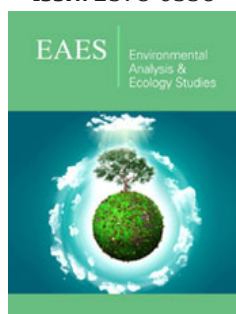


The Baltic Sea Ecosystem Regulation Mechanism

Jari Hanninen*

Associate Professor, Finland

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*Corresponding author: Jari Hanninen, Associate Professor, Finland

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Introduction

Understanding the functioning of the Baltic Sea ecosystem has been one of the most important tasks of the Seili Research Station of the University of Turku, Finland. Understanding requires not only the study of the regulatory mechanisms of the Baltic Sea ecosystem, but also the study of the climatic conditions of the Atlantic, as the climatic conditions of the ocean ultimately determine how the Baltic Sea ecosystem develops [1]. The reason for this is that the origin of all water in the brackish water Baltic Sea, both saline and freshwater, is the Atlantic Ocean. Freshwater originates from evaporation in the Atlantic, which, driven by prevailing winds due to the Coriolis force, rains the catchment area of the Baltic Sea and ends up in the main basin of the sea along the rivers. Saline water enters through the Danish straits as a result of strong winter storms in the North Sea [2]. Thus, the brackish water is a combination of these two water sources.

The regulation mechanism of the Atlantic climate on the Baltic Sea ecosystem is best described by a phenomenon called the North Atlantic Oscillation (NAO). The NAO is an index that measures the difference in air pressure between the two major meteorological centers in the Atlantic [3]. One is relatively constant low pressure, located near Iceland, and the other is high pressure, located between the Azores archipelago and Caribbean (Figure 1). The index indicates the deviation from the long-term mean and can get either positive or negative values (Figure 2). In the case of a positive index value, the air pressure differences between meteorological centers are at their strongest, which means that clouds, formed in the Atlantic, route mainly over the warm Gulf Stream. These clouds are directed towards the northern Europe which results mild and rainy climatic conditions particularly in winters. At the same time, the southern Europe in the Mediterranean area suffers from cold and drought weather. During a negative NAO index, the situation is the opposite - in northern Europe, winters are icy and frosty, while in southern Europe it is mild and rainy [4]. This phenomena were previously referred by elderly people as “marine” or “continental” climates.

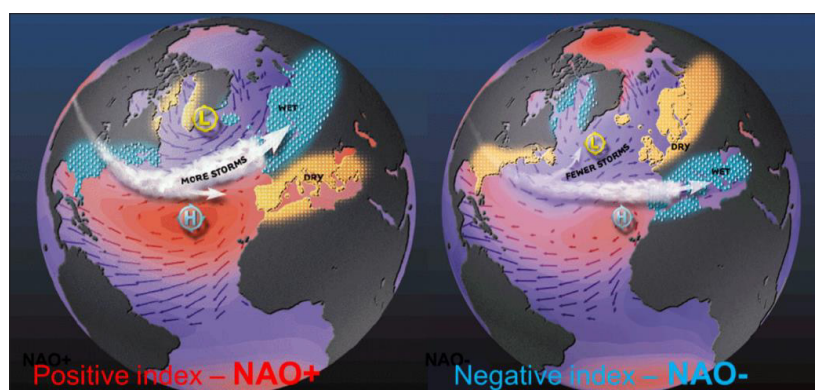


Figure 1: Cloud pathways and the impact of the Atlantic on the European climate at different stages of the NAO index. Yellow L represents constant low pressure near Iceland and gray H high pressure around the Azores (according to Stenseth et al. [4]).

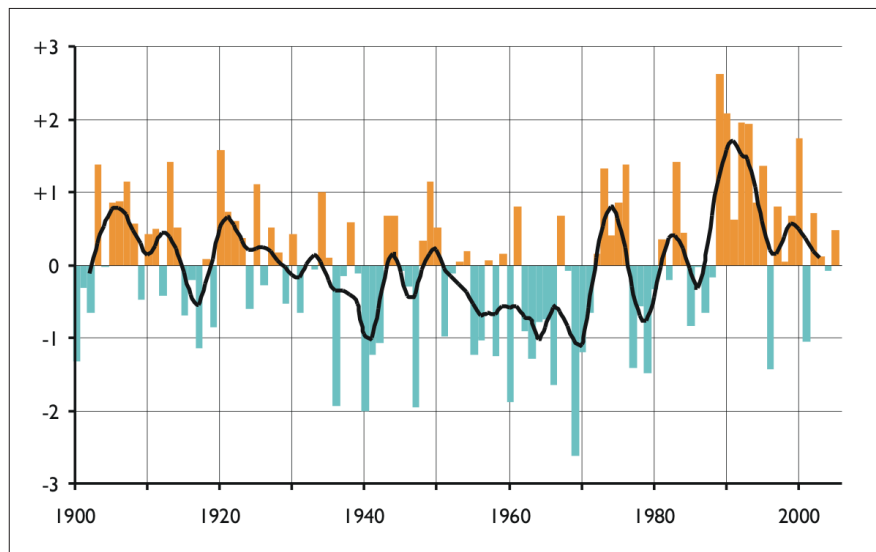


Figure 2: Winter NAO index 1900-2005. The orange bars represent the positive phase of the index, the turquoise the negative. The positive phase has been prevalent since the 1980s [3].

For the regulation of the Baltic Sea ecosystem, I see, the most essential thing is what has happened in the NAO since the 1980s. Then the positive index remained more prevalent at the time, which has led to significant increase in winter rainfall in northern Europe (Figure 3), and this trend has still continued since then. I believe this due to global climate change. The change led to a situation where freshwater runoff from the Baltic Sea catchment area into the main basin has intensified and therefore the salinity of brackish water has started to decline. Together with the warming of seawater, this phenomenon can be seen the most crucial change caused by climate change for the Baltic Sea. The time series of the

marine environmental long-term monitoring conducted by the Seili Research Station since 1964 have been utilized in the study of the effects of climate change in to the Archipelago Sea, northern Baltic. The seawater salinity decrease has been modeled, among other things, on the basis of the changes in the freshwater runoff in to the Baltic Sea [1]. Moreover, the decrease in the salinity and the rise in seawater temperature have modeled further for the biological effects of these changes, e.g. in the composition of the zooplankton community (Figure 4) [5-7], not only in the Baltic Sea but also in the North Sea [8,9], and still in the change in the fitness of plankton-eating Baltic Herring [10].

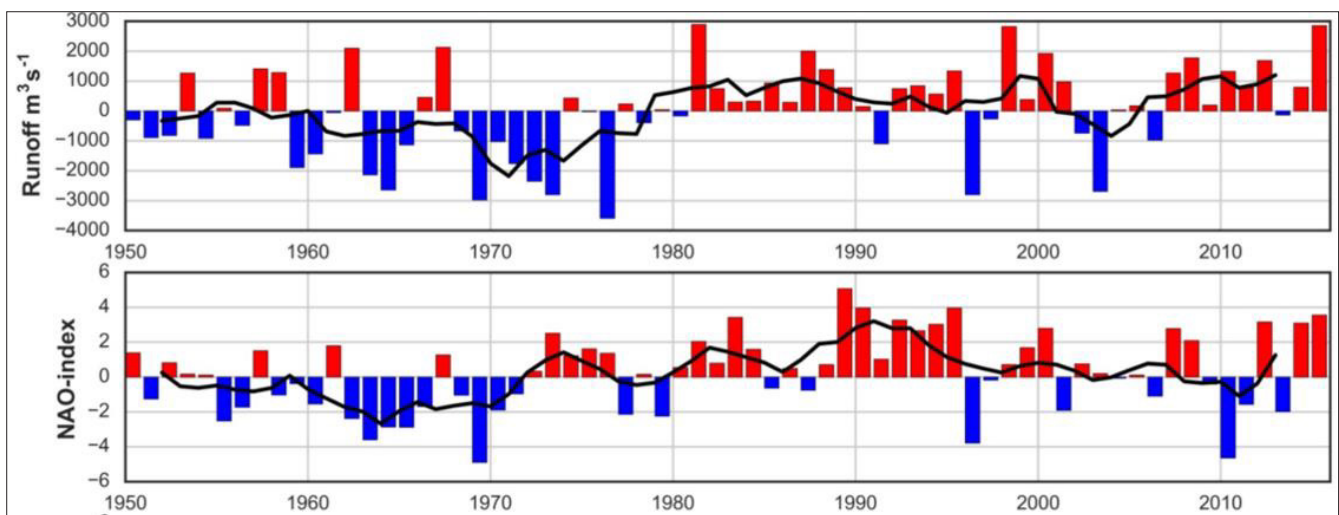


Figure 3: Upper panel: Total runoff deviation during 1950 - 2015 to the Baltic Sea. Lower panel: NAO index during 1950 - 2015 based on winter mean values of the NAO index. Positive index indicates stronger westerly winds bringing warmer and wetter winters to Scandinavia. Black line represents the five-year running mean for each panel (derived from HELCOM [11]).

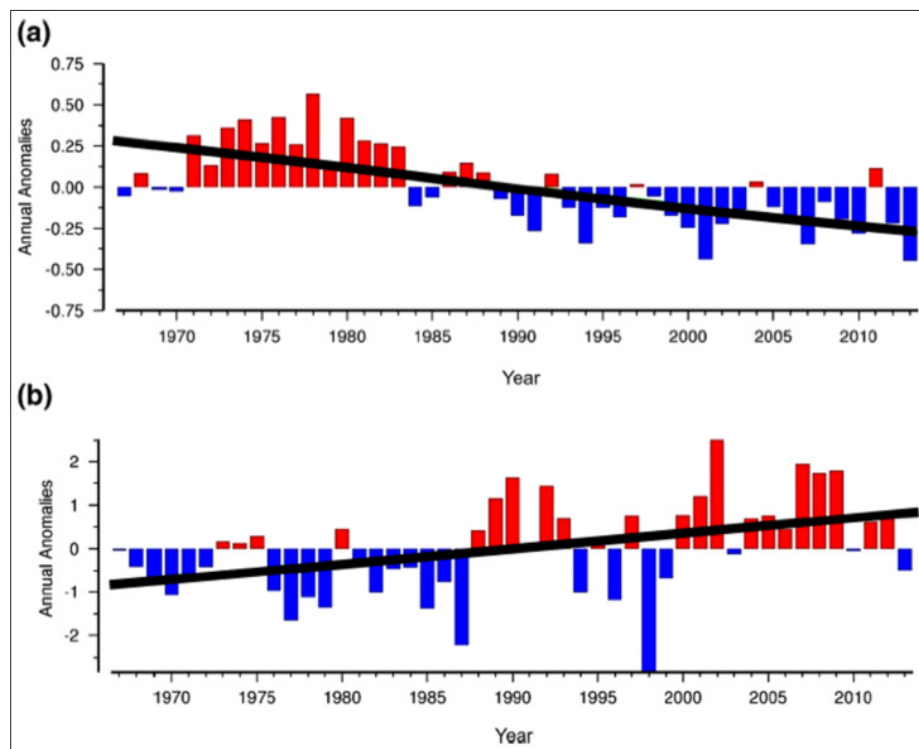


Figure 4: Annual positive (red) and negative (blue) anomalies (May-September, 1967-2013) of a) salinity and b) temperature (°C) at 0-20m water depth in the northern Baltic Archipelago Sea. Lines are linear regressions of the annual anomalies versus year (solid black line = $p < 0.01$). During the period, the salinity of the seawater has decreased some 0.5 PSU, at the same time the temperature has increased by 1.5 °C. Note the difference between y-axes [6].

In a newly launched research project the study will cover also the terrestrial environment. We investigate through biomass changes how the climate induced prolongation of the growing season, due to rising temperatures, has affected the biodiversity of invertebrates living in two different ecosystems. The subjects of the study are marine zooplankton time series in the Baltic Sea and the arctic butterflies from the Finnish Lapland. Our aim in the work is to find out how similar the mechanisms of climate change regulation can be to these groups of organisms that live in marine and terrestrial ecosystems [11].

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