Snakehead Scientific Advisory Panel
First Report to the Maryland Secretary of Natural Resources

July 26, 2002

Introduction

The Snakehead Scientific Advisory Panel was initiated by Maryland Secretary of Natural Resources, J. Charles Fox, when it became known that juvenile snakeheads, a fish native to Asia, were occupying a pond in Crofton, Maryland, from which two adult specimens had been collected by anglers. The presence of juveniles indicated that this snakehead species, identified as the northern snakehead (*Channa argus*), was capable of reproducing in Maryland waters, thus posing a risk of broader invasion with potentially deleterious consequences to indigenous organisms.

Secretary Fox asked Dr. Donald F. Boesch of the University of Maryland Center for Environmental Science to chair the Panel and the two agreed on the objectives of its charge:

1. By July 29, 2002, deliver to the Secretary a report that assesses the risks to Maryland's natural resources posed by the northern snakehead fish; evaluates the options for its control or eradication in and around the pond where it was found, including the probability of success and attendant environmental consequences; and recommends by consensus a preferred course of action to be executed by the Department;

2. By September 1, 2002, deliver to the Secretary a report that evaluates policy and regulatory options to prevent future introductions of potentially invasive non-native fish; and

3. Provide additional advice to the Department throughout implementation of the selected control options, expected to be completed by December 31, 2002.

The Panel assembled (Appendix 1) includes faculty members from Maryland universities, representatives of federal agencies and environmental and advisory groups, and Florida experts on controlling invasive fish species. This report addresses the first objective of the charge and is based on a meeting of the Panel, held on July 19, 2002, and subsequent follow-up deliberations.

Background

On May 18, 2002, an angler caught an 18 to 19-inch fish that he was unable to identify from an unnamed pond (here referred to MacQuilliam pond) in Crofton, Maryland. The angler photographed and then released the fish, which the Department of Natural Resources (DNR) subsequently identified as a species of snakehead. On June 30, 2002, another angler caught and retained a 26-inch snakehead, which he has kept frozen. On July 8 the same angler caught eight juvenile snakeheads with a dipnet. Since then, DNR, using electrofishing, has captured more than 100 young-of -the-year snakeheads, which have been positively identified as *Channa argus*, the northern snakehead. Investigations by the Maryland Natural Resources Police led to the admission by a local resident of a release into the pond of two 12 to 14-inch fish sometime during 2000. These fish had been purchased on the live food fish market in New York.

The northern snakehead is native to eastern Asia and has been introduced to western Asia and eastern Europe during the 20th century (Courtenay et al., 2002). It has been successful in establishing reproducing populations in a variety of freshwater environments at least in Japan and in western Asia, well outside of its native range. Only in the last few years have sporadic observations of this species occurred in the United States, including waters in Florida and Massachusetts. In addition, illegally imported live specimens of the northern snakehead have been confiscated by law enforcement officials in Florida and Texas. The likely source of northern snakeheads that have been found in U.S. waters is live food fish markets, as was the case for the adult specimens found in MacQuilliam pond.

The northern snakehead has been found to live in stagnant shallow ponds, swamps and slow streams with mud or vegetated substrate, with temperatures ranging from 0 to >30^{o}C. The diets of adults are mostly made up of small fish, although some may be as large as one-third of the predator's body length. In addition to fish, the northern snakehead has been known to eat frogs, crustaceans, and insect larvae. It reaches sexual maturity in 2 to 3 years and approximately 30-35 cm (12-14 inches) in length and maximum size exceeds 85 cm (33 inches). Females release 1,300 to 15,000 eggs per spawn, which can occur 1 to 5 times per year. The floating eggs take 28 hours to hatch at 31^{o}C, 45 hours at 25^{o}C and much longer at cooler temperatures. Larvae remain in a nest guarded by their parents until yolk absorption is complete at approximately 8 mm in length. At approximately 18 mm the young begin feeding on small crustaceans and fish larvae. The northern snakehead has been reported to be an obligate airbreather, which means that it can live in oxygen-depleted waters by gulping air at the water's surface and survive several days out of water if kept moist.

The MacQuilliam pond is located in Crofton, Maryland adjacent to Route 3 near the intersection of Crawford Boulevard. It covers approximately four acres with an average depth of 4-5 feet. The pond is apparently a remnant from earlier sand and gravel excavation, as is the case for smaller ponds and sloughs nearby. Its catchment area is small and includes significant impervious surface in the form of commercial buildings, parking lots and roads. It may also be supplied by subsurface springs because the water level appears to remain relatively constant during extended periods of dry weather. Currently the pond has dense growth of several aquatic plant species, including watershield (*Brasenia schreberi*), bladderwort (*Utricularia* sp.), white waterlily (*Nymphaea odorata*), slender pondweed (*Potomogeton* sp.) and duckweed (*Lemna* sp.).

MacQuilliam pond is adjacent to two smaller unnamed ponds (referred to here as Berkshire ponds) on an adjacent property. Fewer than 100 yards of low-lying forested land separate these ponds from the Little Patuxent River. While there is not a regularly flowing connection between the ponds and the river or clear evidence of recent overflow, it seems clearly possible that water is exchanged between the ponds and river during extreme rainfall events or high river stages. There is also some headcutting from the river back toward the ponds.

Panel Findings and Recommendations

Risks to Maryland's Natural Resources

1. The northern snakehead has a wider latitudinal range and temperature tolerance than other snakehead species. It also seems to be adaptable to a wide range of aquatic environments, as evidenced by the spread of reproducing populations in many areas in Asia and Japan where the fish has been introduced. In addition, the presence of juveniles that must have resulted from the successful reproduction of adults in the Crofton pond further demonstrates the significant potential that the northern snakehead would invade ponds, lakes and rivers in Maryland.

2. All introductions of non-native species pose risks to native species and their habitats. Even species propagated and distributed for beneficial reasons often have undesirable side effects. For example, channel catfish and largemouth bass have been shown to affect the abundance of native fish species. Non-native species may also introduce additional parasites or diseases. Although there is very little information in the scientific literature about the effects of northern snakeheads on other fish populations, adult northern snakeheads are large predators that would likely affect the populations of other fish, amphibians and invertebrates. The nearby Little Patuxent River hosts endangered fish species and recovering populations of anadromous fish (e.g. shad) that could be threatened by the establishment of populations of snakeheads. Although it is not possible to predict with specificity what these impacts would be, the Panel advises that it is prudent to presume that they would be adverse and to take all deliberate steps to protect against broader introduction of northern snakeheads.

3. There is no evidence that juveniles or adult snakeheads have yet escaped from the Crofton ponds. Sampling by DNR biologists in the Little Patuxent River has yielded 28 species of fish but no snakeheads. Although overflow connection between the pond and the river probably has not occurred in recent weeks, such an occurrence when there were juvenile fish (assumed to be several months) in the pond cannot be ruled out. Overland locomotion by juvenile or adult northern snakeheads, as exhibited in some tropical snakehead species that live in temporary ponds, is in the Panel's opinion unlikely given the poor morphological adaptation of this species for crawling (compared to mudskippers or walking catfish, for

example) or sinuous movements (such as exhibited by eels, for example). Dispersal by humans is a more likely risk.

4. Heavy downpours or flash flooding of the river pose a real risk of escape of northern snakeheads into the Little Patuxent River, from which they would be much more difficult if not impossible to eradicate. Therefore, the fish should be eradicated from the ponds as soon as practicable. Meanwhile, a hydrological assessment should be immediately conducted to determine the conditions that would breach the existing barriers to dispersal from the pond (this study would also provide information useful in minimizing the movement of biocides used in the pond treatment described below into the river). In addition, DNR should re-examine its current confinement strategy and enhance the sandbagging and add silt fencing across particularly low lying areas between the ponds and the Little Patuxent River, as well as in the low lying area on the west and south sides. The Panel understands that the DNR has, in fact, already responded to this recommendation.

Options for Control

1. The Panel recommends against a wait-and-see approach with the expectation that the population will die out. Northern snakeheads have likely survived for nearly two years in the pond, they have successfully reproduced, possibly hundreds to thousands of juvenile snakeheads remain in the pond, and there is a real risk that they may escape during high water events or be moved about by people. The relatively small size of the ponds and the likelihood that all of the snakeheads are retained in these ponds allows the possibility of complete eradication of this population at this time. This would be far more difficult if they were to enter the river or successfully invade a larger area.

2. The dense aquatic vegetation presents a considerable obstacle to eradication as it affords the fish some refuge from most control measures. Substantial reduction of this vegetation would increase the likelihood of success of any eradication measures. The most effective means of reducing the aquatic vegetation is by use of herbicides, but this is complicated because some of the aquatic plants are floating and others submerged. Fluridone (Sonar) is the only EPA-labeled herbicide that would be effective on all aquatic plant species found in the ponds, but it is slow-acting and could take up to 3 months to eliminate the aquatic vegetation. Glyphosate (Rodeo, Roundup) is fast acting if sprayed on floating vegetation. Diquat dibromide (Reglone, Reward) or 2,4-D can be used to kill submerged vegetation. These substances are moderately toxic to a wide range of organisms, but degrade within a few days to a few weeks in the aquatic environment. Permits for their use would have to be obtained from the Maryland Department of the Environment and maximum permissible dosage concentrations would have to be adhered to. Precautions should be taken to avoid loss of active

herbicide to the river until the degradation process is complete. The aquatic vegetation in the treated ponds should return within months to a few years.

3. For a variety of reasons, physical removal of the fish by nets, traps, angling, or electrofishing; biological control by introduction of predators; and the use of explosives (detonation cord) are unlikely to be 100% effective in eradicating snakeheads in the ponds.

4. Dewatering the ponds and allowing them to dry could potentially eliminate all of the snakeheads, however there would be a number of technical challenges to accomplish this. If the MacQuilliam pond is spring-fed, it may be difficult to keep the pond dry and the fish may survive in the moist residue in the pond bottom. Some effective filtration would have to be developed and monitored to ensure that small fish or fish eggs (1-2 mm) would not escape. Furthermore, holding the filtered water in another impoundment or spraying it over uplands would probably also be required to prevent drainage into the river. All of this would involve uncertainty and take time.

5. Treatment of the pond with a piscicide is the most reliable and practical option. Chlorination by applying calcium hypochlorite (much as one would to disinfect a swimming pool) has been successfully used in aquaculture ponds; however, the dense aquatic plant growth and high organic content of the pond would confound achieving effective but not excessive dosage and potentially toxic chlorinated organics could be created. Furthermore, chlorine is toxic to a broad spectrum of organisms, killing micro-organisms, plants and animals alike. It is not an EPA-approved, registered piscicide. Registered piscicides, including rotenone and antimycin, are preferred. The use of antimycin has a limited track record and is less effective when the pH exceeds 8, which could occur in the Crofton ponds (Finlayson, et al., 2002). Application of rotenone is a time-tested approach that is effective in killing fish if delivered in the right dosage and well-mixed (Finlayson et al., 2000). Rotenone was found to be effective on a test population of juvenile northern snakeheads captured from the MacQuilliam pond based on bioassays conducted on July 24, 2002 (Appendix 2). Complete mortality of the test population was observed within 24 hours at a concentration of 1.5 ppm. Furthermore, the fish exhibited no complicating behavioral responses, such as escape from the containment vessel. Importantly, rotenone rapidly degrades with no lingering toxicity, particularly at high summer temperatures, but should persist long enough to kill larvae hatching from more resistant snakehead eggs that might be in the ponds.

Preferred Course of Action

1. The Panel recommends the use of rotenone to kill the fish in MacQuilliam pond as well as Berkshire ponds (to ensure that the fish are not harbored in these nearby bodies of water) based on the following:

a. Rotenone should be applied to the pond with both surface spay application and injected underwater over the entire pond sufficient to achieve an effective dosage of at least 3 ppm (see Appendix 2 for rationale for that dosage).

b. Approximately one week prior to the rotenone treatment, floating plants should be sprayed with glyphosate. Based on field assessment of the potential interference with rotenone application, treatment of submerged vegetation with diquat dibromide or 2,4-D should also be considered at that time. Concentrates or rates should comply with standard application recommendations and MDE permit requirements.

c. An appropriate window of treatment should be selected (based on the above hydrological assessment) and overflow barriers erected to minimize the risk of any introduction of rotenone or herbicide to the Little Patuxent River.

d. If available, some juvenile snakeheads should be placed in cages in the MacQuilliam pond during the rotenone application as an *in situ* bioassay to verify lethal dosage. Dead and moribund fish rising to the surface of the pond should be quickly removed, examined for the number and size of snakeheads, and buried.

2. The Panel recommends that standard fish survey techniques be applied (seining and electrofishing) to determine if any fish survived the application of rotenone. If so, rotenone should be re-applied. Occasional monitoring of the ponds should be conducted over the next two years. Restocking with desired fish species can be considered on that basis.

Preventing Future Introductions of Potentially Invasive Fish

On July 23, 2002 the Secretary of the Interior proposed that the 28 snakehead species be added to the list of injurious species, which would prohibit the importation of the fish anywhere in the United States and make it illegal to transport the fish across state lines. This measure would go into effect in 60 days. This would go a long way to restrict domestic sources of these alien species in a way that State laws and regulations could not. However, under this federal authority it would still be legal to possess snakeheads in Maryland and other states without such explicit prohibition, thus continuing the risk of purposeful or accidental introduction of these species into Maryland waters. This as well as prevention of the future introductions of other potentially invasive, non-native fish species will be addressed in the Panel's second report to the Secretary of Natural Resources to be delivered on or before September 1, 2002.

Acknowledgements

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Appendix 1
Snakehead Scientific Advisory Panel

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Appendix 2

Acute Toxicity of 5% Rotenone to Northern Snakehead (*Channa argus*) Project Summary

July 25, 2002

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Introduction

In June of 2002, the Northern Snakehead, *Channa argus*, was confirmed to be present and apparently reproducing in a small, privately owned pond in Crofton, MD. This species is native to China and parts of Siberia and known to tolerate a wide range of habitats and temperatures. In addition, it is a highly predatory species and potentially injurious to native fish populations. To address these concerns, a Snakehead Scientific Advisory Panel was formed to assess the risk associated with this introduction, evaluate options for eradication, and recommend a course of action to the Maryland Department of Natural Resources (DNR). Preliminary Panel discussions identified Rotenone as the preferred method of eradication. Since no information is available on the toxicity of Rotenone to this species, a bioassay was conducted to determine the toxicity of the piscicide and effective concentration.

Methods

<u>Fish Collection and Husbandry</u>—On July 11, approximately 90 juvenile snakeheads were collected by DNR personnel using a backpack electrofishing unit and dip net. A total of 77 of these fish were transported to the Cooperative Oxford Laboratory (COL) on July 17 and held in a single 20-gallon aquarium. Fish were fed cut krill daily. On July 22, water from the Crofton pond was delivered to COL by DNR personnel. Fish were acclimated to the pond water over a 20 hr period with constant aeration.

<u>Experimental Design</u>—A completely randomized design with 4 treatments and two replicates was used to test the effect of Rotenone on the Northern snakehead. Eight 10-gallon aquaria were filled with 19 liters of pond water (24.3°C, pH = 7.93, D.O. = 7.9 mg/l, alkalinity = 103.6 mg/l, total hardness = 103.6 mg/l, and total ammonia nitrogen = 0.8 mg/l), aerated, and allowed to set overnight. On July 23, eight fish (mean = 7.5 cm TL, 2.63 g) were stocked in each tank, and fitted with a sloped, styrofoam platform to allow for fish escape. Concentrations tested included 0, 1.5, 3.0, and 6 parts per million of 5% liquid Rotenone (Prenfish Toxicant, Prentiss Incorporated, New York). Each concentration was diluted into 1-liter containers of pond water prior to application and mixed thoroughly within the appropriate aquaria. Fish were observed 15 minutes, 1hr, and 3 hrs post application.

Results

At 15 minutes post application, erratic swimming behavior and gulping of air was noted in both replicates of the 6 ppm and 3 ppm treatments. In addition, several fish were observed either upright on the bottom of the aquaria or listing to one side within the 6 ppm treatment. At one hour, all fish in all Rotenone treatments appeared dead. In both replicates at 1.5ppm, a single fish was observed at the Styrofoam—water interface, but not out of the water. At this time, one fish was removed from each of the 6 ppm replicates for necropsy. Both fish were observed to have limited cardiac activity. Observations were repeated at three hours post treatment with similar results. After 24 hours, no mortality occurred in the control treatment and the experiment was terminated.

Discussion

This study demonstrates that the twenty-four hour lethal concentration for complete mortality of the juvenile Northern snakehead is below 1.5 ppm. This is well within the concentration range known to be toxic to other species of fish, and far below the acceptable limits for application of the piscicide (5 ppm). In addition, even when provided a mechanism for escape, the fish showed no ability to do so. The lethal concentration for mature Northern snakehead is not known, however some information exists on toxicity of Rotenone to 13 to 18 cm fish of the Spotted Snakehead, *Channa punctata.* Perschbacher and Sarkar (1989) found the 24 hr LC_{100} value to be 2.5ppm at 24° C, 120ppm total hardness, and pH of 7.3-7.7.

In conclusion, a minimum of a 3.0 ppm Rotenone concentration would be recommended for the pond in Crofton to allow for any error in pond volume estimation, interaction with organic matter, and possible reduced susceptibility of adult fish.

Literature Cited

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