Marine Pollution Bulletin 104 (2016) 246–256

Contents lists available at ScienceDirect

Marine Pollution Bulletin

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

Ecological quality assessment in the Eastern Mediterranean combining live and dead molluscan assemblages

Yael Leshno [a,b], Chaim Benjamini [a], Yael Edelman-Furstenberg [b,*]

[a] Department of Geological and Environmental Sciences, Ben Gurion University of the Negev, Beer Sheva 84105, Israel
[b] Geological Survey of Israel, 30 Malchei Yisrael St., 95501 Jerusalem, Israel

ARTICLE INFO

Article history:
Received 3 December 2015
Received in revised form 7 January 2016
Accepted 10 January 2016
Available online 16 January 2016

Keywords:
European Water Framework Directive
Ecological Quality Status
Live–dead molluscan assemblages
Eastern Mediterranean
Bentix
AMBI

ABSTRACT

The EU directive to quantify ecological quality by deviation from pre-impacted conditions often fails to be implemented because past information is usually incomplete or missing. Molluscan death assemblages, representing long-term accumulation of shells on the sea floor, average out short-term variability and can serve as a baseline for quality assessment. AMBI, Bentix and Shannon–Wiener indices were calculated for live and dead assemblages from polluted and control stations on the highly oligotrophic Levantine shallow shelf of Israel. Bentix successfully tracked deterioration over time, from moderate EcoQS in the dead to poor in the live assemblage. Additional modification of the ecological classification of species by scoring the naturally abundant *Corbula gibba* as pollution-sensitive improved the utility of the Bentix index in monitoring in this part of the Mediterranean. This adjustment of Bentix, and use of death assemblages for an ecological baseline, should therefore be incorporated in monitoring for compliance with EU directives.

1. Introduction

Recent anthropogenic modification of marine environments has led to the decline of marine ecosystems worldwide (Magni, 2003; Lotze et al., 2006; Halpern et al., 2012). The European Union established two directives in order to better preserve and protect marine environments around the Mediterranean: the Water Framework Directive (WFD, 2000/60/EC) and the Marine Strategy Framework Directive (MSFD; 2008/56/EC). The WFD and WSFD classify marine water bodies according to their ecological health, represented by an Ecological Quality Status (high, good, moderate, poor and bad) (Mee et al., 2008; Borja et al., 2010, 2011; Van Hoey et al., 2010). The directives aim to achieve good environmental status for European water bodies by 2015 and 2020, for WFD and MSFD respectively (Borja et al., 2009a; Rice et al., 2012; Simboura et al., 2014). Chemical, sedimentological and biological indicators are used to determine an Ecological Quality Status (EcoQS) of a system (Simboura and Zenetos, 2002). The WFD and WSFD promoted the use of, and search for, new ecological quality indicators for comparative purposes (Borja and Muxika, 2005; Hering et al., 2006; Borja et al., 2009b, 2012). Following the publication of these directives, many studies have compared various benthic indices aimed at finding the method most suitable for the EcoQS assessment of a particular marine environment (e.g., Muxika et al., 2007; Simonini et al., 2009; Simboura and Argyrou, 2010; Souza et al., 2013; Simboura et al., 2014; Hutton et al., 2015; Brauko et al., 2015). The most commonly used faunal indices are the AMBI (Borja et al., 2000) and Bentix (Simboura and Zenetos, 2002) indices, which categorize species into ecological groups based on their sensitivity or tolerance to pollution, following Pearson and Rosenberg's (1978) model of species response to organic enrichment. The relative scales of other often used diversity indices, such as the Shannon–Wiener index, were standardized to correspond to the EcoQS of the WFD (e.g., Rice et al., 2012). The WFD and WSFD define the ecological status of a system as the deviation from pre-impacted reference conditions. However, in many cases information on natural conditions is incomplete or missing, and left to expert judgment in the absence of robust data (Borja et al., 2012).

A record of the composition and structure of pre-anthropogenic live communities is preserved in long-term accumulations of empty shells on the sea floor, quantified and defined as a ‘death assemblage’ (Kidwell, 2007). Shells from consecutive generations are mixed over time by burrowing organisms and physical reworking of shells on the sea floor, resulting in a ‘time-averaged’ record that can be compared to the living community. This type of record averages out variations in the live community such as subannual, seasonal and reproductive cycles, as well as multiyear variations in the living community and is a long-term baseline record of the ecosystem (see Kidwell, 2013 for review). Under natural conditions, there is good agreement in the structure and composition of species between the dead time-averaged assemblage and the living community (Olszewski and Kidwell, 2007). Rapid and severe anthropogenic changes to the living community

* Corresponding author.
E-mail addresses: yael.leshno@mail.huji.ac.il (Y. Leshno), chaim@exchange.bgu.ac.il (C. Benjamini), yael@gsi.gov.il (Y. Edelman-Furstenberg).

http://dx.doi.org/10.1016/j.marpolbul.2016.01.014
0025-326X/

('live assemblage') from the baseline time-averaged record, create a mismatch in ecological indices between the live and dead assemblages (e.g., species composition, diversity, and dominance). Therefore, the comparison of live vs. dead assemblages is a potentially valuable tool in environmental assessment (Kidwell, 2007).

The method used for creating a comparative database is to collect the dead shells left behind by the macrobenthic fauna by sieving the top of the sea floor sediment, use them to reconstruct an ecological baseline, and then compare them to the live assemblage from the same locality (Kidwell, 2007, 2013). A statistically robust baseline can be constructed for comparative purposes, overcoming the subjective bias inherent in 'expert judgment' in monitoring compliance with the WFD and MSFD.

This study compares live and dead assemblages of molluscan faunas from a monitored station near the Dan Region Wastewater Project (Shafdan), to control stations at the same depth representing the highly oligotrophic natural shallow shelf of the Levantine margin offshore Israel. The AMBI, Bentix and Shannon–Wiener (H′) indices were calculated for live and dead assemblages of molluscan faunas, to evaluate their utility as indicators of EcoQS of polluted and control stations for the Eastern Mediterranean. This study is the first application of the AMBI and Bentix indices on time-averaged molluscan death assemblages, an approach that could be widely used to determine EcoQS in environments for which there is no available reference database. This is also the first test of utility of the AMBI and Bentix indices in the Eastern Mediterranean, east of Greece.

2. Material and methods

2.1. Study area

The Levantine coast of Israel trends N-NE–S-SW in a nearly straight line over 180 km, varying in width from 10 to 25–30 km (Inman and Jenkins, 1984; Rosentraub and Brenner, 2007). The upper 120 m of the water column is stratified during most of the year and becomes mixed in winter (Herut et al., 2000; Rosentraub and Brenner, 2007). The Levantine basin is naturally oligotrophic, characterized by primary production estimated at ca. 45 gC/m^2y (Berman et al., 1984; Kress and Herut, 2001; Kress et al., 2004) and Chlorophyll a values that range between 0.009 and 0.4 μg/l (Yacobi et al., 1995). This extreme nutrient depletion is attributed to the westward transport of deep water as part of the anti-estuarine circulation of the Mediterranean (Coll et al., 2010). Furthermore, in the past, the Nile River was the main supplier of nutrients, until the construction of the High Aswan Dam in 1965 (Stanley, 1988; Herut et al., 2000). Since then, nutrient levels have become exceedingly low in the coastal zone (Inman and Jenkins, 1984), with negative changes to the marine food webs and on fisheries (Nixon, 2003).

On the other hand, recent urbanization of the Israeli coast reversed this trend with considerable input of nutrients to the shallow shelf via direct outfalls (EEA, 2001; Kress et al., 2004). The largest single discharge is from the Shafdan wastewater treatment plant that has been discharging sewage sludge onto the shelf at 36 m water depth since 1987 (Kress et al., 2004; Hyams-Kaphzan et al., 2009). The Shafdan produces 292,000 dry metric tons of activated sewage sludge annually, most of which is redirected to agriculture and landfill. On average 16,000 m^3/day of excess sewage sludge are discharged through a single seabed pipe line emptying 5 km offshore 15 km to the south of Tel Aviv (Kress et al., 2004) (Fig. 1). The area was not polluted prior to the activation of the outfall (Galil and Lewinsohn, 1981). Permanent control and polluted monitoring stations have been established in the area by the Israel Oceanographic and Limnological Research institute (IOLR) to the north and south of the outfall, sub-parallel to the coastline (Kress et al., 2004). Previous research in the area focused on the effects of sewage sludge on polychaetes (Kress et al., 2004) and benthic foraminifera (Hyams-Kaphzan et al., 2009), showing that the impact was localized.

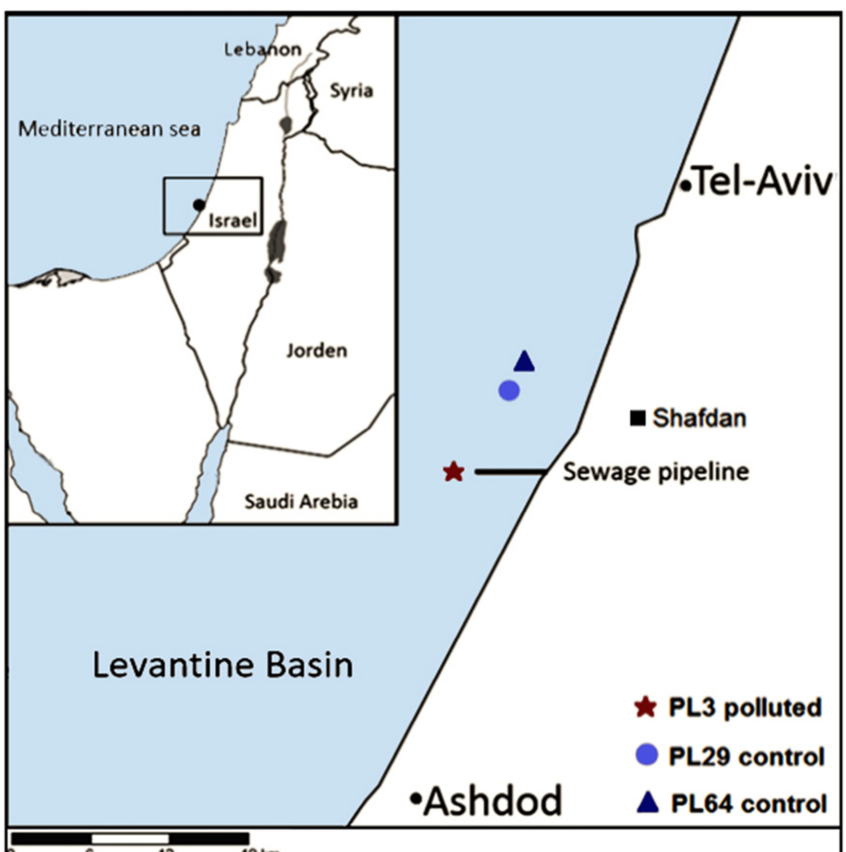

Fig. 1. Location map of the Israeli coast showing the position of the Shafdan sewage sludge outlet and polluted and control sampling stations.