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Effect of drifting macroalgae *Cladophora glomerata* on benthic community dynamics in the easternmost Baltic Sea

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ABSTRACT

The present study focuses on dynamics of macroinvertebrate communities in shallow waters of northern coast of the Neva Estuary, Russia under eutrophication consequences such as proliferation of fast-growing filamentous algae *Cladophora glomerata* and oxygen depletion during the algae decomposition. Habitat characteristics (temperature, salinity, total phosphorus, and oxygen in water), taxonomical composition and abundance of zoobenthos were studied from May to October of 2003–2005. Temporary deoxygenation (0.6–2.8 mg cm^{-3}) of water near bottom caused by the decomposition of detached *C. glomerata* was recorded annually from July to August. At the same periods, abundance of macroinvertebrates decreased significantly, from 23.6 to 3.6 (2003), 51.9 to 0.4 (2004) and 34.9 to 1.4 thousand ind.m^{-2} (2005). The coastal eutrophication in the Neva Estuary causes the destabilizing fluctuations in benthic abundance that can facilitate the shifts in littoral community structure.

1. Introduction

Eutrophication can be defined generally as nutrient enrichment, primarily in regard to phosphorus and nitrogen (Cloern, 2001; Schernewski and Schiewer, 2002), which leads to proliferation of fast-growing ephemeral macroalgae in shallow coastal waters. This phenomenon increasingly observed worldwide is generally considered as a symptom of coastal eutrophication (Valiela et al., 1997; Blomster et al., 2002; McGlathery et al., 2007). In the Baltic Sea ecosystem it results in increase of drifting algae biomass ("macroalgal blooms"). A green filamentous alga *Cladophora glomerata* (L.) is one of the most abundant species among bloom-forming macroalgae (Vahteri et al., 2000; Norkko et al., 2000; Berglund et al., 2003). Decomposition of the drifting *C. glomerata* inducing momentary response to gradient deviations of physical factors (deoxygenation of water near bottom and further hydrogen sulphide production) and functional shifts in coastal invertebrate communities has been considered as the most serious threats for marine environment in Archipelago Sea, south–western Baltic, the whole Estonian coast and the northern coasts of the Gulf of Finland (Norkko and Bonsdorff, 1996; Bonsdorff et al., 1997; Lehvo and Bäck, 2001; Vahteri et al., 2000; Berglund et al., 2003; Martin et al., 2003; Salovius and Kraufvelin, 2004; Lauringson and Kotta, 2006). Although these wide-spread effects of the eutrophication are well-described, the functional response of benthic invertebrates to the threats and main tendencies of changes in aquatic communities, perhaps discriminate in different regions, are poorly understood.

The top of the Gulf of Finland, the Neva Estuary is known as one of the most eutrophic areas of Baltic Sea (Lappälainen and Ponni, 2000). Annually about 3000 t of total phosphorus and 57,000 t of nitrogen enter to the eastern part of the gulf,

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i.e. approximately 8% of macronutrients entering the Baltic Sea with rivers flow (HELCOM, 2004). The most part of this load enters from the Neva River; the "natural phosphorus" accounts for approximately 40% and the "anthropogenic phosphorus" for 60% (Frumin and Leonova, 2004). A little is known on consequences of coastal eutrophication in this area (Golubkov et al., 2003; Berezina et al., 2005). This paper aims to identify main physical characteristics in water near bottom and shifts in density of macrozoobenthos during *C. glomerata* vegetation and period of the filamentous algae decomposition in the Neva Estuary. The study based on seasonal monitoring of zoobenthos and oxygen and total phosphorus contents in shallow zone of northern part of the estuary.

2. Material and methods

2.1. Study site

The sampling site locates in stony littoral of the northern part of the eastern Gulf of Finland, the St. Petersburg city area (60°11′ N, 29°44′ E, Fig. 1), where the highest biomass of filamentous algae (*C. glomerata*) was recorded (Golubkov et al., 2003). Macroinvertebrate communities were monitored in the shallow coastal zone, 20 m from shoreline every 2 weeks during May to July and once a month in September–October of 2003, 2004 and 2005. Samples of water for chemical analysis were collected together with biological sampling from near bottom area. Depths at study site varied from 40 to 75 cm. Fluctuations of the water level are induced by winds, seiches and changes of the Neva River runoff. The substrate at study site consists of coarse sand, gravel and stones. The coverage of bottom by hard substrates averages 90%. During observation period water salinity varied in the range of 0.3–1.4 PSU (Table 1).

Water temperature during December to March was close to 0 °C; it rapidly increased after the ice-breaking since late April to May. By the end of May the temperature reached 9–11 °C. The summer daytime temperatures of water varied in the ranges of 18–23 °C in 2003, 14–27 °C in 2004 and 16–28 °C in 2005. It decreased to 8 °C in late September and 2–3 °C in October.

The biomass of attached *C. glomerata* varied in the range of 0.5–411.9 g DW m^{-2} (Table 1). Storms affect dramatically the growing filamentous algae, detaching them from substrates. Great masses of *C. glomerata* are drifted into shallow littoral zone, forming drifting and loose-lying algal mats and accumulating on beaches as storm casts. The drifting algae are spatially and temporally stochastic phenomenon in the Neva Estuary. They occur more frequently from the middle of

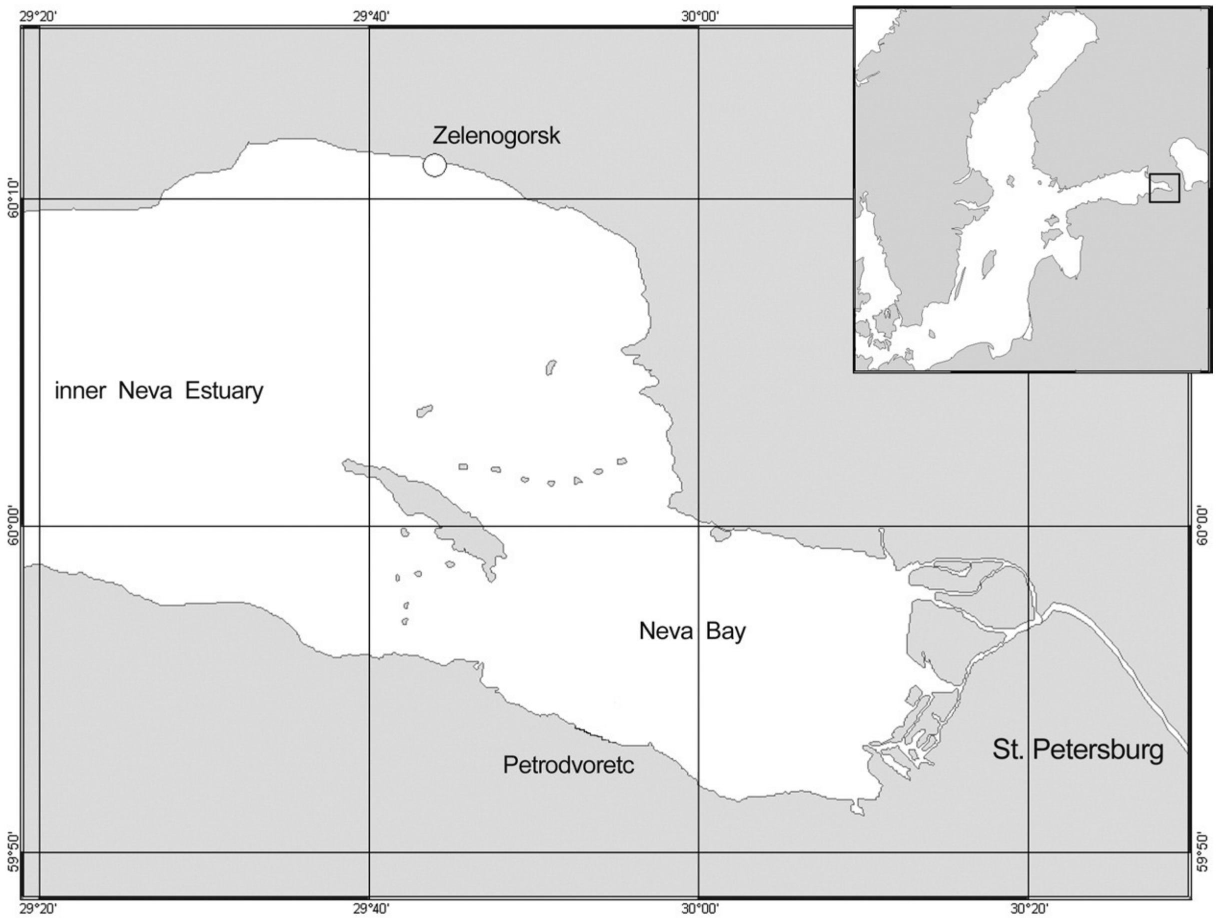

Fig. 1. Map of the eastern Gulf of Finland with indication of the study site (filled circle).