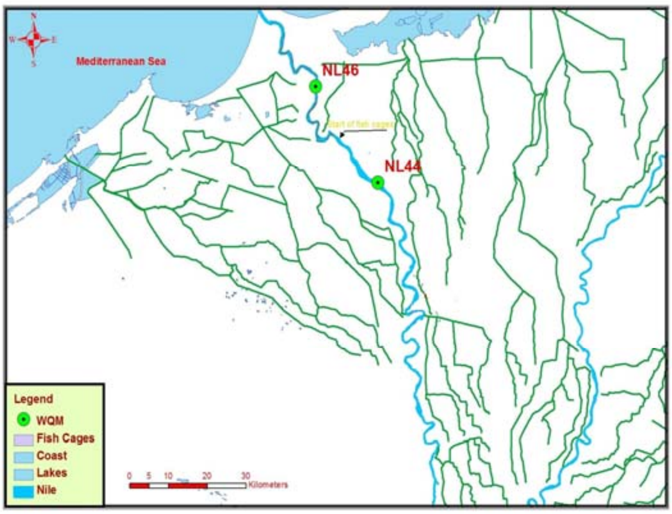


**Figure 8: Location of NWQM monitoring sites (NL44 and NL46) before and inside the areas of fish cages**

Analyses were carried out on the data sets from 1998 till 2010 to verify the impact of fish cages on the water quality in the surrounding area. Figures 9 and 10 present the cross sections of these sites where the water samples are taken with an intermediate placing (shown as an axial vertical line cutting the bed level BL). The cross section at NL44 is almost one kilometer wide while that of NL46 is 500 meters wide, the maximum depths of the two cross sections vary between 10 and12 meters depth.

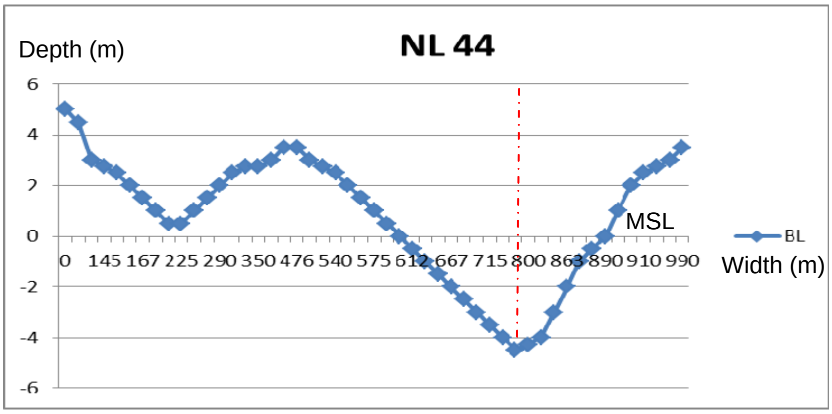


**Figure 9: The cross section at the monitoring site NL44**

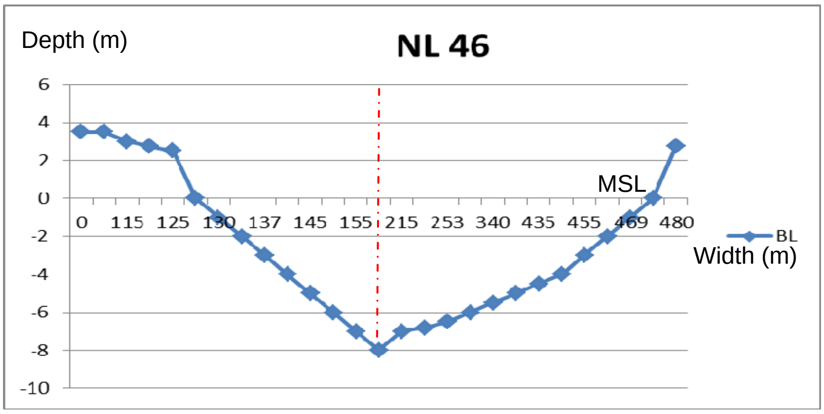


**Figure 10: The cross section at the monitoring site NL46**

Analysis indicates large quantities of organic compounds and nutrients induced in Rosetta branch from fish wastes and fish sludge in the area of fish cages at site NL 46 at km 1156.5 from Aswan High Dam compared to site NL 44 at km 1123 from Aswan High Dam (before fish cages). Ammonia level rise from 1.5 mg/l to more than 3 mg/l, while a major rise in the concentration is witnessed starting year 2009 as shown in figure 11. The variation of nitrate concentration is wide and noticeable where the minimum recorded value was round 1 mgl/l at years where fish farming was not existant and it reached more than 20 mgl/l in the last two years as shown in figure 12. The negative impact is clearly identified in the examination period of ten years from 2002 to 2012 on seasonal basis (summer and winter). It should be mentioned that less rate of dissolved oxygen was recorded in the fish farming area where this oxygen deficiency resulted in declining the water quality as well as the natural biological communities as shown in figures 13 and 14.

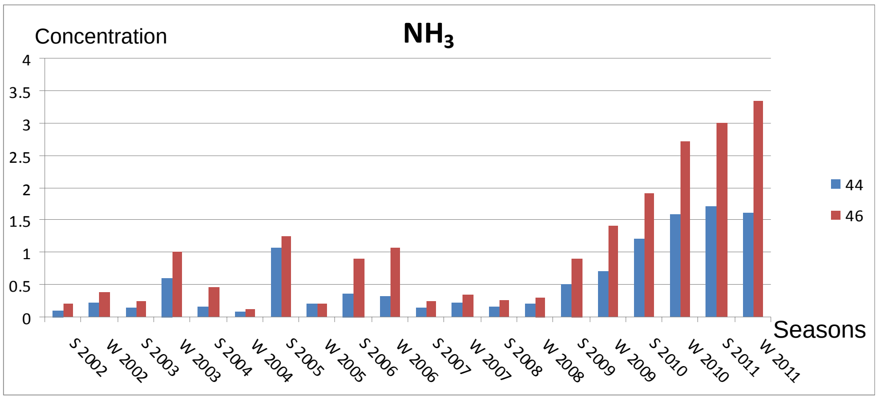


**Figure 11: Ammonia ($NH_3$) values per the selected locations from year 2002 to 2011**

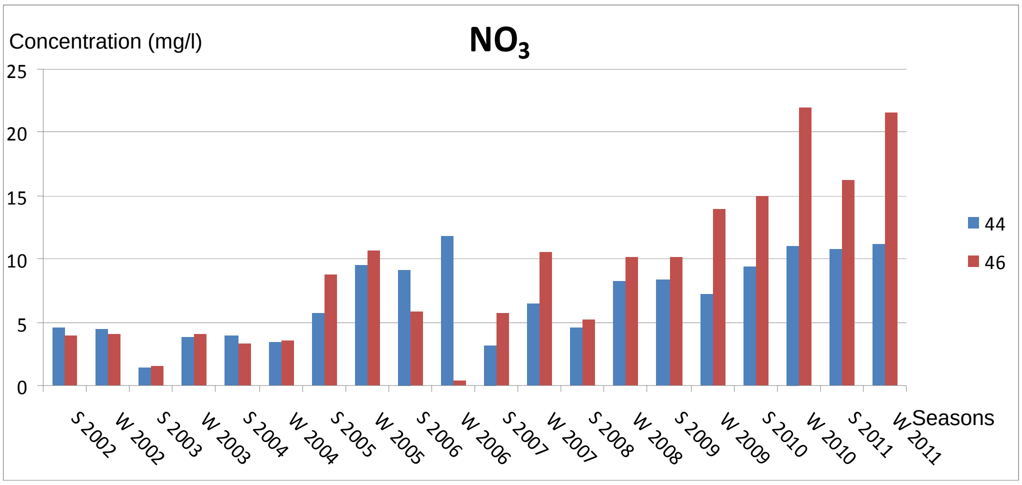


**Figure 12: Nitrates ($NO_3$) values per the selected locations from year 2002 to 2011**

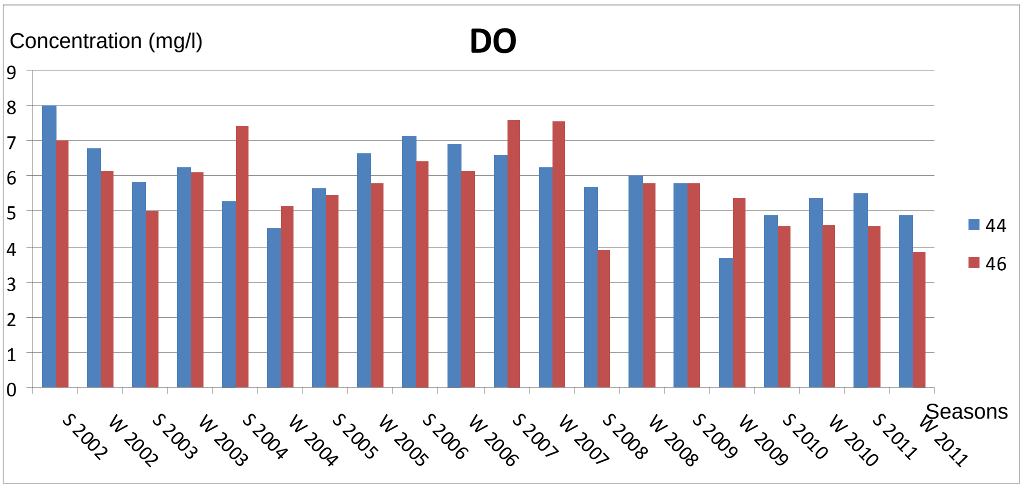


**Figure 13: Dissolved Oxygen (DO) values per the selected locations from year 2002 to 2011**

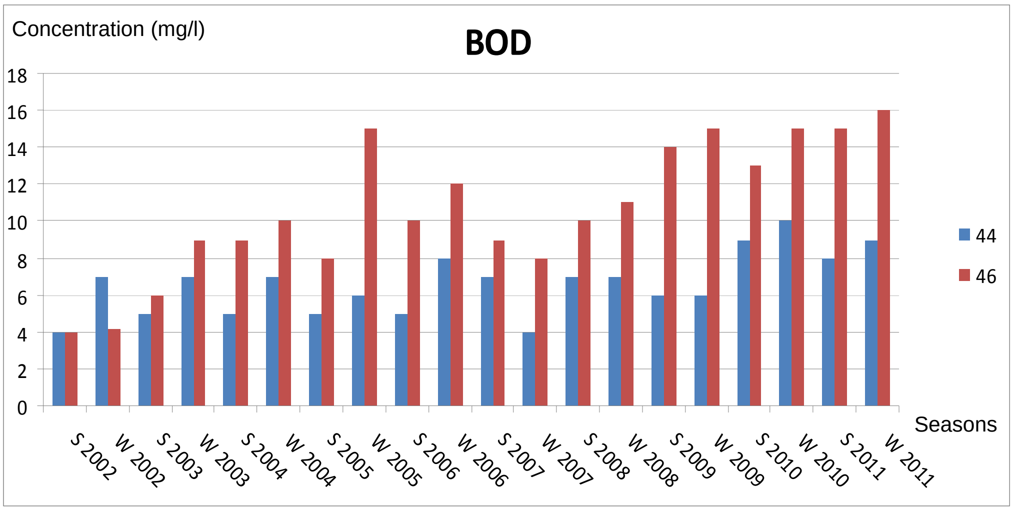


**Figure 14: Biological Oxygen Demand (BOD) values per the selected locations from year 2002 to 2011**

### 3.2.2. Fish cages and drinking water

As per the Ministry of Water Resources and Irrigation, there were many incidents of fish deaths reported in the segment of the Rosetta branch between NL 44 and NL 46. Low water quality is a threat to the intake of drinking water further downstream on the identified reaches. Yet a complete picture must be clear for the placement of intakes and sampling locations for a discreet comparison. Fowa drinking water treatment plant intake is located at km 1137 from Aswan High Dam which is almost mid way between NL 44 and NL 46. The intake's location is on the right side of the site cross section of more than 500 meters wide as shown in figure 15 while fish cages are on the left side. Through year 2011 samples were collected for the drinking water intake to assess the impact of the branches pollution and fish cages existence on the water used for drinking purposes for humans.

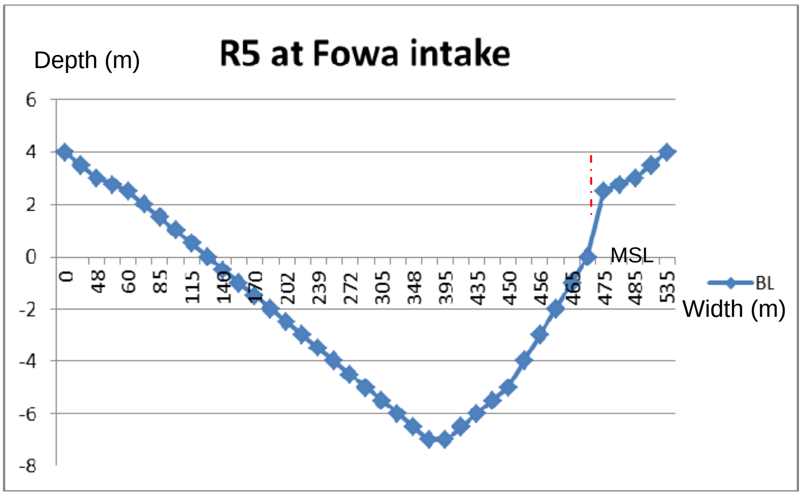


**Figure 15: The cross section at the monitoring at Fowa drinking water intake**

The results show that there is a slight impact on the water quality with respect to $NH_3$ and BOD. All $NH_3$ values violated the limit all over the year and 63% of BOD values are above the permissible (the Law 48/1982, article 60 states that $NH_3$ should below 0.5 mg/l and that of BOD should be less than 6 mg/l) as shown in figure 16. It's worth mentioning that these two variables are being taken care of in the water treatment process.

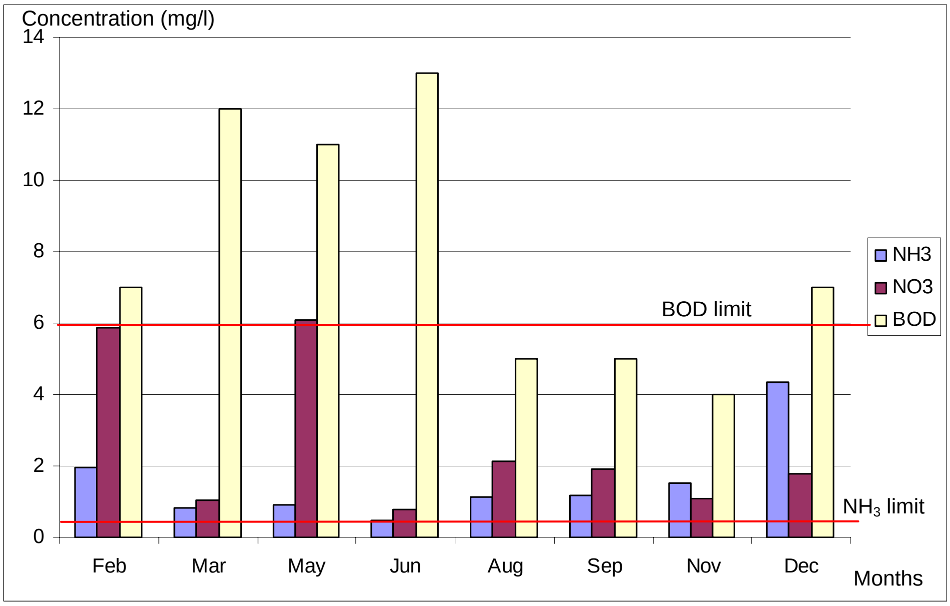


**Figure 16: Water quality parameters at Fowa drinking water intake in 2011**

## 4. SUMMARY AND CONCLUSIONS

Random and un-managed existent of fish cages form a remarkable threat to water quality. The current study investigated this threat using Remote Sensing (RS) technique and comprehensive data analysis in Rosetta Branch of the Nile River which is considered one of the most important water ways in Egypt. RS technology was utilized very efficiently to completely identify the fish cages precise locations since traditional monitoring methods usually fail in this task because fish farmers find several ways to hide the cages by submersion under the water. This identification showed that fish cages have been increased by 12.5 % from year 2007 to year 2010. The precise locations of these cages, identified by RS, are considered asset knowledge to decision makers towards better management of the cages' random existent. Reaches before Edfina barrages, where many drinking water intakes exist, are mainly medium to low intensity of fish cages while records with high intensity are found in reaches close to the Mediterranean Sea.

On the other hand, detailed current and historical water quality data were collected and analyzed from the study area of Rosetta Branch to accurately determine the complete picture of the fish cages impacts on water quality. This comprehensive analysis and efforts showed a direct impact from the random fish farming activities on water quality deterioration all over the study area. An increase in the impact is also reflected in the vicinity of the existent drinking water treatment plant. However, this impact is always taken care of by the treatment activities within the plant facility.

Finally, it can be easily concluded that random and un-managed fish cages are having direct and remarkable impacts on water quality deterioration and certain management actions from all concerned authorities are urgently needed.

## 5. RECOMMENDATIONS

A practical way to control pollution from open fish cage farming is to control the stocking density in relation to the carrying capacity of the receiving water. Also regulating the status of fish cages in addition to intensifying efforts to monitor water and sediment quality at fish culture sites. Periodical monitoring should become mandatory in Egypt.

As fish farming is a considerable source of income for the community yet its wide random spreading negatively impacts this community. It needs better management and supervision to limit the environment's degradation through controlling the farming intensity, monitoring the types of feed for fish in addition to imposing aeration for these cages and a frequent follow up for the farming process. Highly trained personnel can aanneal the use of modern technologies for fish farming techniques development.

Other partial recommendations for better fish farming involve the expansion of the fish farm rotation, using self–sufficiency cultivated crops for feed ingredients and investing generously in scientific research for fish farming development.

RS technique is a very useful tool in spatially monitoring the fish cages locations along water bodies. Statistically correlated relationships are recommended to be developed between field data and RS analyzed images to obtain water quality status in the area of fish cages using RS directly in these locations and others when the approach and methodology are verified.

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