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Temperature and Salinity Effects in Sensitive Area of Qeshm Island: Mangrove Forests

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ABSTRACT

Mangrove forests of Qeshm Island could be considered as one of the most important and sensitive ecosystems of the Persian Gulf. The Growth and evolution of mangrove forests are affected by various factors such as pollution, light penetration, depth, water flow, and water quality. Consequently, it is vital to monitor the environmental changes of these mangrove forests. Hence, this study was aimed to evaluate the effects of sea surface temperature and salinity changes on vegetation level in the Khor-e-khoran protected area in two distinct time periods (1986-1999 & 2001-2015). In order to achieve the desired accuracy and details, various data sources were applied including recorded data in the department of environment of Iran, satellite imagery, drawing profiles and charts by standard models of ECMWF and Giovanni. The results of the present study clarified that Sea Surface Temperature and Salinity increased by about 0.2°C and 0.5 ppt respectively. Comparing the total areas of studied mangrove forests indicated that the total area of Khor-e-khoran protected area was decreased from about 6800 hectares in 2003 to 6350 hectares in 2015 which was more than 1.5%. It was suggested sewages and wastewaters delivered from shrimp farming pools as well as fuel and crude oil leakage caused salinity and pollution anomalies in this region.

1. Introduction

Qeshm Island located on the eastern side of the Strait of Hormuz which is one of the most important and sensitive areas of the Persian Gulf, due to its unique geographical, economical, geopolitical, environmental, and ecological conditions. In order to achieve sustainable land use, it is vital to consider the conservation and restoration of regional ecosystems, which should be the priority of the regional environmental programs [1]. Therefore this area was classified as an international sensitive area based on the Ramsar Convention which was designated in 1971 [2]. In the 1992 IUCN's agenda, governments have been urging to identify and protect sensitive areas with the priority of coral reef ecosystems, tropical wetlands, mangroves, sea buckthorns, aquaculture spawn, and regeneration areas. Therefore, the presence of mangrove forests in the list of sensitive and protected national and international areas is one of the most important factors in the coastal areas of Qeshm Island [3]. Determining the coastal protected areas, especially the national parks in the northern coasts of the Persian Gulf is not only an issue but also politically important and gaining global credibility for the country, due to the presence of major biodiversity focal areas such as coral rocks, mangroves, birds and aquatic species [4].
Sea surface temperature can affect the metabolism and biological activities rate of aquatic organisms [5] and thus affect the habitats [6]. Some of these species, especially aquatic plants, flourish at higher temperatures, while others prefer lower temperatures [6]. The mangrove plant does not expand when the annual average temperature is less than 19 °C and the ecosystem is out of balance [7]. The photosynthesis rate of most mangrove species decreases sharply when the temperature is more than 35 °C. Temperature seems to be important regulators for the survival or destruction of mangrove habitats. Some adaptations of mangrove ecosystems to prevent excessive dehydration are sweating, thick leaves, small hairs on leaves, adjustment of respiratory pores, and water conservation in leaves [8].
There are various water-soluble salts which improve salinity balance. Major ions in seawater (with a practical salinity of 35 ppt) are chlorine, sodium, magnesium, sulfate, calcium, potassium, bicarbonate, and bromine[6].Salinity anomalies could be considered

as one of the major disturbances of aquatic plants. Generally, salinity anomaly leads to physiological drought, nutritional imbalance, or a combination of all of these factors. Due to the lack of oxygen in the manure habitats, the vertical roots are efficient for gas exchange and respiration in the sludge. The concentration of salt in the stem of different mangroves species is recorded from 0.5 ppt to 8 ppt, usually higher values might be observed in Avicennia marina specie. This relatively consistent value is much lower than the salinity of the seawater [9].

According to the carried out studies, physicochemical factors such as water temperature, salinity, penetration, local flow, and contamination that play a decisive role in identifying coastal-marine protected areas are highly effective parameters in the reproduction and survival of mangrove ecosystems species [10]. By comparing and interpreting the aerial photos of two separate periods in 1985 and 1993, it was identified that the area of Mangrove forests observed in the Qeshm region (including Mangrove forests in the north and southeast) was decreased from an approximate area of 8026 hectares to 8016 hectares [11].

Manson et al. (2003) applied two methods of spatial-temporal analysis and variation detection to estimate and report the variations in the distribution and expansion of mangrove habitats in the Moreton Gulf and southwest areas of Queensland over the past 25 years. Results indicated that about 3800 hectares have been destroyed by natural losses and clearing mangroves because of urban development, aquaculture, industrial and agricultural development and only about 15,000 hectares of mangrove habitats remained in this bay currently [12].

Coastal-marine protected areas, despite being more sensitive, fragile, and rich are not old enough, and their conservation and management have many failures due to this negligence, today [3]. Therefore, the importance of further investigation in the area of Khor-e-khoran and filling of the existing gap highlights the necessity for this research. Also, the scientific background shows that the area of Mangrove forests in Khor-e-khoran has been decreased over the last decades.

Since the physical factors such as sea surface temperature and sea surface salinity are affected directly or indirectly the resilience and rehabilitation of Mangrove habitats of this region [13], this study was aimed to investigate the changes of temperature and salinity in two distinct periods and its relationship with reducing the area of mangrove forests. Mangrove forests in Iran are mainly composed of the Avicennia marina species, moreover, the marshlands of Rhizophora mucronata were observed around the Qeshm Island, and the Khamir port. The mangrove tree of Rhizophora mucronata, a dominant biotic species of Qeshm Island, is a fundamental ecologic specie that grows in tropical and subtropical waters and absorbs large quantities of carbon dioxide, and its existence is a factor for the regulation of salinity in the area, also it is considered as the habitat of many birds and rare species [14]. The economic value of natural products and ecosystem services generated by mangrove ecosystems is significant. Mangrove forest provide various economic and ecological services such as protection against floods and shoreline recession as well as maintenance of biodiversity [15].

2. Materials and Methods

2.1. Study area

The present investigation was accomplished in a mangrove protected area which is located between the north of Qeshm Island and Bandar Khamir (Khor-e-khoran International Lagoon). The mangrove habitats of this area could be considered as the most conserved mangrove ecosystem of the Persian Gulf in terms of quality. According to reports of the department of environment of Iran, the area of Mangrove forests has declined over recent decades [14]. The Mangrove forests of Qeshm Island are located between the delta of Mehran and Gavarzin rivers in the northern section of the Qeshm Island (45' 26 ° to 27 ° N and 20' 55 ° to 51' 55 ° E) (Figure 1).

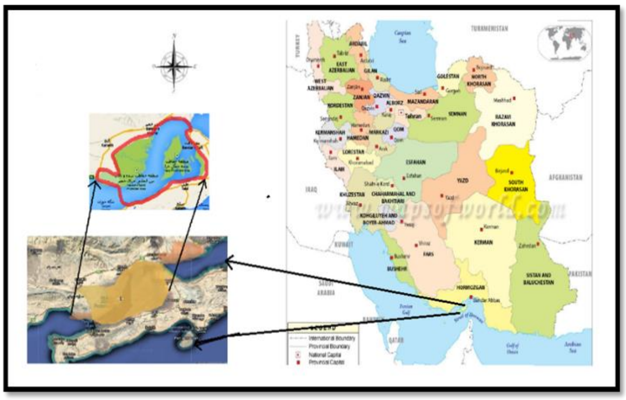

Figure1: Geographical location of Khor-e-khoran international lagoon

2.2. Temperature Data

The ECMWF model was used to measure sea surface temperature data. This model provides weather forecasts for an average period of time. The main task of this model is to generate numerical predictions as well as, conduct scientific and technical researches to improve the accuracy of forecasting and maintaining the meteorology data archives. The sea surface temperature data for over 30 years in two distinct periods were applied for the present study (1968-1985 and 2001-2015). Totally, 24 data collection points were considered and parameters were recorded in two interval times periods per day (12:00 am and12:00 pm). The data files were downloaded in net CDF format and retrieved using Panoply software, and then the average monthly sea surface temperature was calculated using Excel software.

2.3. Salinity Data

Regarding the collection of sea surface salinity data for the statistical period, only there were continuous data for 7 years available (2007 to 2014). Seasonal variations were plotted for 3 years by the Giovanni model, and the data used for the years 2007 to 2011, was found in the reports of the Iran Fisheries Research Institute and documentation available at the Library of the Persian Gulf and The Oman Sea Ecological Institute [16].

2.4. Variable Vegetation Changes Data

Changes in vegetation over the past 30 years investigated by Landsat 4 and 5 satellite images (TM sensors) from 1985 to 1986 and 1999 to 2000, Landsat 7 (ETM + sensor) from 2000 to 2014, and Landsat 8 (OLI Sensor) was been used for 2015. Khor-e-khoran is located at the 160-41 scene of Landsat data [17]. Detection of variations and determining the most appropriate indicator in a region depends on the applied remote sensing technique to specify the spatial, and temporal characteristics of the sensor system. Satellite data from the OLI, ETM +, TM, and MSS sensors from Landsat satellite was used to a large extent for monitoring vegetation changes [18]. In this study, OLI, ETM +, and TM images from the Landsat satellite were used. The satellite images which were used for 2015, 2001, 1999, and 1986. In order to achieve the highest possible efficiency in terms of identifying the changes in vegetation over time, the input pictures were in the same tidal conditions. Additionally, Khor-e-khoran mangrove vegetation was also at the peak of physiological potential. Some studies suggested that in order to characterize land cover changes in tidal areas with a desirable accuracy, the best time is winter season and around March. Therefore, winter tide images were prepared from the study area [17].

In this research, the normalized difference vegetation index (NDVI) was applied. The NDVI vegetation index is a two-variable index that has been developed to describe vegetation and can be used to differentiate between near-infrared (which is strongly reflected by plants) and red light (which is absorbed by plants), that provides vegetation points. This index is widely used based on spectral values in identifying vegetation [19, 20]. In order to reveal vegetation changes, two methods of differentiation and comparison after classification were used with a threshold of twice the mean deviation. In the variation method, the depicted image of a date decreased from the image shown on another date (the second date from the first date). If the result of this difference was not significant, it was indicated that changes were neglectable. Negative values mean a decrease and positive values mean an increase [21]. In the comparison method after classification, a map of the Khor-e-khoran mangrove forest area was required at two-time intervals. After categorizing, images were compared independently. For categorization, they were first selected on each colored image in the forest class and non-malleable. Then, the degree of separation between classes and the appropriate selection of samples with divergence criteria were examined. Classification is performed using the maximum probability algorithm [22].

3. Results

3.1. Sea Surface Temperature

The sea surface temperature data in the study area was collected throughout 30 years-1985 to 2015-by the ECMWF model. The results are presented in Table 1 and Table 2. Furthermore, changes in the sea surface temperature are plotted in Figure 2. Results exhibited an average increase in the sea surface temperature in two studied periods (1986-1999 and 2001-2015) in Khor-e-khoran, which was about 0.2 °C. These variations had a short-term fluctuation and also in recent years, there has been an increase in sea surface temperature average.

Table 1: Mean sea surface temperature changes (°C) in Khor-e-khoran over the 1986-1999 period

Year / Month	JLY	AGU	SEP	NOV	OCT	DEC	Annual Average
1985	32.77	33.09	31.61	30.18	28.26	24.86	28.25
1986	32.86	32.2	31.61	30.67	28.08	25.83	28.15
1987	32.66	32.94	31.64	30.71	27.95	24.48	27.95
1988	32.08	31.9	31.3	30.41	27.81	24.27	27.6
1989	31.99	32.04	30.85	29.89	28.02	25.26	27.68
1990	32	32.95	32.19	30.58	28.05	25.58	27.73
1991	32.17	32.12	31.48	30.56	27.98	24.19	27.75
1992	32.07	32.61	31.82	29.88	27.61	25.25	27.57
1993	31.9	32.1	31.3	30.41	27.42	24.46	27.46
1994	31.81	31.92	31.92	30.09	27.28	24.54	27.27
1995	31.93	32.22	31.54	30.61	27.84	25.3	27.82
1996	31.77	32.07	31.81	30.22	27.49	24.58	27.5
1997	31.78	31.87	31.7	30.11	27.64	24.82	27.19
1998	31.63	31.58	31.13	30.18	27.14	24.67	27.21
1999	32.22	32.07	31.82	30.21	26.73	24.44	27.31

Table 2: Mean sea surface temperature changes (°C) in Khor-e-khoran over the 2001-2015 period

Year / Month	JLY	AGU	SEP	NOV	OCT	DEC	Annual Average
2001	32.01	32.68	31.02	29.95	27.48	24.49	27.68
2002	31.39	32.73	33.03	30.86	27.55	28.46	28.05
2003	33.33	33.67	32.23	30.75	28.15	25	28.14
2004	31.81	32.84	31.61	30.16	28.51	25.56	27.78
2005	32.13	32.66	31.76	30.52	25.35	25.42	27.38
2006	32.85	27.36	31.84	30.43	28.27	25.78	27.48
2007	31.53	31.45	30.87	29.52	27.46	24.93	27.2
2008	31.46	32.34	32.06	29.88	28.05	25.03	27.24
2009	32.43	33.07	32.38	30.21	28.07	25.2	27.69
2010	31.61	32.34	31.86	30.02	28.17	24.91	27.84
2011	31.81	32.32	32.1	30.67	27.53	24.44	27.55
2012	32.71	32.57	31.68	29.57	27.23	24.56	27.72
2013	32.16	32.06	32.3	30.99	28.07	25.33	27.6
2014	32.38	33.2	32.16	30.56	28.62	26.43	28.24
2015	32.57	33	31.56	30.56	28.65	25.92	28.73

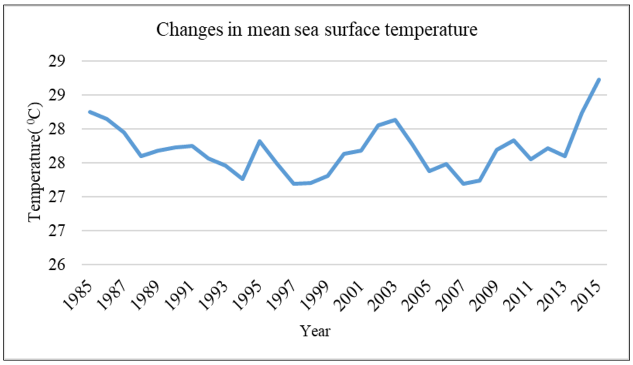

Figure 2: Mean sea surface temperature changes (°C) in Khor-e-khoran for the last 30 years, ECMWF model.

3.2. Sea Surface Salinity

The seasonal variations in sea surface salinity between 2012 and 2015 were indicated by Giovanni model and plotted in figure 3. This chart indicated the average sea surface salinity values in Khor-e-khoran were increased in winter, spring, and summer-during 3 years while only there was a decrease in the mean salinity in fall. The trend of Figure 3 and library documentation indicated that the mean sea surface salinity increased during the studied periods (Figure 4). Since our goal was to investigate the effect of salinity changes on the mangrove trees growth at a low depth. The study of the trend of salinity changes in deep areas was not in line with our objective and could be ignored.

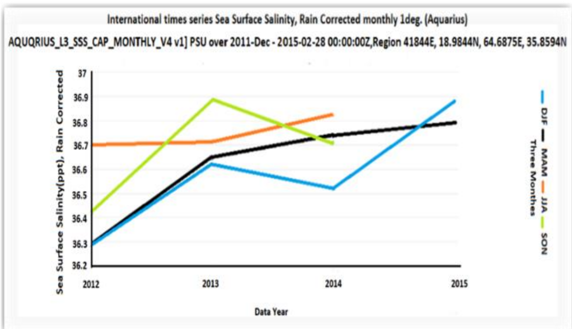

Figure 3: Seasonal variations of sea surface salinity (ppt) in Khor-e-khoran, the Giovanni model, during 2012-2015.

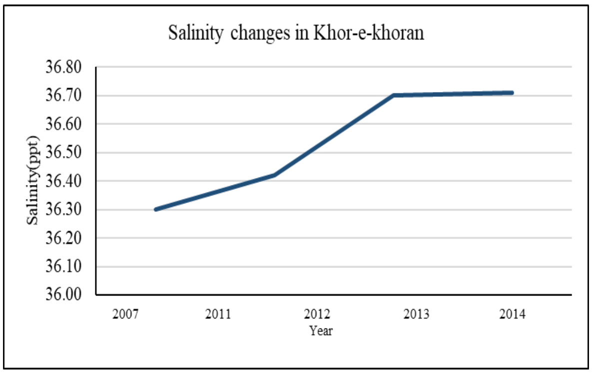

Figure 4: sea surface salinity changes (ppt) in Khor-e-khoran during 2007-2014.

3.3. Vegetation cover

Various methods applied to determine the variation of vegetation cover of mangroves included (i) reduction percentage of mangrove forest by comparison after classification, (ii) reduction percentage of mangrove forest by the variation, (iii) secondary area by comparison after classification, (iv) secondary area by the variation, (v) reduction rate by comparison after classification, and (vi) reduction rate by the variation. The average salinity, average temperature and initial area of mangrove forest per hectares in mangrove habitats of the Khor-e-Khoran area tabulated in table 3. The results of the reduction percentage of mangrove forests by comparison after classification and variation indicated that the area of studied mangrove habitat declined about 2.85 and 2.3%, respectively. Additionally, based on the secondary area by comparison after classification and variation results, it was clarified that the area of studied mangrove habitat is decreased about 2000m2. Moreover, the rates of reduction were recorded about 194 and 151 hectares by comparison after classification and rate of reduction by variation, respectively. As well as, a relative increase was recorded in average sea surface temperature (about 0.2 °C) whereas the initial area of mangrove forest decreased about 1700 hectares during the studied period. Accordingly, all studied methods shown similar results. Results implied a significant decrease in the area of mangrove habitats in the Khor-e-khoran during the last decades.

4. Discussion and Conclusions

This study was aimed to investigate the sea surface temperature and sea surface salinity changes and its impact on the area of mangrove forests in the Khor-e-khoran region in the last 30 years. The results of satellite and field data showed that the temperature and salinity levels have increased during the studied period, while the area of the mangrove forests has been decreased. In other words, the highest rates of area changes were recorded between 2001 to 2015 which was coincided with the highest variations in sea surface salinity and temperature. So it is suggested that salinity and temperature growth affected the resistance and resilience of mangrove ecosystems of the Khor-e-khoran region against harsh environmental conditions which led to a significant decrease in the area of the studied mangrove habitats.

The observed changes in the mean sea surface temperature in two distinct periods during the last 30 years (1989-1999 and 2001- 2015) indicated that the mean temperature increased 0.2 °C and the average salinity was increased by 0.5 ppt in the second statistical period (2001-2015), compared to the first period (1986-1999). Also in the second period, the decreasing trend of mangrove forests was observed on a larger scale. Therefore, it could be suggested that temperature and salinity anomalies adversely affected the growth of this biological species. As well as, other regional anthropogenic sources of contamination and hypersaline sewages such as wastewaters delivered from industrial areas, petroleum and refinery centers, shrimp farming pools, and fuel and crude oil leakage could ultimately lead to out of balance changes in the natural composition of seawater. The mentioned increase in the sea surface salinity in the Khor-e-khoran area, coincided with a growth in sea surface temperature, indirectly.

Since the temperature and salinity changes are in full interaction, it could not be determined which one has a greater effect on the growth of mangrove forests. Based on the findings of Sabzaghbaei et al. (2015) and Tovisekani and Najafipour. (2016), comparing Landsat satellite images in 2002 and 2014, and monitoring the classification, mangrove forests have decreased by 11%. Which is consistent with the result of this research [23, 24]. Also, Noor et al. (2015), in a paper titled "Effects of siltation, temperature and salinity on mangrove plants", mentioned that fluctuations in temperature and salt stress are two important factors in the creation of different anatomical and physiological characteristics in the mangrove trees of the region, which indicates that the area of this ecosystem was reduced [25]. Mangrove species in this region are similar to those in the Qeshm Island. Therefore, it can be concluded that salinity rise or change in its composition in the region's water has a negative effect on the reproduction and life cycle of mangrove forests and may slow down their growth. Due to the similarity of mangroves in the mentioned studies, this result is also generalized to the mangrove forests of the Khor-e-khoran area.

Additionally, the increase in unemployment and the increase in poverty in the region and the local population's economic dependence on these regions, the difference in the price of fuel in Iran with neighboring countries and its global price has led to an increase in new economic activities for earning money, such as smuggling of fuel. Discharging fuel in water, sometimes in the vicinity of mangrove forests, can damage the roots of mangrove and dehydrate them [22]. The most important regional threats to these forests in the studied area are the wastewater of shrimp farming pools established in the vicinity of the mangrove forests. These hypersaline flows could affect the sea surface salinity of coastal ecosystems. Additionally, the evacuation of fuel and oil in water affected the quality of seawater in shallow ecosystems. Subsequently, unsustainable anthropogenic coastal activities causing biologic changes in the region and ultimately the destruction of its environment [26]. A similar study accomplished by Karimi et al. (2019) reported that untreated wastewaters released from shrimp farms of Say-e-khosh in Bandar-e-Lengeh, located in the western part of the studied area, could be considered as a dominant factor in the degradation of mangrove forests in southern coasts of the Persian Gulf [22]. Besides, harvesting mangrove leaves for livestock, especially camels, during the dry seasons is also a threat to mangrove forests [26].

It is suggested that in order to enrich the region database; more attention will be required to implementing point-to-point water monitoring projects so more sustained programs in line with this issue can be done. Since the rehabilitation of shrimp pools has altered the salinity of the region and has a negative impact on the biology of the area, it is recommended that a proper solution must be adopted in relation to the withdrawal or treatment of wastewaters delivered from shrimp pools in this area. In order to prevent increasing the sea surface temperature and sea surface salinity and to improve the growth of mangrove forests in the target area, managing and monitoring human activities in the region, such as fuel smuggling, is a small, but effective step which can be done.

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