Blue Economy

Volume 1 | Issue 2 Article 6

2023

Long-term Variations in the Salinity off the Egyptian Mediterranean Coast

Ebtessam E. Mohamed
National Institute of Oceanography and Fisheries, NIOF, Egypt

Amna S. Dabbous
National Institute of Oceanography and Fisheries, NIOF, Egypt

Hussein I. Maiyza
National Institute of Oceanography and Fisheries, NIOF, Egypt

Tarek M. El-Geziry
National Institute of Oceanography and Fisheries, NIOF, Egypt, tarekelgeziry@yahoo.com

ISSN: 2805-2986 – e-ISSN: 2805-2994

Recommended Citation

Mohamed, Ebtessam E.; Dabbous, Amna S.; Maiyza, Hussein I.; and El-Geziry, Tarek M. (2023) "Long-term Variations in the Salinity off the Egyptian Mediterranean Coast," *Blue Economy*: Vol. 1 : Iss. 2 , Article 6.
Available at: https://doi.org/10.57241/2805-2994.1012

RESEARCH ARTICLE

Long-term Variations in Salinity Off the Egyptian Mediterranean Coast

Ebtessam E. Mohamed, Amna S. Dabbous, Hussein I. Maiyza, Tarek M. El-Geziry*

National Institute of Oceanography and Fisheries, NIOF, Egypt

Abstract

The variability in seawater salinity, an indicator of the global hydrological cycle, is crucial in basin-scale circulation and many dynamic processes from basin to global scale. Salinity is significant for marine science because fluctuations in salinity can affect physical processes such as climate change, ocean current variations, and water mass formation. From a biological perspective, variations in salinity may pose a threat to marine animals and disrupt their normal functioning. In this study, the long-term variability of salinity in the photic zone (0−200 m) of the Egyptian Mediterranean Sea is examined using an extended data set from 1950 to 2021. On a monthly basis, the western sector of the Egyptian Mediterranean coast usually has lower salinity than its eastern sector. Seasonally, the maximum surface salinity was observed in autumn, while spring was the season with the lowest surface salinity variations. Positive trends in the salinity anomaly variations were found in the upper water layer (0−50 m) and then trends changed to negative patterns along the depths of 100, 150, and 200 m. Therefore, the depth of 50 m is said to divide the surface and subsurface waters with opposite trends. Future research should be undertaken based on our qualitative analysis to foresee and model the progression of salinity in the region.

Keywords: Anomaly, Eastern mediterranean, Egypt, Levantine basin, Salinity, Trend

1. Introduction

Understanding the hydrographical and dynamic processes of oceans requires quantifying salinity variations on both horizontal and vertical scales. These processes comprise, but are not limited to: (1) sea level changes (Antonov et al., 2002; Boyer et al., 2005), (2) habitability and abundance of planktonic communities (Paturej and Gutkowska, 2015; Sun et al., 2023; Wang et al., 2023), (3) water mass formation (Levitus, 1986), (4) circulation pattern (Fedorov et al., 2004), and (5) global climate change (Lagerloef, 2002; Boyer et al., 2005; Cullum et al., 2016; Zhao et al., 2018). According to Antonov et al. (2002), 10 % of the observed sea level rise (SLR) within the latitudinal area 50°S−65°N throughout the period from 1957 to 1994 was attributed to the decrease in the mean surface salinity. Salinity variation is responsible for the observed sea level changes due to the haline contraction factor and the influence of adding/removing freshwater to ocean basins (Boyer et al., 2005). Moreover, the dynamics of circulation is highly influenced by variations in salinity whether in the surface (wind-driven) or deep (thermohaline) oceans and seas (Fedorov et al., 2004). On the long−term scale, fluctuations in these circulation patterns impact the global climate and the regulating air−sea interaction processes such as El Nino and La Nina (Fedorov et al., 2004; Cullum et al., 2016; Zhao et al., 2018). Eutrophication, a global environmental issue, is highly correlated to the variations in seawater salinity, which in the end affect the abundance of the plankton community and hence, the food chain (Wang et al., 2023). Evaporation, precipitation, and freezing processes are responsible for the fluctuations in the recorded

Received 5 October 2023; revised 18 November 2023; accepted 19 November 2023.
Available online 30 December 2023

* Corresponding author. National Institute of Oceanography and Fisheries (NIOF), Kayitbey, Al-Anfoushy, 21556, Alexandria, Egypt. Fax: +2-03-4801174.
E-mail address: tarekelgeziry@yahoo.com (T.M. El-Geziry).

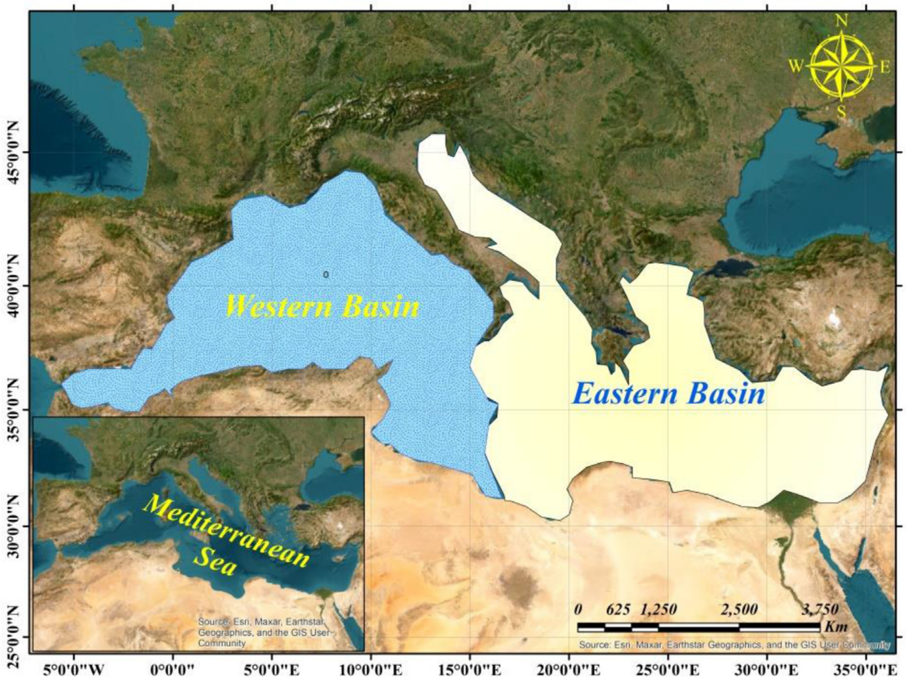
https://doi.org/10.57241/2805-2994.1012

salinity. Variations in the recorded salinity are closely correlated with regional evaporation (E) and precipitation (P) in the global ocean as well as river discharges in the coastal region (Zhao et al., 2018).

As one of the few basins in the world where deep convection and water mass production occur, the Mediterranean Sea (Fig. 1) can be used to explore the interaction of physical and dynamic processes (Wu and Haines, 1996). The Mediterranean produces very salty waters the outflow of which across the Strait of Gibraltar may indirectly influence the North Atlantic's deep circulation (Reid, 1979). In general, the salinity of the Mediterranean fluctuates between 38.60 and 38.80 for the upper 100 m of water, designated as the Atlantic water mass (Sharaf El-Din and El-Gindy, 1987). Below this Atlantic layer, there is an intermediate mass with a salinity of 38.90–39.10. Beneath the 1000 m depth, the salinity ranges between 38.68 and 38.75 (Said, 1990). The Mediterranean is an evaporative basin by nature, with an estimated freshwater loss of 50–100 cm/yr (Béthoux, 1980). Moreover, the Mediterranean Sea loses heat to the atmosphere at a rate of ~4 ± 7 Wm^{-2} (Bunker et al., 1982). These two factors result in higher salinity than most bodies of water, while the rapid turnover rate makes it a little laboratory for researching the consequences of global warming on the world's oceans on a human scale (Lejeusne et al., 2010). Furthermore, the Mediterranean Sea influences worldwide thermohaline circulation and, as a result, plays a significant role in global climate regulation (Serïmözü, 2019; Rohling and Bryden, 1992; Tsimplis and Baker, 2000; Vilibić and Orlić, 2001; Manca et al., 2004; Potter, 2004; Millot et al., 2006), and others have previously investigated the large salinification and warming of the Mediterranean water masses. These studies concentrated on the long-term trends of inflow and outflow waters in the western Mediterranean basin and their impact on the neighboring Atlantic characteristics.

The eastern Mediterranean basin hosts four subsea basins: the Ionian, the Levantine, the Aegean, and the Adriatic. The Levantine Sea has the greatest average salinity among these four subseas and is crucial to the ocean's circulation, being the home to the formation of the Levantine Intermediate Water (LIW) mass (Serïmözü, 2019). Significant anomalies at the sea surface in the eastern Mediterranean may have an impact on the deeper levels, according to observational findings (Astraldi et al., 2002). However, research on the large salinification processes in the eastern Mediterranean basin is scarce compared with that in the western Mediterranean basin (Skliris and Lascaratos, 2004; Rixen et al., 2005; Kruithof, 2018; Nacef et al., 2016; Tukenmez and Altiok, 2022 to name a few).

The Egyptian Mediterranean coast runs across a distance of ~1200 km, from Sallum (31°30′13″N, 25°06′54″E) to Rafah (31°17′19″N, 34°14′28″E), and represents the southern border of the Levantine



Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community

Fig. 1. *The Mediterranean Sea with its two wings: western and eastern basins.*

Sea. It is divided into four regions based on physiographic features (El-Geziry and Said, 2020, Fig. 2).

(1) The northwest Egyptian Mediterranean region, which stretches from Sallum to Alamein, is the most western sector and is distinguished by having the highest elevation above the mean sea level (MSL) along the whole Egyptian Mediterranean coast.
(2) The Middle Northern Egyptian Mediterranean Region, from Alamein to Alexandria, includes Alexandria Western Harbour, the main Egyptian port on the Mediterranean.
(3) The Egyptian Nile Delta region, which stretches from Rosetta to Port Said, is the third segment. This area is where Egypt's largest population density is found, as well as the primary area for agricultural operations.
(4) The northeastern Egyptian Mediterranean region stretches from Port Said to Rafah and includes the Suez Canal as well as the main zone of Egypt's industrial and commercial operations.

Understanding the evolution of seawater salinity off the Egyptian Mediterranean Coast is critical to understanding how changes in seawater physical properties may affect Mediterranean circulation. Changes in water mass formation patterns are also influenced by the salt content of the Levantine Sea. Thus, the long-term variations in salinity anomalies off the Egyptian Mediterranean coast were investigated by Maiyza and Kamel (2010) and Maiyza and Kamel (2010); El-Geziry et al., (2019). However, the subject still needs further investigation, and this work is a fair trial to reach an answer to the question: How may the vertical variations in salinity look like in the upper layer of seawater (0–200 m) along the Egyptian Mediterranean coast? The aim is to find out the vertical variations in salinity on a monthly and seasonal basis off this important coastline.

1.1. Data and methods of analysis

In this research, the Egyptian Mediterranean coast is divided into two sectors: the western sector, from Sallum to Alexandria, and the eastern sector from Abu-Qir to Rafah (Fig. 2). The area of interest extended from the shoreline to Latitude 33° 0.0′ N. Extended salinity records from 1950 to 2021 within each sector based on available data at a scale of 1° grid were subjected to analysis. Table 1 shows the number of hydrographic stations used in the calculations of the present work for each month in each sector. Data were acquired for the Egyptian Mediterranean region from the World Ocean Atlas 2018 (WOA2018), downloaded from the website https://www.ncei.noaa.gov/products/world ocean atlas, from the surface to a depth of 200 m along the water column at each grid point. The performed analysis comprised statistical examination and investigation

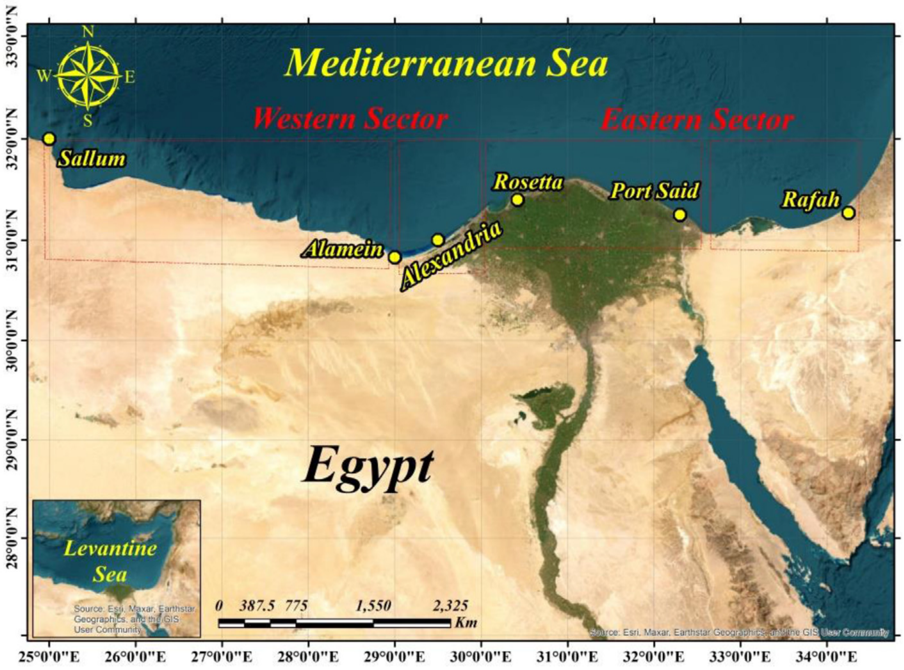


Fig. 2. The Egyptian Mediterranean coast with its four sections.

Table 1. Number of monthly hydrographic stations at each of the investigated sectors along the Egyptian Mediterranean Coast throughout the period 1950–2021.

Month	Eastern sector	Western sector
January	214	0
February	201	368
March	351	264
April	102	66
May	456	237
June	207	276
July	255	354
August	353	357
September	292	364
October	284	400
November	228	337
December	209	108
Total	3152	3131

of salinity vertical variations on monthly and seasonal bases. Double-eye check and the Excel 2010 data filter were used for data quality check and to eliminate odd values before statistical analysis. The salinity anomaly (salinity record minus the mean) was calculated on a monthly basis and the trend was drawn for specified depth levels (0, 20, 50, 100, 150, and 200 m). Due to the well-known bad spatiotemporal distribution of records and measurements, this work is considered qualitative research.

2. Results

2.1. Monthly variations of salinity

Fig. 3 (a-b) depict the monthly variations in the photic zone along the Egyptian Mediterranean coast over the period 1950–2021. It represents the variations off the two specified sectors: western and eastern. The figure indicates that there is a monthly variation, with a minimum surface salinity (0 m) of 38.685 (April) and 38.802 (February) (Fig. 3a) and a maximum of 39.228 (November) and 39.386 (July) (Fig. 3b) in the western and eastern sectors, respectively. Salinity at the deepest level of records (200 m) had a minimum of 39.010 (January) and 38.964 (May) and a maximum of 39.093 and 39.100 (February) in the western and eastern sectors, respectively (Fig. 3a). In general, the western sector of the Egyptian Mediterranean Sea had a minimum salinity of 38.650 at a depth of 50 m in June (Fig. 3a) and a maximum of 39.274 at 20 m depth in September (Fig. 3b), while the eastern sector reached its minimum salinity at 60 m in July (38.74) and its maximum at the surface (39.386) in July, as shown in Fig. 3b. The general distribution of the vertical salinity variation off the Egyptian Mediterranean coast revealed that the eastern sector is often of higher salinity than the western sector all over the year and along the 0–150 m depth. Beneath the 150 m depth, the reverse may be observed. The surface mixing layer of homogeneous salinity, affected by surface dynamical processes such as wind, waves, and currents, can be easily detected from the surface up to a depth of 25 m over 12 months.

2.2. Seasonal variations of salinity

Given the monthly fluctuations, we investigated seasonal variations in salinity as well. Fig. 4 shows the seasonal variations in salinity in the two considered sectors of the Egyptian Mediterranean coast. Salinity profiles show significant seasonal fluctuation between the western and eastern sections. Autumn was the season of highest salinity along the Egyptian Mediterranean coast with a mean salinity of 38.954 (west) and 39.078 (east). The mean spring salinity in the two sectors was 38.911. In winter, the mean salinity was 38.875 (west) and 39.010 (east), while in summer it varied between 38.892 (west) and 38.956 (east). Throughout the study, the eastern sector had the highest seasonal salinity values.

2.3. Annual variations of salinity

The overall annual salinity in the western sector was 38.905, while in the eastern sector it was 38.997. The lowest annual salinity was recorded at 60 m depth in the two sectors, with values of 38.797 and 38.930 in the western and eastern sectors, respectively. The maximum annual salinity value, however, was 39.03 (200 m) and 39.07 (20 m) in the western and eastern sectors, respectively, as depicted in Fig. 5. The homogeneous mean surface salinity is still observed in the upper 25 m layer whether in the western or the eastern sector.

2.4. Salinity anomalies

To investigate the salinity anomalies in the area of investigation, six layers were considered to represent the standard depths. These are the 0, 20, 50, 100, 150, and 200 m levels in both the west and east sectors. For each level, the monthly anomaly over the entire period of interest was calculated and represented. Also, the trend of variation over the different months at the different considered levels was examined (Fig. 6). From this figure, it is obvious that there is an upward trend in the monthly salinity anomaly for the upper 50 m in the area of investigation, whether in the western or the eastern sector.

For the 0 and 20 m levels, this increasing trend was negative in the first 6 months followed by positive anomalies in the remaining months. The same increasing trend of variation is still observed in the salinity anomaly at the 50 m level but not uniform as in the 0 and 20 m depths. The trends of the salinity anomalies changed to be of decreasing tendencies at the 100, 150, and 200 m depths. The surface salinity anomaly reached its lowest value of −0.25 in April in the western and eastern sectors, respectively, while the highest anomalies of +0.28 (west) and +0.33 (east) were in November and July, respectively. At 20 m depth, the lowest salinity anomalies of −0.22 (west) and −0.21 (east) occurred in May and April, respectively, while the highest anomalies were +0.31 in September (west) and +0.26 in October (east). The lowest salinity anomaly of −0.19 occurred at the 50 m depth in the western and eastern sectors, respectively, in June and July, while the highest anomalies occurred in November with values of +0.29 (west) and +0.23 (east). At 100 m depth, the lowest salinity anomalies of −0.06 (west) and −0.09 (east) occurred in April and July, respectively, while the highest anomalies occurred in January, of +0.11 and + 0.09 in the western and eastern sectors, respectively. The lowest salinity anomalies were −0.04 in April and −0.06 in May in the western and eastern sectors, respectively, while the highest were +0.04 and + 0.06 in February (west) and June (east). At the 200 m depth, the lowest salinity anomalies

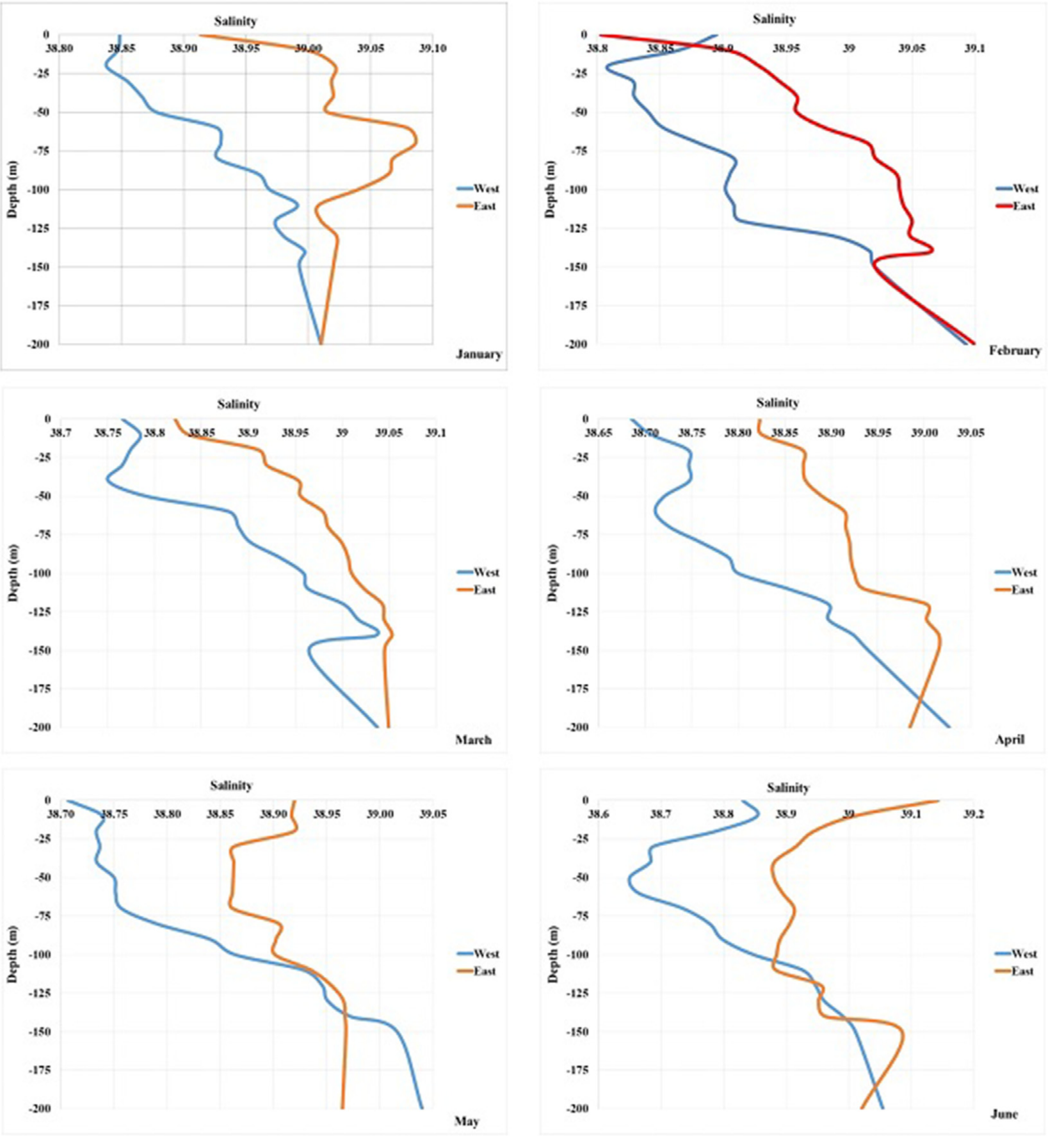


Fig. 3. (a) Monthly variations of salinity in the upper 200 m waters off the Egyptian Mediterranean coast (January–June). (b) Monthly variations of salinity in the upper 200 m waters off the Egyptian Mediterranean coast (July–December).

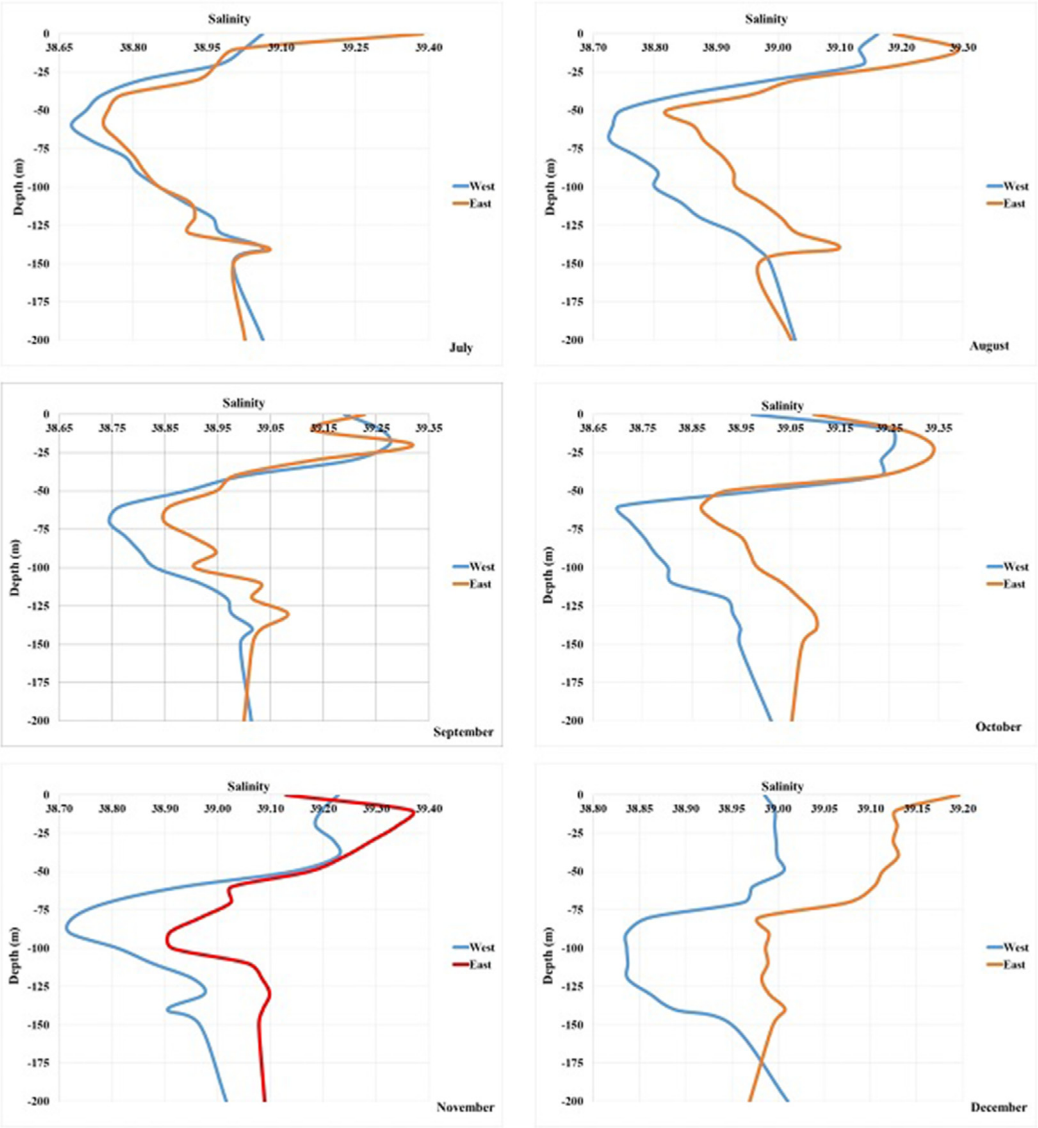


Fig. 3. (Continued).

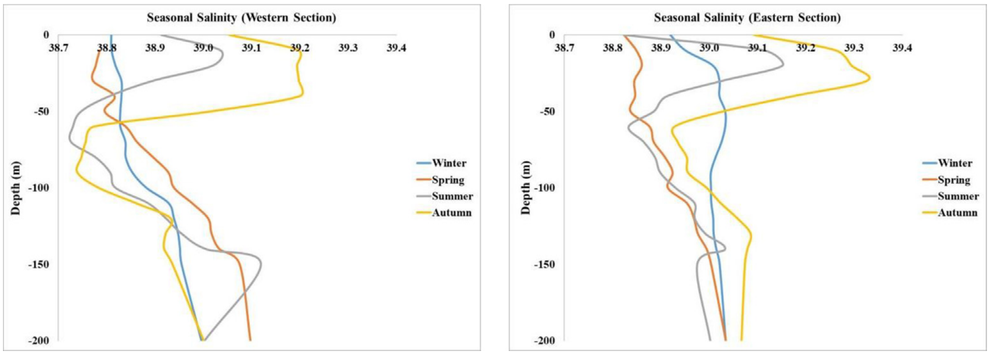


Fig. 4. Seasonal salinity variations off the Egyptian Mediterranean coast.

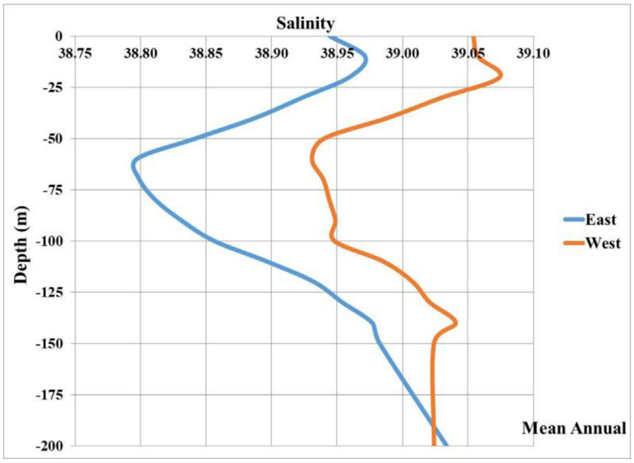


Fig. 5. Mean Annual salinity variations.

were, respectively, −0.02 (west) and −0.06 (east) in January and May, while the highest were, respectively, +0.06 (west) and +0.08 (east).

3. Discussion

Salinity is significant for marine science because fluctuations in salinity can affect physical processes such as climate change, ocean current variations, and water mass formation. From a biological perspective, variations in salinity may pose a threat to marine animals and disrupt their normal functioning. The evolution of seawater salinity off the Egyptian Mediterranean coast is crucial to understanding how changes in this vital physical property may impact the circulation pattern within the Mediterranean basin and the adjacent Atlantic Ocean.

On a monthly basis, the western sector of the Egyptian Mediterranean coast usually has lower salinity than its eastern sector. This is consistent with the intense heating and evaporation, as well as the fact that the Mediterranean Sea's highest salinity and temperature are found in the Levantine Basin (Gertman and Hecht, 2002). The latest eastern salinification seems to be more severe than prior episodes since 2004, as declared by Grodsky et al. (2019) for the eastern Mediterranean basin (general) and off the Egyptian Mediterranean coast (particular). This intense salinification along this coast may be attributed to changes in the Ionian Sea circulation pattern and in the thermohaline structure and volume of freshwater transport along the Cretan Passage, which impact the salinity structure in the Levantine. Another factor, which controls salinity variations in the Levantine Basin, is the variation in its circulation regime induced by the Adriatic−Ionian Bimodal Oscillation System (BiOS) as concluded by Grodsky et al. (2019).

Seasonally, the maximum surface salinity was observed in autumn (September−December) along the two sectors of investigation. This is in agreement with the results of (Gertman and Hecht, 2002) that after the High Dam construction, the seasonal maximum salinity shifted from October to November. Spring was the season of the lowest surface salinity variations whether along the western or eastern Egyptian Mediterranean water depths. This is in agreement with the conclusion of (Serïmözü, 2019) that spring is the season of lowest surface salinity in the Levantine Basin. The formation process of the Levantine Intermediate Water (LIW) during cold winter and spring seasons may justify the lower surface salinity and the higher salinity values in the layers beneath.

Although a multi-decadal Mediterranean salinification trend is typically attributed to corresponding changes in the Mediterranean water cycle depending on evaporation and precipitation (Skliris et al., 2018; Grodsky et al., 2019), shorter-term salinity variations are connected to changes in wind regime and regional circulation (Demirov and Pinardi, 2002; Kruithof, 2018) declared that the Eastern Mediterranean Sea's surface salinity varies as a result of the northeast African monsoon's fluctuation and that vice versa, it is possible to reconstruct the strength of the northeast African monsoon using reconstructions of the eastern Mediterranean Sea's surface salinity (SSS).

Positive trends in the salinity anomaly variations were found in the upper water layer (0−50 m) and then trends changed to negative patterns along the depths of 100, 150, and 200 m. This is in agreement with the results of (Gertman and Hecht, 2002; Maiyza and Kamel, 2010). This, however, contradicts the prolonged anomaly positive trends of up to 150 m water depth concluded by (Grodsky et al., 2019) off the Egyptian Mediterranean coast. This contradiction might be attributed to the difference in the period between the two studies, 2015−2018 in Grodsky et al. (2019) and 1950−2021 in the present study, and the density of the gridded data sets 0.25° × 0.25° (Grodsky et al., 2019) and 1′1° in the present work. Also, the 50 m depth was previously denoted as a depth of a sharp thermocline occurrence, initiating a barrier to vertical mixing and allowing horizontal mixing (Mohamed et al., 1999).

3.1. Conclusion

To conclude, salinity variations off the Egyptian Mediterranean coast, with its two sectors, have monthly and seasonal variations. The depth of 50 m divides the surface and subsurface waters with

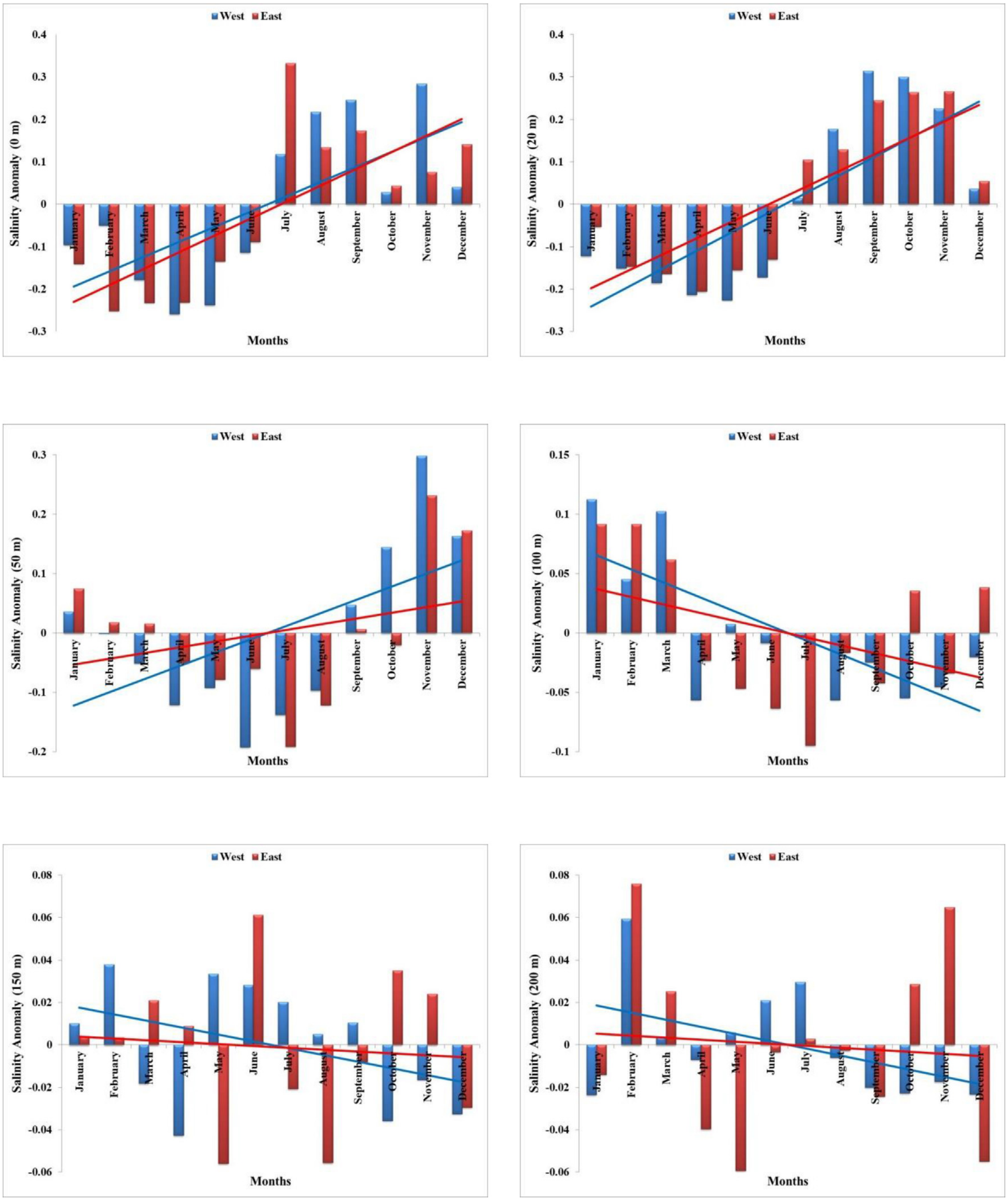


Fig. 6. Monthly salinity anomalies at the standard depths in the area of investigation.

opposite trends observed. Future research should be undertaken based on our qualitative analysis to foresee and model the progression of salinity in the region. Most importantly, the scarcity of data and the clustered structure of data, which is spatially limited and temporally sparse, point to the need for additional scientific expeditions from research institutions to accurately document and predict the forthcoming changes in the physical characteristics off the Egyptian Mediterranean coast. In addition, various variables other than seawater salinity should be examined and measured to provide a more complete picture of the region. Furthermore, the relation between climate change and the salinity variation profile should be calculated to investigate and discuss the impact of climate change on salinity.

Declaration of Competing Interest

None declared.

References

Antonov, J.I., Levitus, S., Boyer, T.P., 2002. Steric sea level variations during 1957-1994: importance of salinity. J. Geophys. Res. 107, 14–18.

Astraldi, M., Gasparini, G.P., Vetrano, A., Vignudelli, S., 2002. Hydrographic characteristics and interannual variability of water masses in the central Mediterranean: a sensitivity test for long-term changes in the Mediterranean Sea. Deep Sea Res. Oceanogr. Res. Pap. 49, 661–680.

Béthoux, J.-P., 1980. Mean water fluxes across sections in the Mediterranean Sea, evaluated on the basis of water and salt budgets and of observed salinities. Oceanol. Acta 3, 79–88.

Boyer, T.P., Levitus, S., Antonov, J.I., Locarnini, R.A., Garcia, H.E., 2005. Linear trends in salinity for the World Ocean, 1955–1998. Geophys. Res. Lett. 32, L01604.

Bunker, A.F., Charnock, H., Goldsmith, R.A., 1982. A note on the heat balance of the Mediterranean and Red Seas. J. Mar. Res. 40, 73–84.

Cullum, J., Stevens, D.P., Joshi, M.M., 2016. Importance of ocean salinity for climate and habitability. Proceedings of National Academy Science, USA 113, 4278–4283.

Demirov, E., Pinardi, N., 2002. Simulation of the Mediterranean Sea circulation from 1979 to 1993: Part I. The interannual variability. J. Mar. Syst. 33 (34), 23–50.

El-Geziry, T.M., Maiyza, I.A., Kamel, M.S., 2019. Salinification in the southeastern Mediterranean Sea. JKAU: Mar. Sci. 29, 1–12.

El-Geziry, T.M., Said, M.A., 2020. Spatial variations of sea level along the Egyptian mediterranean coast. Athens Journal of Mediterranean Studies 6, 141–154.

Fedorov, A.V., Pacanowski, R.C., Philander, S.G., Boccaletti, G., 2004. The Effect of salinity on the wind-driven circulation and the thermal structure of the upper ocean. J. Phys. Oceanogr. 34, 1949–1966.

Gertman, I., Hecht, A., 2002. Annual and long-term changes in the salinity and the temperature of the waters of the Southeastern Levantine Basin. The CIESM Workshop Series n°16, 75–78. Monaco.

Grodsky, S.A., Reul, N., Bentamy, A., Vandemark, D., Guimbard, S., 2019. Eastern Mediterranean salinification observed in satellite salinity from SMAP mission. J. Mar. Syst. 198, 103190.

Kruithof, L., 2018. Unlocking the Eastern Mediterranean Sea Salinity History for the Last 350.000 Years. M.Sc. Thesis, Utrecht University, Netherlands.

Lagerloef, G.S.E., 2002. Introduction to the special section: the role of surface salinity on upper ocean dynamics, air-sea interaction and climate. J. Geophys. Res. 107. SRF 1-1–SRF 1-2.

Lejeusne, C., Chevaldonné, P., Pergent-Martini, C., Boudouresque, C.F., Pérez, T., 2010. Climate change effects on a miniature ocean: the highly diverse, highly impacted Mediterranean Sea. Trends Ecol. Evol. 25, 250–260.

Levitus, S., 1986. Annual cycle of salinity and salt storage in the World Oceans. J. Phys. Oceanogr. 16, 322–343.

Maiyza, I., Kamel, M.S., 2010. Climatological trend of sea surface salinity anomalies in the south eastern Mediterranean Sea. JKAU: Mar. Sci. 21, 63–72.

Manca, B., Burca, M., Giorgetti, A., Coatanoan, C., Garcia, M.-J., Iona, A., 2004. Physical and biochemical averaged vertical profiles in the Mediterranean regions: an important tool to trace the climatology of water masses and to validate incoming data from operational oceanography. J. Mar. Syst. 48, 83–116.

Millot, C., Candela, J., Fuda, J.-L., Tber, Y., 2006. Large warming and salinification of the Mediterranean outflow due to changes in its composition. Deep Sea Res. Oceanogr. Res. Pap. 53, 656–666.

Mohamed, E.E.E., El-Sharkawy, M.S., Saad, N.N., Anwar, H., 1999. A study of circulation, water masses and mixing processes in the southeastern Mediterranean off the Egyptian Coast during winter. JKAU: Mare Sciences 10, 3–15.

Nacef, L., Bachari, N.E.I., Bouda, A., Boubnia, R., 2016. Variability and decadal evolution of temperature and salinity in the Mediterranean sea surface. International Journal of Engineering and Geosciences 1, 20–29.

Paturej, E., Gutkowska, A., 2015. The effect of salinity levels on the structure of zooplankton communities. Arch. Biol. Sci. 67, 483–492.

Potter, R.A., 2004. On the warming and salinification of the Mediterranean outflow waters in the North Atlantic. Geophys. Res. Lett. 31, L01202.

Reid, J.L., 1979. On the contribution of the Mediterranean Sea outflow to the Norwegian-Greenland sea. Deep-Sea Res., Part A 26, 1199–1223.

Rixen, M., Beckers, J.-M., Levitus, S., Antonov, J., Boyer, T., Maillard, C., et al., 2005. The western mediterranean deep water: a proxy for climate change. Geophys. Res. Lett. 32, L12608.

Rohling, E.J., Bryden, H.L., 1992. Man-induced salinity and temperature increases in western mediterranean deep water. J. Geophys. Res. 97, 11191–11198.

Said, M.A., 1990. Horizontal circulation of the Eastern Mediterranean waters during winter and summer seasons. Acta Adriat. 31, 5–21.

Sharaf El-Din, S.H., El-Gindy, A., 1987. Characteristics, spreading and mixing of the intermediate water masses and their seasonal variations in the Eastern Mediterranean. Acta Adriat. 28, 45–58.

Skliris, N., Lascaratos, A., 2004. Impacts of the Nile River damming on the thermohaline circulation and water mass characteristics of the Mediterranean Sea. J. Mar. Syst. 52, 121–143.

Skliris, N., Zika, J.D., Herold, L., Josey, S.A., Marsh, R., 2018. Mediterranean sea water budget long-term trend inferred from salinity observations. Clim. Dynam. 51, 2857–2876.

Sun, X., Zhang, H., Wang, Z., Huang, T., Huang, H., 2023. Phytoplankton community response to environmental factors along a salinity gradient in a seagoing river, tianjin, China. Microorganisms 11, 75.

Tsimplis, M.N., Baker, T.F., 2000. Sea level drop in the Mediterranean Sea: an indicator of deep water salinity and temperature changes? Geophys. Res. Lett. 27, 1731–1734.

Tukenmez, E., Altiok, H., 2022. Long-term variations of air temperature, SST, surface atmospheric pressure, surface salinity and wind speed in the Aegean Sea. Mediterr. Mar. Sci. 23, 668–684.

Vilibić, I., Orlić, M., 2001. Least-squares tracer analysis of water masses in the South Adriatic (1967–1990). Deep Sea Res. Oceanogr. Res. Pap. 48, 2297–2330.

Wang, Y., Jiang, X., Li, Y.-L., Yang, L.-J., Li, Y.-H., Liu, Y., et al., 2023. Interactive effects of nutrients and salinity on phytoplankton in subtropical plateau lakes of contrasting water depths. Water 15, 69.

Wu, P., Haines, K., 1996. Modeling the dispersal of Levantine Intermediate Water and its role in the Mediterranean deep water formation. J. Geophys. Res. 101, 6591–6607.

Zhao, X., Gui, F., Mantravadi, V.S., Wang, L., 2018. Salinity variations over zhejiang province waters, China. OALib 5, 1–11.