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Trophic status of the Iranian Caspian Sea based on water quality parameters and phytoplankton diversity

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ABSTRACT

The present study attempted to test the applicability of the trophic index (TRIX) for assessing trophic status along the Iranian coast of the Caspian Sea (CS). In order to increase the sensitivity of the TRIX for this area, we defined the range (lower and upper limits) from data collected between 1994 and 2005 which have been used as a reference. Several biological and chemical water quality parameters were determined and compared with the TRIX in order to describe the water quality status of the area. Comparisons were also made on two temporarily and spatially varied trophic status at the study site. Sampling was carried out at 36 stations during Phase I (1996–1997: before the introduction of an alien species *Mnemiopsis leidyi*, as a background data) while 24 stations were sampled during Phase II in 2005 (after the introduction of the alien species). A Parallel Study (as supplementary data) from 16 smaller scale sampling at shallower sites was also included in the discussion (1994–2005 on 18 transects). The results show that nutrient concentration (DIN, DIP compounds), oxygen (as absolute %) deviation from saturation (aD%O), chlorophyll a and also the Caspian Sea Trophic Index (TRIXCS) increase significantly after the introduction of an alien species ($p<0.01$). During Phase I and the Parallel Study, the phytoplankton community was dominated (based on important species index) by *Thalassionema nitzschioides*, *Skeletonema costatum* (Chrysophyta) year round but during Phase II, *Spirulina laxissma* (Cyanophyta) dominated annually and in autumn, coinciding with the minimum Shannon–Weaver diversity and Evenness indices recorded. Several trophic status indices and indicators were applied and an overall analysis suggested that the area has low trophic level during Phase I and high trophic level during Phase II. During the Parallel Study, low trophic level was recorded during the pre-invasion period and high trophic level for the post-invasion period.

1. Introduction

The Caspian Sea (CS) is the largest inland water body in the world, with a surface area of about 380,000 km^2 (the northern area 25%, middle 36% and southern area 39%) and volume of approximately 78,000 km^3. The coastal length of the sea is about 6380 km. It measures 1200 km from north to south and 200–450 km from east to west. The CS is shared between five littoral countries namely Iran (900 km) and four nations of the Commonwealth of Independent States, the Russian Federation, Kazakhstan, Turkmenistan and Azerbaijan (Dumont, 1998) (Fig. 1). About 130 rivers of various sizes drain into the sea with an annual freshwater inflow of about 300 km^3. The main input is from the Volga River in Russia (85% of the total volume of inflow) while rivers from Iran contribute an inflow of only 4–5% (CEP, 2002). The northern basin is highly influenced by freshwater input from the Volga and Ural rivers resulting in a salinity average of 0.1‰. The middle and southern basins are normally brackish with salinity varying between 10‰ and 13‰. The water balance in the CS is dominated by river inflow and surface evaporation (Stolberg et al., 2003).

Vollenweider et al. (1992) clearly documented the destructive and harmful effects of nutrient enrichment on the coastal environment. Development of industrial areas, particularly on the northern coast of the CS has been extensive. Effluent discharges from these industries pollute the ecosystem, causing a shift in water quality from an oligotrophic status to an eutrophic condition. The situation in the southern CS near the Iranian coast is quite different. The input of nutrients are very much limited to biotransformation and vertical transport due to the minimum suspended solid as well as low river discharge and atmospheric precipitation (Leonov and Stygar, 2001). EACS (1996) and CSN (2003) reported that advection transport of rich nutrient water

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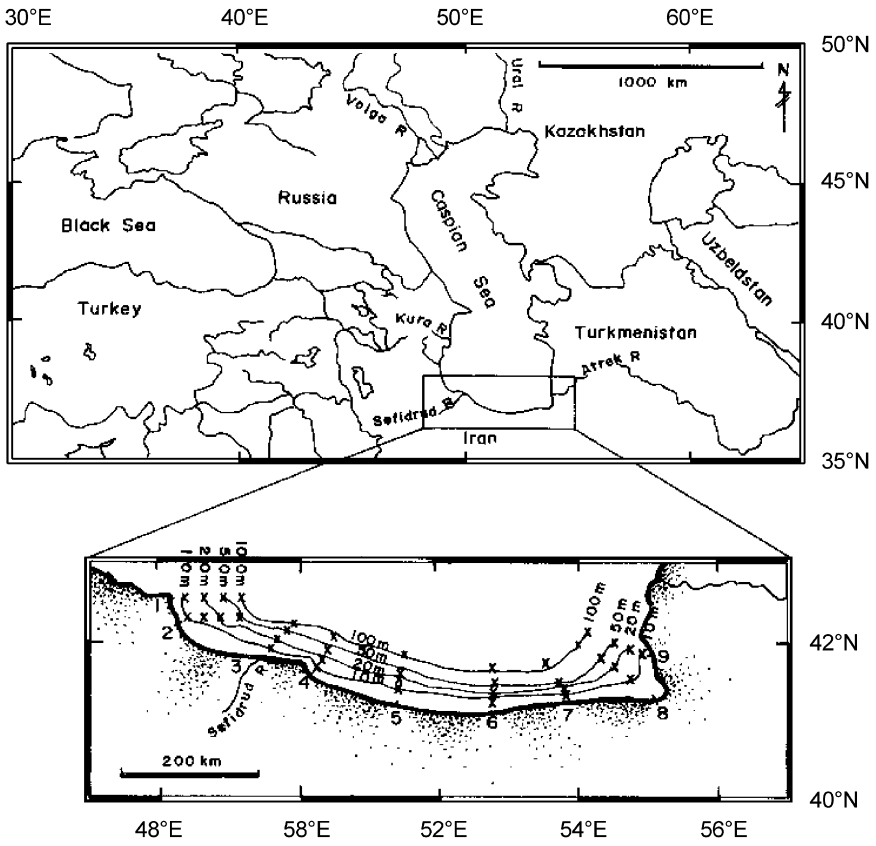

Fig. 1. Map of the Caspian Sea showing the five littoral countries (top) and sampling stations in the southern part of the Caspian Sea—Iranian coast (bottom). The 10, 20, 50 and 100 m depth contours are also shown.

from the north by water current is minimal because water circulation in this area is formed in the deep zone and is not able to affect the inshore zone as in our study.

Many authors have asserted that the introduction of alien species into a marine environment may result in various negative impacts including decline in water quality and fisheries (Vinogradov et al., 1992). In the 1980s, the ctenophore *Mnemiopsis leidyi* invaded the Black, Azov, Marmara and Aegean Seas, and more recently it has been reported to be present in the CS (Shiganova et al., 2001b). *M. leidyi* was first introduced into the Southern (Iranian coast) and Central CS in winter 1999 (Esmueili et al., 2000; Shiganova et al., 2001a). It was likely to have been transported from the Black Sea or the Sea of Azov along with ballast waters from tankers which cruise via the Volga–Don Ship Canal (Ivanov et al., 2000). Dumont (1995) reported that the CS suffers from anthropogenic disturbances including nutrient enrichment (especially in North CS) and presence of invasive species. Shiganova et al. (2003) and Kideys and Moghim (2003) suggested that the trophic status of the CS has changed since after the introduction of the ctenophore *M. leidyi* in late 1999. Shiganova et al. (2003) also reported that under field and experimental conditions the presence of *M. leidyi* was found to cause an increase in phytoplankton abundance (in particular diatoms). *M. leidyi* has also been shown to directly affect the levels of various hydrochemical parameters (Shiganova et al., 2003).

Determination of trophic status is an important aspect of water body surveys and there are numerous indices proposed and used in most of the inland water bodies in North America (Carlson and Simpson, 1996). For example, Vollenweider and Kerekes (1982), OECD (1982) and EEA (1999) proposed single and multiple parameters such as annual phosphate, dissolved inorganic nitrogen (DIN), dissolved oxygen (DO) and chlorophyll a (Chl-a) as an indicator/threshold for classification of water body status (Table 1). Recently, the Italian legislative body suggested the use of the trophic index (TRIX) for monitoring of water body status. This index uses a linear combination of four variables namely total nitrogen (TN), total phosphorus (TP) (as an abiotic component or measure of the potential of biomass), Chl-a (as a proxy for phytoplankton biomass), and aD%O (oxygen (as absolute %) deviation from saturation) (as a biotic component or measure of productivity) to assess the trophic status of a coastal water (Vollenweider et al., 1998; Ærtebjerg et al., 2001; Penna et al., 2004). Subsequently, many other researchers (Moncheva et al., 2001; Giovanardi and Vollenweider, 2004; Penna et al., 2004; Vascetta et al., 2004; Taebi et al., 2005; Yurga et al., 2005; Coelho et al., 2007) have used this index (TRIX) to identify trophic status of coastal waters of the Black, Aegean, Adriatic, Tyrrhenian and Baltic Seas, the coastline of Pesaro (Italy), South Portugal, Venice and North East of the Persian Gulf.

The objectives of this paper are:

- to assess the trophic status of the CS before and after the introduction of an alien species (*M. leidyi*) and
- to compare results of assessments using a modified trophic index (TRIXCS) with results from other assessment tools.

It is also hoped that information generated from this study can be shared by the five littoral countries of the CS (Caspian ecoregion) in order to stimulate the development of appropriate indicators and indices for trophic status of the CS.