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REVIEW ARTICLE

Responses of the seagrass *Halodule uninervis* (*Forssk.*) *Aschers.* to hypersaline conditions

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Abstract Desalination of seawater has become an important and growing field due to the present water shortage in some countries. This activity may result in some environmental impacts, mainly generated by the discharge into the sea of the brine produced, which can affect marine benthic communities. The present study aims to study the response of the seagrass *Halodule uninervis* (*Forssk.*) *Aschers.* to hypersaline stress. The results showed that *H.* uninervis fully tolerate salinity up to 50 psu by accumulation of the organic osmoprotactants (free amino acids, proline and soluble sugars) and inorganic osmoprotactants specially Na+ and K+. Sublethal effects appeared at 55 psu and the plants fully recovered when returned to normal salinity. Salinities 60 and 65 psu have a drastic effect on this seagrass and the plants did not recover after returning to the normal conditions. The results indicated that *H. uninervis* can tolerate salinity above control by 15 psu. To conserve this plant, it is recommended that the brine must be diluted at least to 50 psu before discharging it into the sea.

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Introduction

Desalinated seawater has become an important source of water in coastal regions where demand has increased to exceed rarely available freshwater resources (Tsiourtis, 2001). Recent estimates suggest that up to 25 million m^3 of desalinated water is produced daily around the world (Lattemann and Höpner, 2008). Nations in the Middle East were the first to adopt and depend upon large-scale desalination due to the limited sources of potable freshwater in these arid areas and the availability of cheap energy. Presently, almost half of the world's desalinated water is produced in this region (Lattemann and Höpner, 2008). In Egypt, this technology was developed recently in the recent tourism resorts as Sharm El-Shekh, Hurghada, Marsa Alam and other Red Sea cities.

The development of technologies, such as reverse osmosis (RO), with acceptable costs (in terms of energy and space) is seen as a promising solution to water shortages (Torquemada and Lizaso, 2005). However, desalination plants can have significant environmental impacts, mainly due to the large volume of brine (roughly equivalent to the volume of drinking water produced) discharged into the sea, which can reach salinities between 60 and 90 psu (Lizaso et al., 2008).

The effects of hypersaline water have been assessed for some marine plant species or communities (e.g. Castriota et al., 2001 and Koch et al., 2007b).

Seagrasses are one of the main targets of such investigations, for three reasons: (i) their distribution that overlaps potential discharge points; (ii) their high sensitivity to disturbances; and (iii) their well-known biological and ecological relevance (Green and Short, 2003; den Hartog and Kuo, 2006).

Despite recent advances in the field, knowledge of the effects on seagrasses of exposure to high salinities remains restricted to a few species of the Mediterranean region and very rare to those of Red Sea. Seagrasses exposed to changes in salinity can suffer osmotic stress, with the consequent changes at the biochemical and physiological levels (Touchette, 2007). These include alterations of their photosynthetic rates (Kerr and Strother, 1985; Dawes et al., 1987) and metabolism (van Katwijk et al., 1999), altered growth rates (McMillan and Moseley, 1967; Walker, 1985; Walker and McComb, 1990) and increased mortality (Vermaat et al., 2000; Torquemada and Lizaso, 2006).

Den Hartog (1970) recorded the occurrence of *Halodule uninervis* from Indian Ocean to Western Pacific Ocean and their marginal seas. This Seagrass species is widely distributed from the Ryukyu Islands, Japan, through Malaysia to northern Australia, Fiji, the Tonga islands and New Caledonia (McMillan, 1980; Den Hartog and Zong-Dai, 1988) and extends to the eastern coast of Africa and South Africa. In addition, *H. uninervis* represents one of the commonest seagrasses in the Red Sea (Geneid, 2009). The responses of Egyptian Red Sea seagrasses to hypersaline stress caused by desalination plants have received low attention in the literatures, thus, the present study conducted a mesocosm experiment under controlled conditions to estimate the effects of short-term salinity variations on survival, growth and physiological responses of the seagrass *H. uninervis* as an example of the Egyptian Red Sea seagrasses.

Materials and methods

Plant sampling and experimental design

Halodule uninervis plants (including under and above ground parts) were carefully harvested by skin diving in April 2008 from a shallow meadow (approximately 1.0 m deep) from Hurghada Marine Station, National Institute of Oceanography and Fisheries (NIOF) (27°16′59.60″N and 33°46′24.26″E). The plants were collected from the seafloor using a wide-edged knife to ensure the collection of the underground parts, stored with its surrounded sediments in a large cool container (27 L) with ambient seawater. Sediment and sea water were collected from the same site and analyzed according to