RAPID RESPONSE PLAN FOR THE NORTHERN SNAKEHEAD (*Channa argus*) IN MASSACHUSETTS

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*cover photo taken from the Florida Aquatic Science Center website, http://cars.er.usgs.gov

Species Taxonomy and Identification

The northern snakehead, *Channa argus*, is a long cylindrical bodied fish with a large mouth and sharp teeth. The scales on the top of the head are large compared to those on the rest of the body. The eyes of the northern snakehead are located forward on the head, giving the fish a snake-like appearance. The body consists of a dark blotchy pattern along the sides, and saddle-like markings across the back (Courtenay and Williams 2004). Northern snakeheads typically reach a maximum size of 85 cm, but have been reported to reach 1.5 m total length (Courtenay and Williams 2004). The males of the species tend to be larger than females with a higher dorsal fin, wider interorbital distance, and longer snout, postorbital distance and upper jaw (Courtenay and Williams 2004).

According to Courtenay and Williams 2004, the gular part of head is without patch of scales. The head is somewhat depressed anteriorly, the interorbital area is flat, and the eyes are above the middle of upper jaw. The mouth is large, reaching far beyond the eyes. Villiform teeth are present in bands with some larger canine-like teeth on the lower jaw and palatines. Lateral line scales number 60-67; 8 scale rows above the lateral line to the dorsal fin origin; 12-13 scale rows are present below the lateral line to the anal fin origin. The dorsal fin is elongated, with 49-50 rays; anal fin with 31-32 rays. The origin of pelvic fin is beneath the 4th dorsal fin ray. The pectorals extend beyond the base of the pelvic fins.

Bowfin, *Amia calva*, and burbot, *Lota lota*, are two native species in the United States that may be confused with northern snakeheads. Northern snakeheads have a long dorsal and anal fin compared to these two species. Additionally, the pelvic fins of the northern snakehead are located below the pectoral fins, the tail is truncated and the body is dark with irregular blotches. In comparison the bowfin has a short anal fin, the pelvic fins are located in the belly area of the fish and the tail is rounded. The burbot is easily distinguished by a split dorsal fin and a single barbel under the lower jaw.

Four species of snakehead have been recorded as reproducing in the United States (Courtenay and Williams 2004). Of these, two have been recorded as established within the continental United States. However, in Massachusetts, the only snakehead species of major concern is the northern snakehead, due to its ability to overwinter in the Massachusetts climate.

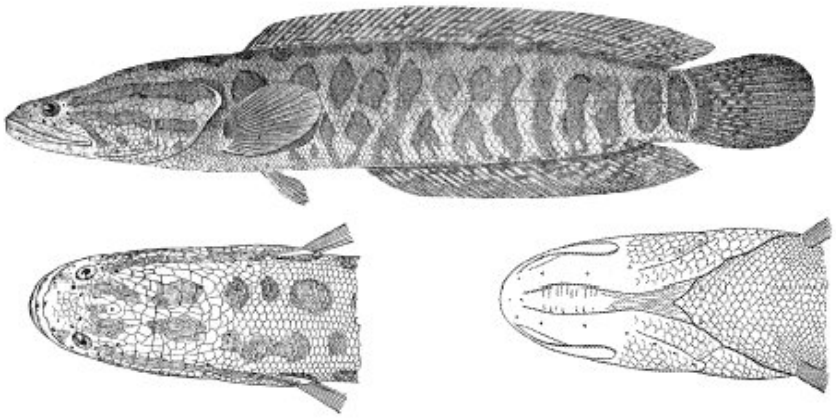

Figure 1 - A representation of the northern snakehead, adapted from Berg 1933, and taken from Courtenay and Williams 2004.

Species Origin and Geography

The northern snakehead is native to freshwater habitats of China and Korea. A subspecies of the northern snakehead is native to Russia and China, and has spread rapidly over the last 40 years. The northern snakehead has been introduced in the United States, Japan, Central Asia, Eastern Europe, Philippines and Madagascar (Courtenay and Williams 2004). Within the United States, northern snakeheads have been collected in California, Florida, Maryland, Massachusetts, North Carolina, Pennsylvania, Virginia and Illinois. Snakeheads have been introduced to the United States through two avenues, the pet trade and the live-food fish trade. Juvenile snakeheads were available in pet stores nation-wide, and were common in live fish markets. Specimens are believed to have been released by owners after they reach an undesirable size, or to create a local population to be harvested for food (Courtenay and Williams 2004). However, all 28 species of snakeheads were listed as injurious fish in 2002 under the Lacey Act. The Lacey Act bans the importation of any live snakehead into the United States, and also bans the interstate transport of these fish. To date, at least 22 states have made it illegal to possess live snakeheads.

The first Massachusetts specimen was collected in Newton Pond in Shrewsbury by the Massachusetts Department of Fish and Wildlife. The likely origin of this specimen is the live-food fish market. The most recent capture of a northern snakehead in Massachusetts occurred in Massapoag Pond, a 353 acre waterbody with outlets eventually feeding into the Merrimack River. This specimen was collected by an angler who reported seeing two specimens “herding” a group of small baitfish. Northern snakeheads are not known to herd baitfish; however, they are known to herd their young. No other specimens have been collected from Massapoag Pond. The northern snakehead has a high probability for spread due to high tolerances of environmental conditions and physiological adaptations, including the ability to live outside of water if kept moist (Courtenay and Williams 2004).

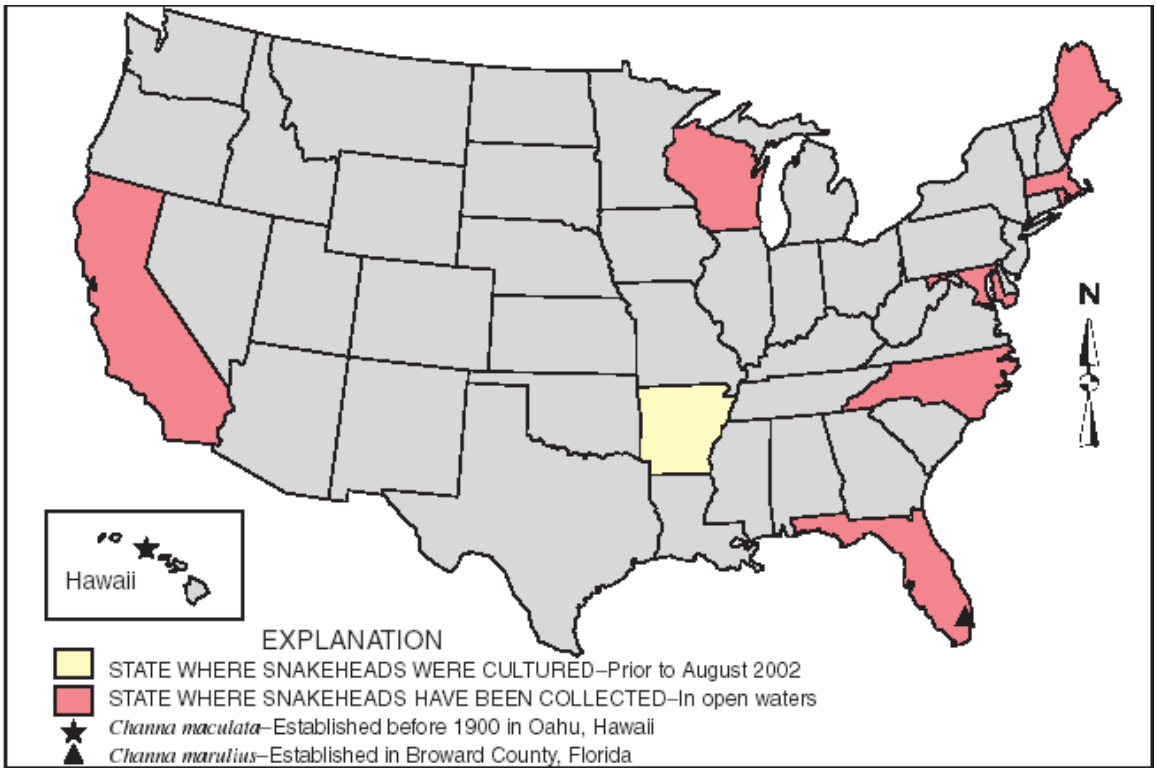

Figure 2 – A map indicating states where snakeheads have been collected. This map is taken from Courtenay and Williams 2004.

Species Ecology

The northern snakehead has the ability to survive a wide range of environmental conditions. They can survive in temperatures ranging from 0 to >30 degrees Celsius (Okada 1960), although optimum growth is achieved at 26°C (Liu et al. 1998). Northern snakeheads prefer stagnant shallow ponds, swamps and slow moving streams with muddy substrates and vegetation (Okada 1960; Courtenay and Williams 2004).

Northern snakeheads are nest builders, and nests are typically circular in shape, 1 m in diameter and located in vegetated areas. Northern snakeheads spawn between one and five times annually (Berg 1965; Dukravets and Machulin 1978). Fecundity in the species ranges from 22,000 to 115,000 eggs (Frank 1970, as stated in Courtenay and Williams 2004; Dukravets and Machulin 1978). Eggs are pelagic, non-adhesive and yellow in color. Eggs hatch after 28 to 120 hours depending on temperature and the larvae are black. Larvae remain in the nest, guarded by one or both parents until the yolk-sacs are absorbed. Parents protect their young until they are approximately 18 mm in length, when aerial respiration begins. At this point the juveniles have developed fins and can fend for themselves (Courtenay and Williams 2004).

Northern snakeheads are voracious feeders (Okada 1960). Post-larval fish feed on plankton and small insect larvae and their diets change to small crustaceans and fish when they reach the juvenile stage. As adults they feed primarily on fishes, but will also eat frogs, crustaceans and aquatic

insects (Dukravets and Machulin 1978). On occasion, northern snakeheads will predate aquatic birds and small mammals. Northern snakeheads are reported to school for feeding, and feeding in this species peaks at dusk and pre-dawn (Courtenay and Williams 2004).

The physiological and ecological characteristics of the northern snakehead allow for competitive advantages over native species. All snakeheads have the ability to breathe air. The advantage to being an air breather is obvious, and snakeheads can live in hypoxic conditions unlike most native species. Unlike some snakehead species, the northern snakehead lacks the ability to migrate over dry land as an adult, but young can migrate over land in areas where some water is present. The temperature tolerance of the northern snakehead gives it the ability to live under ice, ensuring the survival of this species between seasons (Frank 1970, as stated in Courtenay and Williams 2004). Unlike most native fishes, northern snakeheads protect their larvae and offer parental care, giving this species an advantage and increasing survival of larvae through that critical period. As voracious eaters, snakeheads have the ability to consume insects, fish, birds and mammals, yet adults appear to lack any natural predators (Courtenay and Williams 2004).

Detection of Invasion

Most reports of snakeheads in lakes come from fishermen. Fish surveys by the Division of Fisheries and Wildlife, although not frequently performed, may also detect snakeheads. The first step in controlling a snakehead invasion is to determine what species of snakehead is present. Of the four known species in the United States, only the northern snakehead has the ability to survive during the winter months in Massachusetts. If a snakehead is collected, do not release the fish back into the body of water. When a snakehead is collected from a waterbody, an electrofishing survey should be conducted to quantify the extent of the invasion.

There are multiple methods for conducting an electrofishing survey depending on the objective of the survey. To quantify the extent of a snakehead invasion, it is important to be as thorough as time, money and manpower allow. The following steps should be considered when conducting a survey for snakeheads:

1. Acquire a suitable map of the waterbody, preferably with water depth contours.
2. Use the taxonomic information supplied here, or supplementary information from taxonomic guides or fish keys, to identify snakeheads.
3. Concentrate the survey in depths less than 3 meters, as the efficiency of the electroshock gear decreases as depth increases.
4. Concentrate the survey in vegetated areas, as snakeheads prefer vegetation for cover.
5. Perform the survey near dusk or dawn, when snakeheads actively feed in shallow water.
6. If snakeheads are collected, mark the position on a GPS for future reference, and to help pin-point key areas in the waterbody.
7. Do not worry about transects and repeatability of the exact path of the boat. The goal of these surveys will be to collect as many snakeheads as possible from the waterbody and obtain information regarding the extent of the invasion.

Species Confirmation

Unless the invasion is discovered by individuals trained in fish taxonomy, samples or digital photographs should be sent to the appropriate authority to confirm the identification. In Massachusetts, the Department of Conservation (DCR) should be the first point of contact. The DCR can be reached at 617-626-1411 or 617-626-1395. For identification of snakeheads, the photos or specimens should be sent to Dr. Walter Courtenay at the United States Geological Survey in Gainesville, Florida, the leading authority in snakehead invasions. Digital photographs allow rapid identification, and confirmation can be made within minutes. The Division of Fisheries and Wildlife will be notified by the DCR, and is likely to also want the specimen or photos.

Key steps in confirming an invasion include:

1. Collect a specimen of the suspected snakehead and place the fish on ice.
2. Contact the DCR representative at 617-626-1411 or 617-626-1395 and inform him/her that a suspected invasion of snakeheads has been detected in the waterbody. The DCR contact will instruct the caller where to send the sample for confirmation.
3. The sample should be sent as instructed by the DCR representative for confirmation. Note in writing that the enclosed specimen is believed to be a snakehead and include the name of the waterbody, the approximate location where the specimen was collected, the date and time of collection, and the name, address, phone number and email for the collector or sender.
4. The DCR will confirm the identification or provide an alternative identification either directly or indirectly through a recognized taxonomist, and will be responsible for notifying all appropriate agencies, municipalities and citizen groups either potentially affected or responsible for the follow-up actions.

Quantifying the Extent of Invasion

During the identification process a field crew or multiple field crews should be mobilized to quantify the extent of the snakehead invasion. The first step in the quantification process is to determine if the species is isolated within a waterbody. If the body of water contains avenues for the species to move to other waterbodies, these avenues must be identified. If the organism is not isolated, it must be determined how far it has spread or could have spread from the probable introduction site or the detection site. To determine if the organism is isolated or how far it has spread, the most rapid and effective assessment techniques are electroshocking and seining. The main goal of these surveys is to cover as much of the waterbody as possible. Less concern should be placed on a transect method for repeatability, and more concern should be placed on covering the maximum amount of area possible. The most important aspect of these surveys is to determine if the population of snakeheads in the waterbody is established and reproducing or if the introduction is a single or small group of fish. Through the use of electroshocking and seining, agencies will also get an idea of the native species assemblage in the waterbody being surveyed and can use this information when considering possible management techniques.

Species Threat Summary

The native range of northern snakeheads and their temperature tolerance indicates their ability to survive and reproduce within the lower 48 states. This species has the ability to establish itself and reproduce inside the United States (Courtenay and Williams 2004). The ecology and physiology of snakeheads gives them competitive advantages over native species. The four major advantages of snakeheads are large temperature tolerance ranges, a low oxygen requirement, the ability to breathe air, and high fertility with protection of young. Introduced populations of northern snakehead are more likely to be contained within lakes and reservoirs as opposed to streams and rivers.

As voracious predators, the impact of northern snakeheads on the local ecology of streams, rivers, lakes or reservoirs could be drastic. The diet of northern snakeheads consists mainly of fish; therefore, negative impacts to native fish populations could be high. Predation on crustaceans could also be very high. Impacts to rare, threatened and endangered species could be very high if snakeheads are introduced into a waterbody with listed species. Although impacts on other fish species may be high, negative impacts to the physical habitat would be low (Courtenay and Williams 2004). In addition, snakeheads may introduce parasites and disease to native fish populations. Ecosystem balance could be modified due to establishment of snakeheads. Luckily, there appears to be no chance for snakeheads to hybridize with native fishes within the United States (Courtenay and Williams 2004).

It is difficult to predict the economic impacts of a snakehead introduction on the recreational or sport fishing industry. However, over time an introduction could be detrimental to the sport fishing industry due to predation on sport fish. One economic impact that can be estimated or put into perspective is the cost of eradication efforts. The most recent and best example of a northern snakehead invasion and the associated eradication costs is the Crofton, Maryland case. In Crofton, Maryland, snakeheads had been introduced to a single pond at least two years prior to discovery in 2002. The cost of two meetings, herbicides, rotenone, and fish disposal was approximately $110,000 (Courtenay and Williams 2004). The Crofton, Maryland pond was roughly 4 acres in size with an average depth of 4-5 feet. Disregarding physical limitations, financial limitations on eradicating snakeheads in large lakes with connecting drainages may be severe (Courtenay and Williams 2004).

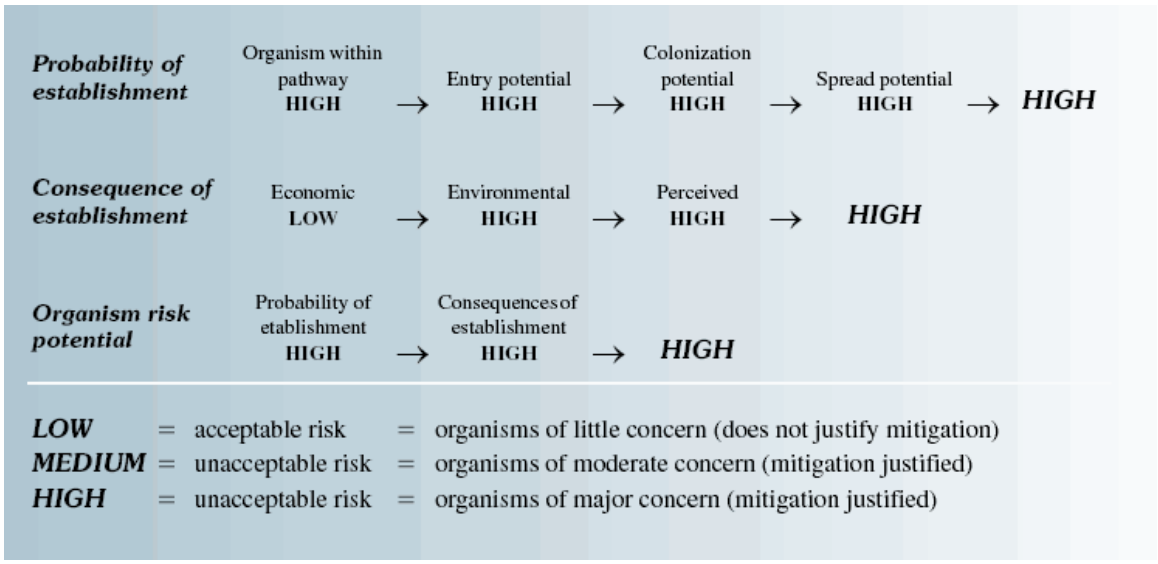

Figure 3 – A risk potential diagram for snakeheads, taken from Courtenay and Williams 2004.

Communication and Education

Preventing and detecting the invasion of northern snakeheads into native waters starts with education of the public, specifically fishermen. For fishes, the first line of defense is often the angler who catches an unusual or strange fish. Education of anglers and the public could be undertaken with a short, concise and easily understood pamphlet or information card. These cards and pamphlets could be made available to the public, and handed out to fishermen each time a fishing license is sold or a boat is registered. This education material would notify anglers of the potential for snakeheads to invade waters of the Commonwealth and give the angler the capability to identify a snakehead should one be caught. Included on the pamphlet should be phone numbers and contact information for the agencies involved with non-indigenous species management.

When an invasion is identified and confirmed it is critical to notify the public and all appropriate stakeholders through the appropriate outlets (i.e., television and radio news, newspaper, bait and tackle shops, boat ramps, town meetings, lake association meetings, etc.) and suggest appropriate actions should a specimen be encountered. Groups who should be informed about the infestation include any active waterbody association, property owners, boaters, anglers, swimmers and any other group of individuals that come in contact with the waterbody.

It is desirable to post access points with warning signs even before an invasion, displaying a picture or drawing of a northern snakehead and asking the waterbody users to be on the lookout for this invasive fish. A local contact (name and phone number) for notification should be given, typically either a representative of a state agency or the town's Conservation Commission, or both. Users should be advised to humanely kill the specimen and keep it for identification. It should be stressed that users should not return this fish to the waterbody from which it was collected. After an invasion has been discovered, access points should be posted with a warning to users. Again, a picture or drawing of a northern snakehead should be provided.

Educating the public is very important, especially since people often move and transport fish. Larger species of snakeheads are popular with anglers in their native and introduced ranges, so the probability of anglers transporting snakeheads to new locations is real. The ability to breathe air and their ability to survive transport by air on land as long as they are kept moist facilitates intentional introductions by anglers.

Responsibility for control of snakeheads does not rest with any one entity under the laws of the Commonwealth of Massachusetts. Approval for control actions may involve the Massachusetts DEP, Division of Fisheries and Wildlife (DFW) and/or the Natural Heritage and Endangered Species Program, all agencies of the Commonwealth, depending upon the resources in the waterbody (particularly if protected species are known from the waterbody). Other agencies and approval programs may apply, depending upon the features of the waterbody (naturally large enough to be a statutory Great Pond), the location of the waterbody (e.g., in an Area of Critical Environmental Concern), or the uses of the waterbody (e.g., as a water supply). However, none of these agencies is charged with controlling invasive species, and there is no legislation in Massachusetts that mandates control of snakeheads. The DCR has taken the lead in Massachusetts with regard to encouraging control of invasive species, and supports control efforts as its budget allows. However, outside of the state parks and reservations, control is largely a function of local desire to protect and maintain the resource, and possibly action by the DFW.

For waterbodies within DCR parks, the following notification procedures are to be followed when a new infestation by snakehead has been confirmed:

1. The DCR contact responsible for confirming the snakehead invasion will notify the DCR Regional Director, Park Supervisor and any regional DCR contact charged with managing water resources. A single letter copied to each party is preferred. The letter should briefly state the problem and outline immediate control steps that are needed, indicating an expected date for a follow up visit by Lakes and Ponds Program staff to begin concerted control measures (see posting procedures below).
2. The DCR contact responsible for snakehead introduction confirmation will also notify the DEP, the DFW and the NHESP in writing; a copy of the letter sent to DCR parties is sufficient. If a contact for an associated citizens' lake or watershed organization is known, notification should be given to that group as well.
3. The Regional Director or a designated park contact for local affairs will notify the town(s) in which the park and waterbody are situated. The appropriate parties within the town(s) to be notified may vary by town, but should include the Conservation Commission and either the Selectmen, Town Manager or Mayor, depending upon local government structure.

For waterbodies within DCR parks, the following posting procedures are to be followed when a new introduction of snakeheads has been confirmed:

1. All access points to the waterbody (e.g., boat launches, swimming areas, fishing piers or obvious shoreline fishing points) shall be posted with a photograph or drawing of a snakehead and a written notice that this invasive plant has been found in the waterbody.

2. Suggested language is as follows: Warning. Northern Snakeheads (*Channa argus*) have been found in this waterbody. This invasive fish represents a threat to this waterbody and its users. Caution should be exercised to avoid the spread of this fish. If caught, do not return this fish to the waterbody, and do not transport this fish to other waterbodies. Keep the fish on ice and contact us immediately.
3. Include a contact name and phone number on all postings.

Quarantine Options

Identification and assessment of expansion routes needs to be undertaken immediately after identification of an introduction. These expansion routes must be accounted for, and methods to prevent or slow expansion need to be undertaken to reduce the spread of the organism. The use of sequestering curtains or screens can be used to restrict access to new connected waterbodies. If the infestation occurs in a lake or pond with outlets, the outlets should be screened to minimize the export or migration of snakeheads to downstream areas. This may be problematic where leaves or other debris are abundant enough to clog such screens, necessitating frequent cleaning. Rotating screens or other automated outflow restrictors are effective but expensive.

In large water bodies with multiple outlets, or in streams and rivers, eradication or stopping the spread of the species may be extremely difficult. There are no management or quarantine options for controlling a snakehead infestation of a stream or river, and options for large lakes or reservoirs are limited. When an introduction is detected in one of these waterbodies, managers should focus on slowing the expansion of the species.

Land ownership and access may hinder or slow the response process. In one snakehead invasion case, the rapid response of the state was hindered by personal property rights. The state had to obtain permission from the landowners to eradicate the northern snakeheads in the pond (Walter Courtenay, personal communication). When an introduction is identified, the responding agencies must ensure that proper permissions are granted and obtained so the management plan can be implemented as quickly as possible.

It may be necessary to close the lake to human uses if there is reason to believe that humans are likely to transport snakeheads to other aquatic systems, but this is usually not appropriate. It may even be beneficial to encourage fishermen to catch snakeheads, as long as proper disposal can be guaranteed (as with a volunteer effort supervised by the DFW or other appropriate group).

Control of Infestations

The potential control methods for a snakehead infestation are limited, but vary with each specific infestation site. Early eradication options and techniques for control of established infestations are similar, but the details of potential options will be dictated by the size and characteristics of each waterbody.

1. **Do-nothing approach** – This option entails doing nothing with regard to eradication or removal of the specimens. With species of snakeheads other than the northern snakehead, this option may be suitable, as these species are unlikely to overwinter, but for the northern snakehead this is not a desitrable option. Northern snakeheads have the ability to over-winter in northern climates. Waiting will increase the probability of these fish reproducing or being transferred to other waterbodies.
2. **Drawdown** – If the infestation is within an impoundment with water level control capability, drawdown may be a viable control technique. Removing all water from a lake or pond and allowing them to dry may eliminate the snakehead infestation; however, this technique involves many technical and biological issues. A drawdown of the lake or pond would result in damage to many desirable plant and fish species. An effort could be made to capture and relocate desirable species, but this would be an expensive and lengthy undertaking. Impoundments that are spring fed may be difficult to keep dry and the snakeheads may survive in the moist bottom sediments if any water is allowed to remain. The water would have to be filtered or otherwise treated to ensure no small eggs or larvae escape. Use of a holding facility or disposed in an area where surface drainage to another waterbody can't occur (e.g., ground water infiltration) is an alternative control. All of these approaches would be time consuming and expensive.
3. **Physical removal** – Physical removal of the fish using nets, traps, angling, electrofishing or biological control by introduction of predators are not likely to be successful for large infestations. If the infestation is believed to be limited to a few individuals the above techniques may be successful in removing the target organisms. Even with a few individuals, it may be difficult to determine if the eradication was 100% successful. One advantage of physical removal is minimal impact on native and desirable species, as these methodologies can be selective.
4. **Piscicides** – The final control and eradication option is the application of a piscicide to the infested waterbody. The most common piscicide and one that has proved successful against northern snakeheads is rotenone. Rotenone is effective in killing fish if applied in the correct doses and well mixed throughout the water column. Rotenone rapidly degrades and there is no lasting toxicity from treatment. Rotenone is most effective in water with limited amounts of vegetation. In waterbodies with high amounts of vegetation, removal of vegetation with an herbicide may enhance the effectiveness of the rotenone treatment. Lab trials of rotenone on snakeheads collected from the Crofton infestation proved successful. Treatment of the Crofton pond with rotenone was a complete success and proved that rotenone is effective against a northern snakehead infestation. However, rotenone is not a selective piscicide and is effective against nearly all species of fish, native and non-native. The major drawback of treating with rotenone is the loss of native fish species along with the target species. Endangered species within a waterbody may be impacted by this technique. However, every fish species may be impacted by the introduction of northern snakeheads. In many cases, rotenone may be the only option to eradicate the population and ensure these fish do not spread to other waterbodies. While rotenone has been used in Massachusetts to reset the fish community in the past (up until about the 1970s), it is currently not approved for use in Massachusetts. Regulatory action would therefore be necessary to add this tool for eradicating snakeheads in Massachusetts.

The aforementioned control techniques can all be very expensive, and the expense of these undertakings alone may limit the ability of the state and public agencies to combat an infestation. In many cases, eradicating an introduced population may not be possible with a high degree of certainty, and instead the control and management of the infestation may be the target goal. In these cases, it becomes a management issue and every effort should be made to control or slow the movements of these fish to other waterbodies.

Each infestation must be handled separately, and the characteristics of each waterbody will dictate which management tools are appropriate. In large lakes, reservoirs or in streams and rivers, eradication of the infestation may be functionally impossible. Physical and financial limitations of the above control techniques will limit their use to small impoundments,

Prevention of Re-Infestation

Once an invasion has been repulsed through any of the above methods, it should be apparent that the waterbody is susceptible to snakeheads. In some cases, complete eradication may not be possible, but in the case that eradication is successful it is important to take steps to prevent re-infestation. Educating the public is the most important step to combating a re-infestation. Key steps to educating the public may include:

- Education through the lake association or town for all users about the threat of snakeheads, how to identify them, and who to contact if one is found. See the other sections in this document for relevant information to be provided.
- Posting of all access points with signs warning of the threat, showing how to identify snakeheads, and urging fishermen to harvest these fish and report their catches to the appropriate agency. See the section on Communication and Education in this document.

Summary

1. The northern snakehead (*Channa argus*) is a non-native fish identified by its cylindrical body, long anal and dorsal fins, blotchy color pattern, and eyes set forward on the head.
2. Northern snakeheads are native to Asia, and were popular in the aquarium and live-food fish markets of the United States. To date, they have been collected in eight states, including Massachusetts, but introduction of this species is now outlawed on a federal level.
3. Northern snakeheads are highly predatory, with no natural enemies within the United States. As voracious eaters, with diets consisting mainly of fish, they may have serious impacts on native fish populations.
4. Northern snakeheads are air breathers, and adults protect their young for the first month of life, giving them two competitive advantages over most native species.
5. Northern snakeheads are most often detected and reported by fishermen.
6. After detection, the source of the introduction must be identified and an attempt to quantify the extent of the infestation must be undertaken. Where possible, the introduction site should be quarantined and blocked off. This will impede the movement of snakeheads to new bodies of water.

7. Eradication of the northern snakehead may be physically and financially very difficult for large lakes and reservoirs, as well as moving water of streams and rivers.
8. Management options include physical removal, lake drawdown and dry-out, and piscicides such as rotenone. Each method has benefits and drawbacks, and the specific circumstances will affect which option(s) can be applied.
9. The do-nothing approach may be justified if the snakehead species is not northern snakehead; only the northern snakehead is known to overwinter in the New England climate.
10. Educating user groups about the impacts of northern snakeheads, and giving them the ability to identify suspected fish and contact the appropriate authorities, is critical. Literature should be developed and handed out with each fishing license and boat registration sold in Massachusetts. Along with the education literature, warming signs should be posted in areas with high angling and boating traffic to inform the public of the dangers of northern snakeheads.

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