State of Michigan's

Status and Strategy for Round Goby Management

Scope

The invasion of round goby (*Neogobius melanostomus*), native to the Black Sea, threatens the waters of the State of Michigan. The goals of this document are to summarize the:

- Current level of understanding on the biology and ecology of the round goby.
- Management options for round goby in Michigan.
- Future possible directions for round goby management in Michigan.

Biology and Ecology

I. Identification

Round gobies are small, soft-bodied fish. Their fused pelvic fin forms a suction disk on their ventral surface and distinguishes them from native sculpins. Adults have brownish gray bodies with dark brown/black blotches. During spawning and nest guarding, males have black bodies with yellowish spots and median fins with a yellow/white outer edge. Generally, a large, oblong, black spot is present at the end of the first white/greenish dorsal fin, beginning at the fifth ray; sculpins usually have a mark in the same area. This black spot on juveniles has a light border. The round goby's head that makes up approximately 22 to 23% of its body length is as wide or wider than it is deep (Charlesbois et al. 1997). In the United States, round gobies reach up to 17.8 cm in length (Jude 1993).

II. Life History

In the spring, when water temperatures range from 9 to 26°C, males migrate from deeper water before the females to establish spawning areas in shallow water (Moiseyeva and Rudenko 1976, MacInnis and Corkum 2000, Murphy et al. 2001, Kornis et al. 2012). Nests are dug out by the male under hard substrates and fanned up to 10 days before eggs are deposited (Meunier et al. 2009). Females spawn repeatedly (every 3-4 weeks) from April to September, eventually returning to deeper waters, while males aggressively defend the nesting sites (Kovtun 1980, Charlebois et al. 1997, Kornis et al. 2012). Nests can contain up to 10,000 eggs from four to six females (Charlebois et al. 1997). When courting females, male round gobies use coloration, posturing, and acoustical displays (Protosov et al. 1965, Moiseyeva and Rudenko 1976). Mating also involves pheromone signaling – gravid females respond to a sex attractant released by the males (Belanger et al. 2004, Corkum 2004); however, these cues may not be as influential as visual cues (Yavno and Corkum 2010, Kornis et al. 2012). Smaller, mature males that generate more sperm relative to body size may use a sneaker spawning strategy; this tactic is more commonly utilized at higher levels of colonization when competition for nests is at its peak (Marentette et al. 2009). Female and male round goby mature at 2-3 and 3-4 years of age, respectively, but may mature sooner in North America (Miller 1986, MacInnis and Corkum 2000a). However, newly established round goby in brackish or lake waters as opposed to marine round goby tend to be smaller, mature earlier, and have a shorter life span; these brackish or lake water populations also have a male biased sex ratio (Corkum et al. 2004).

III. Diet

Round goby larvae are nocturnally pelagic and feed on zooplankton found zero to nine meters below the water surface (Hensler and Jude 2007, Hayden and Miner 2009). Adult round goby are benthic feeders with diets mainly consisting of crustaceans and mollusks, but also including polychaetes, small fish, fish eggs (even their own), and chironomid larvae (Miller 1986, Charlesbois et al. 1997). With a complete lateral line system, round goby are able to feed in complete darkness but do feed at all times of the day (Kornis et al. 2012). In lakes, the round goby diet primarily consists of mollusks. However, the species can adapt to whatever the abundant food source may be, which, in many cases in Michigan, could be zebra mussels (Kornis et al. 2012). Round goby swallow zebra mussels whole, crushing the shells with its pharyngeal teeth (Ghedotti et al. 1995).

IV. Habitat

Round goby are found in a wide range of habitats ranging from fresh to marine waters, demonstrating their wide salinity tolerance. Still, there are no known ocean populations, and natural populations inhabiting high salinity waters (i.e., the Caspian and Aral Seas) are exposed to $CaSO_4$ rather than NaCl. Ballast regulations in which tanks are exposed to ocean water for days are likely to help prevent new introductions, given demonstrated sensitivity to NaCl (Ellis and MacIssac 2009). Round goby can also tolerate a wide range of temperatures (-1°C to 30°C), but prefer warm water (26°C) (Moskal'kova 1996, Lee and Johnson 2005). They are benthic dwellers in littoral zones and prefer rocky substrates or macrophytes that provide shelter. Round goby also utilize fine gravel, shell, or sandy substrates in which they burrow (Jude et al. 1992, Jude et al. 1995, Ray and Corkum 2001, Young et al. 2010). Muddy substrates characteristic of marsh habitats can also support a low density of round goby (Johnson et al. 2005b, Taraborelli et al. 2009, Kornis et al. 2012). While round goby can tolerate dissolved oxygen levels ranging from 0.4 to 1.3 mg/l, wave action in the littoral areas produce the preferred high dissolved oxygen level habitat (Charlebois et al. 1997). Aquatic vegetation likely influences round goby abundance. During spawning season in the summer, round goby prefer shallow waters up to 3 meters while avoiding the surf zone (Kornis et al. 2012). During the winter, they migrate to deep offshore waters (Walsh et al. 2007). Round goby are generally sedentary with home ranges estimated at 5 ± 1.2 m^2; however, it is still possible for individual fish to move long distances (Wolfe and Marsden 1998, Ray and Corkum 2001, Bjorklund and Almqvist 2010). Density-dependent factors contribute to spread in stream habitats but commercial shipping greatly influences in-lake dispersal (Kornis et al. 2012).

V. Effects from Round Goby

Given its distribution and abundance, the round goby has become heavily entwined in the Great Lakes food web resulting in both positive and negative effects on native and non-native species. Where abundant, round goby have led to a decline in native fish species as a result of its predation on small fish and fish eggs and competition (Crossman et al. 1992, Chotkowski and Marsden 1999, Nichols et al. 2003, Schaffer et al. 2005, Walsh et al. 2007, Fitzimons et al. 2009b). In some cases, round goby predation on the eggs of sport fish has resulted in the halt of fisheries and the placement of catch restrictions in order to counteract reduced recruitment (National Invasive Species Council 2004, Kornis et al. 2012). Round goby are known to prey on the fry and eggs of sculpins, darters, and logperch (*Percina caprodes*) and compete with rainbow darters (*Etheostoma caeruleum*), logperch and northern madtoms (*Noturus stigmosus*) for macroinvertebrates (Marsden and Jude 1995, French and Jude 2001, Kornis et al. 2012). The aggressive round goby not only preyed on the native mottled sculpin (*Cottus bairdii*), but the two species also compete for food, space, and spawning sites; small round gobies (less than 60 mm) and mottled sculpin share an arthropod diet and both species occupy the same rocky substrate in the daytime and feeding habits at night (Dubs and Corkum 1996, Janseen and Jude 2001). As the round goby begin to colonize deeper waters, they may pose a risk to deepwater sculpin species (Bergstrom and Mensinger 2009).

Large round goby readily consume zebra mussels, another invasive species in Michigan, creating a trophic linkage between the mussels and piscivores (Hogan et al. 2007, Ng et al. 2008). Established populations of zebra mussels have the potential to support flourishing populations of round goby (Vanderploeg et al. 2002). Additionally, zebra mussels may accumulate *Clostridium botulinum* type E (avian botulism) spores via filter feeding, and round goby may acquire the neurotoxin produced by this bacterium by feeding on zebra mussels. This renders round goby a potential vector of avian botulism; infected round goby are more easily preyed upon by piscivorous birds, increasing the likelihood of *C. botulinum* transmission (Corkum et al. 2004, Yule et al. 2006). On the other hand, the round goby does provide an abundant food resource for many species including fish, like burbot (*Lota lota*) and smallmouth bass (*Micropterus dolomieu*), and has been attributed as the reason why the Lake Erie water snake (*Nerodia sipedon insularum*) was removed from the federal Endangered Species List in 2011 (Truemper and Lauer 2005, King et al.

2006, Taraborelli et al. 2010). High predation levels have some potential to regulate round goby abundance. However, this predatory relationship may allow for round goby to facilitate the transfer of sediment-related toxins to higher trophic levels (Kwon et al. 2006, Hogan et al. 2007, Fernie et al. 2008, Ng and Gray 2009, Azim et al. 2011). As with the possible mechanism for *C. botulinum* transmission, this is due to the inclusion of zebra mussels in the round goby diet (Kornis et al., 2012).

Current status and distribution in Michigan

First documented in 1990 in North America within the St. Clair River, round goby most likely arrived in the Great Lakes via ballast water from transoceanic vessels (Jude et al. 1992). Given the foraging habits of the round goby, nocturnal ballasting activity could easily result in the capture and survival of the fish and, therefore, their successful transport to new waters (Hayden and Miner 2009). Once in North America, round goby have spread to all the Great Lakes through natural dispersal and commercial shipping (Kornis et al. 2012). Over the past 5 to 10 years, round goby abundance has declined in the Great Lakes; this suggests that populations may have reached equilibrium in abundance (Roseman and Riley 2009, Young et al. 2010, Kornis et al. 2012). The round goby has been a successful invader due to a high introduction effort, genetic variability, and multiple founding sources (Brown and Stepien 2009, Kornis et al. 2012). Dams may inhibit inland range expansion of the species from the Great Lakes, but accidental introductions by humans (related to the bait trade) have introduced round goby in many inland waters (Borwick and Brownson 2006, Kornis et al. 2012). According the Midwest Invasive Species Information Network (MISIN), Biodiversity Information Serving Our Nation (BISON), and the State of Michigan fishery databases, round gobies have been found in 38 Michigan counties (Figure 2).

Management of Round Goby

The eradication of round goby from the Great Lakes is impossible, but preventative and early detection methods could lead to successful eradication efforts on a small scale. Bait trade and boating laws in the Great Lake states and Ontario make possession of the species prohibited. Continued improvements to ballast water regulations concerning both no-ballast-on-board ships and ballast water exchange can also help prevent further introduction into the Great Lakes (Duggan et al. 2005).

I. Monitoring

While several standard fishery sampling methods can be used for round goby, the effectiveness of these methods can be low. Electrofishing, kick seining, trawling, angling, and visual surveys can all be utilized. Electrofishing (backpack or towboat) is ideal if waters are wadeable and clear. Since they lack a swim bladder, round goby may need to be collected by overturning rocks during sampling (Phillips et al. 2003, Kornis and Vander Zanden 2010). Seines are limited to shallow waters but can be more effective if placed downstream of rocky habitat to collect disturbed fish (Jude et al. 1995). In non-wadeable habitats, bottom trawls and angling are effective in capturing specimens, but both have their limitations (Clapp et al. 2001, Johnson et al. 2005b, Corkum 2006). When evaluating size and density across varying substrate habitats, visual methods are most efficient (Johnson et al. 2005b). Passive sampling methods, such as minnow traps and gillnets, can also be used to collect round goby with some cost efficiency, but range in terms of success (Johnson et al. 2005b, Diana et al. 2006, Kornis and Vander Zanden 2010). Depending on the substrate, divers can effectively estimate both juvenile and adult densities using quadrats (Corkum 2006). If round goby are to be tagged, subcutaneously injected latex paint or a Floy anchor tag are suggested techniques (Wolfe and Marsden 1998).

II. Prevention

The surveillance of round goby in the bait trade could prevent further introductions in Michigan (Mahon et al. 2014). Currently, live round goby are prohibited in Great Lake states.

III. Management/Control

a. Physical

Electrical barriers could be used to limit the movement of round goby into new waterways. A Smith-Root downstream-deterrence electric barrier with voltage gradients up to 5 V/cm was effective in preventing round goby movement in a Michigan stream, and could be implemented in artificial connections between watersheds (Savino et al. 2001). Sustained trapping, with traps similar to those used to collect rusty crayfish, may also be able to eliminate round goby from a small-enclosed system (Kornis and Vander Zanden 2010). In its native range, round goby are commercially harvested but such markets have not been explored in the North America (Jude et al. 1992, Kornis et al. 2012).

b. Chemical

While round goby sex pheromones may be useful in management and do not seem to interfere with coexisting fish species, there is currently no synthesized steroid that has successfully attracted reproducing females (Corkum et al. 2008). The importance of visual cues would also need to be considered if a pheromone were to be used for management (Yavno and Corkum 2010). Piscicides, such as rotenone, can be used to control populations as well. However, rotenone is not ideal as it is nonspecific in its toxicity (Schreier et al. 2008). More specific chemical controls have not been tested in the field. For example, bottom release formulations of Bayluscide and antimycin select for benthic fish species (Schreier et al. 2008).

Future Directions for Michigan and Round Goby management

There is currently no effective way to eradicate established populations of round goby. More research regarding various aspects of round goby biology and impacts are needed and new management methods have yet to be field-tested. Given their adaptive nature, the threat of round goby establishing in sub-optimal habitats needs to be evaluated in order to protect sites vulnerable to an invasion. After invasion, round goby have the potential to shift energy pathways and become ingrained in the ecosystem in both positive, but mostly negative ways (Kornis et al. 2012).

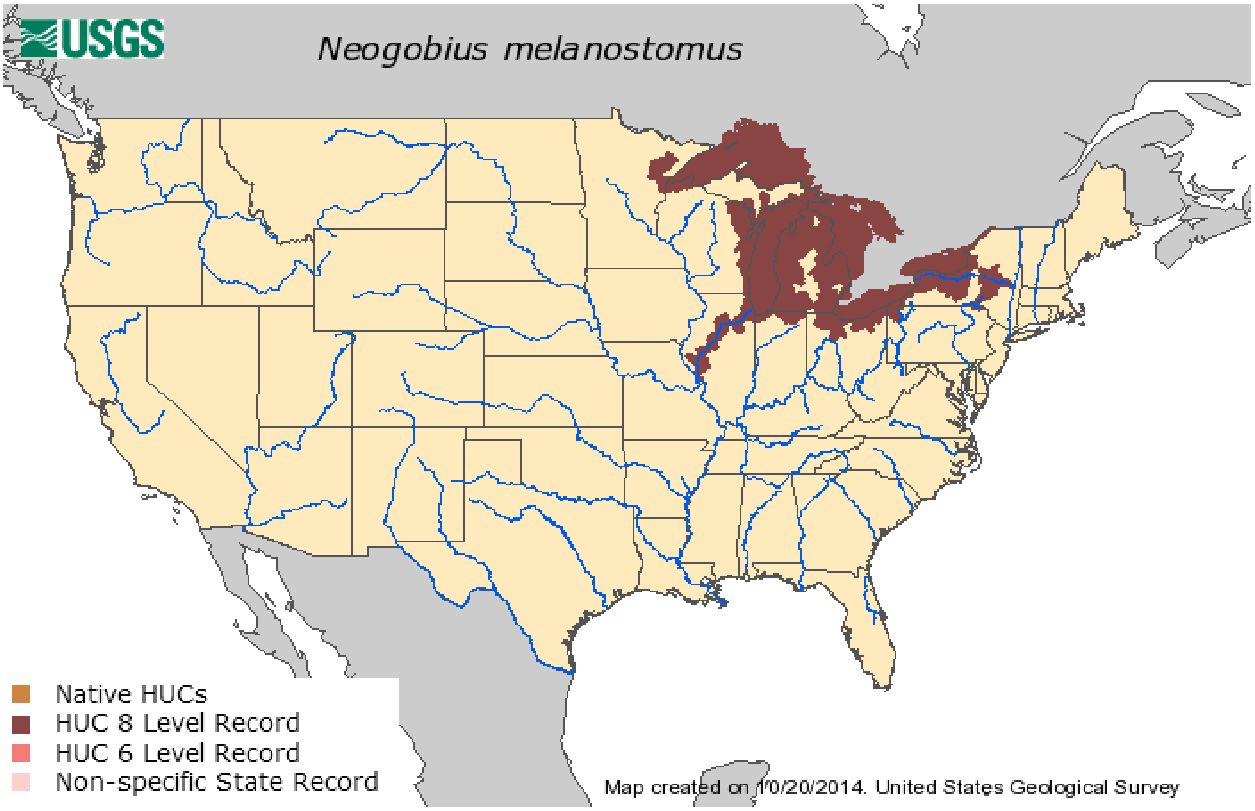

Figure 1. Distribution of round goby in the United States (Nico et al. 2012). Accessed October 23, 2014.

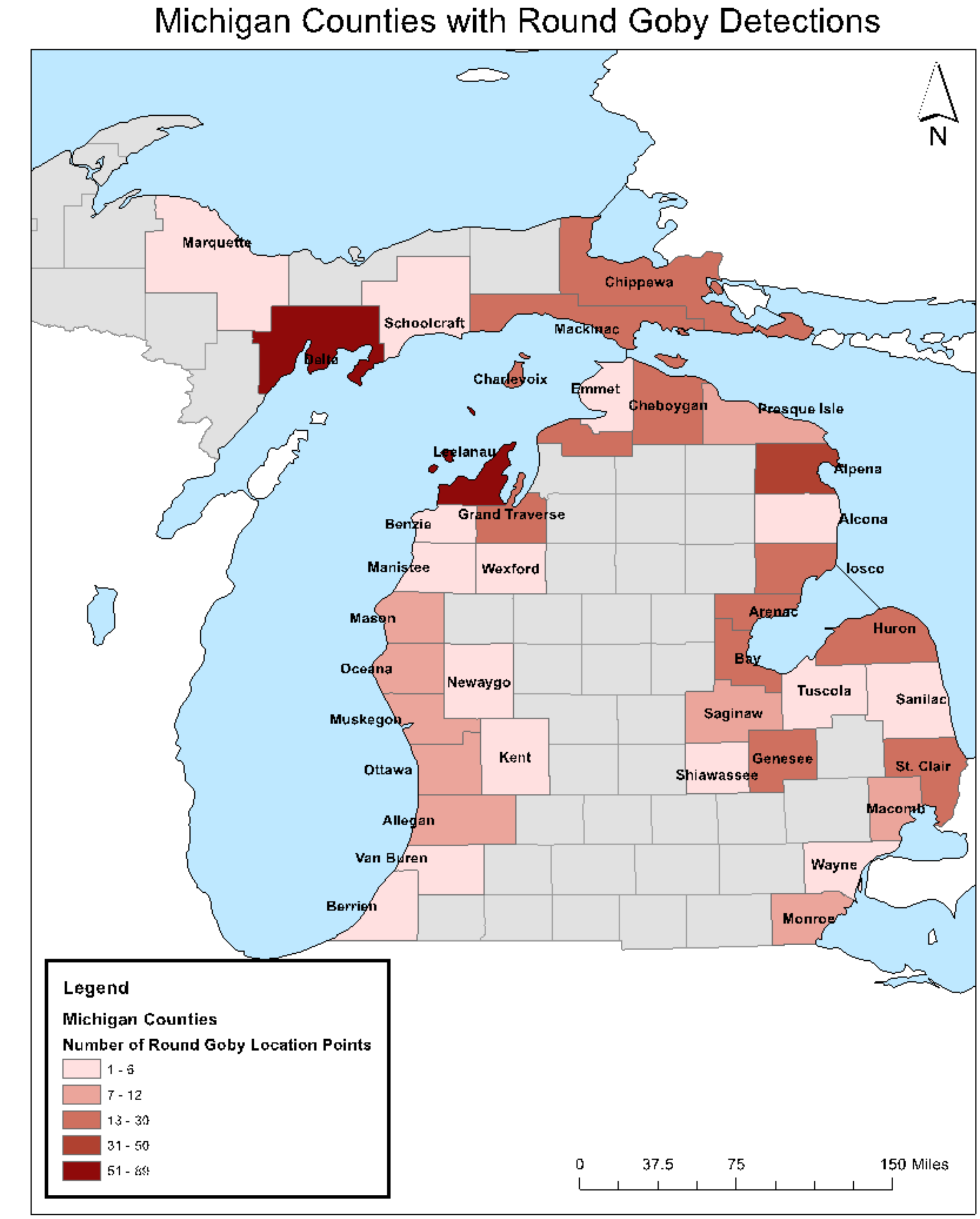

Figure 2. Number of unique coordinate location points within Michigan counties at which round goby were detected. This data is according to the United States Geological Survey (USGS), Midwest Invasive Species Information Network (MISIN), Biodiversity Information Serving Our Nation (BISON), and the State of Michigan fishery databases.

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