American-Eurasian J. Agric. & Environ. Sci., 5 (3): 331-336, 2009
ISSN 1818-6769

Physical Limnology of Bardawil Lagoon, Egypt

Radwan G. Abd Ellah and Maged M. Hussein

National Institute of Oceanography and Fisheries, Egypt

Abstract: Bardawil lagoon is suffered from many problems, which might lead to environment degradation, shortage in fish catch and substantial changes in its ecosystem. The present study was carried out to evaluate Bardawil Lagoon from a physical limnology, through investigation of; climate bathymetry and salinity. Bardawil is a costal lagoon located along the Mediterranean shore of the Sinai region (31°09\N, 33°08\E), Egypt. Over Bardawil Lake, there are two climate periods, rainy season (November to April) and dry season (May to October). The lagoon extends for about 76.37 km length and has a maximal width of 16.65 km, with area of approximately 518.99 km^2. Bardawil Lagoon is extremely shallow; the average water depth is of 1.2 m. The whole water supply of the lagoon comes from the Mediterranean Sea which flows constantly through two openings. The spatial variability observed in the water salinity of the lagoon. The highest salinities reached along the southern shore. The temporal variations of water salinity in the lagoon are in equilibrium between the evaporation and the sea water exchange. There are difficult to determine the annual trend in the water salinity of the lagoon.

Key words: Bardawil lagoon, Bathymetry, Climate and salinity

INTRODUCTION

Coastal Zones and lagoons are important issues in the international debate for the environmental and sustainable development. They have become the major site for extensive and diverse economic activities [1]. Coastal lagoons occupy 13% of worldwide coastal areas and are often subjected to both natural and man-made factors [2]. Importance of many lagoons is coming from fishing and salt extraction along their borders [3, 4]. Depending on local climatic conditions, lagoons which exhibit salinities may be change from completely fresh to hypersaline. This is particularly true for the type of coastal lagoon that is referred to as choked, where the lagoon is connected to the coastal sea, at least intermittently, via a single channel and the tidal variability is largely filtered out during propagation of the tidal wave into the lagoon [5].

Coastal lagoon ecosystems are particularly vulnerable to eutrophication due to often restricted water exchange with the adjacent sea [6]. The distribution of plankton, fauna and flora in lagoons are mostly related to prevailing ecological conditions, beside the nature of bottom sediments and fertility of water [7, 8]. Also, air temperature and hence evaporation rate markedly affects the water salinity [9].

Bardawil Lagoon is located at southeastern Mediterranean coast at 31°09\N, 33°08\E (Fig. 1). It is an oasis for birds migrations as well as Zaranik protected area [10], an important source for economical fish and salt production [4, 11] and a high diversity of habitat for wildlife [12]. The lagoon is nearly clear and it is the least polluted in the entire Mediterranean region [13].

Bardawil lagoon represents a transitional zone between land and sea and it is separated from the Mediterranean Sea along most of its length by a long and narrow sand bar. It is connected to the sea via a three narrow artificial inlets. Two of them are man-made (western and eastern inlets), while the third one has been naturally closed [14]. The lagoon extends along the coast, so it has a micro tidal regime. The Mediterranean Sea tides govern water exchange in the lagoon and have a mean tidal excursion of 25 cm during neap tides and about 35 cm during spring tides [15].

Bardawil lagoon is suffered from many problems, which might lead to environment degradation, shortage in fish catch and substantial changes in its ecosystem. Drying up of some areas inside the lagoon and subsequently loss of its biological and economic values is due to the frequently changes of inlets form and dimension. An extensive salt production system (constructed in the eastern part), leads to considerable

Corresponding Author: Radwan G. Abd Ellah, National Institute of Oceanography and Fisheries, Egypt

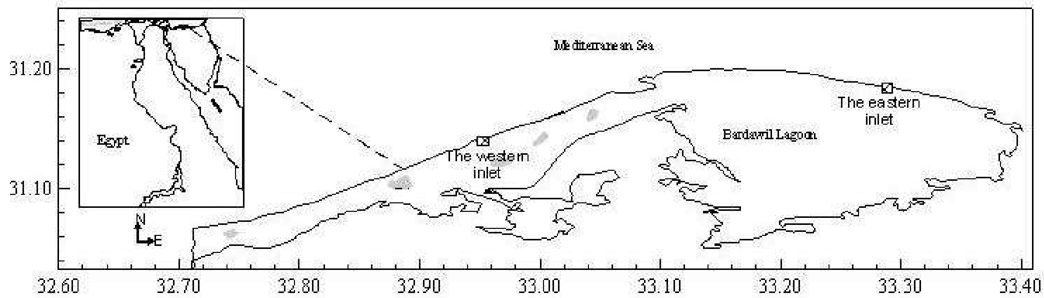

Fig. 1: Bardawil lagoon and Egypt map

ecological changes. There are many investments around the lagoon, like tourism developments. There is a large-scale agriculture reclamation project in North Sinai near the lagoon; the inflow of freshwater from the new reclamation lands will change the lagoon from a saline to brackish lagoon, leading to the deterioration of water quality [7]. otherwise, Bardawil Lagoon development, including urbanization and lagoon engineering such as artificial inlets, promotes some undesirable changes in its system.

The present study was carried out to evaluate Bardawil Lagoon from a physical limnology point of view, through investigation of: climate of the Lagoon, Lagoon bathymetry and its morphometrical features and monthly and annual changes in salinity.

MATERIALS AND METHODS

Data on the climate of Bardawil Lagoon depend on the information of the previous investigations [add references]. Most of these data are relevant to El-Arish Weather Station (20 km east of the Lagoon). The Lagoon's survey of the present study was done during 2004. Global Positioning System (GPS, NAV 5000 PRO) was used to determine the positions and hydrographic stations (Latitudes & Longitudes). The water depth was determined by using Portable Eco- sounder (Lowrance Soner- X- 25 model). Twelve stations were monthly sampled inside the Lagoon, ten of them represent the main body of Lagoon's water and the other remainder stations were located in-front of the Lagoon inlets. In laboratory, water salinity was obtained according to gravimetric method [16]. This method depends on filtering the water sample through glass filter paper (GF/C) 0.45µ and evaporating this sample in oven at 105 Celsius.

RESULTS

Air and water temperatures of Bardawil Lagoon are low in winter and high in summer (13.7- 27.0°C and 13.9- 24.6°C), respectively. Winds are coming from all directions, but the most abundant direction of wind

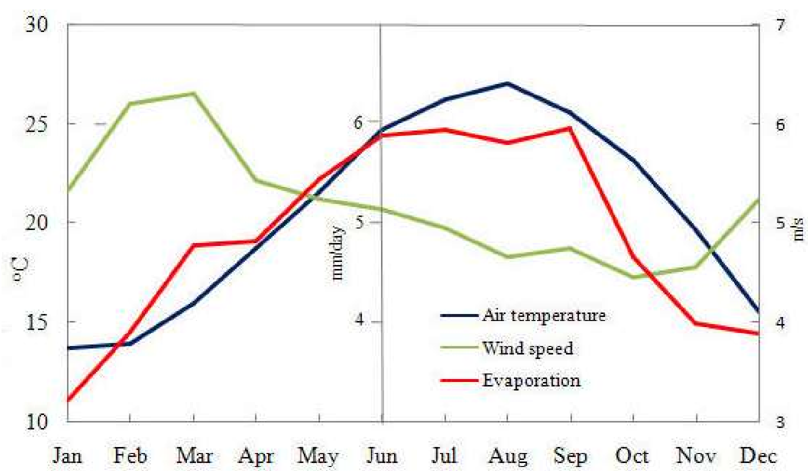

Fig. 2: Air temperature, wind speed and rate of evaperation in Bradawi Lagoon

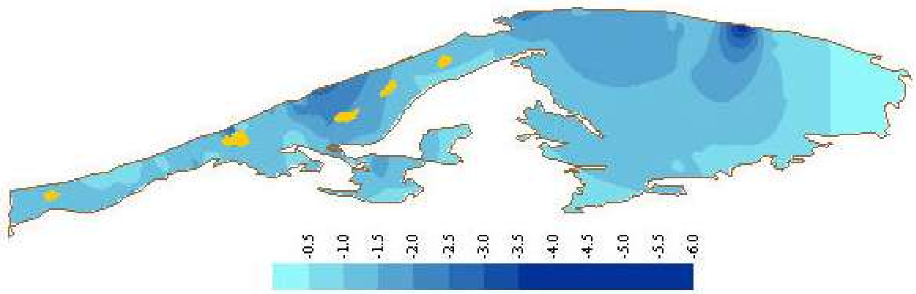

Fig. 3: The bathymetric map of Bardawi Lagoon

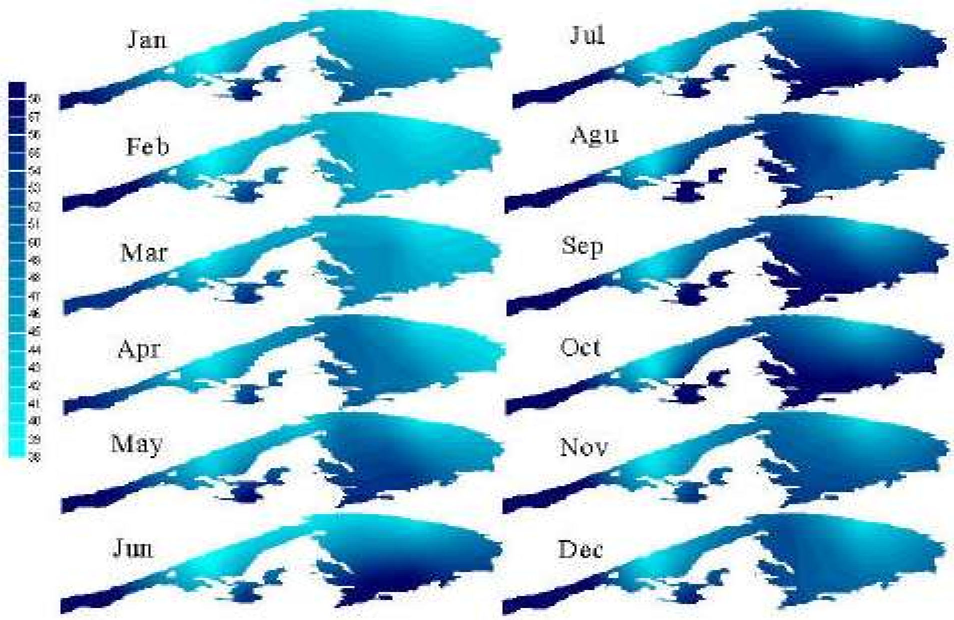

Fig. 4: The spatial and monthly variation of the water salinity in Bardawil Lagoon

direction is often from the north during most times. The recorded wind speed shows great variability from a month to another and it ranged between 4.5- 6.3 m/s. The relative humidity varied between 48.5 and 57.1%. Evaporation rate is low in winter and high in summer (3.23- 6.0 mm/day), Figure (2).

Bardawil is shallow water with irregular bottom topography. Figure (3) shows the lowest water depth (0.3 m) and the highest (6.5 m) are recorded at the extreme eastern region (Zaranik area) and inside the inlets, respectively. The average water depth inside Bardawil Lagoon is around 1.21m.

Figure 4, illustrates spatial and temporal water salinity distributions inside the Lagoon. From the salinity results it could be concluded that, there is a high fluctuation in the salinity range, the lowest value is 38.3‰ and the highest is 71.1‰.

DISCUSSION

Despite the fact that Egyptian coast is semi-arid; its climate can be considered as Mediterranean type. The weather is highly seasonal in nature and is strongly related to the high pressure systems whose limits overstep the boundaries of the Mediterranean area and extend towards the north Atlantic, Eurasia and Africa [17]. Bardawil Lagoon climate as Mediterranean Sea [18, 19], is considered greatly damp. There are two climate periods, rainy season (November to April) and dry season (May to October). The dry months are characterized by the influence of high air temperatures and scarce rainfall promoting high rates of evaporation [20]. The rainy season accompanied by strong winds, precipitation and low air temperatures. This seasonal wind evaluation is obviously related to the cyclonic activity variations [21].

The significant variations in wind during winter season may be related to the deepness and the tracks of the depressions passing over the lagoon area. The wet northerly wind currents are prevailing on Bardawil lagoon, especially in winter which is lead to decrease evaporation rate. On the contrary, the dry easterly and westerly winds in warm period increased the evaporation rate from the Lagoon's surface [22].

From the bathymetry point of view, Bardawil Lagoon is divided into two parts; eastern region that has an elliptical shape and western region that has a rectangle shape. From the bathymetric map, maximum long and width of the lagoon are 76.65 and 16.65 km, respectively. The Lagoon area changed from 600 km^2 during 1991 [23] to 518.99 km^2 during 2004 (present study). This means that, about 13.5% of the total lagoon's area has been lost through 13 years. These lost areas may be due to naturally or man made dried, or cut off by embankment or extensive Salina and Super tidal salts flats (Sabkha) or may be all of the previous reasons together.

The lagoon water depth is never exceeds 3m. The Lagoon water depth could be classified into four categories; 0.5% of the total area is greater than 2.5m (in front of inlets); 16.5% is between 1.5m and 2.5m; 62% is between 1m and 1.5m and 21 % is less than 1m at south and east parts (Zaranik area). The general erosion along the central bulge of Bardawil lagoon barrier and the long shore transport of sand to the east [1, 24].

The Lagoon connects with Mediterranean Sea through two artificial manmade inlets whose termination frequently changes in their form and dimensions. Water exchanges between the Lagoon and Mediterranean Sea play an important role in water circulation and salinity levels [25]. The eastern and western inlets are 153 and 150 meters in wide, with maximum depths equal to 8.8 and 8.6 meters at their centers (inlets depth decreased towards the borders). Wave and current are causing erosion for the inlets borders. So water depths inside the inlets are decreased due to accumulation of sand which is settled on their bottoms (this settlement is coming from the inlets borders erosion) [26].

Inlets shoaling have a direct role on the salinity increasing inside the Lagoon [4]. So annually inlets dredging play a suitable solution to keep the inlets open, overcome the salinity increasing and conserve the Lagoon ecosystem. Also there is sand accumulation at some sites inside the lagoon, especially in the eastern margin [23]. Significant water salinity changes which occur in down coast orientation at the two inlets produce movable sand bars leading to changes in the shape and the width of the Bardawil Lagoon inlets.

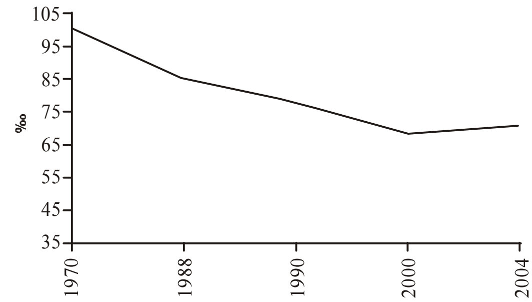

Fig. 5: The Annual variation of maximum water salinity in Bardawil Lagoon

The spatial and temporal variations of water salinity are observed inside the Lagoon. These variations have a high fluctuation and increase in the southern part than northern part [27]. Water salinity of the Lagoon is higher than inlets. Water exchange between the Lagoon and Mediterranean Sea through the inlets play very important role in water salinity variations [28]. The middle area water salinity of the Lagoon is decreased when huge quantities of Mediterranean Sea enter through the eastern inlet.

Western inlet has been subjected to shallowness due to increasing of accretion inside it. As a consequence, the rate of water exchange through this inlet is considerably low. This issue has also previously confirmed [27]. However, the changing of the water exchange through inlets is not only affect the water salinity but, also creating the dangerous status of the Lagoon (some areas are dried and then loss of its biological and economic values).

Spatial distribution of water salinity is affected by prevailing wind. Water masses displacement towards eastern direction due to the high values of north wind. The dry winds in warm period lead to increase the evaporation rate from the Lagoon's surface consequently the water salinity increase, especially in the isolated areas [9]. The increment in salinity is compensated during winter season by rainfall and sea water entrance through the inlets.

Many authors [12, 29- 32] studied the Lagoon salinity for long period of time from 1970 until the present study (2004), Figure (5) represents the annual fluctuation of Bardawil Lagoon water salinity. It is difficult to determine the annual trend in water salinity of the Lagoon due to clearly variations of inlets status (swallowing, nearly closing, dredging and then opening and so on).

During 1969-1971 the Lagoon's openings were completely blocked by sand accumulation. Consequently, the salinity of the Lagoon rose considerably reaching to about 100‰ and in some isolated basins the salinity reached up to 170‰ [30]. During 1988, 1990 and 2000 salinity values decreased gradually after dredging and re-opening of the two inlets, reaching to 85, 78 and 68 ‰, respectively [12,31,32]. However, the recent values of salinity varied between 38.0-71.1‰.

The annual fluctuation in water salinity is considered as a one of crucial tool for studying aquatic ecosystem. According to more than 30 years of salinity time series data, indicate that the Lagoon salinity is largely fluctuates in response to weather and evaporation process. The major factors which can explain the salinity decreasing in the Lagoon are the changes in water exchange between the Lagoon and Mediterranean Sea and the extensive mining of salt from the Lagoon during past decades.

The present study concluded that most of the Lagoon is continuously hyper saline. The spatial and temporal variability are observed in water salinity of the lagoon. The climate circumstances, wind and evaporation over the Lagoon is the dominant factor accounting for the hyper salinity and affect on water salinity distribution of the Lagoon. The intermittent forcing events due to strong winds have less impact on long-term evolution than regular tides acting continuously on Lagoon dynamics. The water exchange between the Lagoon and Mediterranean Sea through the inlets plays an important role in the water salinity levels. Completely closing or water depth decreasing inside the inlets, have a direct impact on the salinity increasing.

ACKNOWLEDGEMENT

The present study was done in the framework of plan of National Institute of Oceanography and Fisheries "Survey and ecological studies of Bardawil Lagoon".

REFERENCES

1. Azab, M. and A.M. Noor, 2007. Change Detection of the North Sinai Coast by Using Remote Sensing and Geographic Information System. Geographia Technica, 2: 10.
2. Sikora, W.B. and B. Kjerfve, 1985. Factors influencing the salinity of Lake Pontchartrain, Louisiana, a shallow coastal lagoon: analysis of a long-term data set. Estuaries, Coastal and Shelf Science, 8: 170-180.
3. Kjerfvea, B., A. Schettinib and H.O. Ferreirab, 1996. Hydrology and Salt Balance in a Large, Hypersaline Coastal Lagoon: Lagoa de Araruama, Brazil. Estuarine, Coastal and Shelf Science, 42: 701-725.
4. Abd Elrazek, F., S. Taha and A. Ameran, 2006. Pulation biology of the edible crab portunus pelagicus (Linnaeus) from Bardawil Lagoon, northern Sinai, Egypt. Egyptian Journal of Aquatic Research, 32: 401-418.
5. Knoppers, B., B. Kjerfve and J. Carmouze, 1991. Trophic state and water turn-over time in six choked coastal lagoons in Brazil. Biogeochemistry, 14: 149-166.
6. Gonzalez, F., A. Herrera-Silveira and L. Aguirre-Macedo, 2008. Water quality variability and eutrophic trends in karstic tropical coastal lagoons of the Yucata´n Peninsula. Estuarine, Coastal and Shelf Science, 76: 418-430.
7. Mageed, A., 2006. Spaio-temporal variations of zooplankton community in the hypersaline Lagoon of Bardawil, north Sinai, Egypt. Egyptian Journal of Aquatic Research, 32: 168-183.
8. Konsowa, A., 2007. Spatial and Temporal Variation of Phytoplankton Abundance and Composition in the Hypersaline Bardawil Lagoon, North Sinai, Egypt. Journal of Applied Sciences Research, 3: 1240-1250.
9. Khalil, M. and K. Shaltout, 2006. Lake Bardawil and Zaranik protected area. Publication of biodiversity unit, 15: 594.
10. Anonymous, 2005. National report on hunting. Building capacity for sustainable hunting of migratory birds in Mediterranean third countries. Project reference: life o4TCY/INT/000054, pp: 57.
11. El Shaer, H., 2008. Potential rate of Sabkhas in Egypt: an overview, Salinity and water stress, Tasks for vegetation sciences. Springer Netherlands, 44: 221-228.
12. Touliabah, H., H.M. Saftik, M.M. Gab-Allah and W.D. Taylor, 2002. Phytoplankton and some abiotic feature of El-Bardawil Lake, Sinai, Egypt. African Journal of Aquatic Science, 27: 97-105.
13. Arvanitids, C., P. Somerfield and A. Eleftheriou, 2009. Do multivariate analyses incorporating changes in pattern across taxonomic levels reveal anthropogenic stress in Mediterranean lagoons?. Journal of Experimental Marine Biology and Ecology, 369: 100-109.
14. El-Shabrawy, G., 2006. Ecological study on zooplankton community in Bardawil Lagoon, Egypt. Thalassia salentina, 29: 3-19.

15. Moursy, Z., 1994. The tidal range and the observed sea level variations at Alexandria harbor. Qatar University Science Journal, 14: 386- 389.
16. APHA, 1995. Standard methods for the examination of water and waste water, New York, pp: 1193.
17. Hussian, M.M.A., 2004. Remote Sensing, GIS and Modelling for coastal zone management case study: Lake Brullus. PhD. Of science thesis, Alexandria University.
18. Hamad, N., C. Millot and I. Taupier-Letage, 2006. A new hypothesis about the surface circulation in the eastern basin of the Mediterranean Sea. Progress in Oceanography, 66: 287-298.
19. Ulbrich, U., W. May, L. Lionello, J. Pinto and S. Somot, 2006. Mediterranean Climate variability. Chapter 8: The Mediterranean Climate Change under Global Warming. pp: 393- 415.
20. Tanny, J., S. Cohen and M.B. Parlange, 2008. Evaporation from a small water reservoir: direct measurements and estimates. Journal of Hydrology, 351: 218-229.
21. Alhammoud, B., K. Be´ranger, L. Mortier, M. Cre´pon and I. Dekeyserc, 2005. Surface circulation of the Levantine Basin: Comparison of model results with observations. Progress in Oceanography, 66: 299-320.
22. Perez, P.J., F. Castellvi and A. Mortinz-Cob, 2007. A simple model for estimating the Bowen ratio from climatic factors for determining latent and sensible heat flux. Journal of Agricultural and Forest Meteorology, 148: 25-37.
23. Gaafar, G., 1991. Marine geological studies on the recent bottom sediments of Bardawil Lagoon, North Sinai, Egypt. Master of Science thesis, Menofia University, pp: 179.
24. El-Shinnawy, I., 2002. El-Zaranik wetland's hydrology study: catchment area studies and water resources. Report presented to Meditreanean wetlands coast Project, Cairo, pp: 31.
25. Ali, M., M. Sayed and M. Goher, 2006. Studies of water quality and some heavy metals in hypersline Mediterranean Lagoon (Bardawil Lagoon, Egypt). Egypt. Journal of Aquatic Biology and Fishery, 10: 45-64.
26. El-Banna, M., A.H. Khedr, P. Van Hecke and J. Bogaert, 2002. Vegetation composition of a threatened hypersaline lake (Lake Bardawil), North Sinai. Plant Ecology, 163: 63-75.
27. Gibali, M., 1988. Studies on the flora of the northern Sinai, Egypt. Master of Science thesis, Faculty of science, Cairo University, pp: 403.
28. Ferrarin, C. and G. Umgiesser, 2005. Hydrodynamic modeling of a coastal lagoon: the Cobras lagoon in Sardinia, Italy. Ecological Modelling, 188: 340-357.
29. Abdel-Star, A., 2005. On the water quality of Bardawil Lagoon, Egypt. Journal of Egyptian Academic Society for Environmental Development, (D–Environmental Studies), 61: 73-79.
30. Ben-Tuvia, A., 1979. Studies of the population and fisheries of sparus aurata in the Bardawil Lagoon, eastern Mediterranean. Investigacion Pesquera, 43: 43-68.
31. Siliem, T., 1989. The chemical conditions in Bardawil Lagoon. III- some limnological studies. Bulletin National Institute of Oceanography and Fisheries, Egypt, 15: 21-33.
32. Abdel-Daiem, A., 2000. Morphological and hydrochemical characteristics of Bardawil Lagoon in comparison with that Manzala Lagoon, northern Egypt. Journal f Environmental Science, 20: 177-200.