First Record of a Northern Snakehead (*Channa argus* Cantor) Nest in North America

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Abstract - A population of *Channa argus* (Northern Snakehead) has been established in the Potomac River catchment, VA and MD, for approximately ten years, and is increasing rapidly in abundance. Little is known about life-history strategies of this species in North American environments. We report the first discovery of a Northern Snakehead nest in North America and discuss some of its nesting habits. Adult Northern Snakeheads constructed a circular nest in a patch of dense *Hydrilla verticillata* (Hydrilla) by clipping stems, thus creating a canopy of floating plants. They laid eggs atop floating stems, and larvae hatched within three days. Both male and female parents were observed guarding the eggs and fry in the nest. Parents also continuously guarded the school of fry as they dispersed from the nest. Prolonged schooling behavior after leaving the nest accompanied parental guarding for up to several weeks. Floating nests and parental care likely increase reproductive success in a tidally influenced ecosystem with abundant predators. These factors contribute to the ability of Northern Snakehead to persist and spread in North America. Based on our findings, nests will likely be located in areas of the Potomac River that are low to no flow, moderately shallow, and highly vegetated.

Introduction

Channa argus Cantor (Northern Snakehead) (formerly *Ophiocephaluarus argus warpachowskii*) is a newly introduced species in the United States. This species is thought to have been introduced as a product from live-fish markets (Courtenay and Williams 2004). The first US specimen was captured in the Potomac River, Fairfax County, VA, in May, 2004 (Orrell and Weigh 2005). By 2005, this species was considered established (Odenkirk and Owens 2005). Using otoliths to age fish captured in 2004, specimens were determined to be up to 6 years old, suggesting an introduction date as early as 1998 (Odenkirk and Owens 2005). Through continued monitoring of Northern Snakehead, Odenkirk and Owens (2007) documented growth in population size and range expansion within the Potomac River catchment. Little is known about what drives the success of this species in the Potomac River and what factors could potentially limit its spread.

The reproductive process may represent a vulnerable link in Northern Snakehead's life cycle, and a more complete understanding of it can enhance

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our ability to manage this species (Jiao et al. 2009). Researchers have described nesting habits for Northern Snakehead in its native range in China (Ling 1977) and introduced range in Kazakhstan (Dukravets and Machulin 1978). Adult fish clear a circular area in shallow aquatic vegetation for a nest (Amanov 1974). Northern Snakehead eggs are positively buoyant and float at the water surface. In China, the adult fish have been observed guarding the eggs and young (Courtenay and Williams 2004). Since Northern Snakehead are a popular food fish and perform well in ponds, observations in its native range occurred at aquaculture facilities, and habits in this artificial environment may have little bearing for the strategies employed by wild Northern Snakeheads in the Potomac River.

Resource managers and researchers have spent many hours on the Potomac River in an effort to monitor and research Northern Snakeheads (J. Odenkirk, Virginia Department of Game and Inland Fisheries, Fredericksburg, VA, pers. comm.). While in the field, researchers actively searched for nests and nesting habitat in an effort to understand more about the species' life history (Lapointe and Angermeier 2009). However, even with information from the literature as to how this species behaved in its native range, Northern Snakehead nests were not identified in the first three years after their populations had been recognized as established (Odenkirk and Owens 2007). In this paper, we document the first observations of a nest and nesting habits for Northern Snakehead in the Potomac River. We compare our observations of Northern Snakehead nesting strategies in this novel ecosystem with nesting strategies documented in its native range.

Methods

The study location for our observations was the Potomac River and its tributaries south of Washington DC. Daily tides influence this stretch of river, causing changes in water depth of up to 1.5 m (USGS gauging station, Alexandria, VA); however, this portion of river does not experience significant levels of salinity (typically 0.1–0.2 ppt). This area features bays at the terminus of each tributary. Bays are often shallow (<2 m), highly vegetated, and, with the exception of tidal fluctuations, have very little current. Aquatic vegetation comprises both emergent plants (*Nuphar varigateum* Durand [Yellow Pond-lily], *Phragmites australis* (Cav.) Trin. ex Steud. [Common Reed], *Typha latifolia* L. [Broadleaf Cattail]) and submerged plants (*Hydrilla verticillata* (L.F.) Royle [Hydrilla], *Myriophyllum spicatum* L. [Eurasian Watermilfoil], *Ceratophyllum demersum* L. [Coon's Tail], and *Najas* sp.water nymph]).

A radio-telemetry study (Lapointe and Angermeier 2009), which took place between October 2006 and October 2007, allowed us to find exact locations of Northern Snakeheads and make repeated visits. The telemetry study included 49 fish, from several locations throughout the Potomac

River, which received a surgically implanted radio transponder. On two separate occasions, brooding fish were located during routine telemetry surveys: the first of these two was guarding a nest of eggs, and the second was guarding a school of young. Both brooding fish were found in August 2007. By tracking the first guarding adult, we were able to follow the school of larval fish after the nest was abandoned. At the nest site, we were able to make observations without disturbing nesting activities due to its location in close proximity (approximately 1 m) to a residential flood wall, built to buffer against high water. We recorded most observations while hidden on the flood wall. No nest was located for the second guarding snakehead, and the young were discovered after the eggs had hatched and the young had left the nest.

We took additional measurements from a boat to record the size and shape of the Northern Snakehead nest without disturbing its structure. Habitat measurements such as water depth, substrate and aquatic vegetation type, temperature, and dissolved oxygen were recorded to help characterize nesting location and sites used by the school of young. We recorded GPS location to track distance movement of the larval Northern Snakeheads after they dispersed from the nest. At each visit, our goal was to collect approximately 30 larval fish by dip net; however, the range of captures was between 8 and 50 fish. This level of collection allowed us to obtain a representative sample size, yet keep our impact on the school of larvae minimal. Additionally, we captured several *Gambusia holbrooki* Girard (Eastern Mosquitofish) observed feeding on Northern Snakehead fry. All fishes were preserved in 10% formalin and returned to the laboratory. The total lengths of Northern Snakehead larvae were measured and presented as means with standard deviation. Eastern Mosquitofish stomach contents were examined.

Results

The breeding pair of Northern Snakeheads guarding a nest was found in Little Hunting Creek, a tributary of the Potomac River. The nest was located in a small, side-channel creek, dredged to allow access to personal docks and a boat launch, even at times of low water. Hydrilla dominated the shallow shoreline, while the central channel was free of vegetation. Adult Northern Snakeheads had clipped Hydrilla stems, which then floated at the water surface. Unclipped, living Hydrilla surrounded the clipped Hydrilla stems. A mass of eggs floated at the water's surface above the radio-tagged fish in the matrix of clipped Hydrilla. Bright orange-yellow eggs were held in place by the floating Hydrilla leaves and stems. Although floating freely, the eggs had formed into rows resembling a honeycomb, which were one to three layers deep and 25 cm in diameter. Below the canopy of floating Hydrilla, an open area was created in which parents could patrol (Fig. 1). The nest was approximately circular in shape, with a diameter of 1.8 m, and depending on tidal variation, had a depth between 25 and 125 cm. Several openings (10–20 cm in diameter) in the floating Hydrilla mat were located around the perimeter of the nest. These were used by adults for obligate air-breathing. Substrate at the nest site was sand. Dissolved oxygen and temperature on the day we found the nest were 7.8 mg/L and 29.4 ˚C, respectively. Pictures of the nest, eggs, and young, along with descriptions, are available at www.fishwild.vt.edu/snakeheads.

Both the male and female Northern Snakeheads guarded eggs and fry throughout incubation and development. Guarding behavior was exemplified by active swimming underneath the eggs and fry. Swimming typically occurred in a circular pattern with occasional breaks for aerial respiration. These activities probably protected the eggs and young from aquatic predators. Previous field observations and dissection for diet analysis noted sexual dimorphism for Northern Snakehead (N.W.R. Lapointe, unpubl. data). Male fish have a darker coloration and a broader head than female fish. Both morphs of fish were present; thus, we concluded that the two fish guarding the nest were male and female parents.

On the third consecutive day of our observations, Northern Snakehead eggs had begun to hatch. Fry moved from the original hatching site, but stayed within the larger nest area on the third day after hatching. By the fourth day after hatching, fry averaged 6.3 mm ± 0.5 SD (*n* = 29 individuals) total length and had moved 5 m from the nest site. Movement of the school progressed in a downstream direction, and fry remained in the cover of Hydrilla. On the eleventh and final day of observation, fry averaged 12 mm ± 0.5 SD (*n* = 30) in length and were located an average

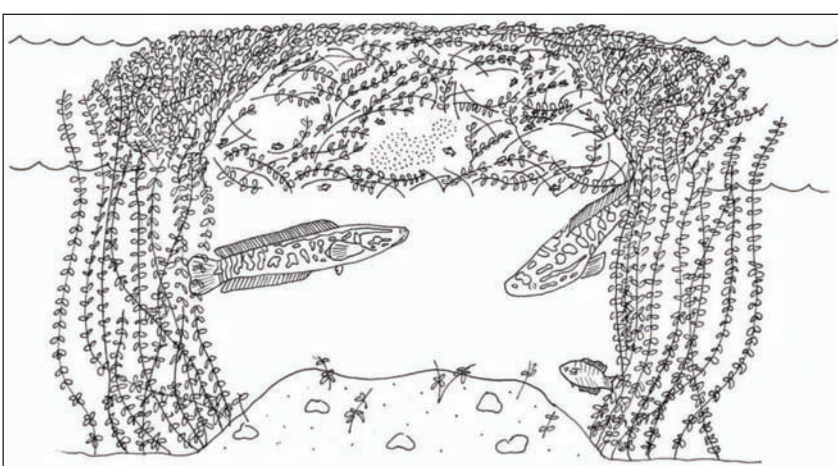

Figure 1. Artistic rendition of a male and female Northern Snakehead guarding eggs in a circular nest of Hydrilla.. Black dots represent eggs floating in a matrix of floating fronds of clipped Hydrilla.

of 80 m ± 9 SD from the nest site. Daily distances moved by the school were sporadic, but averaged about 10–15 m per day. The movement of the school was accompanied by the tagged parent. Parents were not always observed guarding the school, but the school was located via telemetry. It is unclear whether the untagged parent continued to guard the school after it moved beyond the nest.

While observing the nest immediately after start of hatching, we noted that individual Eastern Mosquitofish began invading the nest site and observed them consuming Northern Snakehead eggs and fry. To document predation of egg and fry, we captured four Eastern Mosquitofish for laboratory diet analysis. All four specimens contained eggs and newly hatched Northern Snakehead fry; the largest Eastern Mosquitofish (43 mm) contained 60 snakehead eggs and fry, and the smallest (31 mm) contained 21 snakehead eggs and fry. There appeared to be a correlative relationship between the size of predator and the number of fry consumed.

Concurrent to our nest observation, the second radio-tagged Northern Snakehead we followed was guarding young that were 14.3 mm ± 0.9 SD (n = 30) in length. These fish, located in Douge Creek Bay, also utilized dense Hydrilla mats. We followed this school of young fish for 13 days after its discovery. Mean fish size at the end of the observation period was 39.9 mm ± 2.0 SD (n = 8) total length.

Discussion

Our efforts identified the first recorded Northern Snakehead nest in North America. Despite intensive searching, Northern Snakehead nests have proven difficult to locate. In the concurrent radio telemetry study (Lapointe and Angermeier 2009), 49 fish were tracked twice a week from April through August, which corresponds to the predicted breeding season. This extensive time in the field yielded only two brooding fish. Although the primary focus of the radio telemetry study was not locating Northern Snakehead nests, tracking repeatedly brought us in close proximity (≈1 m) of many Northern Snakeheads, and our sampling included quantifying vegetative habitat, ensuring an examination of potential nesting sites. The size and shape of the nest discovered in the Potomac River catchment matched the description of nests from Northern Snakeheads in their native range (Courtenay and Williams 2004); however, there are important distinctions. Courtenay and Williams (2004) reported nests of Northern Snakehead from China that are 1 m in diameter, in approximately 0.6–0.8 m of water that had been cleared of vegetation. Also, in China, Ling (1977) documented that a congener of Northern Snakehead, *Channa striata* Bloch (Chevron Snakehead), bit off aquatic vegetation to clear an area for a spawning nest, and its floating eggs were contained by the vegetation. The descriptions from the Asian literature portray a nest as an area cleared of vegetation with the parent fish visibly occupying the interior. From our observations in the Potomac River, Northern Snakehead nests are quite difficult to discover because floating vegetation camouflages the nest and eggs, and masks the parents' presence.

Our observations in the Potomac River expand on the literature and can help us identify factors related to nesting habitat requirements and behaviors that make Northern Snakeheads successful invaders. Nesting habitat requirements include low current velocity and low wave action plus dense beds of submerged aquatic vegetation; additionally, long-term parental brooding contributes to their invasiveness.

Although the two areas in which we located guarding adults were fundamentally different (one was an open bay, the other a coastal plain stream), they shared some habitat features. The sites had little to no flow and were largely protected from wave action. These features are necessary because Northern Snakeheads produce a floating cluster of eggs that could potentially break apart and float away.

All observations of young Northern Snakeheads occurred in dense beds of submerged aquatic vegetation. Floating, clipped macrophytes provided ideal cover for guarding parents from avian or terrestrial predators, while simultaneously providing an open area immediately below the nest where parents could patrol and guard eggs or young. Most importantly, floating macrophytes surrounded the floating egg mass, keeping it in place. Interestingly, all schools of juvenile Northern Snakeheads that we observed in the Potomac River catchment in 2007 were associated with dense patches of Hydrilla. While Hydrilla is an introduced species in the Potomac River, it provides a greater abundance of aquatic macroinvertebrates than do open water areas (Thorp et al. 1997). In lakes in Florida, Hydrilla harbored higher macroinvertebrate abundance than the neighboring native vegetation (Schramm et al. 1987). Success of young Northern Snakeheads might be linked to abundance of Hydrilla in the waterways of the Potomac River because it provides cover and abundant food resources. More research is necessary to establish the connection between these two exotic organisms.

Our observations showed that adult Northern Snakeheads guard their young after they leave the nest and stay with them for at least four weeks. Ling (1977) was able to observe that male fish closely guarded their young for six to nine weeks, which coincided with juvenile dispersal. Continued guarding is possible due to the schooling behavior of snakehead fry when they leave the nest. Extended parental guarding has potential to increase larval and juvenile survival, helping Northern Snakeheads to be successful in the Potomac River (Odenkirk and Owens 2007).

Separate from our observations of the factors leading to the success of Northern Snakeheads, we documented Eastern Mosquitofish consuming snakehead eggs. Eastern Mosquitofish routinely prey on eggs and larvae of many species (Mills et al. 2004) and significantly reduce invertebrate, amphibian, and fish populations in a wide range of ecosystems (Courtenay and Meffe 1989). We documented substantial egg predation by only a few individuals of Eastern Mosquitofish in a short period of time. The true impact of this egg predator is unknown, but it could have the potential to impact Northern Snakehead recruitment.

We hope this information will give resource managers and researchers a better search image for Northern Snakehead nests in the future. Through understanding nest placement, structure, and habitats, future studies can be conducted to improve our knowledge of this novel predator. Based on our findings, nests will likely be located in areas of the Potomac River that are low to no flow, moderately shallow, and highly vegetated.

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