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The political decision caused the drastic ecosystem shift of the Sivash Bay (the Sea of Azov)

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ABSTRACT

Political and economic decisions have led to more drastic changes of aquatic ecosystems, than those caused by hydrological extremes (drought, floods). Examples of this are two transformations of the Sivash Bay (Sea of Azov); a review and analyses of them are given in the paper. Sivash Bay was a hypersaline lagoon before 1963. The North Crimean Canal was built to improve water supply to the Crimean peninsula by using the waters of the Dnieper River. After the initiation of Dnieper water via the North Crimean Canal and the subsequent development of irrigated agriculture, runoff waters from the fields began draining into Bay Sivash. The salinity began to drop. Pre 1997 the average salinity in Sivash Bay was 140 g L^{-1}; in 1997 it had dropped to 17 g L^{-1}. A fundamentally new brackish water ecosystem gradually formed in Sivash Bay. In April 2014, Ukraine made a political decision to stop supplying Dnieper water via the North Crimean Canal. Discharge of fresh water to the bay almost ceased. Salinity began to increase, and a new transformation of the Sivash ecosystem started. Six complex expeditions were conducted in the Sivash region; their results are described and analyzed in the article. The salinity of the lagoon has now risen to 55–75 g L^{-1}, and drastic changes have occurred in the plankton, benthos, and aquatic vegetation.

1. Introduction

Humans live and act simultaneously in two worlds – the real physical world and the virtual world of ideas, traditions, myths, scientific concepts, etc. and they are closely intertwined. Long ago scientists (J. Lamarck, A. von Humboldt, V. Vernadsky) came to an understanding that human thought has become a geological factor affecting the planetary processes; Vernadsky wrote "Mankind taken as a whole is becoming a powerful geological force" (Vernadsky, 1945; Zavarzin, 2003; Shadrin, 2013). Now scientists talk about Anthropocene, which is the current epoch in which humanity has become a global geophysical force overwhelming natural forces (Steffen et al., 2007). In 1944, V. Vernadsky proposed the concept of the noosphere (ancient Greek νόος – «mind» and σφαῖρα – «ball»): the biosphere enters a new state when a reasonable humanity takes over the management of the development of the biosphere in the interests of all mankind – "emergence of the noosphere as a critical evolutionary step is needed for preserving and reconstructing the biosphere in the interests of humanity as a single entity" (Vernadsky, 1945; Levit, 2001). However, in reality all humans are witnessing the transition of the biosphere not into the noosphere, but into the opposite of the noosphere – the kakosphere (ancient Greek κακός – «bad» and σφαῖρα – «ball»), when developing humanity more damaging himself (Zavarzin, 2003; Shadrin, 2013). Why is this happening if environmental science is evolving, and science better understand the relationship of processes and phenomena? One of the main reasons for this is a lack of understanding that people live in both real and virtual worlds. People make the solutions in the virtual world, but their implementation is generally carried out in the real world. People, when making political and economic decisions, rarely understand and take into account interrelations in the real physical

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world – landscape connectivity of systems and processes in an integrated system "water body – catchment – people", as well as the probabilistic nature of many linkages and responses in this system (Walker et al., 2004; Soranno et al., 2009). Decision makers want to have an accurate unambiguous forecast, but such a task is not realistic as it was shown, for example, for Lake Qarun in Egypt (El-Shabrawy et al., 2015; Shadrin et al., 2016). These often give a simplified model, with uncertainty and probability omitted from them. These models may be easily understood by decision makers, but they are far from the real physical world.

Now there is a lack in scientific understanding of landscape connectivity. However, it might be suggested that often effective communication between scientists and decision makers is a more important problem, rather than any available lack of understanding (Sarewitz and Pielke, 2001; Sayers et al., 2002). The accumulation of the results in analysis of the consequences of specific decisions made for the water bodies and their catchment areas can contribute to an understanding of the complexity and uncertainty in the responses of natural systems to human decisions. There are many examples where political and economic decisions have led to more drastic changes of aquatic ecosystems, than caused by climate fluctuations - hydrological extremes (drought, floods) (Vörösmarty et al., 2013). Giving their review is not a task of the authors. Examples of political decisions leading to environmental change are two transformations of Bay Sivash (Sea of Azov); to review and analyze them is the aim of this paper. The first of the transformations will be briefly described, relying mainly on data published by other scholars, the second on data of the authors, only partially published previously (Sergeeva et al., 2014).

2. Study area

2.1. The bay ecosystem before the first anthropogenic transformation

Sivash Bay is the largest bay in the Sea of Azov (Fig. 1). It is separated from the sea by the narrow sand Arabat Spit (length 112 km), covers an area of around 2560 km^2 and on the north connects with the sea by the narrow Henichesk Strait (Vorobyev, 1940). This unique hypersaline bay has attracted the attention of many researchers, since the 18th century (Zuev, 1782; Pallas, 1795; Meyer, 1925). Prior to the construction of the North Crimean Canal (1963–1975), Bay Sivash and its shores was a highly productive semi-closed shallow hypersaline lagoon (average salinity of about 140 g L^{-1}, in the southern part – >200 g L^{-1}) with bars, spits and islands; saline depressions with small salt lakes and pools surrounded the lagoon (Vorobyev, 1940; Zenkevitch, 1963). The bay contained one of the world's largest populations of *Artemia* sp. (Shadrin et al., 2012).

2.2. The first anthropogenic transformation of the Sivash ecosystem

To improve water supply to the Crimean Peninsula using the waters of the Dnieper River, the North Crimean Canal was built with a total length of 465 km (375 km in Crimea). Development of irrigated agriculture, mainly rice cultivation, was started. The channel provided irrigation to 4000 km^2 of agricultural land. After the initiation of Dnieper water via the North Crimean Canal and the development of irrigated agriculture, drainage water from the fields began discharging into Sivash Bay. For example, in 1985, 521 million m^3 of water was discharged from the territory of the Crimea and 109 million m^3 from the Kherson region, and in 2009–1100 million m^3 in total (Sotskova and Sirik, 2011). The salinity in Sivash Bay began to fall. By 1989 average salinity had dropped from 140 g L^{-1} to 22.6 g L^{-1}, and by 1997, down to 17 g L^{-1} (Grinchenko, 2004). The local hydrological cycle dramatically changed with a rise in the groundwater level. A fundamentally new brackish water ecosystem was gradually formed in Sivash Bay (Yanovsky et al., 1988; Getmanenko et al., 1996; Zagorodnyaya, 2006; Kireeva and Potekha, 2013). Changes have occurred not only in the Sivash lagoon, but also on its shores, where large reed swamp areas developed, the width of which in some places reached from a hundred meters to kilometers. The development of intensive reed wetlands led to stabilization of the water level in the lagoon, reducing its seasonal fluctuations. Significant changes in the avifauna also occurred. For example, Ciconiiformes birds, which were absent pre-discharge, have become the indicator components of the Sivash area (Grinchenko, 2004). The human population in the

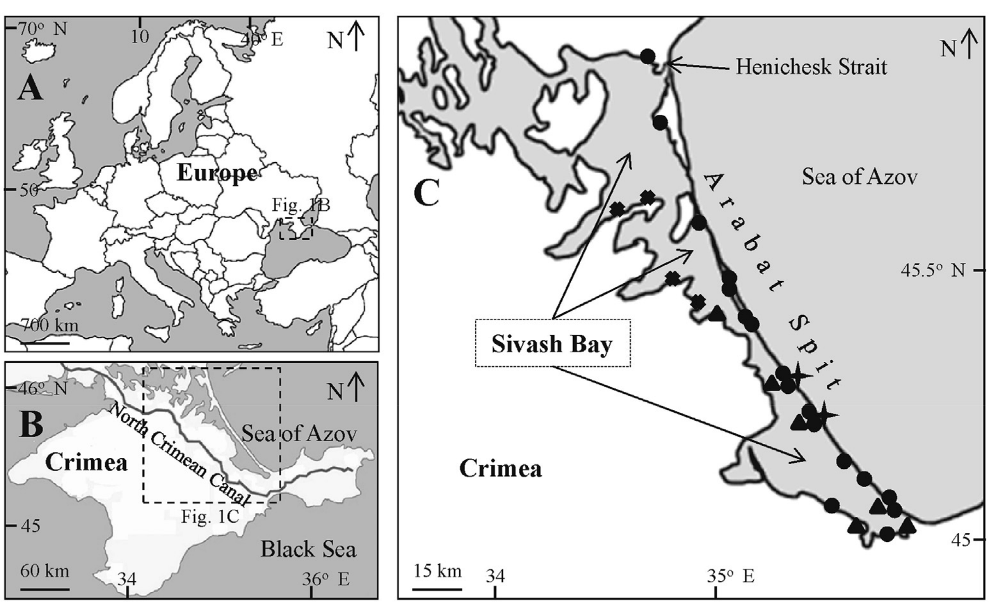

Fig. 1. The Sivash Bay (The Sea of Azov) and sampling stations in the different expeditions (● – 2013, June; ✱ – 2014, June, October and 2015, second half of October; ▲ – 2015, August; + – 2004–2015).

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