Egyptian Journal of Aquatic Biology & Fisheries
Zoology Department, Faculty of Science,
Ain Shams University, Cairo, Egypt.
ISSN 1110 – 6131
Vol. 28(4): 2011 – 2023 (2024)
www.ejabf.journals.ekb.eg

Monitoring and Predicting Potential Fishing Grounds of *Trachurus mediterraneus* Using Remotely Sensed Data Along the North Sinai Coastal Zone, Egypt

Mohammad A. El-Gharbawy[1*], Samy A. Saber[1], Amr F. Zeina[1], Mohamed E. El-Raey[2]

[1]Zoology Department, Faculty of Science, Al-Azhar University, Cairo, Egypt
[2]Department of Environmental Studies, Institute of Graduate Studies and Research (IGSR), Alexandria University, Alexandria, Egypt

Corresponding Author: m_algharabawy@yahoo.com, mohammad-elgharbawy.201@azhar.edu.eg

ARTICLE INFO

Article History:
Received: Aug. 5, 2024
Accepted: Aug. 21, 2024
Online: Aug. 25, 2024

Keywords:
Chlorophyll-a,
Sea surface temperature,
Potential fishing zone,
Trachurus mediterraneus,
North Sinai

ABSTRACT

The Mediterranean horse mackerel, *Trachurus mediterraneus*, is the second most important species, economically and yield contributory, in the North Sinai fisheries after *Sardinella aurita*. Although the fishing grounds constantly change due to environmental factors, the fishing activities are still based on traditional methods; therefore, determining the Potential Fishing Zones (PFZs) must depend on effective and advanced techniques to monitor the optimal PFZs for *T. mediterraneus* along the North Sinai Coastal Zone. This study integrates the Sentinel-3 satellite's remotely sensed data, advanced digital imagery processing techniques, and fish yield data obtained from the General Authority for Fish Resources Development (GAFRD) for *T. mediterraneus* in the North Sinai fisheries during 2021 to build a suitable model for determining, monitoring, and predicting the other optimal (PFZs) for *T. mediterraneus* along the North Sinai Coastal Zone. The results confirmed that, regarding the total catch of *T. mediterraneus* in 2021, the highest catch reached 1.4 and 1.3 tons in June and July, respectively, while the lowest catch reached 0.14 tons in January. The predicted PFZs were estimated to be 6 times more than the fishing grounds that fishermen currently fish; moreover, the predicted annual production for *T. mediterraneus* was about 4.6 times the actual production. Furthermore, the North Sinai fisheries were not fully exploited due to the mis-determination of optimal PFZs and undeveloped fishing gears. This study highlights the importance of using remotely sensed data to help increase the national income from the fisheries sector by determining and predicting new fishing zones.

INTRODUCTION

The North Sinai coastline extends about 220km **(Hereher, 2013; Omran & Negm, 2020)**, about one-fifth of the Egyptian Mediterranean coastline. However, the North Sinai fishing grounds yields constitute only 6 % of the total Egyptian Mediterranean fisheries yields **(GAFRD, 2017)**. Even though this area has a high depth and a high biodiversity level, the fleet vessels exploit inshore fishing grounds only **(Papaconstantinou & Farrugio, 2000)** due to the traditional experiential methods the fishermen still use to determine the fishing grounds; therefore, the North Sinai fisheries yields are less than optimal because of the mis-determination of the optimal fishing grounds.

The fishing grounds are constantly changing due to several environmental factors **(Palacios *et al.*, 2006)** that serve as controlling attributes to fisheries and greatly influence fish abundance and distribution in fishing grounds **(Zainuddin, 2007)**. However, Chlorophil-a (Chl-a) and Sea Surface Temperature (SST) represent the mainly critical oceanographic parameters that serve as controlling attributes to fisheries **(Solanki *et al.*, 2003)** since Chl-a is the primary parameter that significantly determines the marine ecosystem productivity and is a typical phytoplankton biomass index, which is firmly related to fish production **(Solanki *et al.*, 2003)**. Moreover, SST is a marine physical ecosystem index that directly impacts marine living organisms and explicitly controls phytoplankton growth and distribution **(Tang *et al.*, 2003)**.

The integration between Chl-a and SST was found to be effective in monitoring fishing grounds and determining the optimum Potential Fishing Zones (PFZs), which represent a significant challenge for fishermen using traditional methods **(Solanki *et al.*, 2003)**. Therefore, determining the PFZs using advanced technologies based on remotely sensed data becomes necessary. The satellite remote sensing has been globally used in detecting and monitoring the PFZs using specific environmental parameters (Chl-a, SST, and productivity data), as discussed in many studies **(Solanki *et al.*, 2003; Lanz *et al.*, 2009; Zainuddin & Jamal, 2009; Mustapha *et al.*, 2010; Zainuddin, 2011; Ali *et al.*, 2022)**.

Furthermore, the suitability models prove more effective in predicting the spatial distribution of fisheries by defining the suitable bio-environment conditions of particular species fishing grounds **(Hirzel *et al.*, 2006; Jędrzejewski *et al.*, 2008; Zorn *et al.*, 2012)**.

The Mediterranean horse mackerel, *Trachurus mediterraneus*, is the second most important species, economically and yield contributory, in the North Sinai fisheries after *Sardinella aurita* **(EL-Aiatt, 2004; Mehanna & Salem, 2011)**. Some studies considered *T. mediterraneus* in the Egyptian Mediterranean fisheries. For instance, **EL-Aiatt (2004)** studied quantities and varieties of fish production in North Sinai and stated that *T. mediterraneus* represents the second most yield contributory fish with about 2% of North Sinai's total catch; another study conducted by **Mehanna and Salem (2011)** studied the monthly population dynamics of *T. mediterraneus* on the El-Arish coast in 2008 and 2009.

This study aimed to monitor and predict the optimal PFZs for *Trachurus mediterraneus* along the North Sinai Coastal Zone by integrating the Sentinel-3 satellite data with Geographic Information System (GIS) modeling techniques and fish yield data obtained from GAFRD for *T. mediterraneus* in the North Sinai fisheries during 2021 to build a suitable model for monitor and predict *T. mediterraneus*.

MATERIALS AND METHODS

1. Study area

The North Sinai Governorate is located north of the Sinai Peninsula, northeast of Egypt. The North Sinai coastal zone extends for about 220km along the Mediterranean Sea, from Port Said in the west to the Egyptian border at Rafah in the east. The study area is located between longitudes 32° 33' E and 34° 22' E, and latitudes 31° 04' N and 31° 34' N, extends offshore for at the most 70km in the Mediterranean Sea, with about 4677.3km^2 of area, as shown in Fig. (1).

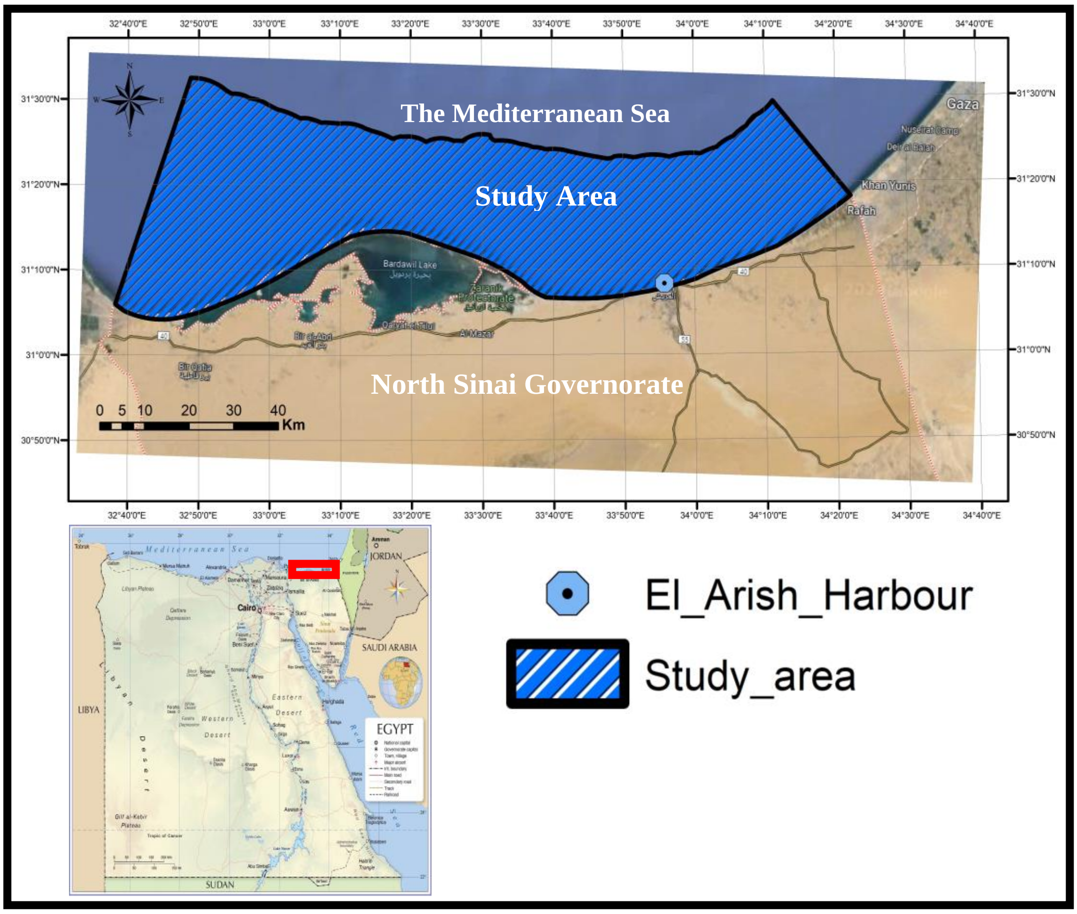

Fig. 1. A map of Egypt showing the study area

2. Data acquisition

2.1. Satellite data

The present study employed daily images of level-2 satellite data from the Sentinel-3 satellite for each parameter of (Chl-a and SST) throughout 2021. The chlorophyll-a (Chl-a) concentration was derived from the ocean and land color instrument (OLCI) with 300m spatial resolution. In contrast, the sea surface temperature (SST) data were derived from The Sea and Land Surface Temperature Instrument (SLSTR), with 1km spatial resolution. The Sentinel-3 data were obtained from The Copernicus Open Access Hub at Level-2 (https://dataspace.copernicus.eu/). The Chl-a and SST data were acquired throughout 2021 to determine and predict the optimal PFZs for *T. mediterraneus* along the North Sinai Coastal Zone. Given that the Sentinel-3-based technique for detecting potential fishing zones (using the integration of chlorophyll-a and sea surface temperature) has provided highly accurate results **(Ali *et al.*, 2022)**, it is confirmed that the detection of PFZs is strongly related to this integration. The Chl-a and SST daily data were monthly averaged and georeferenced using the SNAP toolbox software version 10.0 for Windows. The data cropping (to the study area), modeling, and post-processing were implemented using ArcGIS software version 10.4 for Windows.

2.2. Field survey

Four field surveys were undertaken in El-Arish fishing harbor in March, June, September, and December 2021. Fishermen were interviewed and filled out a pre-designed questionnaire to collect all required data about different fleet types, *T. mediterraneus* catch, and the fishing grounds locations where fishermen engage in their fishing activities. The actual fishing grounds extend from the west side of El-Arish fishing harbor to the Bardawil Lake Strait No. I, with about 560km^2 with 63 catch points. Fishing operations mainly used trammel nets and purse seines nets.

2.3. Ancillary data

The GAFRD published The Fish Statistics Yearbook in Egypt in 2021 via the Central Agency for Public and Mobilization and Statistics (CAPMAS) website, which provided the Egyptian Mediterranean monthly fish production statistical data. The monthly quantities of *T. mediterraneus* in the study area were used to create a reliable database for *T. mediterraneus* catch, integrate it with the field survey outputs, and correlate it with *T. mediterraneus in-situ* mapping. The North Sinai monthly production and quantities of *T. mediterraneus* are shown in Table (1).

Table 1. The monthly production (Ton) of *Trachurus mediterraneus* from the North Sinai coastal zone during 2021

Month	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**June**	**July**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**total**
Trachurus sp. **Catch (ton)**	0.14	0	0	1.1	1.3	1.4	1.3	0.9	0.8	0.6	0.4	0.3	8.24

Source: Author’s calculations using **GAFRD (2021)** data of **CAPMAS (2023)**.

3. Model suitability for *Trachurus mediterraneus*

Suitability models have proven highly efficient in predicting the distribution of specific species based on their suitable environmental conditions **(Hirzel *et al.*, 2006; Jędrzejewski *et al.*, 2008; Zorn *et al.*, 2012)**. The suitable values for *T. mediterraneus* were determined at 0.47 – 9.76mg/ m^3 for Chl-a concentration and at 13.2 – 21.5°C for SST values. The suitability values for *T. mediterraneus* were determined according to different approaches that defined suitable Chl-a and SST values for *T. mediterraneus* **(Fishbase, 2019; Nasri *et al.*, 2024)**.

4. Map and model the potential fishing zones for *Trachurus mediterraneus*

The integration between the suitable environmental conditions of Chl-a and SST for *Trachurus mediterraneus* actual fishing zones, the field data obtained from the fishermen's questionnaires, and the statistical data of fish production obtained from GAFRD led to mapping the actual fishing zones for *T. mediterraneus*. Moreover, the resulting fishing zones were converted into a spatial geographical layer for post-processing operations and analysis. Using the ArcGIS modeler tool, a model was built to detect other regions with similar environmental conditions of *T. mediterraneus*. A similar potential fishing zones model has been provided and confirmed for *Sardinella aurita* by **Ali *et al.* (2022)**.

RESULTS AND DISCUSSION

1. The monthly total catch of *Trachurus mediterraneus*

In this study, the monthly catch of *T. mediterraneus* along the North Sinai fisheries from January to December 2021 showed that fishing operations extended almost through the year except the period from January 15th to March 31st, 2021, as a seasonal closure for fishing, based on an administrative decision by GAFRD. Our results agreed with **Mehanna and Salem (2011)** results that fishing operations in the El-Arish water run all over the year; moreover, regarding seasonal fishing closures, the present study results matched those of **Samy-Kamal (2015, 2020)**, who mentioned that the seasonal closure during the spawning seasons is executed each year as a management strategy to stop overfishing in Egypt.

In this study, the monthly catch of *T. mediterraneus* varied based on SST since the Chl-a concentrations were suitable for *T. mediterraneus* abundance throughout the year. The monthly catch of *T. mediterraneus* reached the highest production during the spring and summer months, reaching 1.3 and 1.4 tons in May and June, respectively, then decreased gradually until it reached the lowest catch during the winter months, as shown in Fig. (2).

Our results are in parallel with a large body of literature on the monthly catch of *T. mediterraneus* in North Sinai waters, which concluded that the monthly highest catch was recorded during the summer months, while the monthly lowest catch was obtained during the winter months **(Faltas, 1983; Mehanna & Salem, 2011; Desouky, 2012)**.

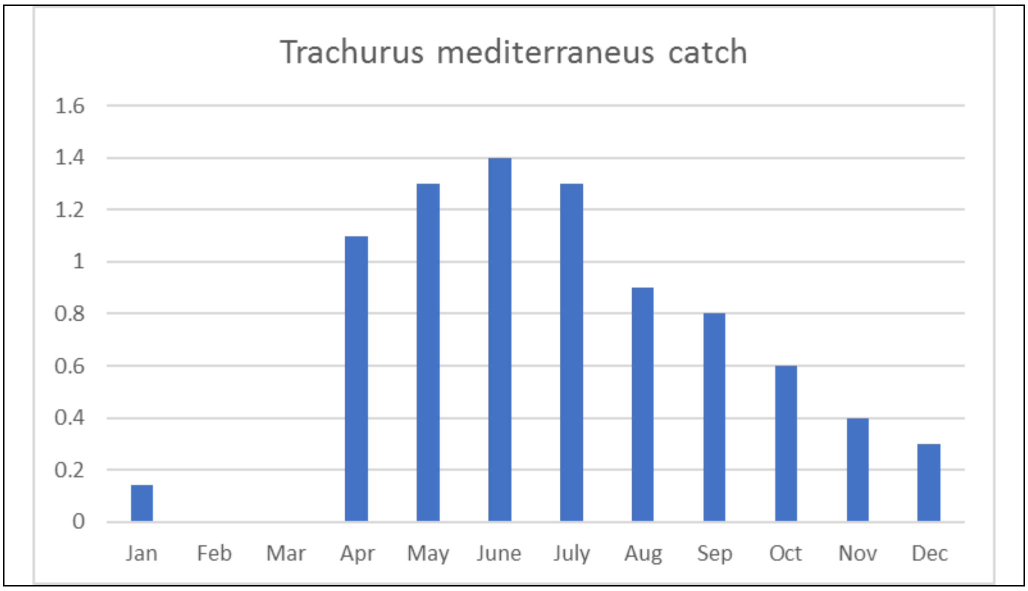

Fig. 2. The monthly total catch (Ton) of *Trachurus mediterraneus* in 2021

2. The monthly variations of targeted environmental parameters (Chl-a and SST)

2.1. The monthly variations of chlorophyll-a (Chl-a) concentrations

In this study, the average monthly variations of Chl-a concentrations obtained from Sentinel-3 data during 2021 months showed that Chl-a concentrations were highly variated and distributed along and near the coast, but the monthly average values vary wildly. However, the highest maximum and the highest minimum values of Chl-a concentration were 21.6 and 2.4mg/ m^3, respectively, and were recorded in March, while the lowest maximum and the lowest minimum values of Chl-a concentration were 7.5 and 1.01mg/ m^3, respectively, and were recorded in December, as shown in Table (2).

Our results agreed with the previous studies in the region, which confirmed that North Sinai Mediterranean waters have high depth and sufficient level of biological productivity; therefore, the fishing runs all over the year **(EL-Aiatt, 2004; Mehanna & Salem, 2011)**. Moreover, the higher Chl-a values in water, the more fertile the water is because Chl-a is the primary food source for fish **(Daris *et al.*, 2021; Putri *et al.*, 2021)**. However, fishing grounds are not only determined by the Chl-a values in water since SST directly impacts marine living organisms and explicitly controls phytoplankton growth and fish distribution **(Tang *et al.*, 2003; Kassi *et al.*, 2018)**.

2.2. The monthly variations of sea surface temperature (SST)

In this study, the average monthly variations of SST obtained from Sentinel-3 data during 2021 months showed that the highest maximum and minimum values of SST were 31.5 and 29°C, respectively, and were recorded in August, while the lowest maximum and minimum values of SST were 19 and 12°C, respectively, and were recorded in February, as shown in Table (2).

Our results are close to those of **Ali *et al.* (2022)**, who worked on the Mediterranean Sea and mentioned that the highest SST was recorded in August, while the lowest SST was recorded in winter months; however, there are little variations in the SST values between the two studies, which could be due to the large scale that **Ali *et al.* (2022)** were working on the Mediterranean Sea that leads to some variations when producing the average SST of that large area, while the present study is targeting the North Sinai coastal zone (which is much smaller); moreover, **Ali *et al.* (2022)** used Moderate Resolution Imaging Spectroradiometer (MODIS) data while the present study used Sentinel-3 satellite data. The SST variations enhance the upwelling movement, which is essential in determining fishing grounds since fish in the region migrate from cooler to warmer grounds; thus, SST controls fish presence and distribution **(Kassi *et al.*, 2018; Paillin *et al.*, 2020)**.

Table 2. Data of the monthly variations (minimum and maximum of Chlorophyll-a (mg/m3) and sea surface temperature (ºC)

Month		Chl-a (mg/m^3)	SST (°C)
January	Min	1.8	12.6
	Max	12.4	21.5
February	Min	1.1	12
	Max	9.3	19
March	Min	2.4	15
	Max	21.6	24
April	Min	1.2	17
	Max	8	24
May	Min	1.1	20
	Max	8.9	27
June	Min	1.2	25
	Max	9.8	28
July	Min	1.2	28
	Max	9.2	31
August	Min	1.1	29
	Max	11.3	31.5
September	Min	1.2	27
	Max	14	29
October	Min	1.2	23
	Max	9.4	28
November	Min	1.6	19
	Max	8.1	27
December	Min	1.01	12
	Max	7.5	26

Chl-a: Chlorophyll-a; SST: Sea Surface Temperature.

3. The monthly spatial distribution of *Trachurus mediterraneus* potential fishing zones

In this study, the monthly (actual and potential) spatial distribution maps of *T. mediterraneus* fishing grounds confirmed that *T. mediterraneus* fishing grounds were significantly affected by the values of Chl-a and SST in the fishing grounds, where the suitable values for *T. mediterraneus* were determined at 0.47 – 9.76mg/ m^3 for Chl-a concentration and at 13.2 – 21.5°C for SST values based on previous studies that studied the correlation between *T. mediterraneus* fishing ground and environmental parameters and determined the suitable values of Chl-a and SST for *T. mediterraneus* fishing grounds as applied in our study **(Fishbase, 2019; Nasri *et al.*, 2024)**.

In this study, the monthly PFZ areas for *T. mediterraneus* varied greatly. The maximum potential fishing areas for *T. mediterraneus* were reached in June (3,484km^2), July (3,476km^2), and May (3,264km^2) due to SST values being optimal for *T. mediterraneus* abundance. These areas then gradually decreased, reaching the lowest catch during the winter months when SST values dropped below the suitable range for *T. mediterraneus*. However, Chl-a concentrations remained favorable for *T. mediterraneus* abundance throughout the year. Table (3) presents the monthly actual and predicted catch for *T. mediterraneus*, along with the corresponding fishing ground areas for 2021. The mapping of the monthly actual and potential fishing grounds is illustrated in Fig. (3).

Table 3. The monthly actual and predicted values for *Trachurus mediterraneus* catch (Ton) and fishing ground areas (Km^2) in 2021

Month	Actual		Predicted	
	Catch (ton)	Area (Km^2)	Catch (ton)	Area (Km^2)
January	0.14	560	0.23	920
February	0	560	0	352
March	0	560	0	1568
April	1.1	560	4.6	2348
May	1.3	560	7.6	3264
June	1.4	560	8.7	3484
July	1.3	560	8.1	3476
August	0.9	560	4.2	2644
September	0.8	560	1.9	1340
October	0.6	560	1.3	1208
November	0.4	560	0.8	1164
December	0.3	560	0.6	1128
Total	8.24	560	38.03	3484

In this study, the PFZ prediction maps showed a wide spatial distribution of suitable fishing grounds for *T. mediterraneus* along the near-coast of the North Sinai coastal zone; moreover, the potential new fishing ground areas ranged between 920Km^2 in January and 3484Km^2 in June, the predicted fishing grounds are 6 times larger than that of actual fishing grounds. To our knowledge, this study is the first one that aims to map and predict *T. mediterraneus* fishing grounds using remotely sensed approach along the North Sinai coast; however, a recent study conducted by **Naguib *et al.* (2022)** on Sardinellas-nei's fishing zones along the Red Sea in 2018 mentioned that the predicted new fishing areas were estimated to be 7 times more than the actual fishing sites area; anyhow, the latter study was conducted in a different sea with a different fish type and with a different remotely sensed approach.

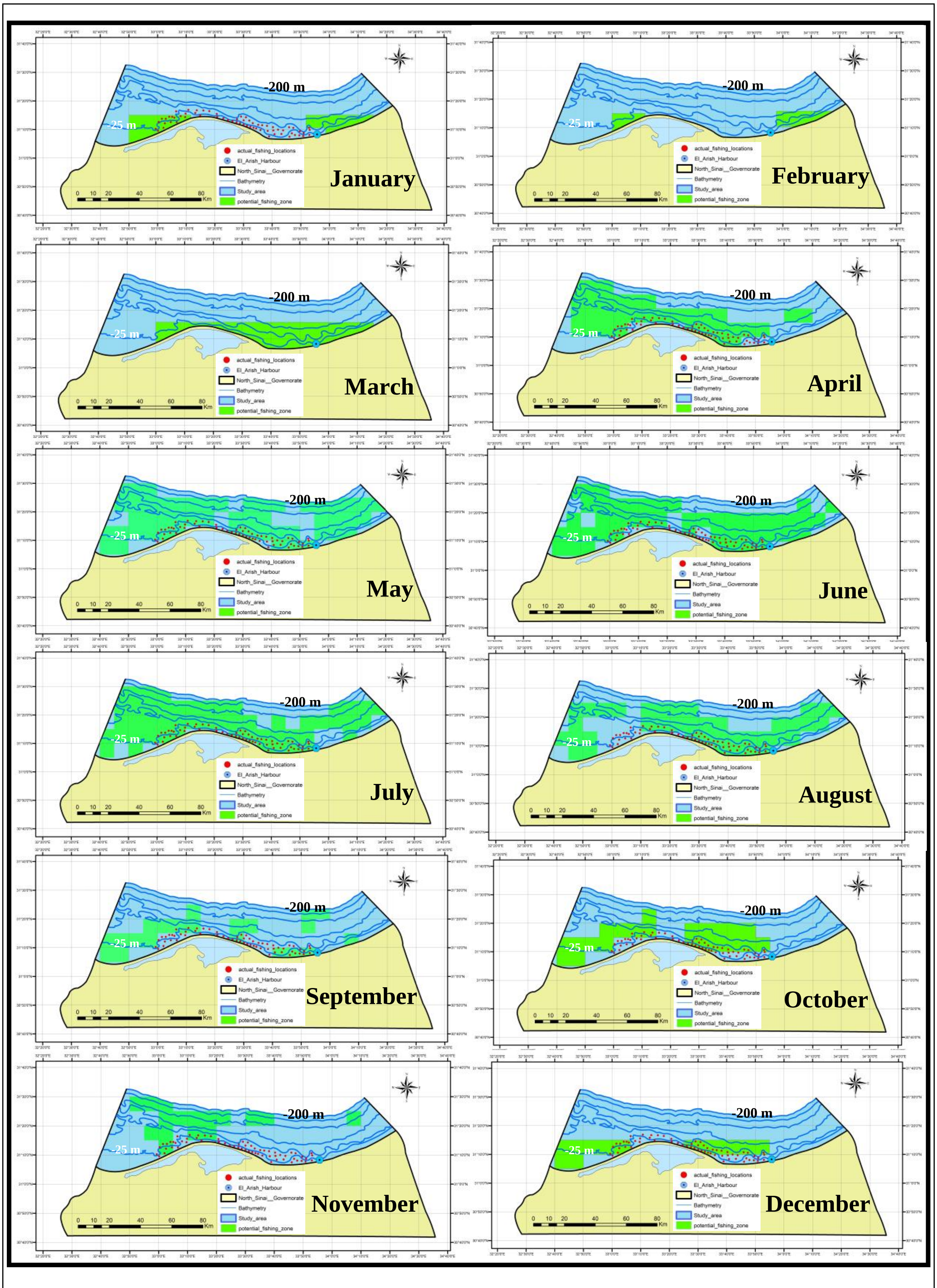

Fig. 3. Monthly actual and predicted map of potential fishing zones for *Trachurus mediterraneus* over 2021 (January – December)

This study revealed that fishing operations are concentrated in shallow waters, between 1 and 25 meters deep, primarily due to the use of trammel nets (locally known as DABBA, with a maximum net depth of 3 meters) and purse seine nets (locally known as CHNCHOLLA, with a maximum net depth of 25 meters). Our findings align with a substantial body of literature on the dominant fishing gears used in the Egyptian Mediterranean Sea, which concludes that North Sinai fisheries are exploited by three main fishing gears: purse seine nets, trammel nets, and longline gear **(EL-Aiatt, 2004; Faltas, 1983; Mehanna & Haggag, 2010)**.

Based on this study's maps and field survey data, it was found that the actual fishing grounds extend from the west side of the El-Arish fishing harbor to Bardawil Lake Strait No. I. There are no commercial fishing operations on the eastern side of the El-Arish fishing harbor, which extends from the east side of the harbor to the Egyptian border at Rafah. This limitation on the fishing area is due to security reasons, as it involves protecting the Egyptian borders and the lives of Egyptian fishermen, as mentioned in **Desouky (2012)**.

CONCLUSION

This study achieved a suitability model for determining and predicting the optimal potential fishing grounds for *Trachurus mediterraneus* along the North Sinai fisheries based on the multidisciplinary integration of the suitable Chl-a and SST parameters derived from Sentinel-3 satellite data, field survey outcomes, ancillary data obtained from GAFRD, and GIS model builder.

This study indicated that the optimal potential fishing grounds for *Trachurus mediterraneus* are distributed along the North Sinai fisheries and concentrated near the inshore. The PFZs produced maps revealed that the PFZs for *Trachurus mediterraneus* are about 6 times the actual fishing ground determined by fishermen's traditional methods; moreover, the predicted annual production for *Trachurus mediterraneus* was about 4.6 times the actual production. The PFZs monthly maps confirmed that the *Trachurus mediterraneus* distribution and abundance are affected more by the SST variations since the Chl-a values were relatively suitable throughout the year. This PFZ model can be applied successfully to other fish species and marine organisms. This approach provides near-real-time robust information to help fishermen, researchers, decision-makers, and stockholders. The North Sinai fisheries are not fully exploited due to the mis-determination of optimal potential fishing grounds and undeveloped fleets and fishing gears.

ACKNOWLEDGMENT

The authors would like to thank the General Authority for Fish Resources Development (GAFRD) for reporting The Fish Statistics Yearbook in Egypt in 2021. Thanks to the Central Agency for Public and Mobilization and Statistics (CAPMAS) for publishing The Fish Statistics Yearbook in Egypt in 2021 via the website. The authors would like to thank Naglaa Atwa Zanaty (Assistant Researcher in the Department of Environmental Studies, The National Authority for Remote Sensing and Space Sciences) for her technical support in the model analyses. The authors would also like to thank Professor Wesam M. A. Ibrahim, Professor of linguistics and English language, Tanta University, for language revisions.

REFERENCES

Ali, E.M.; Zanaty, N. and **Abou El-Magd, I. (2022).** Potential efficiency of earth observation for optimum fishing zone detection of the pelagic Sardinella aurita species along the Mediterranean coast of Egypt. *Fishes*, **7**(3): 97. https://doi.org/10.3390/fishes7030097.

CAPMAS (2023). **Central Agency for Public Mobilization and Statistics:** Annual Bulletin of Statistics Fish Production of 2021from **GAFRD (2021), General Authority for Fish Resources Development**. Retrieved from https://censusinfo.capmas.gov.eg/metadata-ar-v4.2/index.php/catalog/1832/download/6549. Last accessed on July 30, 2024.

Daris, L.; Jaya, J. and **Massiseng, A.N.A. (2021).** Mapping of fishing area (Euthynnus affinis) GIS based in Bone's Bay Waters. *Akuatikisle: Jurnal Akuakultur, Pesisir dan Pulau-Pulau Kecil*, **5**(2): 29-34. https://doi.org/10.29239/j.akuatikisle.5.2.29-34

Desouky, M.G. (2012). Studies on the Mediterranean basin fish production in North Sinai Governorate. Thesis, PhD, Faculty of Environmental Agricultural Sciences, Suez Canal University.

EL-Aiatt, A.A.O. (2004). Study on fish production of the Mediterranean coast of Sinai. Thesis, PhD, Faculty of Environmental Agricultural Sciences, Suez Canal University.

Faltas, S.N. (1983). *Study of purse-seine fisheries in Egyptian Mediterranean waters with special reference to the biology of Sardine in the catch* (Doctoral dissertation, Faculty of Science, Alexandria University).

Fishbase. (2019). World Wide Web electronic publication. *http://www.fishbase.org*.

GAFRD (2017). Fish statistics year book, General Authority for Fish Resources Development. Egypt, 116pp.

Hereher, M.E. (2013). Coastal vulnerability assessment for Egypt's Mediterranean coast. *Geomatics, Natural Hazards and Risk*, **6**(4): 342–355. https://doi.org/10.1080/19475705.2013.845115.

Hirzel, A.H.; Le Lay, G.; Helfer, V.; Randin, C. and **Guisan, A. (2006).** Evaluating the ability of habitat suitability models to predict species presences. *Ecological modelling*, **199**(2): 142-152. https://doi.org/10.1016/j.ecolmodel.2006.05.017.

Jędrzejewski, W.; Jędrzejewska, B.; Zawadzka, B.; Borowik, T.; Nowak, S. and **Mysłajek, R.W. (2008).** Habitat suitability model for Polish wolves based on long-term national census. *Animal Conservation*, **11**(5): 377-390. https://doi.org/10.1111/j.1469-1795.2008.00193.x.

Kassi, J. B.; Racault, M.F.; Mobio, B.A.; Platt, T.; Sathyendranath, S.; Raitsos, D.E. and **Affian, K. (2018).** Remotely sensing the biophysical drivers of *Sardinella aurita* variability in Ivorian waters. *Remote Sensing*, **10**(5): 1-27. https://doi.org/10.3390/rs10050785

Lanz, E.; Nevarez-Martinez, M.; López-Martínez, J.U.A.N.A. and **Dworak, J.A. (2009).** Small pelagic fish catches in the Gulf of California associated with sea surface temperature and chlorophyll. *CalCOFI Rep*, **50**: 134-146.

Mehanna, S.F. and **Haggag, H.M. (2010).** Port Said fisheries: Current status, assessment and management. Proc. Of the 3rd global fisheries and Aquaculture Research

Conference. Foreign Agricultural Relations (FAR), Egypt, 29th Nov.- 1st Dec., pp. 289-303.

Mehanna, S.F. and **Salem, M. (2011).** Population dynamics of round sardine *Sardinella aurita* in El-Arish waters, southeastern Mediterranean, Egypt. *Indian Journal of Fundamental and Applied Life Sciences*, **1**(4): 286-294.

Mustapha, A.M.; Chan, Y.L. and **Lihan, T. (2010).** Mapping of potential fishing grounds of *Rastrelliger kanagurta* (Cuvier, 1871) using satellite images. *Map Asia*, 1-9.

Naguib, D.; Aziz, M.A.; Hashem, S. and **El-Kafrawy, S. (2022).** Using remote sensing techniques to determine environmental characteristics for Sardinellas-nei in Red Sea, Egypt. In *International Conference of Remote Sensing and Space Sciences Applications* (pp. 359-366). Cham: Springer Nature Switzerland.

Nasri, H.; Sabbahi, R.; Abdellaoui, S.; Kasmi, K.; Omari, A.; Azzaoui, K.; Melhaoui, R.; Chafi, A.; Hammouti, B. and **Chaabane, K. (2024).** Ecology, Anatomy, Reproduction, and Diet of the Atlantic Horse Mackerel, *Trachurus trachurus*: A Comprehensive Review. *Egyptian Journal of Aquatic Biology & Fisheries*, **28**(3): 517-539. https://doi.org/10.21608/ejabf.2024.358854.

Omran, E.S.E. and **Negm, A.M. (2020).** Egypt's environment from satellite. *Environmental remote sensing in Egypt*, pp.: 23-91. Springer, Cham. https://doi.org/10.1007/978-3-030-39593-3_3

Paillin, J.B.; Matrutty, D.D.P.; Siahainenia, S.R.; Tawari, R.H.S.; Haruna, H. and **Talahatu, P. (2020).** Daerah penangkapan potensial tuna madidihang *Thunnus albacares*, Bonnaterre, 1788 (Teleostei: Scombridae) di Laut Seram. *Jurnal Kelautan Tropis*, **23**(2), 207-216. https://doi.org/10.14710/jkt.v23i2.7073.

Palacios, D.M.; Bograd, S.J.; Foley, D.G. and **Schwing, F.B. (2006).** Oceanographic characteristics of biological hot spots in the North Pacific: a remote sensing perspective. *Deep Sea Research Part II: Topical Studies in Oceanography*, **53**(3-4): 250-269. https://doi.org/10.1016/j.dsr2.2006.03.004.

Papaconstantinou, C. and **Farrugio, H. (2000).** Fisheries in the Mediterranean. *Mediterranean Marine Science*, **1**(1): 5-18. https://doi.org/10.12681/mms.2

Putri, S.; Rani, A.; Zainuddin, M.; Mustapha, M.A. and **Hidayat, R. (2021).** Mapping potential fishing zones for skipjack tuna in the southern Makassar Strait, Indonesia, using pelagic habitat index (PHI). *Biodiversitas: Journal of Biological Diversity*, **22**(7): 3037-3045. https://doi.org/10.13057/biodiv/d220758.

Samy-Kamal, M. (2015). Status of fisheries in Egypt: reflections on past trends and management challenges. *Reviews in fish biology and fisheries*, **25**: 631-649. https://doi.org/10.1007/s11160-015-9404-z.

Samy-Kamal, M. (2020). Outlook on the fisheries policy reform in Egypt and the draft of the new fisheries law. *Marine Policy*, **120**: 104136. https://doi.org/10.1016/j.marpol.2020.104136.

Solanki, H.U.; Dwivedi, R.M.; Nayak, S.R.; Somvanshi, V.S.; Gulati, D.K. and **Pattnayak, S.K. (2003).** Fishery forecast using OCM chlorophyll concentration and AVHRR SST: validation results off Gujarat coast, India. *International Journal of Remote Sensing*, **24**(18): 3691-3699. https://doi.org/10.1080/0143116031000117029.

Tang, D.; Kawamura, H.; Lee, M.A. and **Van Dien, T. (2003)**. Seasonal and spatial distribution of chlorophyll-a concentrations and water conditions in the Gulf of Tonkin, South China Sea. *Remote Sensing of Environment*, **85**(4): 475-483. https://doi.org/10.1016/S0034-4257(03)00049-X.

Zainuddin, M. (2007). Mapping of potential fishing grounds of *Rastrelliger kanagurta* in Bantaeng waters, South Sulawesi. *Jurnal Sains dan Teknologi*, **7**(2): 57-64.

Zainuddin, M. (2011). Skipjack tuna in relation to sea surface temperature and chlorophyll-a concentration of Bone Bay using remotely sensed satellite data. *Jurnal Ilmu dan Teknologi Kelautan Tropis*, **3**(1): 82-90.

Zainuddin, M. and **Jamal, M. (2009).** Satellite remote sensing dan geographic information system of potential fishing zone for skipjack tuna in Bone Bay, South Sulawesi. In *International Proceeding of World Ocean Conference, Manado* (pp. 15-20).

Zorn, T.G.; Seelbach, P.W. and **Rutherford, E.S. (2012).** A Regional-Scale habitat suitability model to assess the effects of flow reduction on fish assemblages in Michigan streams 1. *JAWRA Journal of the American Water Resources Association*, **48**(5): 871-895. https://doi.org/10.1111/j.1752-1688.2012.00656.x