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An overview of historical harmful algae blooms outbreaks in the Arabian Seas

Maryam R. Al Shehhi *, Imen Gherboudj, Hosni Ghedira

Institute Center for Water and Environment (iWATER), Masdar Institute of Science and Technology, Abu Dhabi, United Arab Emirates

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ABSTRACT

Harmful algae blooms (HABs), often composed of oceanic plants called phytoplankton, are potentially harmful to the marine life, water quality, human health, and desalination plants, a chief source of potable water in the Arabian Gulf. The last decade has seen a noticeable increase in the frequency of HAB outbreaks in the Arabian Seas. This increase is mainly caused by the unprecedented economic growth in the region. The increased human activities in the region have added more stress to the marine environment and contributed to the changes observed in the properties of the marine ecosystem: high temperature and salinity, high evaporation rates, limited freshwater inflow, shallow nature, pollution. However, very few studies that cover the HAB outbreaks, causes, impacts and biological characteristics over the region have been published. This work presents a comprehensive overview of historical HAB outbreaks recorded in the region, and investigate their causes and impact, and seasonal variability.

1. Introduction

The Arabian Gulf, the Gulf of Oman and the Arabian Sea, collectively referred to here as the Arabian Seas, have long been an important trade route (Hamza and Munawar, 2009; Nezlin et al., 2010; Richlen et al., 2010). Given their fragile ecosystem and their high risk of pollution, mapping and monitoring the quality and the physical and biological properties of these water bodies is increasingly needed by local, national and regional authorities (Hamza and Munawar, 2009; Reynolds, 1993; Richlen et al., 2010; Solomon et al., 2009). Currently, the most serious pollutants affecting the physical and biological quality of these water bodies are harmful algal blooms (HABs).

HABs, commonly referred to as *red tide* in the literature, have been occurring more frequently in the Arabian Gulf during the last few years. Most often, they have been transported from the Arabian Sea and the Gulf of Oman which makes them a common threat to the region (Subba Rao and Al-Yamani, 1998). Their presence has been detrimental to the water quality and its surrounding environment. These adverse impacts generally include, but are not limited to: (1) the death of large quantities of fishes and crustaceans such as in Kuwait (2001), Oman (2005) and UAE (2008) (Al-Busaidi et al., 2008; Glibert et al., 2002); (2) their effect on human health by causing respiratory irritation (Tomlinson et al., 2009); (3) the suspension of desalination plants' operation, in some extreme cases, due to the high toxicity level in the water surrounding the plant intakes such as the desalination plants in Kalba, Fujairah, Khor-Fakan and Ras-Al-Khaimah (Ghaleelah) as reported by the Ministry of Environment and Water in the United Arab Emirates (UAE Ministry of Environment and Water, 2011); and (4) the spread of a bad smell in the air resulting from the organic decomposition of dead plant algae, for instance the Fujairah incident in 2008.

Several case studies have been investigated to give an overview of the red tide causes and impacts over the Arabian Seas. This paper presents a summary of the recent studies on this topic that were carried out over the region, including understanding the pattern of red tide occurrences and their impact on the regional maritime ecosystem, exploring the multiple factors causing their outbreaks, and analyzing their temporal/spatial variability (species, concentration) by correlating them with atmospheric/water variables (wind, dust, currents).

2. Arabian Seas description

Fig. 1 shows the location of the Arabian Seas with typical water circulation patterns and freshwater sources. As shown in this figure, even though they are interconnected, these seas have significantly different geometrical and physical characteristics which affect each other in different ways.

* Corresponding author. Tel.: +971 2 810 9124.
E-mail addresses: mralshehhi@masdar.ac.ae (M.R. Al Shehhi), igherboudj@masdar.ac.ae (I. Gherboudj), hghedira@masdar.ac.ae (H. Ghedira).

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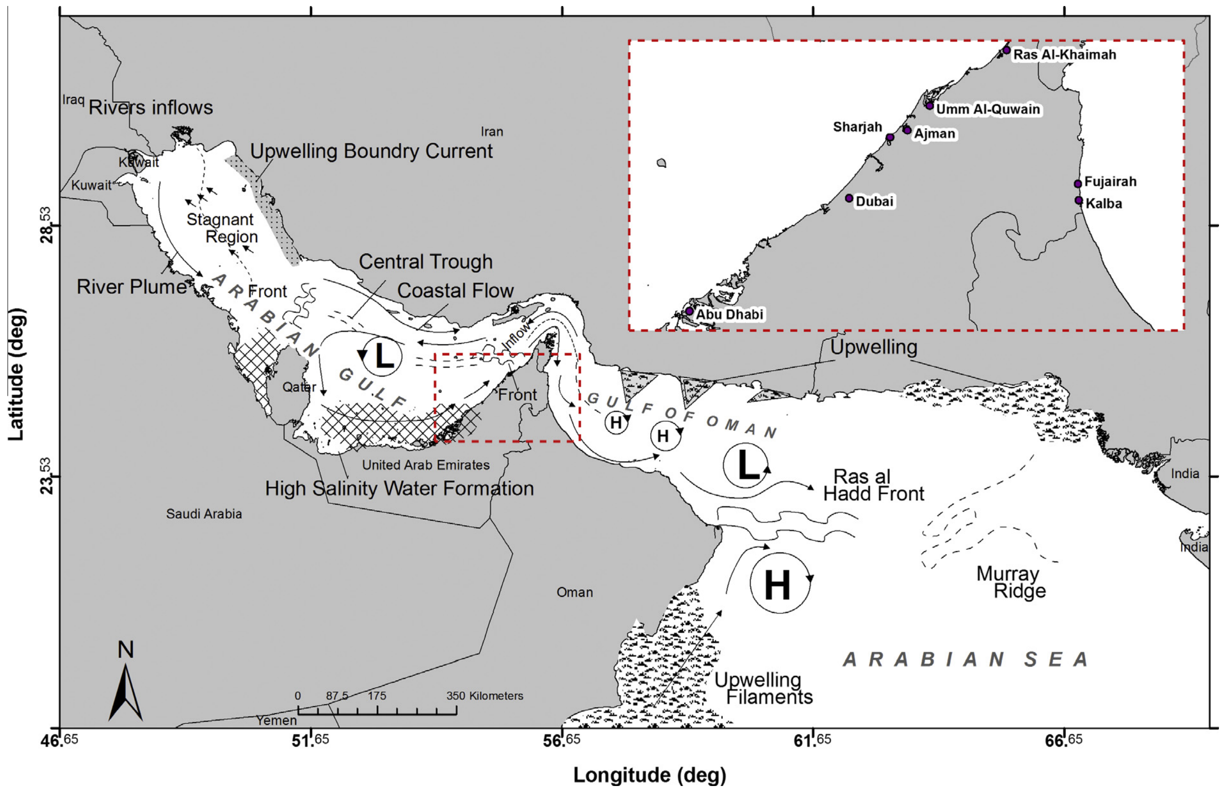

Fig. 1. Geographical location of the Arabian Gulf, the Gulf of Oman and the Arabian Sea with water currents circulations adapted from Reynolds (1993).

The Arabian Gulf is situated between latitude 24°N and 30°N and longitude 48°E and 57°E with Iran covering most of the northern coast and Saudi Arabia most of the southern coast. It occupies a surface area of 8630 km^3 (Richlen et al., 2010). While its width varies from 75 to 370 km, its length extending from the Shatt Al-Arab in Iraq to the Strait of Hormuz is around 990 km (Nezlin et al., 2010). It is shallower in the southern region alongside the coastline of the United Arab Emirates where the depth is mostly less than 20 m. The depth increases toward the northern part of the Gulf in front of the Iranian shoreline reaching up to 80 m deep (Hamza and Munawar, 2009) with a significant sharp increase to 2990 m toward the Arabian Sea. The Strait of Hormuz is the narrow strait between the Arabian Gulf and the Gulf of Oman, located between 22°N to 26°N latitude and 56°E to 60°E longitude (Ministry of Agriculture and Fisheries Wealth, 2010), and stretches 280 km from the Iran coast in the north, to the Oman coast in the south, with a width of 56 km (Kämpf and Sadrinasab, 2006). The Strait of Hormuz is a very significant waterway for the Arab Gulf countries (except the Sultanate of Oman) because it is the only gateway to export their crude oil to international markets (Nezlin et al., 2010). The Gulf of Oman is a western extension of the Arabian Sea bounded by Pakistan and Iran on the north, Oman on the south, and the United Arab Emirates on the west. It is about 545 km long and has a maximum width of 370 km. The Arabian Sea is located in the northern region of the Indian Ocean (Madhupratap et al., 2000) bordered by Pakistan and India on the north with a surface area of about 3.9 million km^2 (Heilman et al., 2008) and a maximum width of 2,400 km.

The Arabian Seas' water bodies are controlled by four major circulation currents/flows and two major freshwater sources. The four circulation currents/flows are: (1) inflow toward the northern Iranian region from the Strait of Hormuz; (2) flows by the density difference force southwards (Hamza and Munawar, 2009); (3) circulation current in the western area of the Arabian sea with clockwise movements; and (4) circulation current in the eastern area of the Arabian Sea where water moves in a counter clockwise direction (Richlen et al., 2010; Tang et al., 2002). Two freshwater sources (the Tigris, Euphrates and Karun rivers) flow into the Arabian Gulf through Shatt Al-Arab near Kuwait and Iraqi coast and the Indus River which flows into the Arabian Sea through Pakistan. The total average fresh water volume discharge varies from 36 to 110 $km^3\,yr^{-1}$ (Nezlin et al., 2010). The average discharge of the Tigris and Euphrates is 22.4 $km^3\,yr^{-1}$, while the outflow of the Karun River is around 23.7 $km^3\,yr^{-1}$. Presently, Shat Al-Arab receives most of the outflow of the Karun river, because around 90% of the Tigris and Euphrates are evaporated or pumped for agricultural purposes (Hamza and Munawar, 2009). The average annual fresh water volume discharge of the Indus River is about 200 billion cubic meters.

Overall, the Arabian Seas are surrounded by a very dusty region, with frequent sand storms throughout the year especially between May and July (e.g. an average of 27 sand storms occur in Kuwait each year) (Gherboudj and Ghedira, 2014; Nezlin et al., 2010). These sand storms are mainly generated by the two monsoon cycles blowing the region which are the summer monsoon (June–September) in the southwestern region, commonly called *Shamals*, and the winter monsoon (November–March) in the northeastern region (Reid et al., 2004). These monsoons have a direct effect on sea surface temperature (SST) parameter which vary between 23 °C in cold seasons and around 35 °C in hot seasons (Al-Azri et al., 2009). Such high temperature values increase the evaporation rates causing a significant rise in water salinity (Hamza and Munawar, 2009). In addition, the summer monsoon contributes up to 70–90% of the yearly precipitation in the Arabian Seas causing therefore the wet deposition of aerosols over the seas. While the recorded precipitation rate is high in the northern part (150–200 mm/year), lower values were generally recorded in the southern part of Gulf of Oman varying from 45 to 60 mm/year