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Lake Champlain offshore benthic invertebrate community before and after zebra mussel invasion

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ABSTRACT

Benthic invertebrates are important bio-indicators of water quality and play a significant role in aquatic systems. Lake Champlain has limited benthic invertebrate data which hinders development of food web models, assessment of invasive species impacts, and evaluation of management actions. In June 2016, we assessed benthic invertebrates along three transects in the main basin of Lake Champlain ranging from 5 to 100 m, and then compared results to densities from a limited survey in 1991 prior to the zebra mussel (*Dreissena polymorpha*) invasion. In 2016, total biomass and density were 1–2 orders of magnitude greater at 5 m than at 20–100 m. Zebra mussels, chironomids, oligochaetes, and gastropods were dominant at 5 m, and oligochaetes and sphaeriids were dominant at 20–100 m. Total density at the 5-m site was 94% lower in 2016 compared to 1991, but similar at the 100-m site. *Diporeia*, while abundant in many freshwater bodies, is historically rare in Lake Champlain and was not detected in our sampling. Because Lake Champlain benthic invertebrate densities are low and display dissimilar distributions to the Great Lakes, we hypothesize the offshore fish community is likely much more reliant on pelagic rather than benthic production. Although the current composition and biomass suggest the benthic community in Lake Champlain may not be greatly impacted by an invasion of quagga mussel (*D. rostriformis bugensis*), the potential for quaggas to re-route energy from pelagic to benthic habitats, as it has in the Great Lakes, could limit the Lake Champlain offshore fish community.

Introduction

Benthic invertebrates play a significant role in aquatic systems, including ecological services such as sediment mixing, breakdown of organic material, nutrient cycling, and enhancement of plant and microbial growth (Covich et al., 1999). Benthic invertebrates also enhance energy flow to higher trophic levels (Vander Zanden and Vadeboncoeur, 2002). Because of their role within aquatic environments, benthic invertebrates can be used as bio-indicators of ecosystem health. Greater diversity of benthic species in streams and lakes indicates exceptional water quality conditions; whereas, lower diversity indicates poor water quality conditions, such as low dissolved oxygen and high pollutant concentrations (Azrina et al., 2006). For example, the decreased abundance of burrowing mayfly nymphs (*Hexagenia* spp.) in the central basin of Lake Erie from 2001 to 2004 was correlated with anoxic environments (Krieger et al. 2007). Because of the importance of benthic invertebrates to ecological processes, the absence of a particular benthic species or functional group may impact the entire ecosystem (Cairns Jr. and Pratt, 1993). Monitoring benthic community composition can thus aid our understanding of system response to environmental changes such as invasive species.

Invasive species have fundamentally transformed the structure and function of the Laurentian Great Lakes. For example, the invasion of zebra (*Dreissena polymorpha*) and quagga (*D. rostriformis bugensis*) mussels have coincided with changes in benthic community assemblages, presumably through direct negative interactions (e.g. reduced nutrient availability through filtering and inhibited native mussel species' ability to feed and respire; Hebert et al., 1991; Vanderploeg et al., 2010). Quagga mussels can survive at greater depths than zebra mussels (Mills et al., 1999) and are common near the deepest regions of the lower Great Lakes (Birkett et al., 2015; Madenjian et al., 2015). The establishment of quagga mussels coincided with declines in *Diporeia* spp., a native deep-water benthic amphipod which is a primary prey of many fishes (Hondorp et al., 2005; McNickle et al., 2006; Thompson et al., 2016). Densities of dominant native benthic invertebrates in southern Lake Michigan declined at depths <50 m between 1980 and 1993 concomitant with increases in zebra mussels (Nalepa et al., 1998). A slight decline occurred in overall major taxa in the main basin of Lake Huron from 1972 to 2000, with a significant decline in *Diporeia* and Chironomidae at depths <30 m (Nalepa et al., 2008). Peak mean densities in both lakes Michigan and Huron occurred at

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intermediate depths (31–50 m). In Lake Ontario, long-term declines in *Diporeia* and sphaeriids were observed from 1994 to 2008, and by 2008, quagga mussels had completely replaced zebra mussels at all sampled depths (Birkett et al., 2015). Maximum benthic biomass densities in 1994 and 2008 were found at intermediate depths (30–90 m) in Lake Ontario, with quagga mussels, chironomids, and oligochaetes as the dominant taxa in 2008 (Birkett et al., 2015). Collectively, these observations suggest maximum densities of native benthic invertebrates (*Diporeia*, Oligochaeta, Chironomidae, and Sphaeriidae) tend to occur at intermediate depths (30–50 m), and a decline in native benthic invertebrates after dreissenid invasion (Nalepa et al., 1998, 2008; Birkett et al., 2015).

Lake Champlain, although much smaller in surface area (1127 km^2) than the Great Lakes, has many similar characteristics (e.g., fish and zooplankton communities; Marsden and Langdon, 2012; Mihuc et al., 2012). Limited research has been conducted on the benthic invertebrate community in Lake Champlain although reports on profundal oligochaetes, *Diporeia*, and dipteran fauna of embayments exist from the 1960s to the 1970s (Pagel, 1969; Wade, 1976; Myer and Gruendling, 1979; Dermott et al., 2006). To our knowledge, the only available historic community data for depths >20 m are limited to a sampling event in 1991 at ~100-m depth (Brown et al., 1992) and profundal community sampling in 1966 and 1974 (Myer and Gruendling, 1979). Nearshore areas of Lake Champlain tend to differ from each other due to variation in substrate, water quality, and abundance of aquatic plants (Myer and Gruendling, 1979). However, bivalves, dipterans, gastropods, and oligochaetes consistently were the dominant groups among sampled areas, but densities were relatively low compared to other large lakes (Myer and Gruendling, 1979).

We conducted a benthic invertebrate survey in Lake Champlain in 2016 with two objectives. First, we compared contemporary and 1991 data to assess possible changes before and after zebra mussels first appeared in Lake Champlain in 1993 (Beekey et al., 2004). We expected biomass and density of native benthic invertebrates to be lower in 2016 versus 1991, consistent with patterns observed in the Great Lakes after dreissenid invasions. Our second objective was to create baseline knowledge of the community composition, biomass, and distribution in anticipation of an eventual invasion of Lake Champlain by quagga mussels.

Methods

Sampling

Benthic invertebrates were sampled during the day along three east-west transects in the main lake basin of Lake Champlain (Fig. 1). Each transect was sampled on a different date in June 2016 (Table 1). Samples were collected in triplicate at each of five depths (20, 40, 60, 80, and 100 m) per transect with a Ponar grab sampler (area = 0.054 m^2). An additional site was sampled in triplicate at a 5-m depth site on transect T1 on 15 June 2016 (Fig. 1; Table 1). A total of 48 samples were collected, 45 from the five 20–100-m depths, and 3 from the 5-m depth.

Invertebrate processing

Each sample was rinsed through a 500-µm mesh sieve. The retained contents were preserved in 70% ethanol. In the laboratory, samples

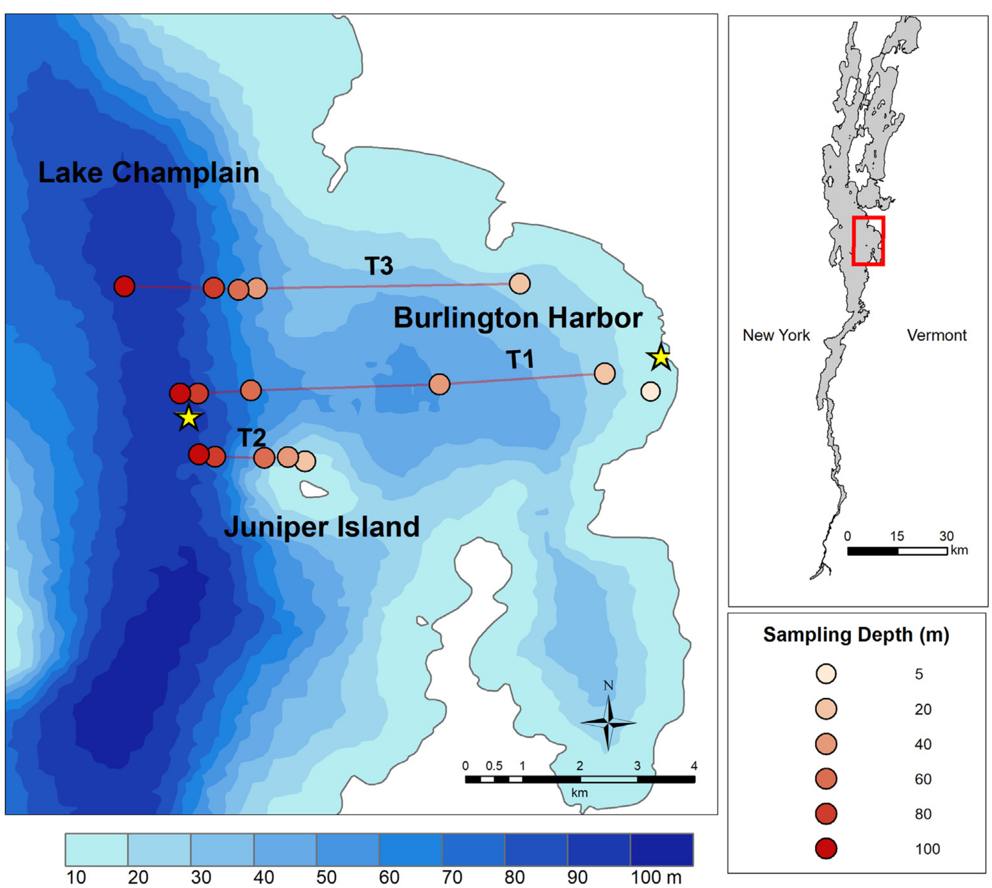

Fig. 1. Bathymetric map and transect locations in the main lake basin of Lake Champlain. The three transects were sampled in 2016 using a Ponar grab sampler, each comprising five sampling depths (20, 40, 60, 80, and 100 m), with an additional 5-m sampling depth near transect T1. Juniper Island is at the southeast end of T2. The two stars indicate the sampling points from the 1991 survey (Brown et al., 1992).

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