

# Mesozooplankton abundance in relation to the chlorophyll maximum in the Neuse River Estuary, North Carolina, USA: Implications for trophic dynamics



David G. Kimmel<sup>a, b, \*</sup>, Benjamin D. McGlaughon<sup>a</sup>, Jeremy Leonard<sup>c</sup>, Hans W. Paerl<sup>c</sup>, J. Christopher Taylor<sup>c, d</sup>, Emily K. Cira<sup>e</sup>, Michael S. Wetz<sup>e</sup>

<sup>a</sup> Department of Biology, East Carolina University, Greenville, NC 27858, USA

<sup>b</sup> Institute for Coastal Science and Policy, East Carolina University, Greenville, NC 27858, USA

<sup>c</sup> Institute of Marine Sciences, University of North Carolina–Chapel Hill, 3431 Arendell Street, Morehead City, NC 28557, USA

<sup>d</sup> National Oceanic and Atmospheric Administration, National Ocean Service, National Centers for Coastal Ocean Science, Beaufort, NC 28516, USA

<sup>e</sup> Department of Life Sciences, Texas A&M University–Corpus Christi, 6300 Ocean Drive, Corpus Christi, TX 78412, USA

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## ABSTRACT

Estuaries often have distinct zones of high chlorophyll *a* concentrations, known as chlorophyll maximum (C<sub>MAX</sub>). The persistence of these features is often attributed to physical (mixing and light availability) and chemical (nutrient availability) features, but the role of mesozooplankton grazing is rarely explored. We measured the spatial and temporal variability of the C<sub>MAX</sub> and mesozooplankton community in the eutrophic Neuse River Estuary, North Carolina. We also conducted grazing experiments to determine the relative impact of mesozooplankton grazing on the C<sub>MAX</sub> during the phytoplankton growing season (spring through late summer). The C<sub>MAX</sub> was consistently located upriver of the zone of maximum zooplankton abundance, with an average spatial separation of 18 km. Grazing experiments in the C<sub>MAX</sub> region revealed negligible effect of mesozooplankton on chlorophyll *a* during March, and no effect during June or August. These results suggest that the spatial separation of the peak in chlorophyll *a* concentration and mesozooplankton abundance results in minimal impact of mesozooplankton grazing, contributing to persistence of the C<sub>MAX</sub> for prolonged time periods. In the Neuse River Estuary, the low mesozooplankton abundance in the C<sub>MAX</sub> region is attributed to lack of a low salinity tolerant species, predation by the ctenophore *Mnemiopsis leidyi*, and/or physiologic impacts on mesozooplankton growth rates due to temperature (in the case of low wintertime abundances). The consequences of this lack of overlap result in exacerbation of the effects of eutrophication; namely a lack of trophic transfer to mesozooplankton in this region and the sinking of phytodetritus to the benthos that fuels hypoxia.

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## 1. Introduction

Phytoplankton are the dominant primary producers in most estuarine waters and play a central role in carbon, nutrient, and oxygen cycling in these systems (Paerl et al., 1998). The fast growth rates of phytoplankton (i.e., doubling times of a day or less) allow a rapid response to physical–chemical forcing; e.g., vertical mixing, changes in flushing and residence times, nutrient inputs and altered optical properties (Paerl et al., 2010). As different estuarine

systems show considerable variability in physical forcing and residence times, phytoplankton should therefore show a wide pattern of distribution and abundance across systems. This is indeed the case, as shown by Cloern and Jassby (2008, 2010), who have demonstrated that no two estuarine systems are the same with respect to phytoplankton distribution, abundance, and seasonality. Despite this wide range of variability, many temperate estuaries contain distinct zones where phytoplankton biomass accumulates, resulting in a persistent feature termed the chlorophyll maximum (C<sub>MAX</sub>) (Cloern, 2001).

C<sub>MAX</sub> is a common feature of estuaries (Pennock, 1985; Fisher et al., 1988; Kocum et al., 2002; Li et al., 2009; Buckaveckas et al., 2011) including North Carolina's Neuse River Estuary (Pinckney

\* Corresponding author. Department of Biology, East Carolina University, Greenville, NC 27858, USA.

E-mail address: [kimmeld@ecu.edu](mailto:kimmeld@ecu.edu) (D.G. Kimmel).

et al., 1998, 1999; Valdes-Weaver et al., 2006). In the Neuse River Estuary (NRE), as much as 60% of the estuary's phytoplankton biomass is found in the CMAX zone (Paerl et al., 1998). The NRE is part of North America's largest lagoonal estuarine ecosystem (Albemarle-Pamlico Estuarine System), an important system for juvenile fish habitat and a variety of commercially fished species (Paerl et al., 2003). The NRE drains some of North Carolina's most rapidly expanding agricultural and urban regions, and has experienced significant eutrophication as a result of anthropogenic nutrient loading, which is further exacerbated by climate-induced changes in freshwater inflow (Paerl et al., 2006). Symptoms of this eutrophication include prolonged, widespread hypoxia/anoxia (Paerl et al., 1998), harmful algal bloom outbreaks (Paerl et al., 2006, 2010; Hall et al., 2013) and fish kills (Burkholder et al., 1999; Paerl et al., 1999). Nutrient sources driving eutrophication of the NRE are well characterized, with non-point source nutrient pollution contributing over 75% of external nitrogen and phosphorous inputs (NCDENR, 2001).

The mechanisms behind the development and persistence of the CMAX, as well as its fate, have not been well characterized in the NRE or other estuarine systems. Much emphasis has been placed on “bottom-up” factors such as nutrient availability and flushing/residence time. Indeed, several studies have demonstrated that the position, magnitude, and composition of the CMAX appear to be highly sensitive to nutrient and hydrologic disturbances in the NRE (Pinckney et al., 1999; Valdes-Weaver et al., 2006). In contrast, the role of “top down” factors, specifically grazing pressure by microzooplankton and mesozooplankton, has not been studied extensively. This is despite recent studies that indicate a potentially important role for zooplankton grazers in controlling phytoplankton growth under nutrient-enriched conditions (Buskey, 2008; Stoecker et al., 2008). In the lower, oligotrophic NRE, Mallin and Paerl (1994) found high mesozooplankton grazing rates on larger phytoplankton size classes. In the upper, more eutrophic NRE, Wetz et al. (2011) found high microzooplankton grazing rates during the summer that in many cases balanced phytoplankton growth rates. This is consistent with studies showing that microzooplankton (ciliates and heterotrophic dinoflagellates) are capable of attaining high growth rates, approaching those of many phytoplankton taxa and can thus respond rapidly to accumulations of phytoplankton prey (Strom and Morello, 1998). Nonetheless, the very presence of a CMAX in the NRE and other estuaries raises important questions about the role of protistan and zooplankton grazers in CMAX ecological dynamics.

The degree of grazing control also has important implications for the fate of CMAX carbon production. For example, lack of grazing would presumably lead to deposition of phytodetritus that fuels subpycnocline hypoxia (Baird et al., 2004; Dagg et al., 2008). In contrast, intense microzooplankton grazing is expected to lead to recycling of CMAX carbon through the microbial food web (Buskey, 2008; York et al., 2011). Mesozooplankton grazing may lead to enhanced upward trophic transfer or alternatively may lead to enhanced sinking flux of the CMAX carbon via fecal pellets (Turner, 2002), which may then contribute to the extensive subpycnocline hypoxia that is prevalent in the NRE and other similar estuaries (Diaz and Rosenberg, 2008).

The purpose of this study was to examine the potential for trophic interactions between the CMAX phytoplankton and the mesozooplankton community in the NRE. We fully recognize the important role that microzooplankton grazers have in this system (Wetz et al., 2011) and in estuaries in general (Rollwagen-Bollens et al., 2011; York et al., 2011); however, the focus of this study was to determine the relationship between the CMAX and the mesozooplankton community. We hypothesized that mesozooplankton grazing pressure on the CMAX would be limited given

the consistent annual development and persistence of the CMAX. In order to test this hypothesis, we estimate the position of the CMAX and the zooplankton community over several years and seasons to determine the relative distribution, community composition, and abundance of both planktonic communities. We also conducted a series of experiments to quantify mesozooplankton grazing on CMAX phytoplankton.

## 2. Material and methods

### 2.1. Field sampling

#### 2.1.1. Sample collection

Samples were collected at 10 fixed stations along the Neuse River Estuary salinity gradient (Fig. 1). On some dates, poor weather prevented sample collection from the full suite of stations. Samples were collected on a biweekly to monthly basis, also weather dependent. Relevant environmental data from this program include physical–chemical (salinity, temperature, dissolved oxygen, inorganic nutrients) and biological parameters (chlorophyll *a* and biomarker photopigments, zooplankton abundance).

#### 2.1.2. Chemical and biological measurements

Vertical profiles of temperature, salinity, and dissolved oxygen (DO) were collected at 0.5 m intervals throughout the water column using a YSI 6600 sonde. Water for nutrient and phytoplankton photopigment concentrations was collected via a Van Dorn sampling device from 0.5 m below the surface and 0.5 m above the bottom. Nutrients were analyzed according to standard wet chemical procedures (APHA et al., 2012). Chlorophyll *a* (Chl *a*) was determined using the modified *in vitro* fluorescence technique, Environmental Protection Agency method 445.0, without acidification (Wetz et al., 2011). Photopigments were separated and quantified, using high performance liquid chromatography (Paerl et al., 2003). Major phytoplankton taxa and their associated diagnostic pigments were: chlorophytes or green algae (chlorophyll *b*), cyanobacteria (zeaxanthin), diatoms or raphidophytes (fucoxanthin), dinoflagellates (peridinin) and cryptophytes (alloxanthin) (Jeffrey et al., 1997).

Zooplankton were sampled from each station by pumping 55–60 L of water from 0.5 m below the surface or 0.5 m above bottom through a zooplankton net with 65  $\mu\text{m}$  mesh size. The pump used had a diameter of 2.5 cm and a flow rate of 30  $\text{L m}^{-1}$ . We also conducted 1 m tows with a 60  $\mu\text{m}$  mesh size and 0.5 m diameter net to estimate the efficacy of the pump in representing

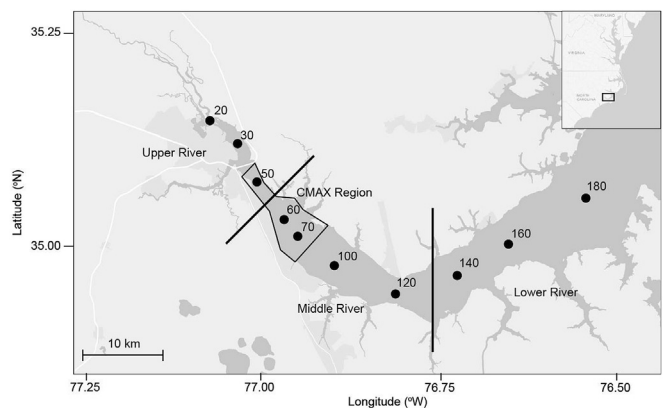


Fig. 1. Map of the Neuse River estuary and sampling stations. The Neuse River was divided into three regions, Upper, Middle, and Lower River. The Chlorophyll Maximum (CMAX) region is indicated.

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