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Seasonal dynamics in the relative density of aquatic flora along some coastal areas of the Red Sea, Tabuk, Saudi Arabia

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Abstract Plants are the producers of all autotrophic ecosystems' and are the base of the food chain taking energy from the sun and converting it into food for all other organisms through photosynthesis. Plants grow in certain places and seasons when the environmental factors are suitable for their germination, growth and developments that influence their diversity. Environmental factors can include abiotic factors such as temperature, light, moisture, soil nutrients; or biotic factors like competition from other plants or grazing by animals. Anthropogenic perturbations can also influence distribution patterns. Monitoring of ecological habitats and diversity of some aquatic flora along some coastal areas of Red Sea has been done to understand the dynamics of aquatic plants influenced by prevailing environmental and anthropogenic perturbations The results of this research showed that the summer season is the most suitable period for the study of aquatic plant diversity along the coastal sites of Red Sea. The aquatic flora had high relative density and diversity in April, May, June and July and these four months of the summer season are best for collection of aquatic plants from the selected coastal areas of Red Sea for medicinal purposes and ecological studies.

Introduction

Biological diversity refers to numbers of different species of plants and animals in an environment. More than 1.7 million species of organisms have been named so far and is continuing to turn up new species at the rate of approximately 15,000 per year. Among them, aquatic ecosystems support a very rich biodiversity (Agarwal and Agarwal, 2007; Sharma, 2005; Ansari and Gill, 2016a). The Species extinction across the globe is mainly governed by changing environmental conditions leading to habitat destruction. Among all, the most important abiotic environmental factors are level of nutrients like nitrogen, phosphorus, calcium, atmospheric CO_2, pH, and climate changes including temperature, light and precipitation. Relative densities of primary producers, consumers like herbivores and carnivores, pathogens, predator species and human population are some biotic environmental factors causing perturbations in biodiversity patterns. Extinction of species would occur because the physiologies, morphologies, and life histories of plants that limit each species to a particular combina-

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tion of environmental constraints (Tilman and Lehman, 2001). A regular monitoring and assessment is required to conserve the ecological habitats and diversity of aquatic flora, as they play very significant roles in energy production, energy flow, pollutants removal and biogeochemical cycling of nutrients in aquatic ecosystems (Ansari et al., 2011a). Phytoplankton community structure and diversity are considered as an ecological indicator for the monitoring and assessment of aquatic environment (Ansari et al., 2016b).

Understanding the mechanism behind the biological diversity patterns in terrestrial and aquatic ecosystems is accepted as a great challenge by the scientific world of today. The studies on species diversity in aquatic ecosystems are much ignored as compared to terrestrial and benthic ecosystems because of the scarcity of experimental data due to unstable conditions of the aquatic environment (Murphy et al., 2003). The excessive addition of pollutants to water causes quality problems and is one of the major causes of habitat destruction and diversity changes in aquatic ecosystems (Ansari et al., 2015). Due to ubiquitous water pollution, many plant species are actually threatened and results into a temporary or permanent change in species composition. Succession of phytoplankton community may occur due to the ecological and environmental conditions (Xiao et al., 2016). The species that can adopt and tolerate the changing environmental conditions are more competitive and had better means of its diversity as compared to the species that have low tolerance limits and are very sensitive to any change (Romermann et al., 2008). The plant species are primary producers and form the important component governing the structure and functioning of an aquatic ecosystem. Area, altitude, trophic status and water quality are the important parameters used to estimate the species richness in aquatic ecosystem. Due to anthropogenic threats and global climate changes the plant diversity is potentially threatened (Murphy, 2002; Ali and El-Magd, 2016). Aquatic macrophytes are photosynthetic organisms, which actively grow permanently or periodically submerged below, floating on, or growing up through the water surface (Chembers et al., 2008). High nutrient concentrations enhance the excessive growth of phytoplankton and macrophytes in the aquatic ecosystem (Rovira and Pardo, 2006). Spatial structure of the phytoplankton community is the direct effect of climatic conditions and physicochemical characteristics of water play a minor role. Floristic structure of the phytoplanktons is influenced by abiotic factors of the aquatic environment (Gabyshev and Gabysheva, 2016).

Materials and methods

Qualitative survey for the diversity of aquatic flora in terms of relative density was carried out on monthly basis (October 2014–September 2015) to investigate the impact of varying environmental conditions on species structure. Three coastal stations of the Red Sea at Haql (29°17′9.9″N 34°56′18.9″E), Sharmaa (28°1′27.9″N 35°16′9.9″E) and Duba (27°20′57.3″N 35°41′46.2″E) near Tabuk, Saudi Arabia were selected to study the seasonal dynamics and diversity of aquatic flora (Fig. 1). After every 200 meters five sampling sites from each station (Haql, Sharmaa and Duba) were selected. Five different sites were considered as replicates for each station. Qualitative survey for the relative density of aquatic flora along the selected coastal areas of the Red Sea was carried out using quadrates of 1 m^2. Data were analyzed statistically for the significance of research using computer software SPSS V. 16 for Windows statistical analysis). The data were subjected to a one way ANOVA with least significance difference (LSD) tests at a significance level of ($p < 0.05$).

To determine the seasonal dynamics in diversity and distribution of aquatic flora along the coastal areas studied in this research, relative densities were calculated as:

$$\text{Relative Density } D_r = \frac{a}{b} \times 100$$

a = Total No. of individuals of plant species in all the sampling units; b = Total No. of sampling units studied.

Relative density in terms of occurrence and water surface occupied was expressed in following six quantitative classes shown in Table 1.

Results

At the selected coastal sites of the Red Sea of Haql, Tabuk, Saudi Arabia, *Jania rubens* showed higher densities in October-14 and May-15. Least occurrence of this species was observed in March-15. This plant species disappeared in November, December 2014 and August, September 2015. Relative density of *Gastroclonium ovatum* was at its peak in October-14 and July-15, where as it was lowest in February-15. *G. ovatum* was not found on any site in January and May 2015. *Padina pavonica* showed higher density in the month of June-15 and lower in February-15. This plant species was not found at any site of Haql in December-14 and January-15. Relative density of *Hildenbrandia rubra* was maximum in July-15 and minimum in October-14. Non-occurrence of the species was observed in November, December-14 and February, March-2015 (Fig. 2 and Table 2).

Nemalion helminthoides occurance was higher in February-15 and lowest in July-15. Existence of this plant species was not recorded in October-14 May, June, August, and September-15. *Polyides rotundus* showed a higher relative density in August-15 but lower in April-15. Plant samples of this species were not found at any site of Haql station in December-14 and January, March 2015. *Cladophora prolifera* was shown the high density in July-15 but very low relative density of this species was recorded in April-15. This plant species disappeared from all the study sites of Haql in November and December-14. *Ulva lactuca* showed higher relative density in April-15 whereas density was low in January-15. Non-occurrence of this species was recorded in November, December-14 and February-15. *Enteromorpha flexuoca* was observed in almost all the seasons of Tabuk with maximum relative density in July-15. The density of *E. flexuoca* was low in November-2014. *Pterocladia capillacea* also showed higher density in most of the seasons. Highest relative density of this species was recorded in July-15 and lowest in March-15. Samples of this plant species were not found at selected sites of Haql station in the month January and February 2015. The aquatic alga *Gracilaria salicornia* was densely populated in July-15 whereas density of this species was lowest in January-15. An irregular appearance and disappearance of *G. Salicornia* were recorded in different seasons (Fig. 2 and Table 2).

Relative density of *Digenia simplex* was maximum in June-15 and lowest in February-15. Non-occurrence of this plant species was observed in November, December-14 and