Turk. J. Fish.& Aquat. Sci. 19(1), 51-57
http://doi.org/10.4194/1303-2712-v19_1_06

RESEARCH PAPER

Turkish Journal of
FISHERIES and
AQUATIC SCIENCES

Warming in Turkish Seas: Comparative Multidecadal Assessment

Fethi Bengil[1,*], **Sinan Mavruk**[2]

[1] Girne American University, Marine School - Earth System Science Research Center Girne, TRNC via Turkey.
[2] Çukurova University, Fisheries Faculty, Department of Marine Biology Balcalı, Adana Turkey.

Article History
Received 06 December 2017
Accepted 20 February 2018
First Online 25 February 2018

Corresponding Author
Tel.: + 90392 650 2000-1331
E-mail: thibengil@gau.edu.tr

Keywords
Sea surface temperature
Trend analysis
The Black Sea
The Marmara Sea
The Mediterranean Sea

Abstract

Although sea temperature characteristics and their variations in the Mediterranean and Black Seas have been studied at length over the course of different time periods and varied areas of spatial coverage, there remains no specific evaluation of Turkish Seas. This study provides an assessment of sea surface temperatures during a period between September 1981 and December 2014; conducted in order to understand characterization of the basic features and to enable description of linear and non-linear inter-annual patterns in Turkish seas: the northern Levantine Sea, the eastern Aegean Sea, the Marmara Sea and the southern Black Sea. The results of our study showed that there are significantly positive trends in all of the aforementioned regions, and that the rate of warming in the two colder basins, the Black Sea and the Marmara Sea, was detected to be higher than the rate discovered found in the Aegean Sea and Levantine Sea.

Introduction

Sea surface temperature (SST) is a key parameter for marine ecosystems, and is closely related with regional climate events (Kazmin, Zatsepin, & Kontoyiannis, 2010; Messie & Chavez, 2011) as well as global climate events (Enfield & Mestas-Nuñez, 1999). It is also an important indicator of climatic impacts on marine environments, and assists to track climate anomalies; achieved through the use and availability of various data sources covering lengthy time periods; which are essential for accumulating a reliable trend analysis (Good, Corlett, Remedios, Noyes, & Llewellyn-Jones, 2007 and references therein).

The general characteristics of Turkish seas are well renowned for demonstrating extreme properties from brackish (Berner & Berner, 2012) to highly saline water types (Akpinar, Yilmaz, Fach, & Salihoglu, 2016 and references therein). Detailed information on the circulation and physical properties of Turkish seas can be found in Oguz, Tugrul, Kideys, Ediger, and Kubilay (2004) and Miladinova, Stips, Garcia-Gorriz, and Macias-Moy (2017) for the Black Sea; in Besiktepe *et al*. (1994) for the Marmara Sea; Kourafalous, and Tsiara (2007) and Olson, Kourafalou, Johns, Samuel, and Veneziani (2007) for the Aegean Sea; and Akpinar *et al*. (2016) for the Levantine Sea. Irregular changes in physical properties of the Black Sea (Miladinova *et al*., 2017) and their impacts on its ecosystem (Miladinova, Stips, Garcia-Gorriz, & Macias-Moy, 2016) are well known processes over varıed time periods. Similarly, changes in seawater dynamics (Theocharis, Nittis, Kontoyiannis, Papageorgiou, & Balopoulos, 1999) and physical properties of the Aegean Sea (Sayin & Besiktepe, 2011) for certain time periods such as The Eastern Mediterranean Transient were also observed. The changes of SST are also relatively well-known around the world (Good *et al*., 2007). Local considerations are also available for the Black Sea (e.g. Ginzburg, Kostianoy, & Sheremet, 2004; Belkin, 2009), the eastern Mediterranean (e.g. Nykaer, 2009), and the Aegean Sea (e.g. Skliris *et al*., 2011). An overview on temperature differences over recent decades for all Mediterranean and Black Sea basins was presented by Shaltout and Omstedt (2014) and references therein. Even though various studies have been conducted in these regions, they have a low spatial resolution for specific evaluation and different computation methods. Furthermore, there are still no specific considerations regarding the SST trends of sea regions surrounding Turkey.

The aim of this study is to therefore characterize the basic physical features, and to describe recent linear and non-linear inter-annual patterns of our time series data set of sea surface temperature, as a key parameter of marine environment in the following Turkish seas: the northern Levantine Sea, the eastern Aegean Sea, the Marmara Sea and the southern Black Sea.

Materials and Methods

Inter-annual changes in the sea surface temperature of Turkish seas (the southern Black Sea, the Marmara Sea, the eastern Aegean Sea and the northern Levantine Sea) were investigated during this study. To remove any possible sources of a bias result from the wide spatial coverage and different sub-regional physical and biological properties, each sea was divided into two sub-areas in the statistical considerations (Figure 1).

A modelled based data source was used to evaluate identified trends of sea surface temperature in Turkish seas. Global monthly optimum interpolation sea surface temperatures (oisst) were downloaded with a time period that spanned between September 1981 and December 2014 from the North Caroline Institute for Climate Studies (NCICS) server (https://ncics.org/DATA/obs4MIPs/OISST/Monthly). The dataset was produced at quarter degree spatial resolution at the National Centre for Environmental Information (NCEI) by combining data from in-situ and satellite platforms. More details on the data-set can be found in Reynolds *et al*. (2007) and the changes in version 2, which have been used in this study, were described in Reynolds (2009).

Regarding spatial analysis, the mean of all data belonging to each defined region is calculated for SST in this study. Monthly mean values were also calculated between September 1981 and December 2014, followed by calculations of the maximum, minimum, average, standard deviation and range, that were used to obtain the descriptive characteristics of each region.

In order to analyse inter-annual changes, a loess based seasonal trend decomposition procedure was performed for each parameter (Cleveland, Cleveland, McRae, & Terpenning,1990), and the trend components of this procedure were used to express the non-linear trends of parameter. Seasonal signals were removed to firstly estimate the linear trends, then the direction and magnitude of trends were detected with a rank based non-parametric Mann-Kendall correlation (Hipel & McLeod, 1994) by using R library “Kendall” (McLeod, 2011). The intercept and slope of the trends were estimated by using Theil-Sen’s regression method, which represents the variation of medians over the selected timeframe (Sen, 1968). Confidence intervals of slopes were calculated in order to compare the slopes of trend lines between different areas, and the R library “zyp” (Bronaugh & Werner 2013) was used for these calculations. In general terms, inter-annual changes in sea surface temperature are non-linear and the trend curves revealed sudden shifts between stable states (Oguz & Gilbert, 2007). To detect these change points in non-linear trends, the Pettitt’s single point change detection test was used: (Pettitt 1979)with the R library “trend” (Pohlert, 2016).

Results

Sea Surface Temperature (SST) records between September 1981 and December 2014 showed typical seasonal sinusoidal changes. The annual range identified during this period was between a minimum of (10.77^{o}C) in the northern Aegean Sea (AS2) and a maximum of

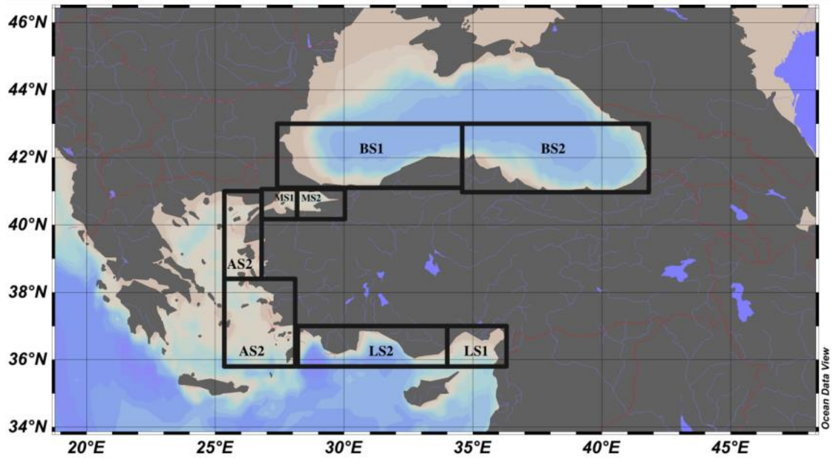

Figure 1. Study area and sub-regions for Turkish seas; LS1: the eastern Levantine Sea, LS2: the western Levantine Sea, AS1: the northern Aegean Sea, AS2: the southern Aegean Sea, MS1: the western Marmara Sea, MS2: the eastern Marmara Sea, BS1: the western Black Sea, BS2: the eastern Black Sea.

(21.02^{o}C) in the western Black Sea (BS1). The annual average SST within the studied regions varied between 15.17^{o}C (±6.22 standard deviation-sd) (BS1) and 22.17^{o}C (±4.25sd) (the eastern Levantine Sea-LS1). The highest maximum SST was 29.48^{o}C from region LS1 in August 2010, and the lowest maximum SST was 25.31^{o}C: belonging to the southern Aegean Sea (AS1) in August 2002.Whistl the lowest minimum SST observed in the BS1 region was 5.86^{o} in March 1987, the highest minimum was 16.99^{o}C from LS1 in March 1993. Descriptive statistics belonging to sea surface temperature are given in Table 1.

During the period of consideration, SST revealed significantly positive trends in all regions. The slope of Theil-Sen regression in the seasonally filtered time series data showed that the annual median increments in SST were between 0.032ºC/year (the Levantine Sea and the Aegean Sea) and 0.047 ºC/year (MS1) with an overall median value of 0.038 ºC/year (Table 2). The slopes calculated for both the Marmara Sea and the Black Sea were significantly higher by comparing regions from the Levantine Sea and the Aegean Sea ($P<0.05$) (Figure 2). The non-linear patterns in SST were also found to be significant in all regions. Pettitt's test for change point detection revealed that the non-linear trends of de-seasonalised time series data curved upward in all areas during the summer of 1998 (Table 2, Figure 3)

Discussion

Our investigations discovered that the trends of SST revealed increasing patterns throughout the study domain, and in 1998 the inflexion points of seasonally filtered non-linear trends were detected in all areas. This apparent consistency amongst regions indicates a large probability of a macroscale coupled shift in climatic parameters, which was also reflected in our study. Our time series analysis of the Black sea over the past three decades also suggested that there has been

Table 1. Descriptive statistics of sea surface temperature in each region of Turkish seas

	Sea surface temperature (°C)							
	LS1	LS2	AS1	AS2	MS1	MS2	BS1	BS2
Max	29.48	29.08	25.31	25.54	26.64	25.98	26.88	27.41
Min	15.99	15.49	12.76	14.77	6.89	5.89	5.86	6.53
Mean	22.17	21.66	18.23	19.48	15.98	15.53	15.17	15.84
SD	4.25	4.19	3.66	2.93	5.87	5.82	6.22	6.16

Table 2. Trends of sea surface temperature throughout Turkish Seas. (MK-Thau: Mann Kendal Thau, a: intercept, b: slope of Theil-Sen's regression, C: confidence intervals, CP: change points derived from Pettitt's test, ***, **, *, ˙: significant at 0.001, 0.01, 0.05 and 0.10 respectively)

	Sea Surface Temperature (SST)							
	LS1	LS2	AS1	AS2	MS1	MS2	BS1	BS2
MK-Thau	0.35***	0.35***	0.31***	0.37***	0.31***	0.32***	0.33***	0.34***
a	21.6020	21.1143	17.6966	18.9324	15.2223	14.7162	14.4209	15.0620
b	0.0027	0.0026	0.0027	0.0027	0.0037	0.0039	0.0037	0.0039
±%95 CI	0.00046	0.00045	0.00050	0.00044	0.00073	0.00074	0.00064	0.00069
CP	7/1998	7/1998	9/1998	8/1998	5/1998	9/1998	5/1998	9/1998

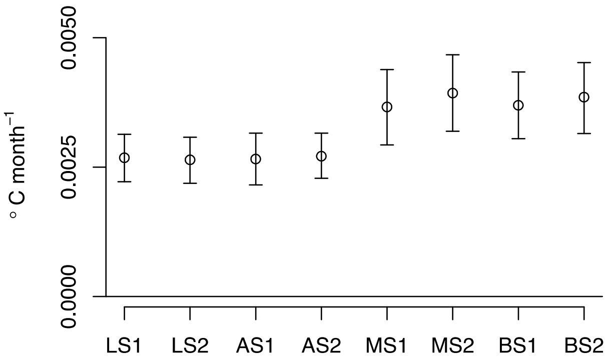

Figure 2. Slope of Theil-Sen regression of time series data (Vertical bars indicate 95% confidence intervals**).**

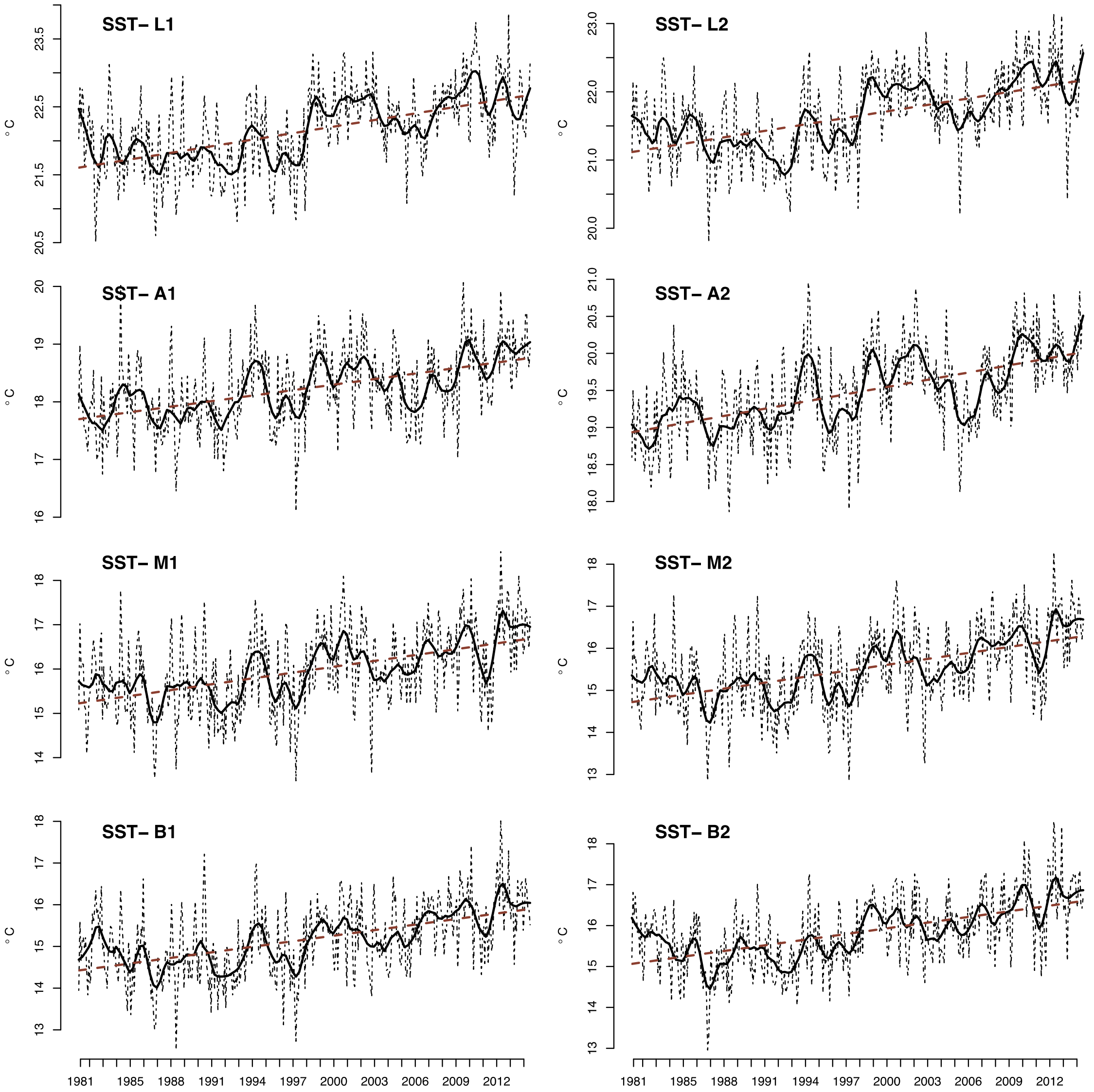

Figure 3. Deseasonalized time series (dash-dot line), non-linear (straight line) and linear (dashed line) trends of sea surface temperature in Turkish Seas (LS1: the eastern Levantine Sea, LS2: the western Levantine Sea, AS1: the northern Aegean Sea, AS2: the southern Aegean Sea, MS1: the western Marmara Sea, MS2: the eastern Marmara Sea, BS1: the western Black Sea, BS2: the eastern Black Sea.)

an increasing trend in winter temperature values since the mid1990s (Oguz, Dippner, & Kaymaz, 2006; Kazmin *et al.*, 2010). This winter warming became more apparent after the year 2000, when there was a strong relationship with a large-scale teleconnection index, the North Atlantic Oscillation (NAO) (Agirbas, Feyzioglu, Aytan, Valente, & Yildiz, 2015). Similar observations based on the analyses of annually averaged SST in the Aegean Sea (Skliris *et al.*, 2011) as well as throughout the Black Sea, have also been reported (Shapiro, Aleynik, & Mee, 2010). According to Kazmin *et al.* (2010) two different teleconnection patterns influence the climatic structure of seas surrounding Turkey, however, both NAO and the East Atlantic – West Russia (EAWR) cause a warming trend, with their levels of stress apparently being slightly different from one another.

The trend of SST has been reported from 0.03 ^{o}C/year (the eastern Mediterranean Sea) to 0.09 ^{o}C/year (the Black Sea) in previous studies (Shaltout & Omstedt, 2014 and reference therein). In accordance with these studies, the rate of warming was also found to be higher in the Black Sea than that of the Levantine Sea in this study, and the slopes of trend increased gradually from the Levantine Sea to the Aegean Sea.

Based on the slope magnitudes of SST trend lines, the regions show two distinctive groups: higher trends were discovered in both the Black Sea and the Marmara Sea, and lower trends were identified in the Aegean Sea and the Levantine Sea. Circulation characteristics appear to be responsible for this similarity pattern, as the waters of the Black Sea prevail in the surface water of the Marmara Sea (Besiktepe *et al.*, 1997; Zapevalov & Dovgaya, 2007).

The Mediterranization process is defined as the colonization of the Black Sea by species that inhabit to the Mediterranean (Turan *et al*., 2009). Eventually, Mediterranean species started to penetrate the Black Sea with the opening of Bosphorus (Shalovenkov, 2017 and reference therein), however, it the penetration was limited by various mechanisms such as climatic, geographic or physiological conditions. However, Turan *et al*. (2009) pointed out that Mediterranization process has accelerated since the early 90s, according to Oguz and Ozturk (2011), there are important physical and physiological barriers, particularly temperature differences, that prevent a natural spreading via the Dardanelles and the Bosporus Strait. Therefore, if we assume that this current situation remains, accelerated warming levels in the Marmara and Black Seas may dilute the effect of this physiological limitation by reducing sharp stratification between water layers of these two seas. This may also make possible the adaptation of some stenotherm species. Thus, Mediterranization of both seas might be faster by increasing the number of adapted species in future. A concrete example for this case was observed in the Levantine Sea where is dramatically invaded by Erythrean species (Golani, 2010), has a weak differences of temperature conditions with the northern Red Sea (Galil & Zenetos, 2002; Oguz & Ozturk, 2011). Here, Mavruk, Yeldan, Manasirli, Bengil, and Avsar (2016) and Mavruk, Bengil, Yeldan, Manasirli, and Avsar (2017) revealed that small increments in annual temperatures in 2010 caused significant changes of fish community structure in favor of lessepsian species. However, the authors give this particular case for Iskenderun Bay, our analyses find out that the same positive temperature anomaly was happened all over the Northern Levantine and Eastern Aegean Seas. Therefore, these changes may refer a widespread event rather than local incidences.

Conclusion

Even though the regions studied for this study showed significantly positive trends over the selected time period, our analysis indicated that two groups occurred in the Turkish seas: one being the Black Sea and the Marmara Sea, and the other being the Aegean Sea and the Levantine Sea. The Black Sea and the Marmara Sea both demonstrated different characteristics with lower values, whilst having a remarkably higher warming trend in sea surface temperature. This descriptive study aims at defining recent linear and non-linear inter-annual patterns of SST as a key indicator for basic climatic conditions that can affect marine ecosystems. However, it should also be noted that such descriptions cannot detect the underlying reasons alone, and that alterations in the environmental conditions are complicated (Daskalov, 1999; Oguz and Gilbert 2007). Further comprehensive studies are therefore required to enhance present understanding of these mechanisms in their entirety.

Acknowledgement

We would like to thank Ayla YILDIRIM for English proofreading.

References

Agirbas, E., Feyzioglu, A. M., Aytan, U., Valente, A., & Yildiz, I. (2015). Are trends in SST, surface Chlorophyll-a, primary production and wind stress similar or different over the decadal scale in the south-eastern Black Sea? *Cahiers de Biologie Marine*, *56*(4), 329–336.

Akpinar, A., Yilmaz, E., Fach, B. A., & Salihoglu, B. (2016). Physical Oceanography of the Eastern Mediterranean Sea. In C. Turan, B. Salihoglu, E. Ozgur Ozbek, & B. Ozturk (Eds.), *The Turkish Part of the Mediterranean Sea; Marine Biodiversity, Fisheries, Conservation and Governance. Turkish Marine Research Foundation (TUDAV)*., 613 pp.

Belkin, I. M. (2009). Rapid warming of Large Marine Ecosystems. *Progress in Oceanography*, *81*(1–4), 207–213. https://dx.doi.org/10.1016/j.pocean.2009.04.011

Berner, K. A. B., & Berner, R. A. C. (2012). *Global environment: Water, air, and geochemical cycles*. *Global Environment: Water, Air, and Geochemical Cycles (Second Edition)*. Princeton, USA, Princeton University Press., 444 pp.

Besiktepe, S. T., Sur, H. I., Ozsoy, E., Latif, M. A., Oguz, T., & Unluata, U. (1994). The circulation and hydrography of the Marmara Sea. *Progress in Oceanography*, *34*(4), 285–334. https://dx.doi.org/10.1016/0079-6611(94)90018-3

Bronaugh, D., & Werner, A. (2013). zyp: Zhang + Yue-Pilon trends package. Pacific Climate Impacts Consortium. Retrieved from https://www.pacificclimate.org/~wernera/zyp/zyp.pdf

Cleveland, R. B., Cleveland, W. S., McRae, J. E., & Terpenning, I. (1990). STL: A seasonal-trend decomposition procedure based on loess. *Journal of Official Statistics*. https://doi.org/citeulike-article-id:1435502

Daskalov, G. (1999). Relating fish recruitment to stock biomass and physical environment in the Black Sea using generalized additive models. *Fisheries Research*, *41*(1), 1–23. https://dx.doi.org/10.1016/S0165-7836(99)00006-5

Enfield, D. B., & Mestas-Nuñez, A. M. (1999). Multiscale Variabilities in Global Sea Surface Temperatures and Their Relationships with Tropospheric Climate Patterns. *Journal of Climate*, *12*(9), 2719–2733. https://dx.doi.org/10.1175/1520-0442(1999)012

Galil, B.S., Zenetos, A. (2002) A sea of change: exotics in the eastern Mediterranean Sea. In: Leppakoski E, Gollasch S, Olenin S. (eds.) Invasive Aquatic Species of Europe: Distribution, Impacts and Management. Kluwer Academic Publishers, Dordrecht, The Netherlands, pp 325–336.

Ginzburg, A. I., Kostianoy, A. G., & Sheremet, N. A. (2004). Seasonal and interannual variability of the Black Sea surface temperature as revealed from satellite data (1982-2000). *Journal of Marine Systems*, *52*(1–4), 33–

50. https://dx.doi.org/10.1016/j.jmarsys.2004.05.002

Good, S. A., Corlett, G. K., Remedios, J. J., Noyes, E. J., & Llewellyn-Jones, D. T. (2007). The Global Trend in Sea Surface Temperature from 20 Years of Advanced Very High Resolution Radiometer Data. *Journal of Climate*, *20*(7), 1255–1264. https://dx.doi.org/10.1175/JCLI4049.1

Golani, D. (2010). Colonization of the Mediterranean by Red Sea fishes via the Suez Canal – Lessepsian migration. In D. Golani, & B. Appelbaum-Golani (Eds.), Fish invasions of the Mediterranean Sea change and renewal (pp. 145–188). Sofia: Pensoft Publishers.

Hipel, K. W., & McLeod, A. I. (1994). *Time Series Modelling of Water Resources and Environmental Systems.* Elsevier. https://dx.doi.org/10.1016/S0167-5648(08)70658-0

Kazmin, A. S., Zatsepin, A. G., & Kontoyiannis, H. (2010). Comparative analysis of the long-term variability of winter surface temperature in the Black and Aegean Seas during 1982-2004 associated with the large-scale atmospheric forcing. *International Journal of Climatology*, *30*, 1349–1359. https://dx.doi.org/10.1002/joc.1985

Kourafalou, V., & Tsiaras, K. (2007). A nested circulation model for the North Aegean Sea. *Ocean Science*, *3*, 1–16. https://dx.doi.org/10.5194/os-3-1-2007, 2007.

Mavruk, S., Bengil, F., Yeldan, H., Manasirli, M., & Avsar, D. (2017). The trend of lessepsian fish populations with an emphasis on temperature variations in Iskenderun Bay, the Northeastern Mediterranean. *Fisheries Oceanography*, *26*(5), 542–554. https://dx.doi.org/10.1111/fog.12215

Mavruk, S., Yeldan, H., Manasirli, M., Bengil, F., & Avsar, D. (2016). Contribution of lessepsian intrusions to the alteration of coastal fish assemblages in Iskenderun Bay (Northeastern Mediterranean). *Rapp Comm Int Mer Médit*, *41*, 436.

McLeod, A. I. (2011). Kendall: Kendall rank correlation and Mann-Kendall trend test. Retrieved from https://cran.r-project.org/web/packages/Kendall/Kendall.pdf

Messié, M., & Chavez, F. (2011). Global Modes of Sea Surface Temperature Variability in Relation to Regional Climate Indices. *Journal of Climate*, *24*(16), 4314–4331. https://dx.doi.org/10.1175/2011JCLI3941.1

Miladinova, S., Stips, A. Garcia-Gorriz, E., & Macias Moy, D. (2016). Changes in the Black Sea physical properties and their effect on the ecosystem. EUR 28060. Retrieved from http://publications.jrc.ec.europa.eu/repository/bitstream/JRC102514/lb-na-28060-en-n.pdf

Miladinova, S., Stips, A., Garcia-Gorriz, E., & Macias Moy, D. (2017). Black Sea thermohaline properties: Long-term trends and variations. *Journal of Geophysical Research: Oceans*, *122*(7), 5624–5644. https://dx.doi.org/10.1002/2016JC012644

Nykjaer, L. (2009). Mediterranean Sea surface warming 1985–2006. *Climate Research*, *39*, 11–17. https://dx.doi.org/10.3354/cr00794

Oguz, T., & Gilbert, D. (2007). Abrupt transitions of the top-down controlled Black Sea pelagic ecosystem during 1960-2000: Evidence for regime-shifts under strong fishery exploitation and nutrient enrichment modulated by climate-induced variations. *Deep-Sea Research Part I: Oceanographic Research Papers*, *54*(2), 220–242. https://dx.doi.org/10.1016/j.dsr.2006.09.010

Oguz, T., & Ozturk, B. (2011). Mechanisms impeding natural Mediterranization process of Black Sea fauna. *Journal of Black Sea / Mediterranean Environment*, *17*(3), 234–253.

Oguz, T., Dippner, J. W., & Kaymaz, Z. (2006). Climatic regulation of the Black Sea hydro-meteorological and ecological properties at interannual-to-decadal time scales. *Journal of Marine Systems*, *60*(3–4), 235–254. https://dx.doi.org/10.1016/j.jmarsys.2005.11.011

Oguz, T., Tugrul, S., Kideys, A., Ediger, V., & Kubilay, N. (2004). Physical and biogeochemical characteristics of the Black Sea. In A. R. Robinson & H. K. Brink (Eds.), *The Sea, Volume 14B: The Global Coastal Ocean* (pp. 1331-1369), Boston, USA, Harvard University Press., 810 pp.

Olson, D. B., Kourafalou, V. H., Johns, W. E., Samuels, G., & Veneziani, M. (2007). Aegean Surface Circulation from a Satellite-Tracked Drifter Array. *Journal of Physical Oceanography*, *37*(7), 1898–1917. https://dx.doi.org/10.1175/JPO3028.1

Pettitt, A. N. (1979). A non-parametric approach to the change-point problem. *Applied Statistics*, *28*, 126–135.

Pohlert, T. (2016). Package ' trend ': Non-Parametric Trend Tests and Change-Point Detection. *R Package*, 26. Retrieved from https://cran.r-project.org/web/packages/trend/trend.pdf

Reynolds, R. W. (2009). What's New in Version 2. Retrieved from https://www.ncdc.noaa.gov/sites/default/files/attachments/Reynolds2009_oisst_daily_v02r00_version2-features.pdf

Reynolds, R. W., Smith, T. M., Liu, C., Chelton, D. B., Casey, K. S., & Schlax, M. G. (2007). Daily High-Resolution-Blended Analyses for Sea Surface Temperature. *Journal of Climate*, *20*(22), 5473–5496. https://dx.doi.org/10.1175/2007JCLI1824.1

Sayin, E., & Besiktepe, S. T. (2010). Temporal evolution of the water mass properties during the Eastern Mediterranean transient (EMT) in the Aegean Sea. *Journal of Geophysical Research*, *115*(C10), C10025. https://dx.doi.org/10.1029/2009JC005694

Sen, P. K. (1968). Estimates of the Regression Coefficient Based on Kendall's Tau. *Journal of the American Statistical Association*, *63*, 1379–1389.

Shalovenkov, N. N. (2017). Non-native zoobenthic species at the Crimean Black Sea Coast. *Mediterranean Marine Science*, *18*(2), 260. https://dx.doi.org/10.12681/mms.1925

Shaltout, M., & Omstedt, A. (2014). Recent sea surface temperature trends and future scenarios for the Mediterranean Sea. *Oceanologia*, *56*(3), 411–443. https://dx.doi.org/10.5697/oc.56-3.411

Shapiro, G. I., Aleynik, D. L., & Mee, L. D. (2010). Long term trends in the sea surface temperature of the Black Sea. *Ocean Science*, *6*, 491–501. https://dx.doi.org/10.5194/os-6-491-2010

Skliris, N., Sofianos, S. S., Gkanasos, A., Axaopoulos, P., Mantziafou, A., & Vervatis, V. (2011). Long-term sea surface temperature variability in the Aegean Sea. *Advances in Oceanography and Limnology*, *2*(2), 125–139. https://dx.doi.org/10.1080/19475721.2011.601325

Theocharis, A., Nittis, K., Kontoyiannis, H., Papageorgiou, E., & Balopoulos, E. (1999). Climatic changes in the Aegean Sea influence the eastern Mediterranean thermohaline circulation (1986-1997). *Geophysical Research Letters*, *26*(11), 1617–1620. https://dx.doi.org/10.1029/1999GL900320

Turan, C., Boero, F., Boltachev, A., Düzgünes, E., Ilyin, Y.P., Kideys, A., … Briand, F. (2009) *Climate forcing and its impacts on the Black Sea marine biota*. Ciesm workshop monographs 39:5-24. Trabzon, Turkey. Retrieved from http://ciesm.org/online/monographs/39/CIESM_Monograph_39_Climate_Forcing_and_Black_Sea_Biota_05_24.pdf

Zapevalov, A. S., & Dovgaya, S. V. (2007). Transformation of black-sea waters in the Sea of Marmara. *Physical Oceanography*, *17*(2), 106–112. https://dx.doi.org/10.1007/s11110-007-0009-5