Extreme weather events in northern Indian Ocean region–An appraisal with respect to cyclones and marine heatwaves

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The abnormal and accelerated warming of the atmosphere since 1950s has contributed to a significant increase in the occurrence of extreme weather events like cyclones, snow storms and droughts globally. This has caused loss of human life and property as well as adversely impacted the local biodiversity. The Northern Indian Ocean region has also experienced this phenomenon in terms of increased occurrence of cyclones and marine heatwaves. Cyclones are strong winds that spiral inward to a central low pressure core and the impacts of cyclones on marine ecosystem are manifold. The super cyclone of 1999 that crossed Odisha coast increased the nutrient concentrations of surface waters causing an increase in the primary production in the south western Bay of Bengal (Madhu *et al.*, 2002, Nayak *et al.,* 2001) and the post-cyclone blooms have implications for pelagic communities and ecosystem dynamics. The extreme hydrodynamic force exerted by tropical cyclones also exerts significant impact on coral reefs and seagrass ecosystems which are important breeding, nursery and feeding grounds of various marine organisms and fishes in particular. Marine heatwaves are prolonged, extreme warm water events with disruptive consequences for marine ecosystems. The intensity (the temperature anomaly exceeding a climatology) and duration (the sustained period of extreme temperatures) are the main parameters which affects the marine flora and fauna including planktons, corals, seagrass, seaweeds and fishes (Benthuysen *et al.*, 2020). It has been observed that, in general, marine heatwaves negatively affect canopy-forming seaweeds while promoting turf-forming seaweeds (Straub *et al.*, 2019). Temperatures changes to the tune of 0.5 ºC can change the recruitment pattern in fish and shellfishes with larval fishes more sensitive to the temperature fluctuation than the adults (Vivekanandan, 2013).

The northern Indian Ocean region which includes the Bay of Bengal and the Arabian Sea, is following the global patterns in terms of the occurrence of extreme weather events especially the cyclones and marine heatwaves. As the pace of global warming is not equal throughout, the trends in sea surface temperature (SST), marine heatwaves and the cyclones are also different for the Bay of Bengal and the Arabian Sea. The global average SST warming during the period 1951– 2015 is approximately 0.7 °C (0.11 °C/decade) while the tropical Indian Ocean reported a rapid basin-wide sea surface temperature (SST) warming of 1.0 °C (0.15 °C/decade) during the same period. The warming trend of northern Arabian Sea is reported to be the maximum and is to the tune of 0.18 °C per decade during the period 1976–2005 (Roxy *et al*., 2020; Krishnan *et al.*, 2020).

Compared to the Arabian Sea, the Bay of Bengal produced maximum number of cyclonic disturbances during the period 1982-2020 (Fig.1). The northwest Bay of Bengal

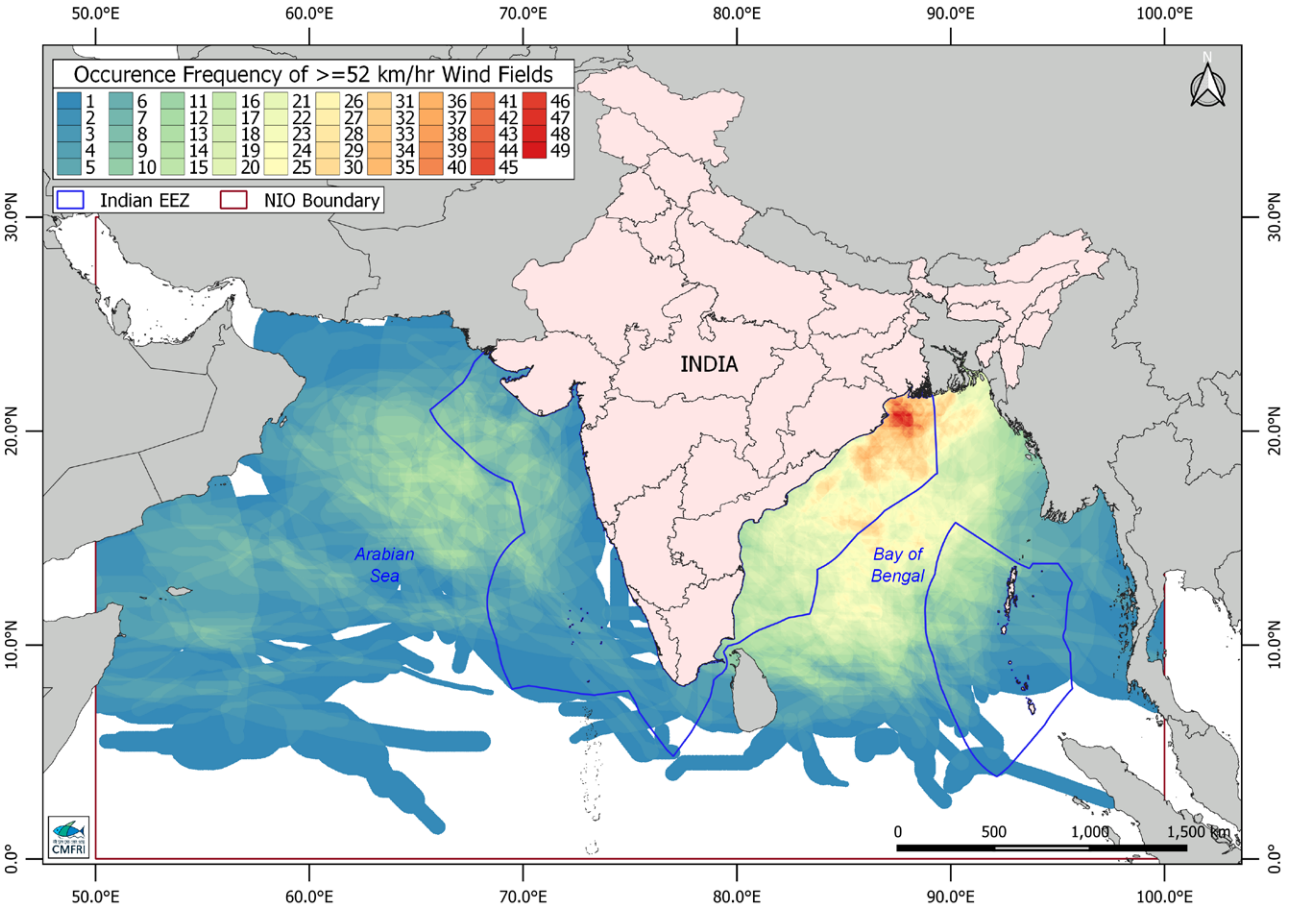

Fig.1 Occurrence frequency of >=52 km/hr wind fields associated with the cyclonic storms over NIO region during 1982-2020

experienced most of the storms followed by northeast, west central and east central Bay of Bengal. The east and west central Arabian Sea experienced the highest number of storms. There is definitely a noticeable distinction between Bay of Bengal and Arabian Sea with respect to the number of occurrences of storms with Bay of Bengal witnessing most of the storms. But, if you analyse the basin-wise trend, we can observe a shift in the trend. Arabian Sea is now producing more cyclonic disturbances compared to the Bay of Bengal (Fig. 2 and 3). Especially, the number of high energy storms is on the rise in Arabian Sea area. Climate change induced rapid pace

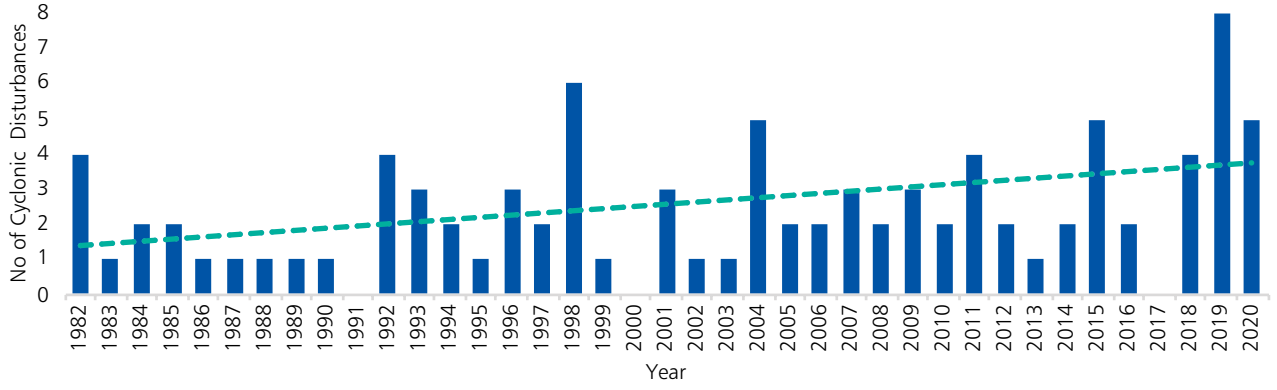

Fig.2 Number of cyclonic disturbances formed over the Arabian Sea during the period 1982-2020

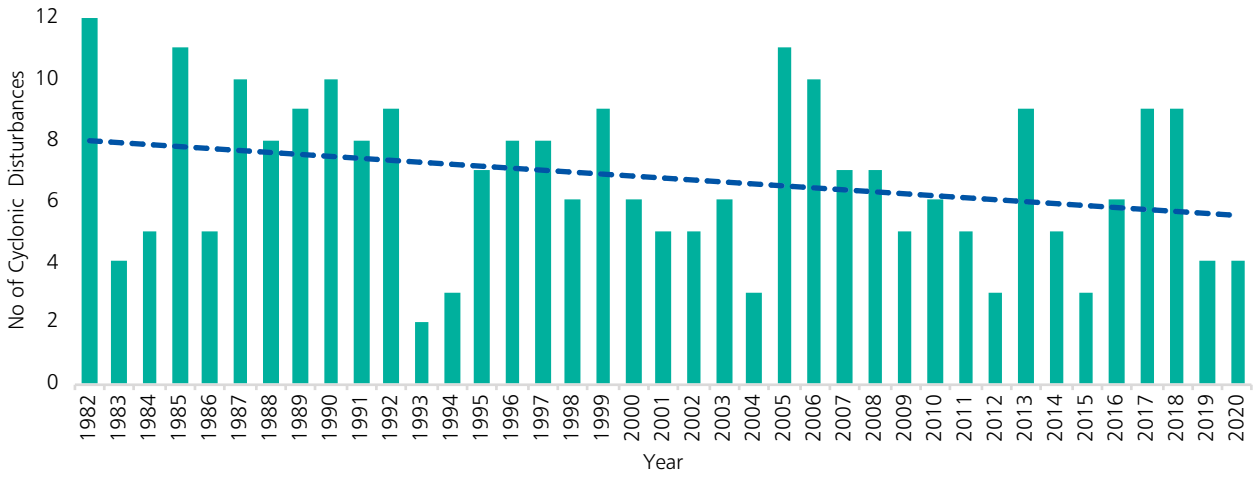

Fig.3 Number of cyclonic disturbances formed over the Bay of Bengal during the period 1982-2020

of warming of the Arabian Sea and increased presence of aerosols may be the factors influencing increased occurrence of cyclonic disturbances in the Arabian Sea (Krishnan *et al.*, 2020).

The occurrence of marine heatwaves in the NIO region also shows a similar trend where the Arabian Sea shows an upward trend and the Bay of Bengal shows a downward trend (Fig 4.). The coastal areas of Tamil Nadu and Andhra Pradesh are very clearly showing negative trends while the

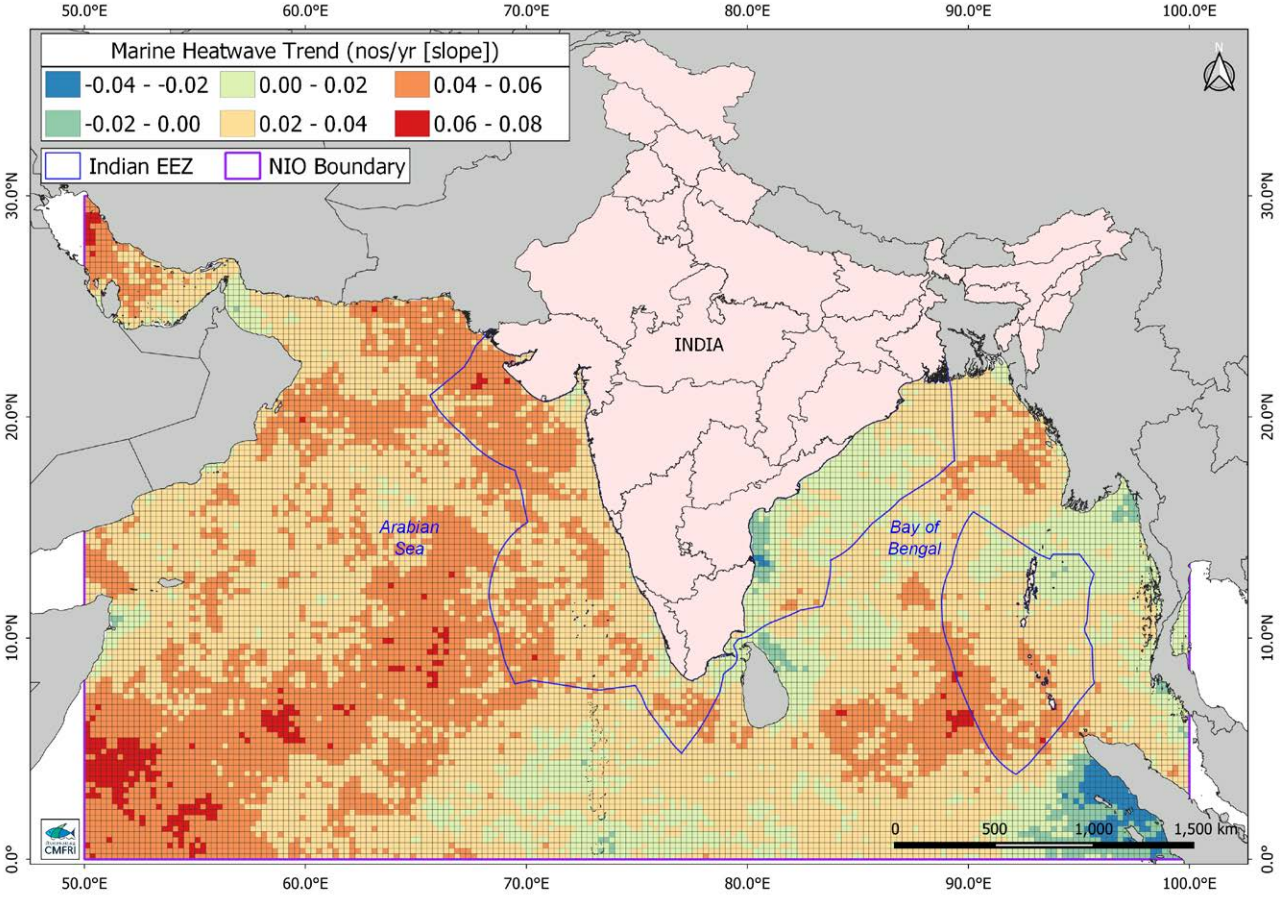

Fig.4 The trend of marine heatwaves in NIO region for the period 1982-2019

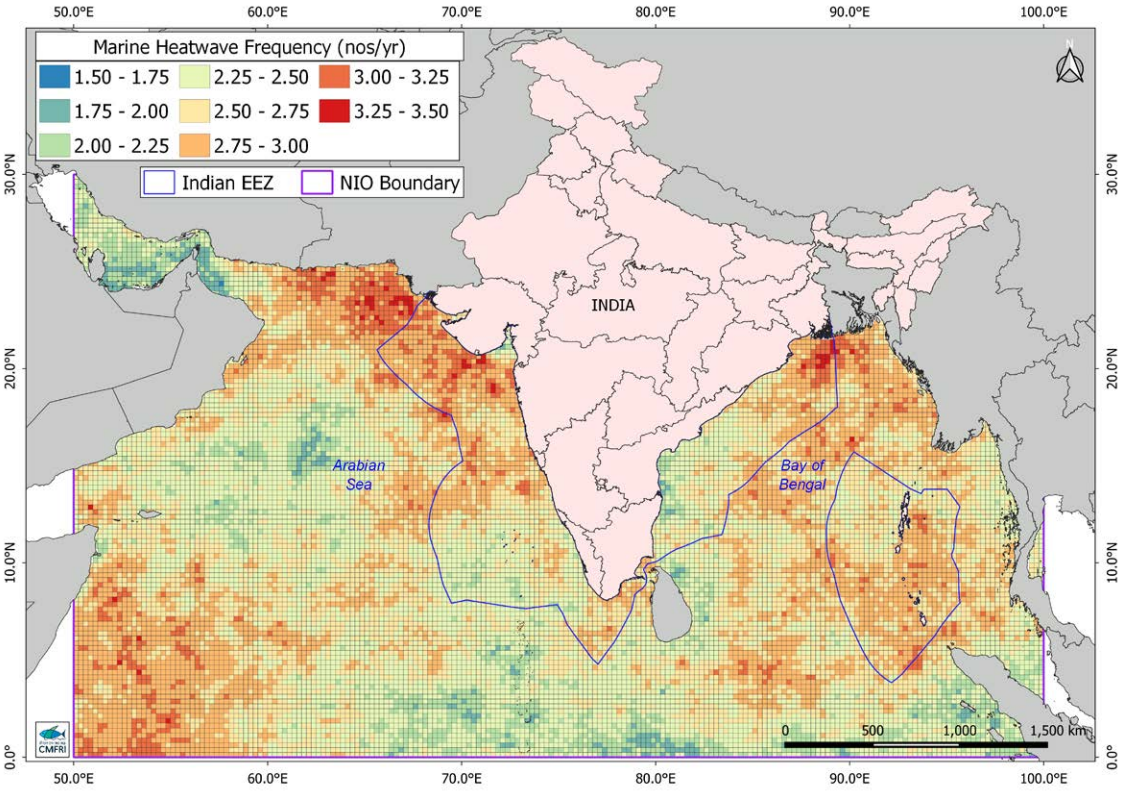

Fig.5 The average frequency of marine heatwaves in NIO region during the period 1982-2019

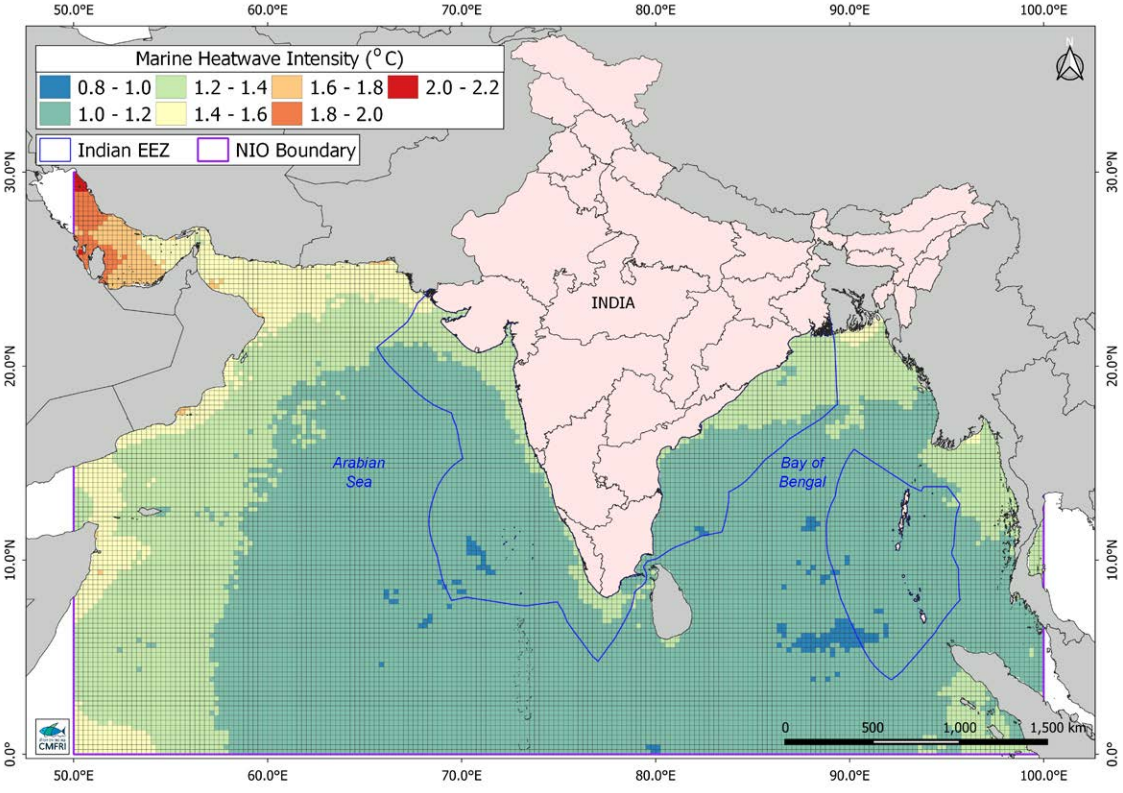

Fig.6 The average intensity of marine heatwaves in NIO region during the period 1982-2019

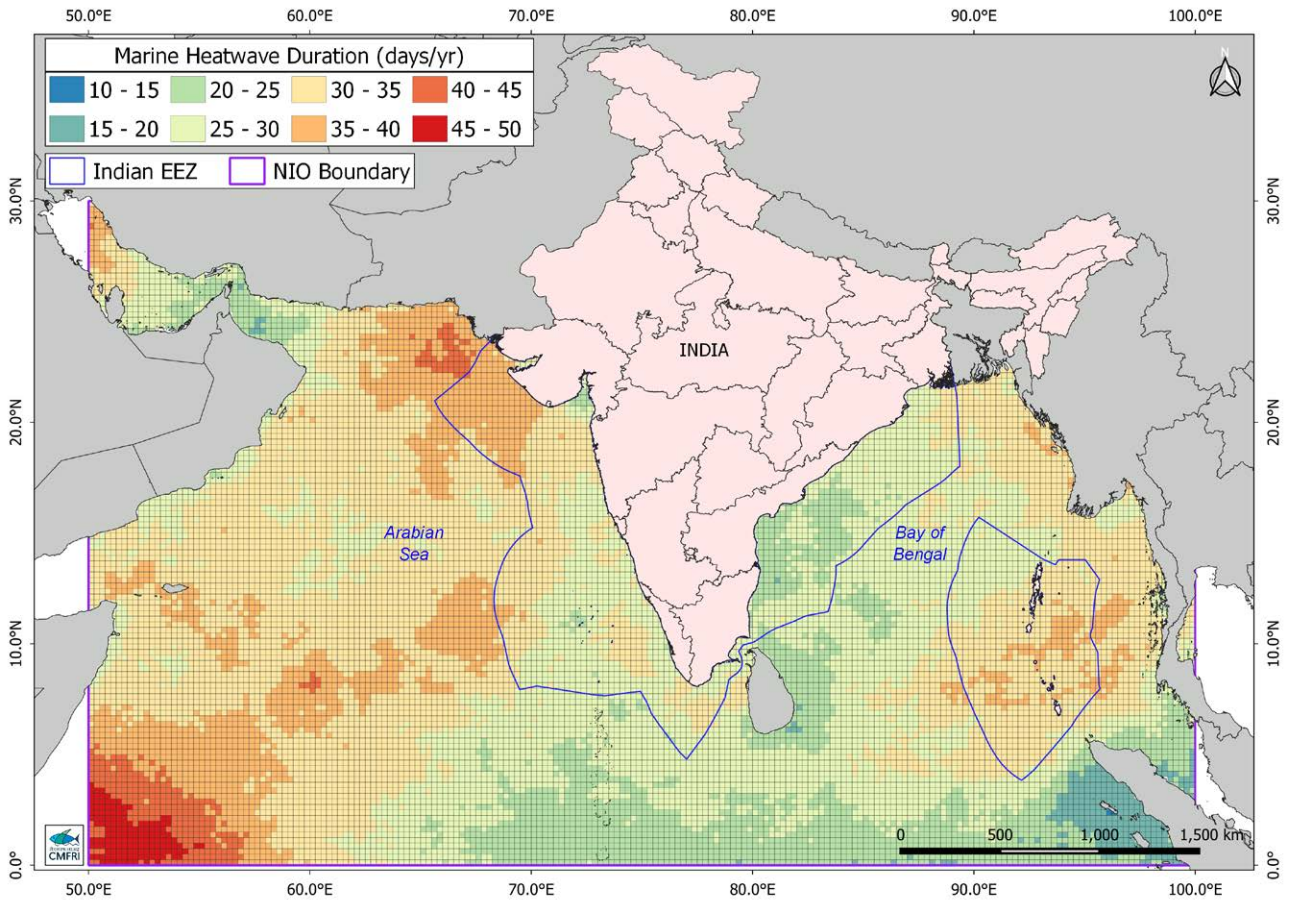

Fig.7 The average number of days in a year affected by marine heatwaves in NIO region during the period 1982-2019

coastal areas of Gujarat and Maharashtra are showing positive trends. The mean frequency (number per year) of the marine heatwave occurrence ranges from 1.5 to 3.5 in the NIO region and the northeast Arabian Sea and the northwest Bay of Bengal report the highest values (Fig. 5). But the mean intensity of the heatwaves in the NIO region indicate that the coastal areas experience more intense marine heatwaves (1.2 – 1.4 °C) while the open ocean experience less intense ones (0.8 – 1.2 °C) and the Persian Gulf experience the most intense (2.0 – 2.2 °C) marine heatwaves (Fig. 6). The mean number of days in a year affected by the marine heatwaves is more in the southwest Arabian Sea (45-50 days) followed by the northeast Arabian Sea (40-45 days). On an average, the east coast of India experiences marine heat waves for 20-30 days in a year while the west coast of India experiences 25-35 days of marine heatwaves in a year (Fig. 7).

More frequent weather and oceanographic extremes could destabilise existing trophic links and favour the shorter-lived, high-turnover fish species at higher trophic levels. It could also lead to increased spatial and temporal variability of plankton productivity. The impact of changes in plankton communities on the pelagic larvae of important target fish species demands additional attention. A misalignment between fish reproduction and periods of high plankton productivity could have a significant impact on fish population replenishment. The fish larvae spend days to months in the planktonic form, whereas important fishery invertebrates like crustaceans spend months in the planktonic form before settling (Hobday *et al*., 2008). Larval starvation is major contributor to mortality and the impact is felt more when the larval duration is more. Hence, a shift between low-nutrient and high-nutrient plankton communities, which might result from extreme weather events, would exert significant influence on fish larvae survival (McKinnon *et al.*, 2003; Johnson *et al.*, 2011).

The above discussions points to the fact that there has been a shift in the pattern of the extreme weather events that occur in the NIO region, especially the cyclones and the marine heatwaves. Moreover, these events have intricate interactions with the marine ecosystems and its ramifications can be felt in the marine fish resources. Even though some sporadic studies are available, a more systematic and comprehensive study on the impact of these extreme weather events on marine fish resources are needed, especially in the NIO region.

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