

Modeling and Time Series Analysis of Climate Change Effects on Fisheries in Iraqi Marine Waters

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ABSTRACT

The importance of using time series to quantify changes in fisheries lies in revealing patterns of variation across different time scales. In this study, two time series methods were used: the smoothing test and the homogeneity test. Our results indicated that air temperatures were 1.5°C higher than the calculated global average of 26.5°C, and Iraqi marine water temperatures were 0.89°C higher than the measured average of 24.6°C. At the same time, salinity concentrations increased significantly, reaching 5.8g/ L, compared to their average of 40.7g/ L. The trend analysis indicated a gradual decline in total catch indicators over the subsequent years. Using nonlinear multiple regression analysis on the impact of water temperature and salinity on fisheries in Iraqi territorial waters, the results indicated that the critical values for water temperature and salinity were approximately 26.06°C and 46.5g/ L. Based on the model projections, fish catches are expected to decline between mid-2027 and 2029, primarily due to horizontal migration driven by rising water temperatures, as revealed by the time series analysis.

INTRODUCTION

Estimating the value of marine ecosystems can provide policymakers with a basis for improving ocean management and promoting investment in the marine environment; this would reduce environmental risks and contribute to climate change mitigation (**Muringai et al., 2022**). Fishermen depend on resources whose distribution and productivity are affected by climate dynamics, and climatic factors affect biotic and abiotic elements that affect the abundance and distribution of fish species, most research on climate variability and fisheries aims to understand in detail the mechanisms causing fluctuations in the size of fish stocks. Fisheries are sensitive to climate change, hence their production processes are likely to be affected by climate change (**Allison et al., 2009; FAO, 2016; Al-Baghdadi et al., 2024**). Climate change puts additional pressure on fishery systems that suffer from other pressures, such as pollution (**Coulthard, 2009**). Climate change has wide-ranging impacts on marine environments globally, altering their physical and

biogeochemical properties and thus affecting marine organisms and the ecosystem services they provide (**Brander, 2010; Halpern *et al.*, 2012**). There is growing concern about the consequences of climate change on fisheries production, as it influences many factors already affecting fish stocks. Therefore, assessing the impact of climate change requires considering additional human pressures that often have large and rapid effects (**Hollowed *et al.*, 2013**). Statistical time series models are widely used to predict fish stock status, supporting decision-making in fisheries management. In general, time series prediction of fishing statistics requires modeling all factors influencing catch dynamics (**Ward *et al.*, 2014**). For instance, overfishing can lead to significant declines in catches (**Shono, 2008**). This affects catch per unit effort (CPUE), a measure of fish abundance used largely in fisheries management (**Maunder *et al.*, 2006**). Moreover, these time series are usually non-stationary, i.e., their statistical properties change over time and require powerful techniques to extract information and detect and predict seasonal patterns (**Ye *et al.*, 2015; Aldoghachi & Altamimi, 2021**). Time-series forecasting of fisheries is an integral part of fisheries management. It allows policymakers to develop strategies and enact management decisions capable of achieving goals in light of uncontrollable events (**Farmer & Froeschke, 2015**). This study aims to employ time series analyses of environmental variables and fish catch data to identify future trends and to develop a mathematical model that quantifies the potential impact of climate change on future total catches.

MATERIALS AND METHODS

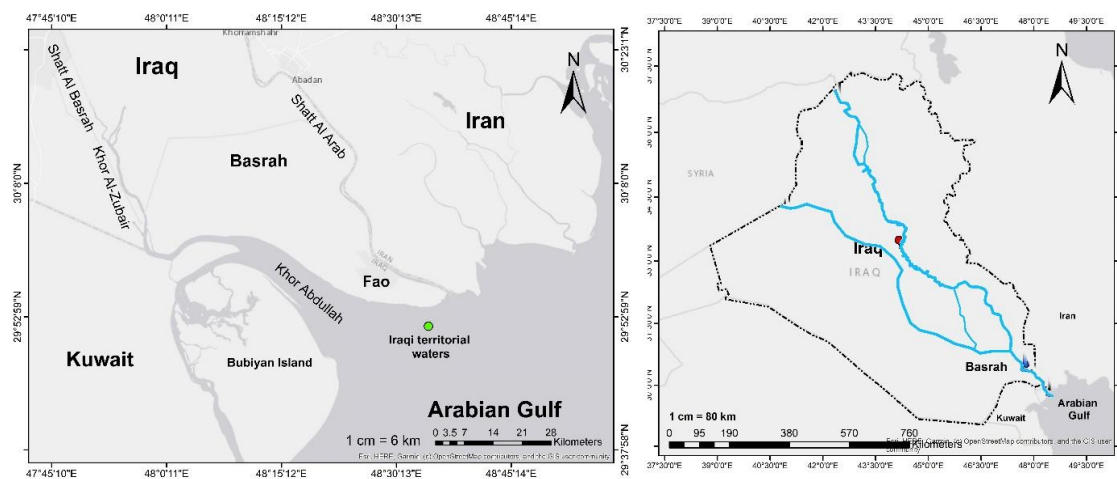
1. Description of the study area

The Arabian Gulf is a semi-enclosed sea located within the subtropical arid zone between latitudes 24° and 30°N. Its location separates the Arabian Peninsula region from southwest Iran, the Strait of Hormuz, and the Gulf of Oman to the south, and Iraq to the north. The Shatt al-Arab estuary is characterized by shallow waters not exceeding 4-10m depth (**Al-Shamary & Younis, 2024**), which extend from the surrounding tidal flats and gradually slope toward open waters. Surface waters are dominated by brackish inflows from the Shatt al-Arab River, whereas deeper layers consist of saline waters from the Arabian Gulf, driven landward by tidal currents due to density differences (**Sale *et al.*, 2011**). Map (1) shows Iraqi territorial waters.

2. Collecting historical data

Air temperature data were obtained from the Basrah Airport Meteorological Station, operated by the General Authority for Meteorology and Seismic Monitoring. In addition, marine regional water temperatures and salinity concentrations were collected from the Marine Affairs and Navigation Department, General Company for Ports of Iraq. Data on catch quantities from the Basrah Agriculture Directorate/ Fish Division were collected

from the fish-landing site at the Al-Nasr Fishing and Fish Marketing Association in the Al-Fao District.



Map 1. Map of the study area

3. Statistical programs

Quantitative data analysis was performed using **XLSTAT (2023)**, a comprehensive statistical software suite that integrates seamlessly with Microsoft Excel.

3.1. Time series data

Time series analysis is a statistical method used to analyze data points collected or recorded at successive intervals over a specific period of time. What distinguishes time series data from other data is that the analysis can show how variables change over time. In other words, time is an important variable because it shows how the data adjusts throughout those data points and the final results.

3.2. Predictive mathematical model

Predictive modeling is a mathematical and statistical approach used to forecast future events or outcomes by identifying patterns within existing datasets. It represents a core component of predictive analytics, which relies on both historical and current data to identify patterns and project future trends.

RESULTS

1. Time series

1.1. Air temperatures

A time series of air temperature averages was studied for 44 years, from 1979 to 2022. The lowest temperature average recorded during that period was 24.7°C, the highest average was 28°C, and the average values for that period reached 26.5°C; the difference between the highest recorded value and the average of these values is 1.5°C. Fig. (1) shows the smoothing time series test: Holt-Winters/ Linear (Holt), which describes the time series plot of air temperature averages and the Holt-Winters plot.

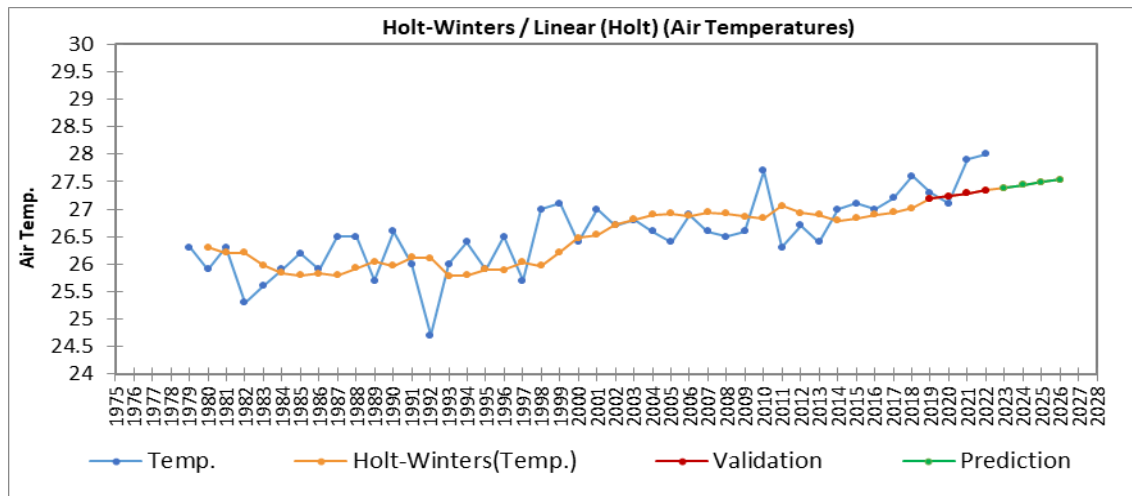


Fig. 1. Smoothing: Holt-winters/ linear (Holt) test for air temperatures

This refers to estimating the smooth trend of the means and variances of the air temperature averages and how the average time series changes, with a validation line and a prediction line for the next four years. We added a polynomial trend line to the equation that predicts the future, and it is noted that the prevailing trend is an increase in temperatures for the coming years. It is noted from Fig. (2) that the homogeneity test for time series: Homogeneity tests, which help in verifying whether there is a sudden change in the average of the time series in a specific place and at a particular time, reveal the specific point or stage in time at which the change occurs. Fig. (2) shows that there was homogeneity from 1979 to 1997, and from 1998 to 2022, another homogeneity appeared that differed from the previous one. The difference in air temperatures between the two phases is $+0.961^{\circ}\text{C}$.

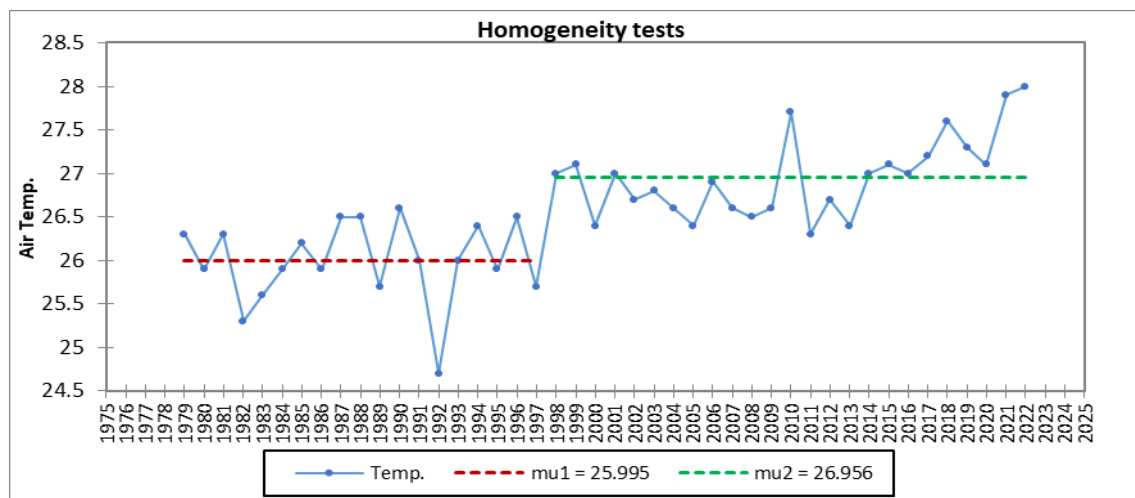


Fig. 2. Time series: Homogeneity tests for air temperatures

1.2. Water temperatures

A time series analysis was conducted for 38 years, from 1985 to 2022. The lowest temperature rate recorded during that period reached 23.6°C, and the highest rate was 25.5°C. The average value for that period was 24.6°C, and the difference between the highest recorded value and the average of that period was 0.89°C. Fig. (3) shows the Smoothing Holt-winters/ linear (Holt) time series test, which describes the time series plot of water temperature averages, the Holt-Winters plot, the validation line, and the prediction line for the next four years. It is clear from Fig. (3) that the prevailing trend is for temperatures to rise in the coming years as well. Fig. (4) shows that there is homogeneity between the years 1985-2002 with an average of 24.06°C and another homogeneity between the years 2003-2022, which differs from it by 25.09°C, and the difference in temperatures between the two stages is 1.03°C.

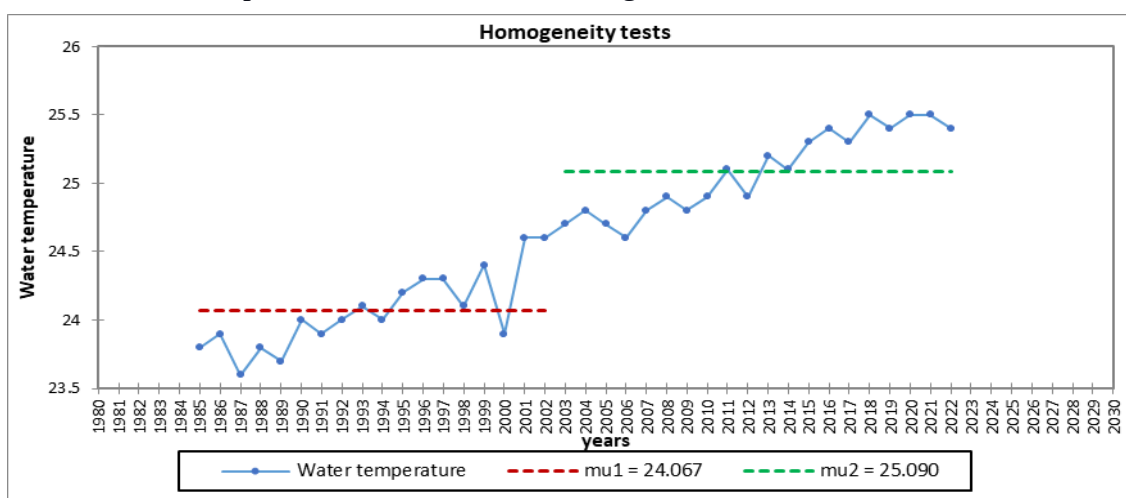


Fig. 3. Smoothing: Holt-winters/linear (Holt) test for water temperatures

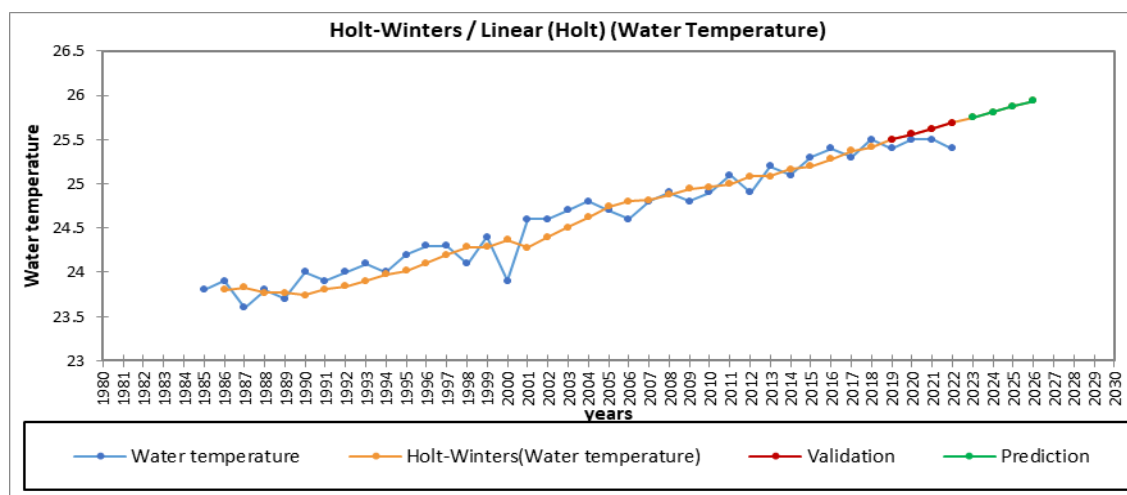


Fig. 4. Time series: Homogeneity tests for water temperatures

1.3. Salinity concentrations

The average of salinity concentration values for previous years was performed in the time series analysis for 33 years between 1990 and 2022. The lowest concentration recorded during that period was 35.4g/ L, the highest concentration was 46.5g/ L, and the average values reached 40.7g/ L. The difference between the highest recorded value and the average of these values is 5.8g/ L; Fig. (5) shows the Smoothing: Holt-winters/linear (Holt) time series test, which describes the time series diagram of salinity concentration, the Holt-winters diagram, the data verification line, and the prediction line for the next four years. It is noted from Fig. (5) that the trend of salinity concentration is slight but in consistent increase, for the coming years.

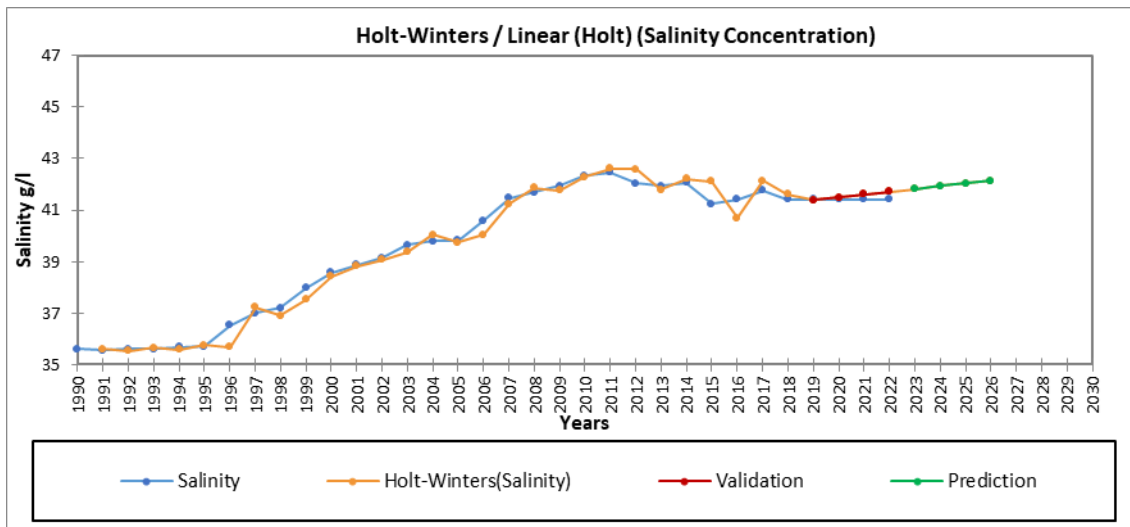


Fig. 5. Smoothing: Holt-winters/linear (Holt) test for water salinity concentrations

Fig. (6) presents the homogeneity analysis of the salinity concentration. It is apparent that the homogeneity was between the years 1990-2005 with an average of 37.39 g/L, while between the years 2006-2022, an average of 41.65 g/L was recorded, and the difference between the two periods was estimated at +4.26 g/L.

1.4. Total catch quantities (fish landing location)

Fish catch data were collected from the Al-Nasr Fishing and Fish Marketing Association in Al-Faw District, which sent its data to the Basra Agriculture Directorate, Fish Division. Fig. (7) notes the Smoothing: the Holt time series test describing the time series diagram of fish catch quantities, the Holt-winters diagram, the data verification line, and the forecast line for the next four years. It is noted that the trend of fishery catches will decrease slightly over the next several years.

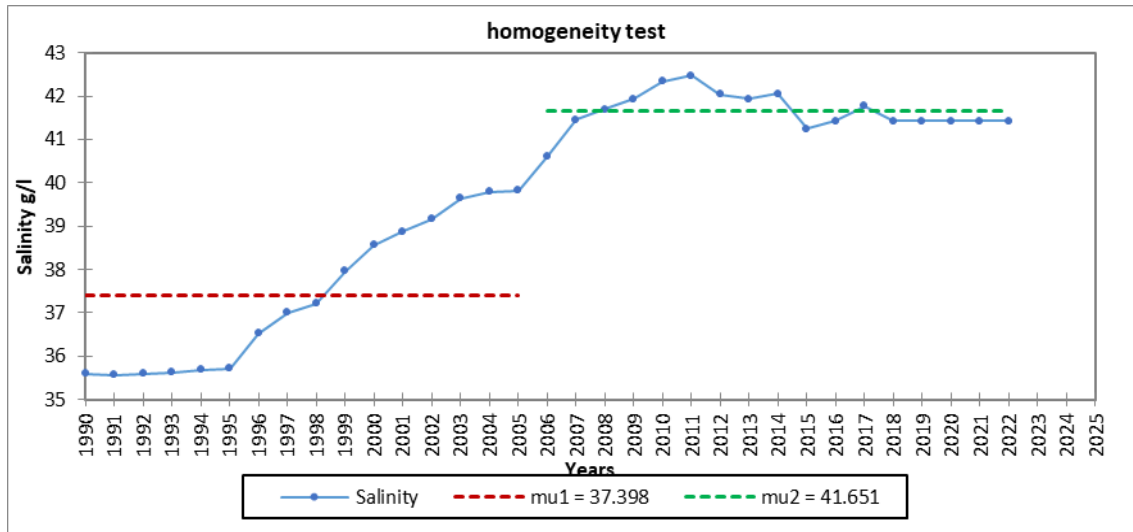


Fig. 6. Test of homogeneity of water salinity concentration time series

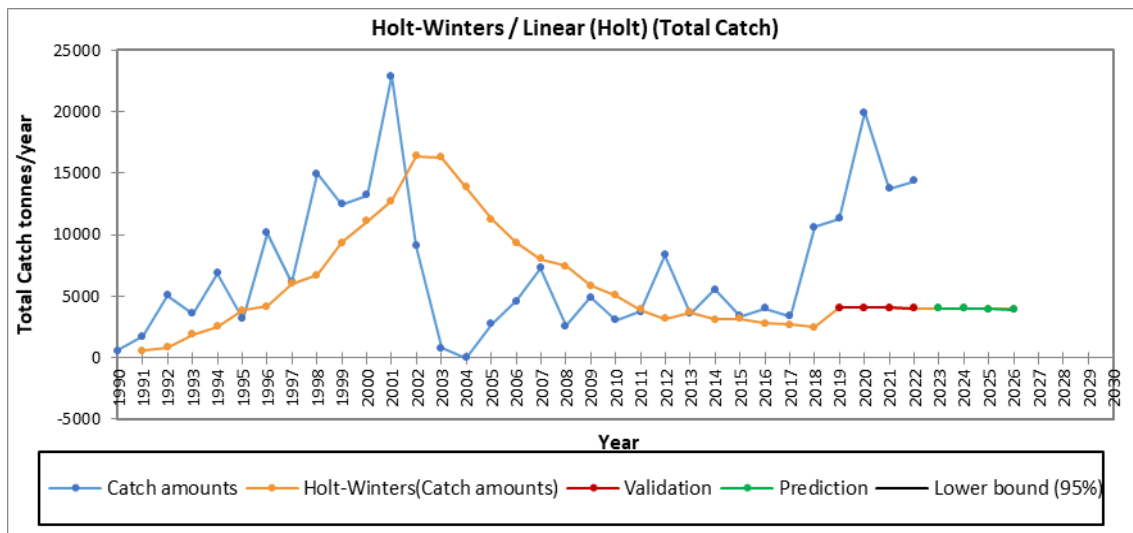


Fig. 7. Smoothing: Holt-winters/linear test for total catches

Fig. (8) shows the homogeneity test for the time series of annual fish catch quantities. It can be deduced that the non-homogeneity of the averages of annual catch amounts over 33 years and that the value of the averages for the first period lasted from 1990 to 2017, with an average of 5994.03 ton/ year, and from 2018 to 2022, with an average of 13,990.2 ton/ year, and the difference between the two averages is 7996.17 ton/ year.

Fig. (9) indicates the analysis of the automatic correlation, which shows that the quantities of fishing began to decline in an inverse relationship with the first period of the 1990 data and with the progress of the years, as the correlation started directly in the first periods, the paths changed in the opposite direction after the first six years of the data on the quantities of fish fishing.

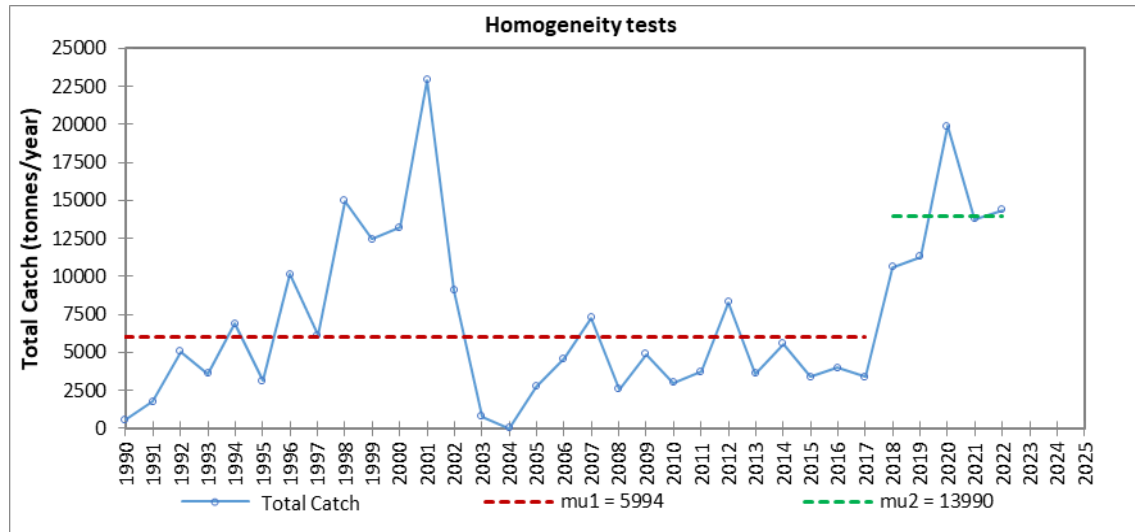


Fig. 8. Time series: Homogeneity tests for total catch quantities

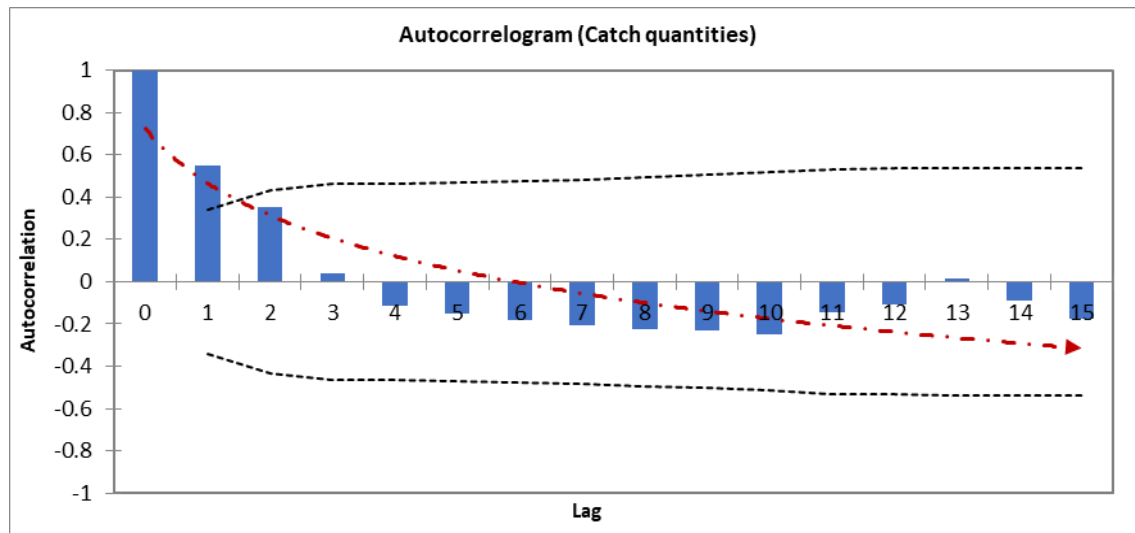


Fig. 9. Autocorrelation analysis of fish catches over 32 years

2. Equation for predicting catch quantities

An equation was created to predict catch quantities for the coming years, and two environmental factors were entered: Water temperatures and salinity concentration. Several models were tested to identify the most statistically reliable equation. The nonlinear multiple regression equation was chosen because it is more suitable for our data models since the catch data collected during the past 33 years have a higher standard deviation than the rest of the data. Table (1) describes the data included in the mathematical equation.

Table 1. Statistics of factor values and catch quantities for previous years included in the prediction equation

Variable	Observations	Minimum	Maximum	Mean	Std. deviation
Water T.	33	23.9	25.5	24.73	0.52
Salinity	33	34.0	46.5	40.38	3.26

The value of the coefficient of determination $R^2 = 0.80$, called the square of the correlation coefficient, and the mean square of the standard error (MSE) = 176734, which is the lowest value obtained from several attempts to extract the mathematical function that achieves the highest value of the coefficient of determination and the lowest value of the mean square of the standard error at the same time.

$$\text{Function: } Y = pr1 + pr2 * X1 + pr3 * X2 + pr4 * X1^2 + pr5 * X2^2 + pr6 * X1^3 + pr7 * X2^3$$

$$\text{Catch} = pr1 + pr2 * \text{Water Temp.} + pr3 * \text{Salinity} + pr4 * \text{Water Temp.}^2 + pr5 * \text{Salinity}^2 + pr6 * \text{Water Temp.}^3 + pr7 * \text{Salinity}^3$$

$$\text{Catch} = 23510438.188 + (-2889946.901) * \text{Water T.} + (-14265.642) * \text{Salinity} + 119277.479 * \text{Water T.}^2 + 375.307 * \text{Salinity}^2 + (-1639.912) * \text{Water T.}^3 + (-3.258) * \text{Salinity}^3$$

Table (2) describes the critical value of temperature and salinity concentration, which gives us negative catch quantities.

Table 2. The critical value of temperatures and salinity concentrations extracted from the prediction equation

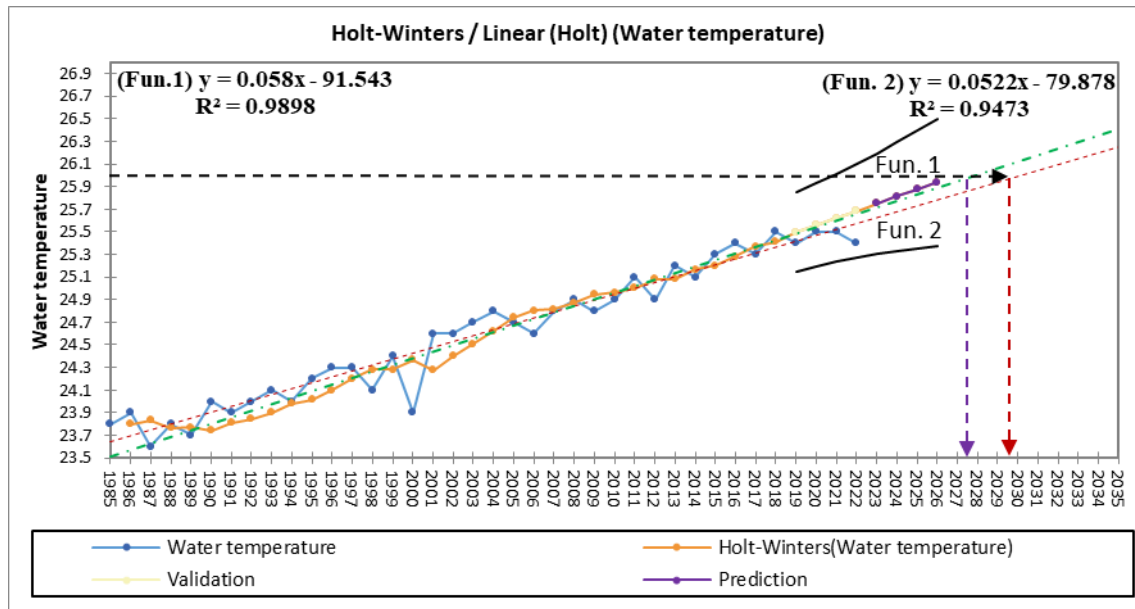
Factors involved in the prediction equation	Water temperature	Salinity concentration
Highest rates in previous years	25.5	46.5
Critical value of factors	26.06	46.5
The difference between the critical value and the highest rates of previous years	0.56	0.0
Catch amounts at critical values	(-30.9) ton/year	

Table (3) also shows examples of the expected catch quantities with a decrease or increase in temperature and salinity concentrations beyond the critical values that result in negative catch projections, that is, the collapse of fish stocks under the pressure of environmental factors because of climate change.

Table 3. Expected catch quantities based on the values of influencing environmental factors

Salinity concentration	Water temperature	Expected catch amounts (ton/year)
46.5	25.4	5998.79
46.5	26	797.00
46.5	26.05	112.17
46.5	26.06	-30.09
46.5	26.08	-319.97
46.7	26.06	-133.45
46.8	26.06	-187.55
46.6	26.06	-80.97
46.4	26.06	19.20
45	26.06	553.70
40	26	1597.13
46	27	-22508.34

After applying the two equations of the prediction line for the rise in water temperature rates in Fig. (10) with a coefficient of determination ($R^2=0.9473$), and through the values of the critical.

**Fig. 10.** The period determined for expecting critical temperature rises

Based on the temperature rates extracted from the prediction equation (26.06°C), we conclude, as in Fig. (10), that the probability of the temperature rates reaching the critical stage will be in the middle of 2029, while if we apply the second equation with a

coefficient of determination ($R^2=0.9898$), we obtain a decline in the quantities of fisheries during the middle of 2027, which is the time when the quantities of fishing are supposed to decrease to below zero ton/year in both cases.

It is clear from the equations depicted in Table (4) that, between the years 2027-2029, the temperature rates will be extremely high and subsequently fish will not be able to live in our territorial waters.

Table 4. Equations of the prediction line in Fig. (10)

Function1 $Y = 0.058*(X) - 91.543$ $R^2 = 0.9898$	Function2 $Y = 0.0522*(X) - 79.878$ $R^2 = 0.9473$
$X = (Y + 91.543) / 0.058$	$X = (Y + 79.878) / 0.0522$
Year = 2027.638	Year = 2029.464
Month = $0.368*12 \rightarrow 7.656$	Month = $0.464*12 \rightarrow 5.568$
Day = $0.656*30 \rightarrow 19.68$	Day = $0.568*30 \rightarrow 17.04$
19/07/2027	17/05/2029

DISCUSSION

Specialists utilize time series of catches and fishing efforts to ensure the sustainable availability of fisheries resources. Such data allow fisheries organizations to assess stock status and sustainable production levels, and implement management systems that maintain food security and support economic sustainability (Coro *et al.*, 2016). Time series data differ from other types of data in that they allow analysts to observe how variables change over time, thereby providing valuable information for management decisions. Effective time series analysis requires large, representative datasets to capture any extreme trends or patterns and to ensure consistency and reliability. Moreover, time series data can reveal seasonal variations and can be used to forecast future values based on historical trends (Vandaele, 1983).

The researchers confirmed that the average global air temperature for July 2023 was the highest ever recorded, with an increase of 1.5°C , exceeding the pre-industrial average (1815–1900) before the industrial era. This result is entirely consistent with our current study using analysis of air temperature time series (Figs. 1, 2). In addition, global sea surface temperatures rose in April 2022, which continued to rise until July and reached about 0.51°C above the average for 1991–2020. While our study found that the highest value above the average is 0.89°C using time series analysis of water temperatures (Figs. 3, 4). Moreover, it should be noted that the period from 2015 to 2022 was the “eight warmest years,” according to records dating back at least 170 years. Changes in ocean salinity were observed, with an increase in the salinity of near-surface water in areas of

greater evaporation in almost all ocean basins (**Barange *et al.*, 2018; IPCC, 2022; Sanderson, 2023**).

Upon comparing the results of average water temperatures in recent studies, we find that they are higher than those recorded in studies from previous decades. **Mohamed and Ali (1993)** stated that the average water temperatures during 1989–1990 reached 22.9°C, while the study of **Mohamed *et al.* (1998)** recorded average temperatures. The water was 23°C between the years 1995–1996, while the study of **Ali *et al.* (2000)** showed that the average temperature of our regional waters for the years 1997–1998 was 25°C, slightly lower than the previous record, as in Fig. (3, 4) as well as the record of **Mohamed *et al.* (2001)**, which reported the same average of 25 °C for the years 1998–1999. The average water temperature in the study of **Mohamed and Resen (2010)** reached 24.4°C during 2007–2008, while **Mohamed and Al-Hassani (2021)** recorded an average water temperature of 28°C during their studies for the period between 2020 and 2021.

The rising trend in surface temperatures reflects the profound human impact on the climate system since the Industrial Revolution and climate science talk spread into the public and political arenas in the 1990s, characterized by the term "Global warming hiatus". Statistics has developed methods to measure the warming trend and detect points of change: Statistics plot error bars and other uncertainty measures for estimated trend parameters. Uncertainties exist in all natural and life sciences, and error bars are an indispensable guide to interpreting any estimated valuation curve (**Romilly, 2005; IPCC, 2007; Ye *et al.*, 2013**). For example, if global temperatures stopped after 1998, then statistics reveal no basis for concluding that global warming stopped after that year. The gap after 1998 was hidden behind large error bars when looking at data until 2013 (**Mudelsee, 2019**).

These findings confirm the reliability of our results, as illustrated in Fig. (2), as well as its consistency with previous results in testing the homogeneity of time series in air temperatures, as the year 1998 was the period that separated the average temperatures for two periods of time (1979–1997) and (1998–2022). Water temperatures were affected by the rise in air temperatures after five years, with an average elevation of 25.09°C and a difference of 1.03°C. The first thing affected by the rise in water temperatures in the region is the salinity of the water. Since the region is essentially subtropical and the Arabian Gulf is considered a sea, it is semi-closed, and the average salinity concentration has increased since 2005, after three years, with an average salinity difference of 4.25 g/L. Salinity concentrations play a significant role in fish growth, especially in their effect on the nervous system, endocrine systems, egg fertilisation and incubation, yolk sac absorption, early embryogenesis, and larval growth. Salinity is the main factor in controlling growth for adult individuals in terms of metabolic rate, food intake, food conversion, and hormonal role, such as osmotic and growth regulation (**Boeuf & Payan, 2001**).

The results of our current study have revealed clear temporal in the ranges of salinity concentration between previous years, as shown in Fig. (5, 6). For example, **Ali *et al.* (1998)** showed that the ranges of salinity concentration were between 27 and 38g/ L in the period between 1990 and 1994. **Mohamed and Mutlak (2006)** stated that the highest salinity concentration was recorded in August and amounted to 41.2g/ L, while the lowest concentration reached 22.5g/ L in March. The values of salinity concentration in the study of **Mohamed *et al.* (2008)** between 1999 and 2000 were 22.5 and 41.2g/ L during March and August, respectively, reflecting a gradual increase in salinity levels over time.

It should be noted here that the time series analysis in the homogeneity test for environmental factors shows the effect of the increase in average air temperatures starting in 1998, followed by the increase in average water temperatures in 2003. In the year 2006, the increase in average salinity concentrations began, meaning that the effects of changing climate and global warming successively changed water temperatures and subsequently affected salinity concentrations, which means that the cumulative impact of climate change has become increasingly evident across interconnected environmental parameters.

The analysis of annual catch data suggests a gradual decline in fish landings in the coming years (Figs. 7, 8), despite the temporary increase recorded between 2018 and 2020. This problem does not only concern Iraqi marine waters. **Sheppard *et al.* (2010)** showed that the extent of all natural habitats in the Arabian Gulf is changing, and their condition is deteriorating for several reasons, including severe and occasional warming episodes. **Al-Mutairi (2014)** explained that the temperature of seawater in Kuwait Bay has increased at a rate of 0.6°C per decade, about three times the global average reported by the Intergovernmental Panel on Climate Change (IPCC), and the impact of temperature rise on fish. Therefore, **Algattan and Gray (2021)** showed a decline in stocks of nine fish species, primarily in Kuwait. There is growing evidence that climate change is already affecting environmental conditions in the Arabian Gulf region, in areas including sea temperature and salinity, which are set to continue to change over time, and the cumulative impacts of these changes on coastal and marine ecosystems are likely to be significant. Climate-induced environmental changes include the loss of coral reefs and declines in fish communities (**Lincoln *et al.*, 2021**).

Forster *et al.* (2012), **Mazumder *et al.* (2015)** and **Huang *et al.* (2021)** have confirmed that the reduction or decrease resulting from warming in the size, growth, and body composition of ectothermic species was ten times greater in aquatic ecosystems than in terrestrial ecosystems. In any case, despite the assurances of global researchers on this issue, the decrease in fish length in our waters is more likely attributed to overexploitation rather than climate change. Indicators of size and age composition depend on estimates of the length, weight, and age of fish and these indicators tend to paint a static picture of the community. Although conclusions about community dynamics can be drawn from its composition and the average length of fish in

standardized samples, it is used to indicate community composition, as shifts indicate that smaller average lengths of the fish sampled lead to increased exploitation (Guy et al., 2007). Iranian regional water species in the Arabian Gulf have been classified according to their vulnerability to the vulnerability index as a result of several factors, including the impact of climate change, with values ranging from 0 to 100, to low-vulnerability fish such as *Planiliza klunzingeri* with values from 0 to 25, and a moderate vulnerability index for *Platycephalus*, with values from 25 to 50, and severe weakness in *Pumpus argenteus*. *Tenuulosa ilisha* from 50 to 75 (Hashemi & Motlagh, 2021).

Mounting evidence indicates that exposure to environmental changes caused by climate warming leads to an uncertain future for both wild fish diversity and global fisheries (Xenopoulos et al., 2005; Comte & Olden, 2017; Free et al., 2019). Climate change threatens and impacts the entire biosphere, especially coastal marine ecosystems, as a major driver of coastal marine biodiversity loss and ecosystem functioning associated with increased frequency and intensity of marine heatwaves (abnormally long periods of warm ocean temperatures or extremely warm temperatures during short periods) (Harley et al., 2006; Smith et al., 2023). Complex pathways and shifts in environmental conditions can directly affect species ranges, movement, abundance, and fitness, as well as the relationship between multispecies assemblages or communities and their environment (Troast et al., 2020; Baker et al., 2023). Furthermore, there is the potential for food web destabilisation as species are less likely to respond to stress at the same rate (DiLeone & Ainsworth, 2019).

It is noted from Table (3), which represents an application of the non-linear multiple regression model equation, that water temperature has the main effect on the abundance and presence of fish and consequently on the catch quantities, followed by the salinity factor in the second degree of influence and directly linked to the rise in temperatures as a result of climate change, specifically marine heat waves, which have a major role in the decrease in catch quantities during the hot months. As a result, Table (4) estimates the critical temperature period, which is between 2027 and 2029, specifically at the beginning of summer. It is also noted that the prediction line ($R^2 = 0.9473$ Fun.2), which indicates that water temperature rates have reached the critical value, has shown the progress of marine heat waves to the middle of May. If this happens, marine heat waves will extend from the middle of May to the end of August, and the habitats of the ecosystem may decline dangerously, and it will be difficult to restore the environment.

Marine heatwaves are becoming increasingly common, with devastating ecosystem impacts. Their understanding is based almost exclusively on sea surface temperature, with limited knowledge of their subsurface characteristics and the vulnerability of biodiversity to their effects. They are typically found to be most intense below the surface at 50– 200m depth and their duration increases by up to twofold with depth. However, there is significant spatial variability associated with different oceanographic conditions.

High cumulative densities overlap with the warm-range edge of species distribution and are therefore more sensitive to thermal stress (**Fragkopoulou et al., 2023**).

Fredston et al. (2023) showed that marine heatwaves consistently lead to community reorganization and fish biomass collapse and have catastrophic consequences for ecosystems and fisheries, with severe biomass declines sometimes occurring after marine heatwaves. **Smith et al. (2023)** stated that marine heatwaves are discrete periods of unusually warm waters, and they are becoming more frequent and widespread stressors on marine ecosystems, affecting the health of those systems globally. **Cheng et al. (2017)** showed that the warming trends were represented by an increase in warm days and nights and a decrease in cold nights and days, with nighttime maximum temperatures being more than twice the average of their corresponding daytime maximum temperatures. The intensity and frequency of hot days increased, and the minimum temperature averages increased.

The important question is: What are the measures and strategies for adapting our region's fish during marine heat waves? Intuitively, they will seek cooler, more suitable habitats. One conservation scenario is for them to descend to deeper areas less affected by rising temperatures (vertical migration). However, this scenario is unlikely to succeed due to the shallow depth of our territorial waters, which means they are affected by rising temperatures, just like surface waters. The second scenario is for them to move away to distant areas (horizontal migration) within the deeper open sea. **Sale et al. (2011)** indicated that the average depth of the Arabian Gulf is 34m, with a maximum depth of 94m. There are other reasons: Some fish species are tolerant of environmental stress, but they will follow their prey that has left their environment, which may be difficult to obtain during such conditions. This could disrupt the food chains of many species. In this regard, environmental loss and gain must be included, as well as the ecosystem services provided in terms of the decline in sensitive species and perhaps the increase in tolerant species, and so on for other marine organisms. The important question that must be asked is who is most affected? It appears that attention will turn to benthic fish, which, unlike surface fish, may not have the rapid opportunity to shift their location in a direction that ensures their survival requirements.

CONCLUSION

The study demonstrated that climate change, manifested through marine heatwaves, plays a significant role in reducing fish catches during the hot months of July and August. Predictions indicate that water temperature will increase in the near future, with its intensity and timescale expanding from June to August. This will place pressure on the Iraqi marine ecosystem. A greater understanding of these impacts on the resilience of the region's ecosystems and food webs is needed.

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CONFLICT OF INTEREST

The authors declare that there is no conflict of interest regarding the publication of this manuscript. In addition, the authors have fully addressed the ethical issues, including plagiarism, informed consent, misconduct, data fabrication and/or falsification, double publication and/or submission, and redundancy.

REFERENCES

- Al-Baghdadi, N.M; Abbas, M.F.; Al-Najare, G.A; Younis K.H. and Karim, R.M.** (2024). Monitoring Environmental Changes in the Shatt al-Arab River Using the Organic Pollution Index (OPI) and Two Species of Benthic Invertebrates *Melanoides tuberculata* and *Neritina violacea*. Egyptian Journal of Aquatic Biology and Fisheries, 28(3): 889-909. DOI:10.21608/ejabf.2024.361082.
- Aldoghachi, M.A. and Altamimi, E.D.** (2021). Assessment of Water Quality Using Heavy Metals Concentrations in Several Water Resources of Shatt al-Arab and Tissues of the Nile Tilapia (*Oreochromis niloticus*) and the Shrimp (*Metapenaeus affinis*). Egyptian Journal of Aquatic Biology and Fisheries, 25(2): 803-817. doi: 10.21608/ejabf.2021.169923
- Ali, T.S.; Mohamed, A.R.M. and Hussain, N.A.** (1998). The status of Iraqi marine fisheries during 1990-1994. Marina Mesopotamica, 13 (1): 129-147.
- Ali, T.S.; Mohamed, A.R.M. and Hussain, N.A.** (2000). Growth, Mortality and Stock Assessment of Silver pomfret, *Pampus argenteus* in the Northwest Arabian Gulf, Iraq. Marina Mesopotamica, 15 (2): 373-387.
- Allison, E.H.; Perry, A.L.; Badjeck, M.C.; Neil Adger, W.; Brown, K.; Conway, D. and Dulvy, N.K.** (2009). Vulnerability of national economies to the impacts of climate change on fisheries. Fish and fisheries, 10(2): 173-196.
- Al-Mutairi, N.; Abahussain, A. and Al-Battay, A.** (2014). Environmental Assessment of water quality in Kuwait bay. Int. J. Environ. Sci. Dev. 5, 527–532. doi: 10.7763/IJESD. 2014. V5.539.
- Alqattan, M.E. and Gray, T.S.** (2021). Marine Pollution in Kuwait and Its Impacts on Fish-Stock Decline in Kuwaiti Waters: Reviewing the Kuwaiti Government's Policies and Practices. Frontiers in Sustainability, 2, 667822.

- Al-Shamary, A. and Younis, K.H.** (2024). Evaluation of the environment of the Shatt Al-Arab estuary and Iraqi marine waters using the Estuarine Biological Integrity Index (EBI). *Iraqi Journal of Aquaculture*, 21(2): 45-65.
- Baker, S.M.; Reyier, E.A.; Ahr, B.J. and Cook, G.S.** (2023). Assessing the Effects of Physical Barriers and Hypoxia on Red Drum Movement Patterns to Develop More Effective Management Strategies. *Fishes*, 8(4): 171.
- Barange, M.; Bahri, T.; Beveridge, M.C.; Cochrane, K.L.; Funge-Smith, S. and Poulain, F.** (2018). Impacts of climate change on fisheries and aquaculture. United Nations' Food and Agriculture Organization, 12(4): 628-635.
- Borelli, G.; Mayer-Gostan, N.; De Pontual, H.; Boeuf, G. and Payan, P.** (2001). Biochemical relationships between endolymph and otolith matrix in the trout (*Oncorhynchus mykiss*) and turbot (*Psetta maxima*). *Calcified Tissue International*, 69(6): 356-364.
- Brander, K.** (2010). Impacts of climate change on fisheries. *Journal of Marine Systems*, 79 (3-4): 389-402.
- Cheng, W.L.; Saleem, A. and Sadr, R.** (2017). Recent warming trend in the coastal region of Qatar. *Theoretical and Applied Climatology*, 128, 193-205.
- Coro, G.; Large, S.; Magliozzi, C. and Pagano, P.** (2016). Analysing and forecasting fisheries time series: purse seine in Indian Ocean as a case study. *ICES Journal of Marine Science*, 73(10): 2552-2571.
- Coulthard, S.** (2009). Adaptation and conflict within fisheries: insights for living with climate change. *Adapting to Climate Change: Thresholds, Values and Governance* (eds. Adger, W.N., Lorenzoni, I. and O'Brien, K.L.), Cambridge: Cambridge University Press. 255-268.
- DiLeone, A. G. and Ainsworth, C. H.** (2019). Effects of *Karenia brevis* harmful algal blooms on fish community structure on the West Florida Shelf. *Ecological Modelling*, 392, 250-267.
- FAO** (2016). The state of world fisheries and aquaculture 2016. Publications of Food and Agriculture Organization of the United Nations Rome. 23pp.
- Farmer, N.A. and Froeschke, J. T.** (2015). Forecasting for recreational fisheries management: what's the catch? *North American journal of fisheries management*, 35(4): 720-735.
- Forster, J.; Hirst, A.G. and Atkinson, D.** (2012). Warming-induced reductions in body size are greater in aquatic than terrestrial species. *Proceedings of the National Academy of Sciences*, 109(47): 19310-19314.
- Fragkopoulou, E.; Sen Gupta, A.; Costello, M.J.; Wernberg, T.; Araújo, M.B.; Serrão, E.A.; De Clerck, O. and Assis, J.** (2023). Marine biodiversity exposed to prolonged and intense subsurface heatwaves. *Nature Climate Change*, 13(10): 1114-1121.

- Fredston, A. L.; Cheung, W.W.; Frölicher, T.L.; Kitchel, Z.J.; Maureaud, A.A.; Thorson, J.T.; Auber, A.; Mérigot, B.; Palacios-Abrantes, J., Palomares, M.L.D.; Pecuchet, L.; Shackell, N.L. and Pinsky, M.L.** (2023). Marine heatwaves are not a dominant driver of change in demersal fishes. *Nature*, 621(7978): 324-329
- Free, C. M.; Thorson, J.T.; Pinsky, M.L.; Oken, K.L.; Wiedenmann, J. and Jensen, O.P.** (2019). Impacts of historical warming on marine fisheries production. *Science*, 363 (6430): 979-983.
- Guy, C.S.; Neumann, R.M.; Willis, D.W. and Anderson, R.O.** (2007). Proportional size distribution (PSD): a further refinement of population size structure index terminology. *Fisheries*, 32(7):348.
- Halpern, B.S.; Longo, C.; Hardy, D.; McLeod, K.L.; Samhouri, J.F.; Katona, S.K. and Zeller, D.** (2012). An index to assess the health and benefits of the global ocean. *Nature*, 488(7413): 615-620.
- Harley, C.D.G.; Randall Hughes, A.; Hultgren, K.M.; Miner, B.G.; Sorte, C.J.B.; Thornber, C.S.; Rodriguez, L.F.; Tomanek, L. and Williams, S.L.** (2006). The impacts of climate change in coastal marine systems. *Ecology Letters*, 9(2): 228–241.
- Hashemi, S.A. and Taghavi Motlagh, S.A.** (2021). Vulnerability assessment of capture fishing major fish species based on demographic parameters in Persian Gulf and Oman Sea. *Iranian Scientific Fisheries Journal*, 30(4): 53-63.
- Hollowed, A.B.; Barange, M.; Beamish, R.J.; Brander, K.; Cochrane, K.; Drinkwater, K. and Yamanaka, Y.** (2013). Projected impacts of climate change on marine fish and fisheries. *ICES Journal of Marine Science*, 70(5): 1023-1037.
- Huang, M.; Ding, L.; Wang, J.; Ding, C. and Tao, J.** (2021). The impacts of climate change on fish growth: A summary of conducted studies and current knowledge. *Ecological Indicators*, 121, 106976.
- IPCC** (2007). *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, In: Solomon, S., Qin, D., Manning, M., Chen, Z., Marquis, M., Averyt, K. B., Tignor, M. and Miller, H. L. (eds.). Cambridge, Cambridge University Press. 74pp.
- IPCC** (2022). *Climate Change 2022: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change* [Pörtner, H.O., Roberts, D.C., Tignor, M., Poloczanska, E.S., Mintenbeck, K., Alegría, A.M., Langsdorf, S., Löschke, S., Möller, V., Okem, A., and Rama, B. (eds.)]. Cambridge University Press. Cambridge University Press, Cambridge, UK and New York, NY, USA, 3056 pp., doi:10.1017/9781009325844.

- Lincoln, S.; Buckley, P.; Howes, E.L.; Maltby, K.M.; Pinnegar, J.K.; Ali, T.S. and Le Quesne, W. J.** (2021). A regional review of marine and coastal impacts of climate change on the ROPME sea area. *Sustainability*, 13(24): 13810.
- Maunder, M.N.; Sibert, J.R.; Fonteneau, A.; Hampton, J.; Kleiber, P. and Harley, S.J.** (2006). Interpreting catch per unit effort data to assess the status of individual stocks and communities. *Ices Journal of marine science*, 63(8): 1373-1385.
- Mazumder, S.K.; De, M.; Mazlan, A.G.; Zaidi, C.C.; Rahim, S.M. and Simon, K.D.** (2015). Impact of global climate change on fish growth, digestion and physiological status: developing a hypothesis for cause-and-effect relationships. *Journal of Water and Climate Change*, 6(2): 200-226.
- Mohamed, A.R.M. and Ali, T.S.** (1993). Growth, mortality, and evaluation of the zubaidi fish *Pampus argenteus*, in the northwestern Arabian Gulf. *Ibaa Journal of Agricultural Research*, 3 (1). (*In Arabic*)
- Mohamed, A.R.M. and Mutlaq, F.M.** (2006). Monthly changes in the catch of three Species of goatfish in Khor Al Amaya, northwest of the Arabian Gulf. *Mesopotamian Journal of Marine Science*. 21 (2): 257-270. (*In Arabic*)
- Mohamed, A.R.M. and Resen, A.K.** (2010). The population status of sulphur goatfish *Upeneus sulphureus* in the Iraqi marine waters, northwest Arabian Gulf. *Mesopotamian Journal of Marine Science*, 25(1): 31-40.
- Mohamed, A.R.M. and Al-Hassani, A.H.** (2021). Population dynamics of Arabian yellowfin seabream, *Acanthopagrus arabicus* Iwatsuki, 2013 from Iraqi marine waters, Arabian Gulf. *International Journal of Fisheries and Aquatic Studies*, 9(4): 15-25.
- Mohamed, A.R.M.; Hussain, S.A. and Saleh, J.H.** (1998). Ecology, growth and Stock assessment of golden mullet (*Liza carinata*) in the north-western Arabian Gulf/Iraq. *Mesopotamian Journal of Marine Science*, 13 (1): 201-220. (*In Arabic*)
- Mohamed, A.R.M., Ali, T.S. and Hussain, N.A.** (2001). Stock assessment of Hilsa shad *Tenualosa ilisha* in the Iraqi marine waters, northwest Arabian Gulf. *Marina Mesopotamica*, 16 (1): 1-9.
- Mohamed, A.R.M.; Hussain, S.A. and Mutlaq, F.M.** (2008). Growth and stock of Sultan Ibrahim fish (*Upeneus sulphureus*) in Iraqi marine waters, northwest of the Arabian Gulf. *Basra Journal of Veterinary Research*, 7(1): 104-119. (*In Arabic*)
- Mudelsee, M.** (2019). Trend analysis of climate time series: A review of methods. *Earth-science reviews*, 190, 310-322.
- Muringai, R.T.; Mafongoya, P. and Lottering, R.T.** (2022). Climate Change Perceptions, Impacts and Adaptation Strategies: Insights of Fishers in Zambezi River Basin, Zimbabwe. *Sustainability*, 14(6): 34-56.
- Romilly, P.** (2005). Time series modelling of global mean temperature for managerial decision-making. *Journal of environmental management*, 76(1), 61-70.

- Sale, P.F.; Feary, D.A.; Burt, J.A.; Bauman, A.G.; Cavalcante, G.H.; Drouillard, K.G.; Kjerfve, B.; Marquis E.; Trick C.G.; Usseglio P. and Van Lavieren, H.** (2011). The growing need for sustainable ecological management of marine communities of the Persian Gulf. *Ambio: A Journal of Environment and Society*, 40: 4-17.
- Sanderson, K.** (2023). Earth's average 2023 temperature is now likely to reach 1.5°C of warming. *Nature*. 2023 Sep 22. doi: 10.1038/d41586-023-02995-7. Epub ahead of print. PMID: 37740018.
- Sheppard, C.; Al-Husiani, M.; Al-Jamali, F.; Al-Yamani, F.; Baldwin, R.; Bishop, J. and Zainal, K.** (2010). The Gulf: a young sea in decline. *Marine Pollution Bulletin*, 60(1), 13-38.
- Shono, H.** (2008). Application of the Tweedie distribution to zero-catch data in CPUE analysis. *Fisheries Research*, 93(1-2): 154-162 .
- Smith, K.E.; Burrows, M.T.; Hobday, A.J.; King, N.G.; Moore, P.J.; Sen Gupta, A.; Thomsen, M. S.; Wernberg, T. and Smale, D.A.** (2023). Biological impacts of marine heatwaves. *Annual Review of Marine Science*, 15(1): 119–145.
- Troast, B.; Paperno, R. and Cook, G.S.** (2020). Multidecadal shifts in fish community diversity across a dynamic biogeographic transition zone. *Diversity and Distributions*, 26(1): 93-107.
- Vandaele, W.** (1983). *Applied Time Series and Box-Jenkins Models*. Academic Press, 417p.
- Ward, E.J.; Holmes, E.E.; Thorson, J.T. and Collen, B.** (2014). Complexity is costly: a meta-analysis of parametric and non-parametric methods for short-term population forecasting. *Oikos*, 123(6): 652-661.
- Xenopoulos, M.A.; Lodge, D.M.; Alcamo, J.; Marker, M.; Schulze, K. and Van, D.P.** (2005). Scenarios of freshwater fish extinctions from climate change and water withdrawal. *Global change biology*, 11(10): 1557-1564.
- Ye, H.; Beamish, R.J.; Glaser, S.M.; Grant, S.C.; Hsieh, C.H.; Richards, L.J. and Sugihara, G.** (2015). Equation-free mechanistic ecosystem forecasting using empirical dynamic modeling. *Proceedings of the National Academy of Sciences*, 112(13): E1569-E1576.
- Ye, L.; Yang, G.; Van Ranst, E. and Tang, H.** (2013). Time-series modelling and prediction of global monthly absolute temperature for environmental decision-making. *Advances in Atmospheric Sciences*, 30, 382-396.