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Original Research Article

Long-term decrease of the vendace population in Lake Pluszne (Poland)—result of global warming, eutrophication or both?

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ABSTRACT

Numbers of vendace (*Coregonus albula* L.) in Lake Pluszne were monitored twice a year from 1999 until 2013 by hydroacoustic methods and pelagic trawls. Since 2002, the numerical density of vendace has decreased continuously. Young-of-year fish were caught in large numbers only in 2001, when a strong year class was recruited, and very few in subsequent years, indicating that natural reproduction after 2001 was hampered. Observed changes in the vendace population were related to temperature and oxygen conditions and we suggest that mainly worsening hydrological conditions, associated with increased eutrophication, have been responsible for scarcity of coregonids.

1. Introduction

Climate change is affecting many European waters (Dokulil and Herzig, 2009; Pomati et al., 2012; Salmaso and Cerasino, 2012; Wojtal-Frankiewicz, 2012) and threatens to alter many of the trophic interactions that occur in food webs. Knowledge of climatic impacts is thus essential for the future conservation and management of aquatic ecosystems. The general effects of climate change on freshwater systems will likely include increased water temperatures, decreased dissolved oxygen levels, and increased pollutant-related adverse effects (Ficke et al., 2007). All these will change fish habitat availability and quality and add novel biotic pressures to aquatic communities. Due to species-specific temperature and oxygen requirements, climate change may restrict open water habitat availability for many species, particularly salmonids and coregonids. Increased heating will deepen and stabilize the epilimnion, and increase microbial metabolism, which will result in decreased concentrations of dissolved oxygen in the hypolimnion. Loss of hypolimnion habitat has been observed in many temperate lakes including some in Poland that support coregonids (Doroszczyk et al., 2007).

Although the role of climate variability in the ecology of freshwater fishes is of increasing interest (George, 2010; Jeppesen et al., 2010, 2012; Comte et al., 2013), there are relatively few tools available for examining how freshwater fish populations respond to climate variations. The relationship between climate change and eutrophication is also complex, and separating their effects is difficult. Climate change alone, or when coupled with the input of anthropogenic pollutants, can increase the symptoms of eutrophication (Adrian et al., 2009). Eutrophication in temperate lakes generally replaces economically important species such as coregonids, with smaller, less desirable species such as some cyprinids. This has been noted in Lake Pluszne, Poland, from hydroacoustic and fish-catch monitoring, conducted continuously since 1999 and is related here to changes in variables associated with both eutrophication and climate.

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2. Materials and methods

Lake Pluszne is a deep (maximum depth, 51 m) mesotrophic lake located in northeastern Poland (53°58′30″ North, 20°42′06″ East). It is a typical vendace lake, although other species are also present, including roach *Rutilus rutilus*, perch *Perca fluviatilis*, smelt *Osmerus eperlanus*, bleak *Alburnus alburnus*, stickleback *Gasterosteus aculeatus*, pike *Esox lucius*, and pikeperch *Sander lucioperca*.

Hydroacoustic measurements were made from a 5-m long boat, cruising at a constant speed (8 km h^{-1}) along predetermined zigzag transects (Fig. 1). Sampling occurred each year from 1999 to 2013, usually twice a year, during June and October. In some years, sampling also took place in other months. Data were collected at night, starting one hour after sunset, to ensure that fish were dispersed. A split-beam echo-sounder Simrad EY500, 120 kHz was used throughout the study with a transducer mounted 0.5 below the surface and aiming vertically down. The pulse duration was set to medium (0.3 ms), and the ping interval to "as fast as possible". Before each survey the echo-sounder was calibrated with a copper sphere of a target strength equal to −40.4 dB. The abundance estimates were carried out using the echo integration method and *in situ* estimates of mean target strength (TS) in decibels (dB) over each 100 m of boat travel. The TS threshold was set to −56 dB, which equates to a fish length of c. 30 mm (Love, 1971).

Simultaneously with hydroacoustic measurements, a pelagic trawl was deployed at depths of maximum fish concentrations to sample fish species composition and size-structure. The trawl mouth was 15 m^2 (3 m × 5 m), and the trawl was fished at a speed of 80 m min^{-1}. All fish caught, or a random sample of at least 200 individual fish from each catch, were measured (total length, ±0.1 cm) and

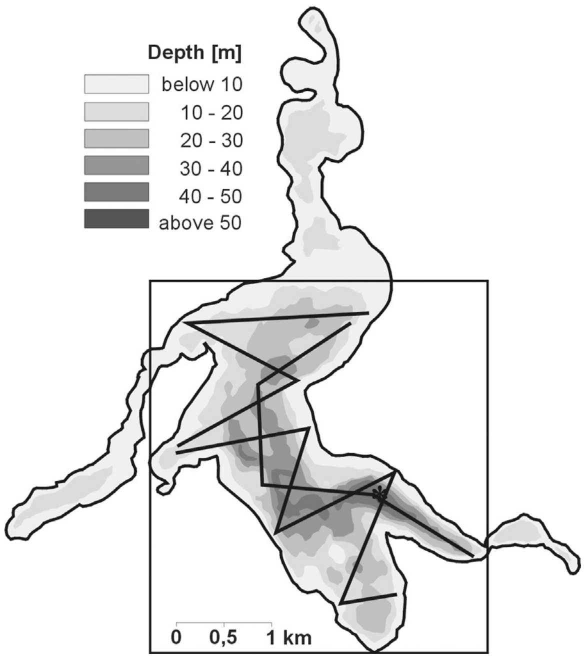

Fig. 1. Lake Pluszne bathymetry, hydroacoustic transects and sampling point for temperature and oxygen profiles.

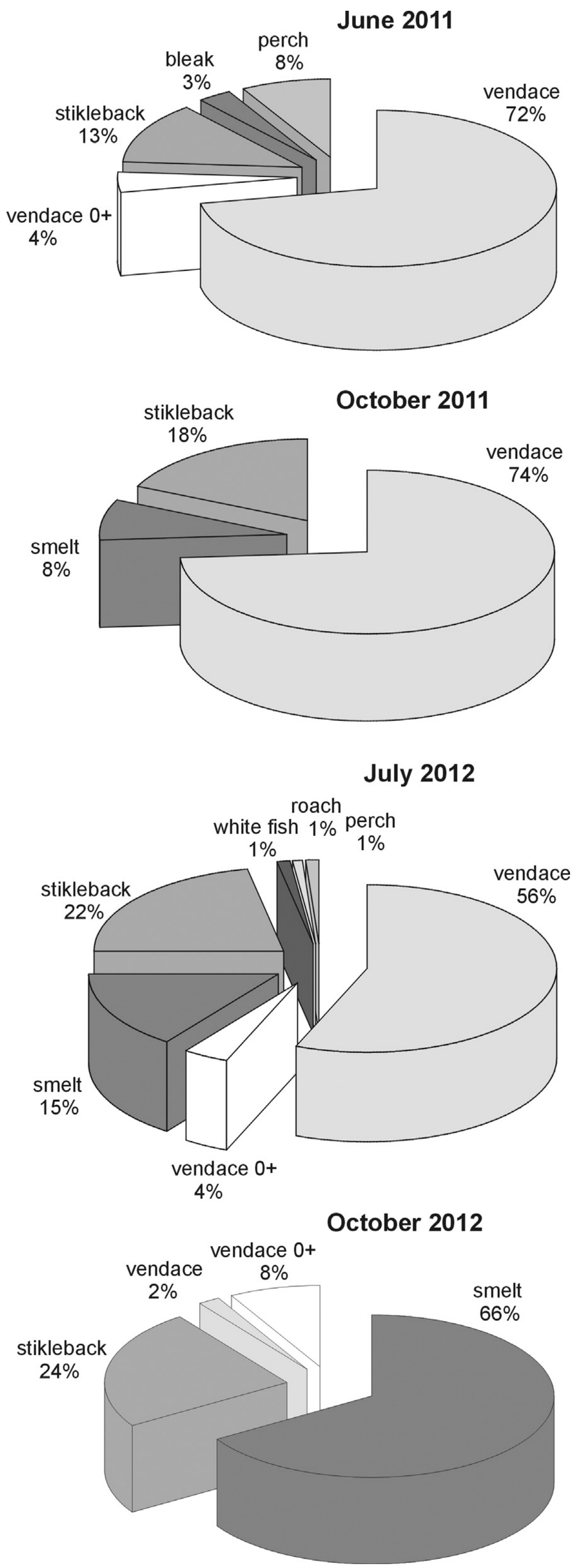

Fig. 2. Fish population structure in the hypolimnion of the Lake Pluszne in June/July and October 2011 and 2012.