Oceanologia (2018) xxx, xxx–xxx

Available online at www.sciencedirect.com

ScienceDirect

journal homepage: www.journals.elsevier.com/oceanologia/

ORIGINAL RESEARCH ARTICLE

Ecosystem of the Polish part of the Vistula Lagoon from the perspective of alternative stable states concept, with implications for management issues

Q1 Ryszard Kornijów *

Q2 *Department of Fisheries Oceanography and Marine Ecology, National Marine Fisheries Research Institute, Gdynia, Poland*

Received 21 November 2017; accepted 21 February 2018

KEYWORDS
Baltic Sea;
Coastal management;
Regime shift;
Food-web interactions;
Drivers

Summary The alternative stable states concept finds broad application in reference to both terrestrial and aquatic ecosystems. For some reason, attempts to implement the concept to explain processes observed in estuaries and Baltic lagoons are very rare. Based on information included in publications issued over the last 60 years, three co-existing states were designated within the strongly elongated basin the Vistula Lagoon, namely: phytoplankton-dominated (Middle Basin), macrophyte-dominated (Elbląg Bay), and transition state balancing between the two former ones (West Basin). Regions of the lagoon representing such states are similar in terms of nutrient concentrations, but they considerably differ in terms of: exposure to wind and wave action, salinity, anthropogenic impact, and multi-level top-down regulations. The paper discusses the role of such drivers, responsible for both the maintenance of a given state, and the past transition into the present alternative state. Moreover, it presents chances for the improvement of the situation, as well as threats which can undermine them.

* Correspondence to: Department of Fisheries Oceanography and Marine Ecology, National Marine Fisheries Research Institute, Kołłątaja 1, 81-332 Gdynia, Poland.
E-mail address: rkornijow@mir.gdynia.pl.
Peer review under the responsibility of Institute of Oceanology of the Polish Academy of Sciences.

https://doi.org/10.1016/j.oceano.2018.02.004

Please cite this article in press as: Kornijów, R., Ecosystem of the Polish part of the Vistula Lagoon from the perspective of alternative stable states concept, with implications for management issues. Oceanologia (2018), https://doi.org/10.1016/j.oceano.2018.02.004

1. Introduction

According to the alternative stable state theory, a given system can remain in one of multiple possible states defined by a specific composition of biocoenoses and habitat properties over ecologically-relevant timescales (Holling, 1973; Scheffer and Carpenter, 2003; Scheffer et al., 2001). During the persistence of a given state, a system of ecological feedbacks develops, counteracting the shift into another state. The transition of the ecosystem into another alternative state precedes exceeding ecosystem thresholds, and usually requires the interference of a sufficiently strong driver able to disturb the current balance, and as a consequence lead to profound transformations of the entire system. Transition states, considered unstable, can occur in between. The theory has become an important framework for understanding and managing both terrestrial ecosystems (e.g. grass-dominated vs. shrub dominated), as well as aquatic, freshwater, and marine ecosystems (e.g. clear-water vs. turbid water, kelp forests vs. urchin dominance) (review in Folke et al., 2004).

Ocean ecosystems naturally respond to environmental stress very slowly, and the rate of the occurring processes is distinguished by considerable inertia. Due to such characteristics, the majority of regime shifts in oceans unfold slowly and smooth transitions between equilibrium states are easy to overlook or ignore (Hakanson and Lindgren, 2008; Knowlton, 2004; Lyytimäki and Hildén, 2007; Petraitis and Dudgeon, 2004). The stability of open zones of oceans contrasts with the dynamics of processes occurring in coastal lagoons and estuaries. They are transitional zones where the influences of the aquatic and terrestrial, as well as freshwater and marine environment clash (Perez-Ruzafa et al., 2011). This is additionally combined with the destabilising effect of human activity, usually strongly evident in these areas. In such conditions, the risk of a shift from one state into another is particularly high (Viaroli et al., 2008). Therefore, it is important not only to define the current state of lagoons, but also to determine the rate of changes and drivers causing them, as well as the ecological thresholds exceeding of which can result in a shift to a new state (Lyytimäki and Hildén, 2007). The knowledge of such conditions can permit management of resources preventing the transition into another state, and therefore dramatic changes in the biocoenosis and the provision of ecosystem services to the coastal communities (Hughes et al., 2013; Mollmann et al., 2015). On the other hand, such knowledge can provide the basis for programmes aimed at the management or restoration of the degraded systems (Hakanson and Bryhn, 2008; Jeppesen et al., 1994; Moss, 1994).

In spite of high interest in the stable states concept among marine ecologists, attempts of its implementation aimed at the explanation of phenomena observed in the lagoons and estuaries of the Baltic Sea have been undertaken only in several cases and in a limited scope (Dahlgren and Kautsky, 2004; Munkes, 2005; Rosqvist et al., 2010). This paper is the first attempt of implementation of the theory in reference to a Baltic lagoon, taking into consideration the majority of trophic levels. It concerns the Vistula Lagoon, the second largest and one of the most thoroughly investigated lagoons in the region. The study is based on information included in publications issued over the last 60 years. The objective of the study was to organise knowledge available in the literature regarding the lagoon's ecosystem in order to provide the basis for: i. defining the (current and past) state of the lagoon in the context of the alternative state theory and regime shifts, ii. analysing drivers and buffer mechanisms maintaining a given state, with consideration of bottom-up and top-down regulations, and iii. presenting chances for the improvement of the ecological status of the lagoon, and diagnosing potential threats to the ecosystem which can undermine them. In the paper, alternative states correspond to situations in which one of the groups of primary producers is dominant, namely macrophytes (corresponding to macrophyte-dominated state) or phytoplankton (phytoplankton-dominated state) (Scheffer and Carpenter, 2003; Scheffer et al., 1993).

2. Material and methods

The Vistula Lagoon is located in the south-eastern part of the Baltic Sea. It is a strongly elongated, N–S oriented water body with a length of 91 km, width from 7 to 11 km, and surface area of 838 km^2. The eastern part of the lagoon with an area of 328 km^2 is located on the Polish side (Fig. 1), and the remaining part on the Russian side. To the north, it is separated from the open sea by the Vistula Spit – a shallow belt of sandy land with a width of 1–2 km and length of approximately 50 km. Contact with marine waters occurs through the Baltiysk Strait (the inlet length, width and depth: 2 km, 400 m and 10–12 m, respectively). The extensive surface area of the lagoon contrasts with its low depth (mean depth 2.5 m; max. depth 5.2 m).

The shoreline of the lagoon on the Polish side is weakly developed. The only bay strongly extending into the land is the Elbląg Bay, located in the south-western part of the lagoon, and fed by the Elbląg River (Fig. 1). It has an area of 7.23 km^2, and is very shallow (max. depth in the central area of the bay usually not exceeding approximately 0.8 m).

The lagoon is fed by several rivers draining an area of 23,871 km^2. In comparison to the lagoon's water surface area, the drainage area is exceptionally large (Łomniewski, 1958). More than half of the area is under agricultural use, and approximately 25% is covered by forests. The total number of residents in the lagoon's catchment slightly exceeds one million. Industry is not extensively developed.

Until the end of the 19th century, the Vistula Lagoon was nearly a freshwater basin supplied mainly by two rivers: Vistula and Pregolya. In 1895, for the purpose of protection of areas located at the mouth of the delta of the Vistula River against flood, a new mouth of the river to the Baltic Sea was dug. Moreover, a cascading system of four locks and weirs was constructed on the Nogat River (a distributary channel of the Vistula River) the main stream feeding the lagoon at the time (Łomniewski, 1958). This reduced the inflow of waters from the Vistula River to the lagoon 10 times, resulting in a gradual increase in the salinity of the lagoon waters. Nowadays, the highest salinity, reaching 6.5‰, is observed in the vicinity of the Baltiysk inlet. It gradually decreases towards the east and Western, reaching values close to zero at the mouths of the largest rivers.

Please cite this article in press as: Kornijów, R., Ecosystem of the Polish part of the Vistula Lagoon from the perspective of alternative stable states concept, with implications for management issues. Oceanologia (2018), https://doi.org/10.1016/j.oceano.2018.02.004