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First direct confirmation of grass carp spawning in a Great Lakes tributary

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ABSTRACT

Grass carp (*Ctenopharyngodon idella*), an invasive species of Asian carp, has been stocked for many decades in the United States for vegetation control. Adult individuals have been found in all of the Great Lakes except Lake Superior, but no self-sustaining populations have yet been identified in Great Lakes tributaries. In 2012, a commercial fisherman caught four juvenile diploid grass carp in the Sandusky River, a major tributary to Lake Erie. Otolith microchemistry and the capture location of these fish permitted the conclusion that they were most likely produced in the Sandusky River. Due to this finding, we sampled ichthyoplankton using paired bongo net tows and larval light traps during June–August of 2014 and 2015 to determine if grass carp are spawning in the Sandusky River. From the samples collected in 2015, we identified and staged eight eggs that were morphologically consistent with grass carp. Five eggs were confirmed as grass carp using quantitative Polymerase Chain Reaction for a grass carp-specific marker, while the remaining three were retained for future analysis. Our finding confirms that grass carp are naturally spawning in this Great Lakes tributary. All eggs were collected during high-flow events, either on the day of peak flow or 1–2 days following peak flow, supporting an earlier suggestion that high flow conditions favor grass carp spawning. The next principal goal is to identify the spawning and hatch location(s) for the Sandusky River. Predicting locations and conditions where grass carp spawning is most probable may aid targeted management efforts.

Introduction

Multiple species of invasive Asian carp have been monitored for potential range expansion into Great Lakes watersheds for years and are considered threats to ecological function of the lakes (Mills et al., 1993). Grass carp (*Ctenopharyngodon idella*) differ from other potential invaders because after their import to the United States in 1963, triploid individuals have been widely stocked for vegetation control since 1983 (Rasmussen, 2011). These triploid fish are intended to be functionally sterile and therefore incapable of founding naturally reproducing populations (Zajicek et al., 2011). Stocking of triploid individuals has been legally approved in multiple states, including Ohio (Chapman et al., 2013). Nevertheless, errors in the production of triploid individuals, illegal stockings of diploids, and the live fish trade have resulted in the potential for naturally reproducing grass carp populations to establish in unplanned locations (Wittmann et al., 2014). Adult grass carp individuals have been found in all of the Great Lakes except Lake Superior, but no self-sustaining populations have yet been verified in Great Lakes tributaries (Kocovsky et al., 2012).

In 2012, a commercial fisherman caught four juvenile diploid grass carp in the Sandusky River, a major tributary to Lake Erie (Chapman et al., 2013). Otolith microchemistry indicated that these fish were most likely produced in the Sandusky River due to the elevated strontium:calcium ratio distinctive of the Sandusky River (Chapman et al., 2013). Based on the age of these fish, it was established that all individuals were most likely spawned during a high-flow event occurring July 23–29, 2011 (Chapman et al., 2013). Multiple studies have found that the Sandusky River would be a suitable spawning and recruitment habitat for grass carp based on hydraulic characteristics (channel velocity, shear velocity, and temperature) and undammed river length (Garcia et al., 2015; Kocovsky et al., 2012; Murphy and Jackson, 2013). Therefore, we focused sampling efforts on the Sandusky River to determine if there was evidence of naturally spawning populations.

Grass carp are thought to require large, turbid rivers for reproduction (Stanley et al., 1978). In China, the native range for grass carp, spawning is correlated with high-flow events (Duan et al., 2009; Tan et al., 2010). This correlation has been found to exist in the non-native

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range in the United States, with mass spawning events occurring primarily on the rising portion of significant peaks in the hydrograph (Chapman et al., 2013). Spawning during high-flow events may be adaptive due to increased turbulence. Grass carp spawn near the surface and hatching success is greatest when their semi-pelagic eggs remain in suspension in the water column before hatching (George et al., 2015). Additionally, laboratory and field measurements have shown that Asian carp spawning success declines at temperatures below 18 °C, thus this temperature is considered to be the minimum thermal threshold for spawning (Kolar et al., 2005). Following egg hatching, larvae swim vertically while drifting downstream until gas bladder inflation (George and Chapman, 2015). They then actively swim from the fast-flowing channel into still backwater areas where they mature (George and Chapman, 2015). The Sandusky River is turbid, experiences high-flow events, and exceeds the thermal minimum for spawning and development, and is therefore suitable for grass carp reproduction.

Due to their voracious appetite and large adult size, grass carp have the ability to alter vegetation structure, thus affecting native communities of fishes and invertebrates, as well as water quality (Mandrak and Cudmore, 2010). Possible specific detrimental effects resulting from the removal of submerged macrophytes include the reduction of critical spawning and recruitment areas for native fishes, decreased mitigation of nonpoint source pollution, and increased turbidity and shoreline erosion (Chapman et al., 2013; Wilson et al., 2014). The Great Lakes have fisheries valued at more than $7 billion annually and provide drinking water for 40 million people, and these ecosystem services could be damaged by grass carp (Cuddington et al., 2013; Wilson et al., 2014). Therefore, early detection and a rapid management response are necessary to prevent detrimental effects of grass carp to the Great Lakes basin.

As a principal step in determining the threat of grass carp in the Great Lakes, it is necessary to verify that naturally reproducing populations exist. Here we report on the sampling efforts we undertook in the Sandusky River during the summers of 2014 and 2015 for the presence of grass carp spawning. We targeted high-flow events in the main channel to detect eggs and slow-water areas for larvae. In addition to the first documented evidence of spawning, we aimed to provide information that can aid targeted management efforts.

Methods

The Sandusky River is the third largest tributary to the western basin of Lake Erie, flowing for approximately 215 km into the lake at Sandusky Bay (Fig. 1). There are six dams on the Sandusky River, the downstream-most at Ballville, approximately 25 km from the mouth at Muddy Creek Bay. Ballville Dam is impassable; hence the primary study area is the length from Ballville Dam to Muddy Creek Bay. Some areas of this portion nearest Fremont, Ohio are ~1 m deep, with the majority of the river ~5–6 m deep during low-flow conditions. For this portion of the Sandusky River, width varies between ~32 and 160 m, but at our sampling locations ranged between ~80 and 120 m wide.

To determine if grass carp eggs were present in the stretch of the Sandusky River below Ballville Dam, we sampled ichthyoplankton during June–August of 2014 (pilot study) and 2015 (full sampling implemented). We hypothesized that spawning might occur approximately 1 km downstream of the Ballville Dam, in Fremont, Ohio due to the characteristic turbulent water and shallow depths of this reach (Kocovsky et al., 2012). Asian carp eggs are semi-buoyant and it is thought that they need to remain suspended in order to hatch (Stanley et al., 1978). In the Sandusky River, Asian carp eggs have an increased probability of settling beyond ~15–16 km of the spawning site (Garcia et al., 2013). Therefore, the area we sampled included sites extending a total of ~10 km downstream of Fremont, Ohio to 11 km upstream of Muddy Creek Bay (Fig. 1).

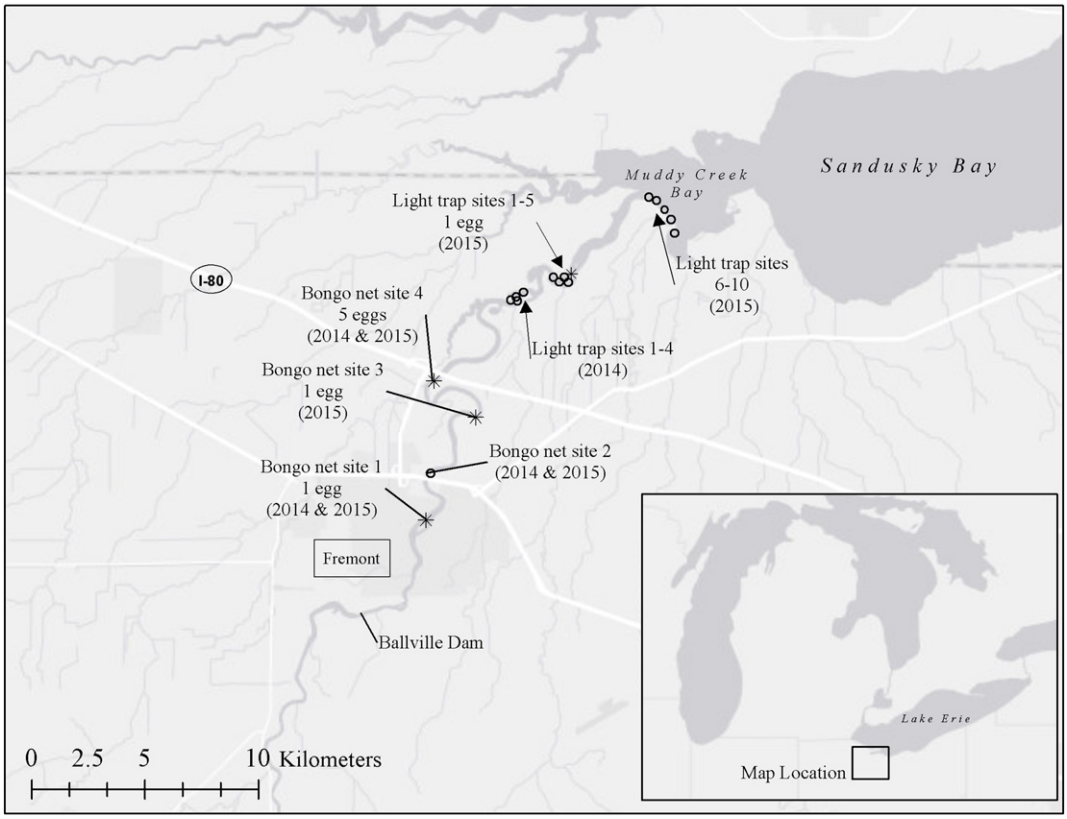

Fig. 1. Sampling locations in the Sandusky River in 2014 and 2015. Sites where eggs were collected are designated with *, while sites where no eggs were collected are marked with °.