Ecological Indicators 82 (2017) 175–182

Contents lists available at ScienceDirect

Ecological Indicators

journal homepage: www.elsevier.com/locate/ecolind

Original Articles

Using multiple indicators to assess the environmental status in impacted and non-impacted bathing waters in the Iranian Caspian Sea

Haniyeh Nemati[a], Mohammad Reza Shokri[a,*], Zohreh Ramezanpour[c], Gholam Hossein Ebrahimi Pour[a], Iñigo Muxika[b], Ángel Borja[b]

[a] Faculty of Life Sciences and Biotechnology, Shahid Beheshti University, G.C. Evin, Tehran, Islamic Republic of Iran
[b] AZTI. Marine Research Division, Herrera Kaia Portualdea s/n, 20110 Pasaia, Spain
[c] International Sturgeon Research Institute, Agricultural, Research, Education & Extension Organization (AREEO), Rasht, Islamic Republic of Iran

ARTICLE INFO

Keywords:
Water quality
Indicators
Ecosystem approach
NEAT
Caspian Sea

ABSTRACT

Human activities have increased in the Caspian Sea in last decades, impacting the coastal zone ecosystems. One of the increasing activities is recreation, including bathing areas in the south of the Caspian Sea, which have been scarcely studied and assessed. Investigating the interactions between human activities and the resulting environmental status in bathing areas, by using adequate indicators and assessment methods, is necessary to undertake management measures for ecosystem restoration. In this study, for the first time, we use the Nested Environmental status Assessment Tool (NEAT) outside the European waters to assess environmental status in bathing waters, to differentiate areas impacted and non-impacted by bathing activities. We have assessed the status in winter and summer seasons, by combining multiple indicators from different ecosystem components (8 physico-chemical, 4 bacteria, 2 plankton, and 1 benthos indicators). Despite the interactions between season and human affection, NEAT determined that the Caspian Seas is not in good status, differentiating, in summer, between impacted and non-impacted bathing areas, with a significant correlation with the number of beach users. Accordingly, management measures should be taken in the southern Caspian Sea to improve the environmental status in general and that of bathing areas in particular.

1. Introduction

Human activities at sea, including both traditional (i.e. fishing, shipping) and emerging (i.e. renewable energy, deep-sea mining), are increasing dramatically worldwide in recent decades and can result in increasing pressures and impacts on marine ecosystems (Korpinen and Andersen, 2016). Among these activities, the use of seas for recreation is becoming more and more popular, being considered as a cultural ecosystem service (Hernández-Morcillo et al., 2013). Among these activities, the use of beaches for leisure, including sunbathing, water sports and bathing are the most common, and require ecosystem services such as clean bathing waters (Ghermandi et al., 2012).

The quality of bathing waters (i.e. those legally designed for human bathing) has been long-time monitored in many countries and under different legislation (e.g.: EEC (1976) and European Commission (2006), in Europe; US Government (2000), in USA; Health Canada (2012), in Canada) requiring, among others, the control of faecal bacteria (Salas, 1986). The bathing waters monitoring is just a control of the variables that can affect the activity itself (bacteria concentration), determining the opening or closing of the bathing areas, to avoid risks to human health. However, the activity (beach use, bathing) can also affect the quality of the bathing area in different ways, e.g. the need of beach nourishment, which can impact on beach biodiversity (Cooke et al., 2012; Vanden Eede, 2013).

In addition, the environmental status of the area in which the activity is undertaken could be already affected by other activities (e.g. waste water discharges, agricultural activities, etc.). Such activities may compromise the bathing waters quality and lead to risks to human health, but also may limit the environmental conditions, so that it becomes more prone to disturbance. Hence, an ecosystem-based management system for beaches would be needed to maintain the ecosystem integrity while enabling the sustainable use of ecosystem services (Sardá et al., 2015).

One of the problems when assessing the environmental status of marine waters is that methods able to include multiple ecosystem components in an integrative evaluation, as those used in ecosystem-based management, were not available until recently or that they had major statistical or other flaws preventing their use (Borja et al., 2009).

* Corresponding author.
E-mail address: M_Shokri@sbu.ac.ir (M.R. Shokri).

http://dx.doi.org/10.1016/j.ecolind.2017.06.054
Received 30 March 2017; Received in revised form 24 June 2017; Accepted 26 June 2017
Available online 08 July 2017

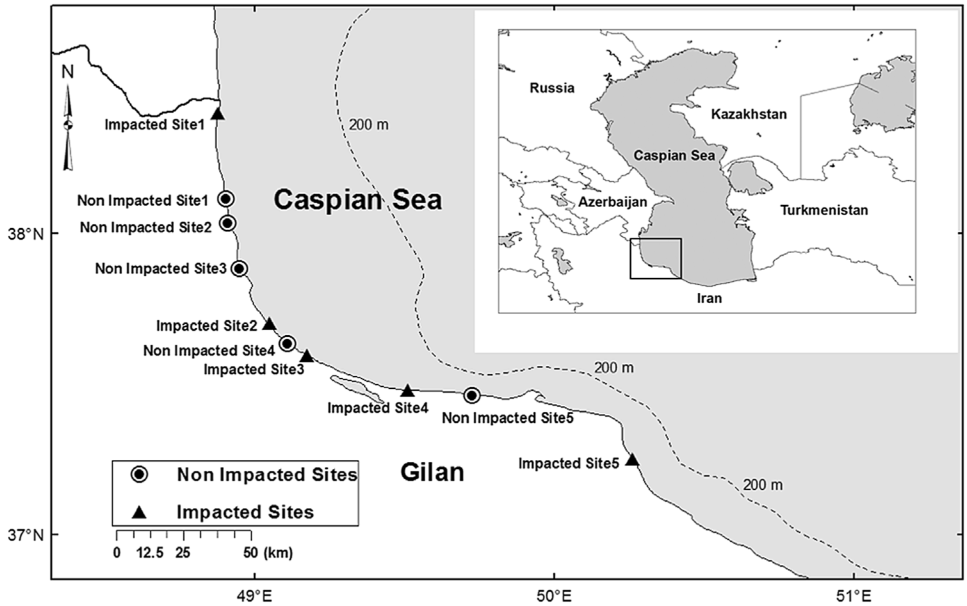

Fig. 1. Study area within the Caspian Sea.

Some of the available methods include, among others (see Borja et al., 2016a), the Ocean Health Index (Halpern et al., 2012), and recently the Nested Environmental status Assessment Tool (NEAT, Andersen et al., 2014; Borja et al., 2016b).

NEAT was primarily developed to assess the environmental status of marine waters within the European Marine Strategy Framework Directive (MSFD; 2008/56/EC, European Commission, 2008). This method has been successfully applied to all European Regional Seas (Uusitalo et al., 2016), but until now no application outside Europe has been undertaken.

Extending its use to other biogeographic regions, such as the Caspian Sea, could assist in demonstrating the applicability of NEAT under different geographic circumstances. The Caspian Sea is situated in Central Asia (Fig. 1) and is an enclosed water body that has supported decades of human activities (i.e. oil and gas extraction, fisheries, agriculture and tourism), which has resulted in a degradation of its environmental status (Barannik et al., 2004; Stolberg et al., 2006; UNEP, 2011), aggravated by decades of environmental mismanagement (Fendereski et al., 2014). Hence, the Caspian Sea ecosystem has changed dramatically (Karpinsky et al., 2005), with impacts on habitats, plankton and fish biomass, chlorophyll-a concentration, primary production and nutrient increase (Nasrollahzadeh, 2010; Shiganova, 2011), resulting in a eutrophic status (Leonov and Stygar, 2001; UNEP, 2011).

Despite this, trends indicate that bathing activities and recreation will continue to increase, but no coordinated bathing waters monitoring exists, and few research studies have been undertaken to assess the quality of bathing sites, in countries such as Iran and Turkmenistan (Pond et al., 2005; Binesh Barahmand et al., 2012).

Hence, the objective of this investigation is to check whether NEAT can be used in assessing the status of a sub-region of the Caspian Sea, in Iran, discriminating between areas impacted and non-impacted by bathing activities, and studying the potential interactions with other human activities in the area.

2. Methods

2.1. Study area and sampling design

The study area is located on the southwest coast of Caspian Sea in Gilan Province (Iran). Sampling was carried out at 10 sites: five sites were at recreational bathing areas (Impacted Sites 1–5), and five sites were not affected by bathing (Non-Impacted Sites 1–5) (Fig. 1). The bathing water areas present distinct use pressure, from absence of users (non-impacted sites), to low-moderate bathing practice (impacted sites 2 and 3, with an estimated number of swimmers between 15,000–20,000 swimmers per month), and high practice (sites 1, 4, and 5, with 25,000–40,000 swimmers per month). The number of swimmers per month was estimated during the summer sampling surveys since in winter there was no swimming activity. In addition, the bathing sites are subjected to regular beach nourishment to maintain the sand and to make the activity more pleasant. The assignment of sites to ‘impacted’ or ‘non-impacted’ was done only based on their use for recreation and bathing (and associated activities, such as beach nourishment). The sub-region studied presents also other additional pressures, such as runoff of polluted waters from rivers, rice agriculture inputs and industrial wastewater inputs (Zonn, 2005; Stolberg et al., 2006; UNEP, 2011), which could affect both impacted and non-impacted sites.

The sampling was undertaken in February 2015 (non-bathing period), and once a month from July to September 2015 (bathing period). Water surface temperature was measured on site using a digital thermometer.

Samples to analyse bacteria were collected in sterilized plastic bottles, at 10–20 cm below the surface (3 replicates per site), stored and transported in a cold box kept below 4 °C and analysed within 5–6 h of sampling (Clesceri et al., 1998).

Phytoplankton samples were collected with a Niskin bottle (3 replicates per site) (Venrick, 1978). The samples were preserved using buffered formaldehyde (4%). Conversely, zooplankton was sampled (3 replicates per site) filtering 1 m^3 per replicate through a plankton net (mesh size: 100 μm). Zooplankton samples were preserved in 4% formaldehyde (Harris, 2000).

Sediment samples were taken using a PVC Corer (3 replicates per site), to analyse Total Organic Matter (TOM) and particle size. Similarly, benthic macroinvertebrates were sampled by inserting a 20 cm wide 10 cm deep PVC Corer (5 replicates per site) into the sediment in the swash zone. Samples were then sieved through a 0.5 mm mesh. The retained macroinvertebrates were preserved in 10% buffered formalin/seawater.

2.2. Laboratory analyses

Water temperature was measured *in situ* with a digital thermometer. Samples for Dissolved Oxygen (DO) analysis were preserved after