Tennessee
Aquatic Nuisance Species
Management Plan

Developed by the
Tennessee Aquatic Nuisance Species Task Force

September 2007

Tennessee Wildlife Resources Agency
Nashville, Tennessee

Acknowledgments

In addition to the research and deliberations by the Tennessee Aquatic Nuisance Species Task Force to develop this plan, several members wrote specific sections the document. Their voluntary efforts were extraordinary. Special thanks to:

Dennis Baxter, Tennessee Valley Authority - Problem definitions, aquatic animal descriptions, glossary
Mark Fagg, Tennessee Wildlife Resources Agency - Introduction, program monitoring and evaluations
Frank Fiss, Tennessee Wildlife Resources Agency - Aquatic plant descriptions
Becky Gunn, Tennessee Wildlife Resources Agency - Task Force minutes and meeting preparations
Terri Hogan, National Park Service – Aquatic plant descriptions
Don Hubbs, Tennessee Wildlife Resources Agency-Goals and objectives, aquatic animal descriptions
Sue Lanier, Tennessee Wildlife Resources Agency - Maps, pathway descriptions, strategies and action plans
Steve Nifong, Tennessee Wildlife Resources Agency - Goals and objectives, state law summaries
Anni Self, Tennessee Department of Agriculture - Problem definitions, program monitoring and evaluation
Jeff Simmons, Tennessee Valley Authority - Aquatic animal descriptions
Greg Spradley, Tennessee Comptroller's Office - Existing authorities, program monitoring and evaluation, executive summary
David Webb, Tennessee Valley Authority - Problem definitions, aquatic plant descriptions
Carl Williams, Tennessee Wildlife Resources Agency - Strategies and action plans
Bobby Wilson - Introduction, pathway descriptions, executive summary
David Withers, Tennessee Department of Environment and Conservation - Problem definitions, pathway descriptions

Special thanks to Marilyn Barrett-O'Leary, Southeast Aquatic Resources Partnership, for advising TANSTF throughout the development period and assisting with the final draft.

Executive Summary

Tennessee is one of the most bio-diverse states in the nation. Currently there are 315 species of fish, 77 mammals, 56 reptiles, 70 amphibians, and 340+ birds known to inhabit or migrate through Tennessee. The number of invertebrate species, many of which are endemic to Tennessee, is equally impressive with 256 land snails, 99 aquatic snails, 120+ mussels, 77 crayfish and many insects. The state has three major river systems (Mississippi, Tennessee, and Cumberland Rivers) which contribute to 700,000 acres of impounded reservoirs and 19,000 miles of streams. Together these waters and biota support rich ecological and economic systems for the benefit of plants, animals, and people.

Aquatic nuisance species (ANS) pose serious problems to the ecology and economy in Tennessee. This management plan will guide Tennessee towards the development of coordinated actions to respond to such problems. This document is an adaptive plan, to be updated periodically as new techniques for prevention are identified and developed.

Over a period of approximately two years, the Tennessee Aquatic Nuisance Species Task Force (TANSTF) examined the existing ecological health of the state's aquatic habitats, identified needs and existing tools for responding to ANS problems within the state. It ranked 22 invasive or potentially invasive plant species and 30 animal species, identifying the pathways by which each was introduced into Tennessee. Based upon all of this information, the TANSTF set goals and objectives, and proposed strategies for action.

The main focus of this ANS management plan is to prevent new introductions. Prevention requires some regulations and a wide variety of communication and education efforts. Many, but not all, are described in this document. Prevention however, will only assist in reducing the number of new species entering Tennessee waters. Management and control of existing nuisance species must also be undertaken to limit their negative impacts. Strategies for management and control are also described.

The goal of this plan therefore is to control existing aquatic nuisance species in Tennessee in order to minimize the adverse impacts on native species, water quality, and economies by preventing the introduction and spread of any invasive species and by managing the impacts of those that are already in Tennessee. To accomplish this goal, the Tennessee ANS task force identified two major objectives:

1. Prevention of new aquatic nuisance species, and
2. Management of existing aquatic nuisance species.

There are 26 strategies and 67 actions listed in the plan to address the objectives. Some of the first actions are anticipated to be the development of educational materials such as pamphlets, posters, DVDs, and an ANS web site; hiring a statewide ANS coordinator; improving enforcement and regulations that prohibit the possession, purchase, and transport of ANS in Tennessee; developing a rapid response plan to control or eradicate priority ANS populations; and developing plans and coordinate responses with full partner participation.

The TANSTF recognized that implementation of this plan has to be evaluated in order to progress towards achieving the goal, and that funding will be necessary to accomplish many of the tasks. Evaluation will be shared by leaders in the agencies with primary jurisdiction over wildlife and resource issues related to ANS – the Tennessee Wildlife Resources Commission, the Tennessee Department of Environment and Conservation, and the Tennessee Department of Agriculture. The information upon which evaluation will be based will be provided by the ANS Coordinator. Securing and hiring a person to fill that position will be one of the first actions taken after the management plan has been approved. The funding mechanism, undoubtedly including partnerships, will be developed by the ANS Coordinator.

This plan was written to meet the requirements of Section 1204 (a) of the Nonindigenous Aquatic Nuisance Species Prevention and Control Act (NANPA) of 1990. It will be submitted by the Governor of Tennessee to the National Aquatic Nuisance Species Task Force for their approval and acceptance. It will, more importantly, provide guidance for the prevention, management and eradication of aquatic nuisance species that threaten the waters of the Volunteer State, our native inhabitants, and their recreational, commercial, and other public uses.

Approval of this plan will allow the Tennessee Wildlife Resources Agency, the lead agency in the plan development process, and its partners to apply for federal grants and other assistance to implement the various strategies described in this document.

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I. Introduction

Tennessee is blessed with an abundance of waters, yet some of these waters are in trouble. The state is one of the most biodiverse states in the nation, supported by a wide range of aquatic habitats such as ponds, lakes, reservoirs, wetlands, streams and seven of the most ecologically rich river systems in North America (TWRA, CWCS, 2005, p.4). These waters, along with many others in these United States, face challenges from nuisance aquatic plants and animals. The aquatic invasive species among those nuisance plants and animals pose a threat to Tennessee's waterways and other aquatic environments, both economically and ecologically.

An aquatic invasive species is defined as a nonnative plant or animal that is likely to cause economic and/or environmental harm, and some may cause harm to human health as well. Other terms used in place of "invasive" may include "nuisance, alien, nonindigenous, exotic, and undesirable." Examples of these in the United States include the sea lamprey in the Great Lakes, giant salvinia in the marshes of Louisiana, and the snakehead fish in the Potomac River.

Not all nonnative plants and animals are considered invasive. In fact, some nonnative fish, such as brown trout and striped bass, are considered by some to be desirable and highly sought after in Tennessee. However, such is not the case with most nonnative species of plants and animals in our state. There are currently over 79 nonnative aquatic species of plants and animals reported in Tennessee, with the likelihood that many more species are present but have yet to be detected or reported (USGS NAS website, 2006).

Some of the more problematic aquatic nonnative species in Tennessee include zebra mussels, Eurasian water milfoil, and Asian carp (USGS NAS website, 2006). Although they are more of a concern in the Great Lakes region, zebra mussels have impacted some areas of Tennessee economically by fouling intake pipes, and ecologically by competing with the native mussels for food and habitat. Zebra mussels are transported to other aquatic environments, often unknowingly, by boat owners through live wells, boat hulls, and boat trailers.

Eurasian water milfoil provides excellent cover for many species of fish, however, its ability to grow and proliferate makes it a nuisance to boaters and dock owners, as was the case in several reservoirs along the Tennessee River a few years ago. Invasive submersed plants such as this are often accidentally spread from one waterbody to another by clinging to outboard motors and boat trailers.

Asian carp, including the grass, silver, bighead, and black carp, cause ecological problems. Grass carp eat native aquatic vegetation that is also needed and desired by waterfowl. Bighead and silver carp compete directly for plankton with native fish such as paddlefish, larval sport fish and buffalo fish. Silver carp also pose a threat to human health due to their leaping ability, colliding into boaters, water skiers, and personal watercraft when startled. These species, already abundant in the Mississippi River, have been found in the Cumberland and Tennessee river systems as well. Similar in appearance to our native shad species of fish, juvenile bighead and silver carp can easily be accidentally spread in bait buckets to other waterbodies by anglers. The black carp, though not yet found in Tennessee waters, has the potential to devastate the state's native mussel populations. These large fish feed heavily on mussels and snails. Tennessee is home to over 123 species of freshwater mussels, 46 of which are on the federal threatened and endangered species list (TWRA CWCS, 2005).

Other nonnative, non-game species of concern include aquatic reptiles or amphibians (such as snakes, turtles, frogs or salamanders) brought into Tennessee from other states or countries as well as exotic snail species that are usually transported through the pet trade or aquatic garden business and crayfish used as bait or educational tools. Many exotic gastropods (snails, slugs), crustaceans and herptafauna (reptiles and amphibians) can harbor parasites, which can potentially affect human health.

Aquatic nuisance species (ANS) have the potential to negatively impact all types of fishing and musseling. In addition, many of the most problematic nonindigenous plants and animals in Tennessee were introduced or spread through sport fishing, commercial fishing, waterborne commerce, or aquarium and water garden hobbies. It is estimated that the economic impact of sport fishing in Tennessee during 2001 was over 1.1 billion dollars (U.S. Fish&Wildlife Service, 2001). The estimated wholesale value of commercial fishing is $2.7 million (TWRA Strategic Plan, Commercial Fish, 2006) and commercial musseling is $1.5 million dollars (Hubbs, TWRA Commercial Mussel Report, 2005).

The call to action to curb the introduction and spread of ANS was initiated in 1990 with the passage of the Nonindigenous Aquatic Nuisance Prevention and Control Act (NANCPA) that was later amended by the National Invasive Species Act of 1996. In addition to coordinating action to prevent new introductions and control existing populations, the Act also authorized each state to develop a comprehensive management plan, which must be approved by the National ANS Task Force. Each state must identify areas and/or activities within the state for which technical, enforcement, and/or financial assistance is needed to eliminate or reduce the environmental, public health, and safety risks associated with aquatic nuisance species. Plan approval makes the state eligible for federal financial assistance for implementation.

The recently completed Strategic Plan for the Tennessee Wildlife Resources Agency (2006-2012) identifies aquatic nuisance species as a problem in five of the 19 programs (commercial mussels, large rivers, non-game/endangered species, reservoirs, and streams). Strategies for addressing these problems ranged from monitoring the spread of ANS to preventing their introduction. A common strategy among all five programs was the development of a statewide aquatic nuisance species management plan.

In February 2005, Tennessee Governor Phil Bredesen approved the formation of a task force to develop a management plan for aquatic nuisance species. The Tennessee Aquatic

Nuisance Species Task Force (TANSTF), with members representing governmental as well as non-governmental interests, met for the first time on March 22, 2005. The initial task force consisted of members representing the Tennessee Department of Environment and Conservation, the Tennessee Department of Agriculture, the Tennessee Department of Safety, the Tennessee Wildlife Resources Agency, the Tennessee Comptroller's Office, the Tennessee Valley Authority, the U.S. Army Corps of Engineers (Memphis District), the University of Tennessee Knoxville, the Tennessee Exotic Plant Pest Council, Trout Unlimited, the Tennessee Striped Bass Association, and the Southeast Aquatic Resources Partnership. In the process of identifying ANS problems and threats and proposing prevention and control strategies, TANSTF identified gaps in the authorities and programs associated with ANS. These gaps result from diversity of jurisdiction. No single agency or group has complete responsibility for preventing and controlling ANS within the state of Tennessee. The members of the TANSTF and their affiliations are listed in Appendix G.

The development of this plan was the result of many hours of meetings and correspondence among stakeholders and partners. The plan provides information on existing ANS in Tennessee and describes strategies to control them. Details in this document focus on a five-year period. As a living document, this plan will be revised periodically in response to changing ANS conditions. Because the plan was developed by many stakeholders, its recommendations lay the groundwork for cooperative activities between governmental and nongovernmental organizations to reduce the impacts of aquatic invasive species in Tennessee. This document is designed to meet the requirements of Section 1204(a) of the Nonindigenous Aquatic Nuisance Species Prevention and Control Act (NANPA) of 1990, as reauthorized in the National Invasive Species Act (NISA) of 1996.

The goal of this plan is to control existing ANS in Tennessee in order to minimize the adverse impacts on native species, water quality, and economics by preventing the introduction and spread of any invasive species and by managing the impacts from those that are already in Tennessee.

II. Problem Definition

Species and Pathways

The wildlife, natural habitats, people, and economy of the state of Tennessee are threatened by aquatic invasive plants and animals. These are nonnative and native species outside of their native range that have disrupted ecological and/or economic aquatic systems upon which Tennesseans depend. In most cases, ANS were able to disrupt these systems because of specific physiological characteristics common in most invasive species: they produce large numbers of offspring (high fecundity), reach sexual maturity quickly, adapt easily to a wide range of environments and available food sources, and tolerate a broad range of geophysical conditions. In addition, their natural predators are not present to control the new population.

The Tennessee Aquatic Nuisance Species Task Force (TANSTF) has identified certain plants and animals that threaten or have harmed some element of the state's aquatic environment, and ranked them to assist in developing prevention and control strategies for this ANS management plan (Table 1). Some of the identified animals are native to other areas of North America, while others are native to other continents. Individual descriptions of the biology, distribution and harmful impacts of each of these species can be found in Appendix A. A detailed description of the species ranking processes can be found in Appendix B.

The TANSTF noted that certain pathways appear to facilitate the introduction and spread of the problem species. It developed management strategies that focus on the pathways of introduction in relation to the specific species.

Pathways can be defined as "the means by which species are transported from one location to another." These "means" can be natural or man-made, accidental or intentional, and include many activities, media, and occurrences. The effects of pathways on ANS distributions are shaped by Tennessee's geographical location as an interior state and its geological composition. The state's diverse habitats occur in mountain ranges, cave networks, and bottomland hardwood forests, which are all linked, nourished, and strengthened by major and minor rivers (TWRA, CWCS, 2005 p.4). Preventing the introduction and spread of ANS requires strategies that consider these pathways.

Are some pathways more important to ANS spread in Tennessee? The TANSTF conducted a ranking process to answer this question. Through this process, which is described in detail in Appendix B, the following pathways were identified as important for ANS management in Tennessee. They are described below in order of importance, according to their existing and potential impacts on the state's ecology and economy, and on the health of Tennessee's people.

Accidental Pathways Transporting Invasive Species in Tennessee

Recreational Boating

Tennessee has three major river systems (Mississippi, Tennessee, and Cumberland Rivers) which contribute to 700,000 acres of impounded reservoirs and 19,000 miles of streams. Because they provide water to the people, animals and plants in the state to some extent, these and other Tennessee's waters should be protected from the introduction of invasive ANS. Protection is difficult because these waters are also major locations for recreational boating and associated activities, pathways for spreading ANS.

1. Recreational vessels

In 2005, Tennessee registered over 265,000 mechanically powered vessels, ranking it 18th in the nation and 2nd highest of any non-coastal or Great Lakes state for total boats registered (TWRA Strategic Plan 2006-2012, March 2006). The recreational boating pathway has several components that make it one of the most common pathways for the spread of ANS in the State of Tennessee. These components include live wells, boat trailers, propellers, boat hulls, and bait buckets. Many invasive aquatic species, such as zebra mussel larvae, spiny water fleas, and juvenile silver carp, may survive in the live well of a boat long enough to be released into another body of water if it is not properly cleaned and rinsed before moving from one waterbody to another. Undesirable aquatic vegetation like hydrilla and Eurasian watermilfoil can be snagged on a boat trailer or entangled in a boat propeller and accidentally transported into another water body if not removed before leaving a contaminated lake or river. Zebra mussels will attach to a boat's hull if it is left in the water long enough, and they can survive on a hull several days out of water while being transferred to another location.

2. Bait distribution

Because of its association with recreational boating and angling, the bait distribution pathway is an important consideration for ANS management in Tennessee. Some boating anglers using live bait can accidentally introduce an ANS such as the juvenile silver carp mixed with other live native bait fishes when releasing leftover or unused live bait into an aquatic system where the species does not exist. Popular live baits in striped bass tournaments are the blueback herring and alewife, two fish species identified by the TANSTF as ANS in Tennessee. In addition to recreational boating anglers and other fishermen may unintentionally introduce invasive species such as the rusty crayfish from their bait buckets into a lake or river without such ANS populations.

Bait dealers sometimes receive and unknowingly distribute brook stickleback minnows in shipments with live, wild-caught fathead minnows from some northern states. Brook stickleback is an ANS identified by the TANSTF.

3. Fishing gear

Many Tennessee anglers travel to other parts of the country and beyond to pursue their hobby, while other anglers come to Tennessee, most carrying their own fishing gear. Some trout enthusiasts fish in out-of-state waters that are contaminated with invasive species such as the New Zealand mud snail, didymo, or zebra mussels. These and other highly fecund ANS are able to live for long periods out of the water. Transfer of only a small number of animals or fragments of an invasive plant can be enough to establish new populations. Such introductions into Tennessee waters will occur if anglers fail to clean their fishing gear before leaving a contaminated fishing location. Likewise, visitors can unknowingly bring these or other ANS into this state unless they thoroughly clean all gear, from boots to reels, before entering Tennessee.

Natural Forces

Tennessee's waters are at the root of natural pathways for spreading ANS. Five major watersheds are part of the state of Tennessee – the Mississippi River, Tennessee River, Cumberland River, Barren River, and Conasauga River. Portions of these watersheds are interrupted by man-made locks and dams while others are connected by canals and waterways. Most of these watersheds contain some disturbed habitats that are ideal for invading species. All but the Barren River system have documented problems with aquatic invasive species (TWRA, CWCS, 2005, pp. 130-130). Although spread of ANS through natural forces associated with these waterbodies is not preventable, it can be managed by educating the people associated with them.

1. Interconnected waterways

Few states have the extensive network of locks and canals that operate within Tennessee. Some were constructed many years ago by agencies such as the Tennessee Valley Authority to allow the free movement of vessels for commerce and industry. But these same networks can block or promote the movement of fishes and floating materials. The networks remove the physical barriers that would prevent invasive species from migrating from one waterbody to another. These same locks and canals also facilitate accidental transport of ANS on recreational boats and fishing gear, and on commercial vessels and barges. At the same time, the locks and dams can confine species to particular areas, slowing the spread of an invasive species.

2. Pond breaches

Ponds serve as drainage basins, water sources, aquaculture catchments, ornamental gardens, and fishing holes. Some are purposefully stocked; others contain species that naturally occurred in them. All are vulnerable to spreading their species during flood events. ANS, like nonnative carp species stocked in isolated ponds, have escaped into public waterways during flood events. Exotic watergarden plants have floated into public waterways, disrupting or even destroying existing ecosystems.

3. Waterfowl

Tennessee supports abundant and varied populations of resident and migratory waterfowl. However, waterfowl such as ducks and geese may be responsible for dispersing ANS plants. Seeds and plant fragments may be ingested or attach to their feet and feathers. Additionally, waterfowl hunters may pick up nonnative plants or animals on their boots or gear and carry them to new locations (Figuerola J. et al. 2003).

Commercial and inland shipping

Commercial shipping is nationally ranked as the number one pathway to spread ANS. This rank is based upon the huge volume of waterborne commerce and shipments of 'exotic' cargo to markets around the world, resulting in both accidental and deliberate transfer of ANS during repeated transoceanic transport. Although commercial shipping occurs in Tennessee's three major navigable waterways (Tennessee River, the Cumberland River and the Mississippi River), its cargo is primarily domestic, and the vessels move mainly between North American inland ports. Thus, the commercial shipping pathway is significant but not the number one pathway for introducing and spreading ANS in Tennessee.

Discharges and hull fouling from commercial vessels, towboats and barges are the major media for accidental aquatic introductions through inland navigation in Tennessee. Anchors, bumpers, and ropes may also carry ANS. Zebra mussels have been dispersed throughout the Mississippi River drainage system by hitchhiking on the hulls of barges moving through these waterways. Although metal hulls and anti-fouling paints can make vessels less susceptible to hull fouling by hitchhiking species, they are not complete deterrents. Raw water intakes and cooling systems in commercial vessels can contain zebra mussel veligers

Exhibit 1. Major waterways in Tennessee.

(larvae) and other aquatic species that can be discharged into uninfested waters (Allen, 1998). Although the National Invasive Species Act of 1996 (NISA) has developed guidelines to prevent aquatic species introduction via ballast water by requiring all vessels that enter U.S.

territorial waters to manage ballast water according to prescribed measures, these guidelines have little impact on commercial shipping in Tennessee, which has no coastline. Because of its volume in Tennessee, commercial barge traffic is the primary vector of transport to large rivers, but pleasure craft will also continue to provide a pathway for spreading some ANS into Tennessee's waters.

Intentional Pathways Transporting Invasive Species in Tennessee

Many nonnative species cause no ecological or economic problems, and they do not threaten human health. Some of these are actually important to development, industry, and other human endeavors. However, sometimes these benign species become problematic after a period of time. Knowledge of nonnative species and their interactions in various habitats can provide information for carefully controlling such introductions and preventing such problems. Before the intentional introduction of any nonnative species through commercial endeavors is allowed in Tennessee, a thorough review and environmental assessment of potential impacts should be conducted carefully to avoid the spread of problem species. The TANSTF has noted that ANS have been intentionally introduced through the following pathways, and identified methods to manage these pathways to minimize accidental spread.

Live stock and commerce

1. Fish/plant stockings

Occasionally ANS are stocked by people not knowing the serious effects that these organisms may have on the ecology of the affected water systems. Alligator weed, a low spreading, aquatic plant with white flowers, may be planted along the shoreline of a public reservoir near summer homes, but its invasive characteristics will help it flourish and expand along the shoreline and into the lake to form sun-blocking, floating mats. (Invasive & Exotic species website; USDA Forest Service website, USGS 2006)

On some occasions, people unintentionally stock invasive plants and animals through intentional actions. Aquarists not wanting to kill their overgrown aquatic pet may release it into a lake or river. In Maryland, this resulted in the release of a snakehead (Family *Channidae*), a very competitive and invasive fish. Resident anglers originally from other states have stocked a fish species from a former state such as yellow perch into a lake or pond in an effort to establish a local sport fish population. Bass anglers have intentionally stocked aquatic vegetation such as hydrilla to increase the amount of cover in a water body. These actions ultimately rendered these waterbodies less useful for angling and boating.

In 1976, the Tennessee Wildlife Resources Agency intentionally stocked alewives into Watauga Lake in east Tennessee to provide more tolerant forage species for walleye and smallmouth bass. Although negative effects on native fish were not known at the time, reduced recruitment of subsequent walleye year classes was later attributed to the alewives (TWRA, Warm water Stocking Report, 1964-2006).

2. Aquarium & water garden trades

Pet and garden stores sell nonnative species. "Exotic" is profitable. These plants and animals can be released intentionally or unintentionally into the natural environment, where they establish populations that compete with native species. Sometimes unwanted plants or fish are improperly dumped into aquatic systems. Invasive plants and fish can also contaminate local streams or ponds during flooding. Many of these unwanted species cannot overwinter in their new environment, but those that survive compete with native species, becoming ANS.

3. Aquaculture industry

Although many ANS have wreaked havoc on aquatic ecosystems in the U.S., some of these same species live in aquaculture facilities in and around Tennessee. Black carp are being utilized to control snail populations in catfish ponds in some southeastern states. They can spread into water systems through flooding or release and eventually end up in Tennessee waters. Invasive aquatic plants such as dotted duckweed and curleyleaf pondweed may be included accidentally with a shipment of fish from hatchery ponds and stocked into a body of water without a population of such ANS. The Tennessee Department of Environment and Conservation has some jurisdiction over introductions of new species on public lands (see Chapter IV), but unintentional movement is beyond their control.

Even though possession of live silver and bighead carp is illegal in Tennessee, federal commerce laws allow their transport by interstate highways through the state. Vehicular accidents can lead to the escape and development of an ANS population. In 1996 a transport vehicle hauling 12,000 pounds of live bighead carp from Arkansas to an Asian food market in New York overturned on Interstate Highway 81 in Virginia. The local fire rescue crew salvaged some of the fish by placing them in a local farm pond and requested permission to stock others in South Holston Lake (Pers. Com. Gary Martel, Virginia Dept. of Game and Inland Fisheries).

Ranking: Aquatic Plants, Animals, and Pathways

Twenty-two species of aquatic flora (21 vascular plant species and one species of algae) were ranked in order of importance by a TANSTF committee consisting of Jack Raney (University of Tennessee – retired), Anni Self (Tennessee Department of Agriculture) and David Webb (Tennessee Valley Authority). Thirty species of aquatic fauna (22 species of fish, five species of mollusks, and five species of crayfish) were similarly ranked by a TANSTF committee consisting of Dennis S. Baxter (Tennessee Valley Authority), Bobby Wilson and Carl E. Willams (both Tennessee Wildlife Resources Agency).

Five criteria were used:

1. Ecological Impacts – potential to impact aquatic ecosystems based on literature, discussions with colleagues, field observations and personal experience;
2. Current Distribution and Status – documented current distribution in Tennessee (i.e., how widespread is this species within the State);
3. Trend in Distribution and Abundance – anticipated spread of this species within the next ten years;
4. Management Difficulty – difficulty in controlling this species (primarily with the use of mechanical apparatus, pesticides, molluscicides, and herbicides) including availability of proven management techniques and a need for repetitive and ongoing treatments;
5. Economic Impact – ability to negatively impact the economy of Tennessee based on historical information from within the State or the potential to negatively impact the economy of Tennessee based case histories from adjacent regions.

Each species was given a relative numerical ranking of 1, 2 or 3 for each of the five criteria with 1 being the lowest impact and 3 being the highest impact. The committee members ranked each species independently for each criterion. A mean for the three independent rankings was then calculated for each criterion and the five means (i.e., one for each criterion) for each species was summed to give a composite score (See Table 1).

Some of the species in this table have not yet actually affected the ecology and/or economy of the state, but their impacts in neighboring states or in similar ecological and or economic systems raised awareness of the need to prevent their establishment or spread to Tennessee waters.

The pathways also were ranked and composite scores also are listed in Table 1 below. Appendix B also contains a detailed description of the pathways ranking process.

Table 1. Species and pathways of concern for ANS management in Tennessee

	Plants & Animals		Boating, bait, angling	Commercial shipping	Aquaculture & stocking	Garden & pet trades	Natural forces
Rank	**Species**	**Score**	**Pathways**				
1	Hydrilla	13.67	X		X	X	X
2	Brittle naiad	13.33	X		X	X	X
3	Silver carp	12.33	X		X		X
4	Eurasian watermilfoil	12	X	X	X	X	X
5	Bighead carp	11.67	X		X		X
6	Western mosquitofish	11.5	X		X	X	X
7	Purple loosestrife	11.33				X	
8	Didymo	11.33	X				
9	Round Goby*	11.33	X	X	X	X	X
10	Zebra mussel	11	X	X			X
11	New Zealand mud snail*	11	X				
12	Rusty Crayfish	11	X	X			X
13	Redbreast Sunfish	10.5	X		X	X	X
14	Yellow Perch	10.5	X		X		X
15	Common carp	10.33			X		X
16	Black carp*	10	X		X		
17	Reed Canary grass	9.67	X	X			X
18	Northern Snakehead*	9.67				X	X
19	Rudd*	9.5		X		X	
20	Alligatorweed	9.33	X	X		X	X
21	Asiatic clam	9.33	X	X	X	X	X
22	Ruffe*	9.33					X
23	Watercress	9				X	X
24	Blueback Herring	9	X		X		X
25	Virile crayfish	9	X		X	X	X
26	Swamp eel*	9			X		X
27	Brazilian elodea	8.67	X			X	
28	Common reed	8.67			X		X
29	Alewife	8.67	X		X		X
30	Peppermint	8.33					X
31	Giant Salvinia	8.33	X	X		X	X
32	Parrot's feather	8.33	X			X	X
33	Pale yellow iris	8				X	
34	Uruguayian primrose	8	X				
35	Eastern mosquitofish	8	X		X	X	X
36	Chinese mystery snail	8	X		X	X	X
37	Snail bullhead*	8	X				X
38	Flat bullhead*	8	X		X		X
39	Curley-leaf pondweed	7.67	X		X		
40	Asian spiderwort	7.67					X
41	Spearmint	7			X		X
42	Water clover	7				X	X
43	Water hyacinth	6.67	X	X	X	X	X
44	White catfish	6.5	X		X		X
45	Grass carp	6.33			X		X

Table 1. continued							
	Plants & Animals		**Boating, bait, angling**	**Commercial shipping**	**Aquaculture & Stocking**	**Garden & pet trades**	**Natural Forces**
Rank	**Species**	**Score**	**Pathways**				
46	Water lettuce	6	X		X	X	
47	Dotted duckweed	6	X	X		X	X
48	Channeled apple snail*	6	X		X	X	X
49	Margined madtom	5.5	X		X		
50	Cumberland crayfish	5	X				
51	White river crawfish	5	X				
52	Brook stickleback*	5	X		X		X
53	Red swamp crawfish				X		
54	Inland silverside						X
55	Bigclaw crawfish		X				

*Potential threat to Tennessee. Not yet present in state.
X= a pathway of introduction.

III. Goals & Objectives

To reduce or reverse problems asspciated with ANS, the TANSTF has set the following goal:

Goal: To manage ANS in Tennessee to minimize adverse impacts on native species, water quality, and socio-economics.

Much effort is needed to accomplish this goal. The TANSTF proposes two overarching objectives to be supported by multiple strategies:

Objective 1: Prevention – To prevent the introduction of any nonnative invasive species in Tennessee and to prevent existing invasive species from spreading to other watersheds in Tennessee.

Objective 2: Management – To manage priority aquatic invasive species in Tennessee to minimize their impacts on native species, aquatic habitats, socio-economics and water quality.

IV. ANS Authorities and Programs

Existing authorities, laws, and regulations in Tennessee will play a significant role initially in minimizing adverse impacts of nonindigenous aquatic species, preventing new introductions, and managing those species already designated as priority by the relevant agencies. However, Tennessee state laws relating to nonindigenous species cannot be discussed without a basic understanding of federal authorities. The policies regarding nonindigenous species are controlled and enforced by a network of regulatory agencies and organizations. An overview of state and federal legal authorities relating to ANS are included in this section of the plan. A more detailed summary of relevant state laws and rules relating to ANS is in Appendix C. A list of prohibited animals and plants in Tennessee is in Appendix E.

Division of Authorities

State and local efforts play a large role in controlling the spread of nonindigenous species. States have authority to decide which species can be imported and/or released within their borders. However, the United States Constitution vests the power to regulate interstate commerce to Congress. Therefore, federal law may preempt state law in some cases, but for the most part, states retain the power to specify which species are imported and/or released. In addition, interest generated from state and federal policy stimulates action by nongovernmental organizations. This section of the Tennessee ANS Management Plan will describe this somewhat flexible division.

Major Agencies With ANS Responsibilities

Tennessee is unique in that a number of agencies have some degree of jurisdiction or control over the various waterways in the state. Several of these agencies have some level of enforcement authority. Others manage the waterways for varying purposes (See map, Exhibit 2 below) and employ biologists to monitor and (in some cases) manage aquatic life within their respective jurisdictions for purposes of complying with environmental and conservation-related laws and regulations. The work of Tennessee Valley Authority biologists, for example, adds a different perspective to the work done by state agencies. The major players with regard to managing aquatic resources in Tennessee include:

The Tennessee Wildlife Resources Agency (TWRA) – The TWRA has the legal responsibility to manage fish and other aquatic animals in all waters of the state, public and private. The agency also operates a number of family fishing lakes, boat ramps, wildlife management areas, and refuges dependent on productive water resources and healthy aquatic ecosystems (State of Tennessee, 70-1-301 & 302; Tenn. Comp. Rules & Regs. Title 1660, Ch. 1-17.01).

The Tennessee Department of Environment and Conservation (TDEC) – This agency has jurisdiction over designated natural resource areas (State of Tennessee, 11-14-101 &104). Primarily through the Division of Natural Areas (Tenn. Comp. Rules & Regs. Title 0400, Ch. 2-8.25), Division of State Parks (Tenn. Comp. Rules & Regs. Title 0400, Ch. 2-2.13), and the Division of Water Pollution Control (Tenn. Comp. Rules & Regs. Title 1200, Ch. 4-3.01; State of Tennessee, 69-3-101 & 103), TDEC has the legal responsibility for protecting and maintaining native plant species, while managing exotic invasive plant species in all waters of the state.

The Tennessee Department of Agriculture (TDA) – This department may play a limited role in enforcing animal importation laws through its Agricultural Crime Unit (http://www.tennessee.gov/agriculture/crimeunit/index.html). It has been used to regulate the introduction of domestic (food) animals for production. The Division of Regulatory Services, which regulates nurseries, greenhouses, and plant dealers (State of Tennessee 43-6-101, 102 & 104; Tenn. Comp. Rules & Regs. Title 0080, Ch. 0080-6-24), may play a limited regulatory role with regard to exotic aquatic plants. Under this authority, inspection has been used primarily to prevent introduction of insect pests or plant diseases. It could be used to prevent introduction of invasive plant species as well. TDA has, in the past, also occasionally imposed regulations on the importation of specific plants in cooperation with the USDA-Animal and Plant health Inspection Service (APHIS). The action protected Tennessee from introduction of specific plant diseases or pests that had been identified and restricted by APHIS (http://Tennessee.gov/agriculture/suddenoak.pdf). Vigorous use of this authority might assist in preventing the introduction of invasive plants into Tennessee.

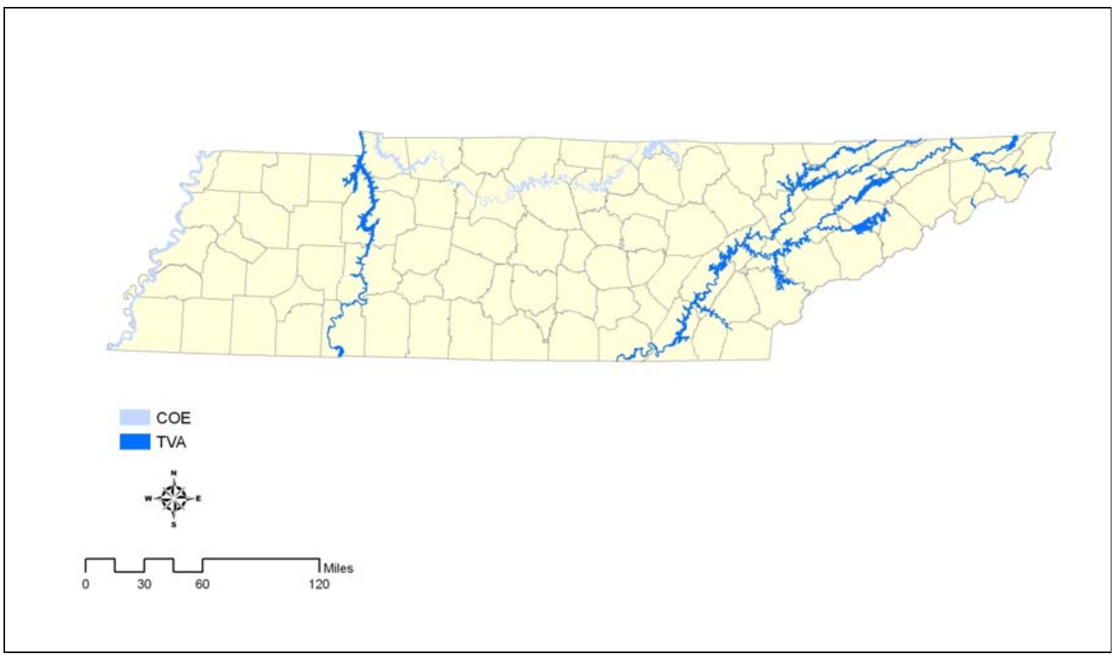
The Tennessee Valley Authority (TVA) – The TVA is a power corporation and a federal agency. It manages the entire Tennessee River system for power generation, flood control, navigation, water supply, recreational, and biological purposes. TVA's system of dams, locks, and reservoirs provide habitat for multitudes of aquatic species, both native and nonnative, as well as control mechanisms and potential pathways for ANS introductions (i.e., Tennessee Tombigbee Waterway). It employs biologists who monitor the agency's impact on aquatic ecosystems throughout the Tennessee Valley and work to mitigate any negative impacts while continuing to fulfill the agency's primary missions. One example of such work is a research project examining the effectiveness of strobe lights to prevent impingement of aquatic life on TVA water intakes. TVA biologists work to improve water quality by collecting and sharing data, identifying problems, and working with the Tennessee Valley's citizens to achieve solutions. (TVA website, http://www.tva.gov/environment/water/index.htm)

The U.S. Army Corps of Engineers (USACE) – This federal agency's engineers, scientists and other specialists work hand in hand as leaders in engineering and environmental matters. Staffs of biologists, engineers, geologists, hydrologists, natural resource managers and other professionals execute the corps' mission to provide engineering services to the nation, including planning, designing, building and operating water resources and other civil works projects, such as the spillway at Reelfoot Lake and levee system on the Mississippi River. Corps biologists review permit applications for water resource projects, as well as other permits including those necessary to dredge U.S. waterways for sand and gravel. They sometimes treat waterbodies to control nonindigenous species, as it relates to navigation. The

COE's environmental program has two major focus areas: restoration and stewardship. Efforts in both areas are guided by the Corps environmental operating principles, which help balance economic and environmental concerns. (COE website, http://www.corpsresults.us/environment/default.htm)

The U.S. Fish and Wildlife Service (USFWS) - The U.S. Fish & Wildlife Service works primarily with state wildlife agencies to conserve, protect, and enhance fish, wildlife, and plants and their habitats for the continuing benefit of the American people. The agency provides policy assistance, technical assistance, and other guidance, while also allocating excise tax revenues to the states and providing grants and other financial assistance for fish and wildlife programs throughout the nation. For example, Tennessee received $ 7,268,842 in federal Sport Fish Restoration funds through the USFWS for fiscal year 2006. A portion of these funds may be used for aquatic education, also, perhaps relating to preventing the spread of ANS. (USFWS website, http://federalasst.fws.gov/apport/SFRFINALApportionment2006.pdf)

Exhibit 2: Map of general areas of authority for Tennessee Valley Authority (TVA) and U.S. Army Corps of Engineers (USACE) in Tennessee's Waterways



Shared Jurisdictions Among State Agencies

Tennessee Animal Programs and Regulations

In Tennessee, the aquaculture trade is regulated at both the state and federal levels, with permits required for importation. Because of permitting requirements, aquaculture is the more regulated pathway of nonindigenous introductions when compared to the aquarium trade (State of Tennessee, 70-2-212; 70-2-221; Tenn. Comp. Rules & Regs. Title 1660, Ch. 1-15.01 & 1-26.02). The Tennessee Wildlife Resources Agency regulates aquarium trade on a more limited scale as the law requires no permit to import fish held in aquaria. The agency lists in its rules as “Class V” wildlife (injurious to the environment) “all nonnative freshwater aquatic life” except goldfish, triploid grass carp, all salmon species, and all species approved for fish farming. The Law Enforcement Division of the agency enforces other rules and laws relating to aquatic life held in aquaria. (State of Tennessee 70-4-403 et seq; Tenn. Comp. Rules & Regs. Title 1660, Ch. 1-18.03).

Currently few state regulations and programs exist concerning the regulation of non-indigenous animals. Tennessee regulations addressing the introduction of nonindigenous species include Rule 1660-1-18-.03, which places animals in various classes, including Class V wildlife designated by the Wildlife Resources Commission (in conjunction with the Commissioner of Agriculture) as injurious to the environment. A list of those animals is in Appendix C. TWRA, under state law, has jurisdiction over all importation of live wild animals, and existing regulations governing such importation (State of Tennessee 70-4-401).

The Department of Environment and Conservation (TDEC) has jurisdiction over designated natural resource areas, which include many aquatic resources potentially vulnerable to invasive species. This agency also enforces rules establishing control of and prohibiting the introduction of exotic species within these natural resource areas. Any control activities, by rule, must be provided for in a master plan adopted for each area. Note that the rules specifically state that the TWRA will be consulted in matters of management or control of wildlife populations (Tenn. Comp. Rules & Regs. Title 0400, Ch. 2-8.25). TDEC’s Division of State Parks prohibits the transplanting or introduction of any live fish or eggs in to the waters of any park (Tenn. Comp. Rules & Regs. Title 0400, Ch. 2-2.13) .

TDEC’s Division of Water Pollution Control is the primary enforcement authority for the Clean Water Act in Tennessee. The act makes it unlawful to alter many characteristics of waters of the state, including the biological characteristics, which may be applicable to the introduction of exotic aquatic species (Tenn. Comp. Rules & Regs. Title 1200, Ch. 4-3.01; State of Tennessee, 69-3-101 & 103).

The Department of Agriculture plays a limited enforcement role through its Agricultural Crime Unit. This unit enforces state laws, rules and regulations relating to the import of animals into the state, but primarily deals with agricultural livestock rather than aquatic species (Tennessee Dept. of Agriculture website, http://www.tennessee.gov/agriculture/crimeunit/index.html).

Tennessee Plant Programs and Regulations

TDEC’s jurisdiction over natural resource areas and state parks with regard to exotic animals also extends to exotic plants (State of Tennessee, 11-14-101 & 104; Tenn. Comp. Rules & Regs. Title 0400, Ch. 2-8.25). In addition, the Department of Agriculture’s Division of Regulatory Services, which regulates nurseries, plays a role with regard to exotic plants. The division inspects plant dealers in the state, which sometimes sell aquatic plants. Rules define pest plants as injurious to agricultural, horticultural, silvicultural, or other interests of the state. The Rules include a list of designated pest plants, but it currently includes only a few which may be considered aquatic (Tenn. Comp. Rules & Regs. Title 0800, Ch. 6-24; Tennessee Department of Agriculture, plant certification jurisdiction website http://www.tennessee.gov/agriculture/regulate/plants/index.html). Among these are two species of concern in Tennessee, *Salvinia molesta* (giant salvinia) and *Lythrum salicaria* (purple loosestrife). A complete list of these plants is in Appendix E.

TDEC administers funds derived from the sale of the "Iris Tag," a license plate depicting Tennessee's state cultivated flower. These may help in the battle against aquatic invasive plants. Since 1993, purchases and renewals have amounted to over $1.4 million. For the first two years, TDEC earmarked receipts for purchase of equipment and maintenance of parks. In June 1995, an amendment shifted the fund's purpose to cover the planting of native trees and shrubs for landscape maintenance. Finally, in February 1997, the Tennessee State Parks' Program Services Section was authorized to administer the fund to all Tennessee State Parks for the task of exotic pest plant removal. It is primarily intended to encourage the use of native plants in State Parks. Although the program has focused primarily on terrestrial plants, it could provide funding and services for managing or eliminating aquatic exotic plants as well (Tennessee State Parks Specialty Plate information described online at http://tennessee.gov/environment/parks/specplate.shtml).

The Tennessee Exotic Pest Plant Council (TN-EPPC) is a non-governmental agency with a direct interest in preventing and controlling invasive species. Since its organization, TN-EPPC has educated stakeholders and the public by hosting statewide annual symposia, and giving presentations at similar conferences. TN-EPPC publishes a newsletter, an educational brochure, and has held numerous workshops. The organization has also published the Tennessee Exotic Pest Vegetation Manual and the Tennessee Invasive Exotic Pest Plant list for Tennessee, though it has no legal effect. TN-EPPC serves as a technical advisory body and has participated in cooperative efforts to reduce the use of nonnative plants in Tennessee by federal and state government agencies. TN-EPPC is also a member of the National Association of Exotic Pest Plant Councils (Tennessee Exotic Pest Plant Council information online at http://www.tneppc.org).

Current Known Gaps in Tennessee's Authorities & Programs for ANS

Although these programs and associated jurisdictions are essential for the management of ANS in Tennessee, existing gaps reduce their effectiveness. A description of some of the known gaps and impediments includes:

1. A central collection point for information on ANS and methods for maintaining that information in an easily accessible format (including GIS) for those agencies and individuals who need it;
2. Central repository for research on ANS including monitoring current and encouraging new control methods, efficacy of control methods, economic and ecological damage from introductions, and benefits of controlling ANS;
3. Central coordination of disjointed official efforts to manage ANS and an institutionalized structure to maintain cooperative efforts and information sharing;

4. State-wide public education and information efforts geared toward preventing uninformed introduction of exotic invasive species to the state (through pet stores, nursery operations, big box retailers, hunting and fishing regulations, boater education, bait stores, and other contacts with citizens);
5. Institutionalized monitoring of markets for ANS;
6. Institutionalized regular monitoring of the aquatic pond plant and pet trade;
7. Rapid response mechanisms and pre-approved permits necessary for rapid eradication;
8. Institutionalized mechanism for coordinating responses to new introductions and managing existing populations; and
9. New regulations to prevent the commercial sale of nonnative aquatic species that have the potential to be invasive.

Federal Regulations

The current federal management of ANS is a patchwork of laws, regulations, policies, and programs. At least 20 agencies are currently involved in researching and controlling nonindigenous species. Table 2 outlines the responsibilities of a number of these government agencies and summarizes their current role in the control of introduced species. Federal laws which apply directly to the introduction of nonindigenous species include the Lacey Act, the Federal Noxious Weed Act, the Federal Seed Act, the Nonindigenous Aquatic Nuisance Prevention and Control Act of 1990, and the National Invasive Species Act of 1996. The full text of these laws will not be included in this report, though copies may be requested from the TWRA. The Endangered Species Act also has indirect application when an ANS is shown to threaten or endanger the survival of a federally listed species. (See Tables 2 & 3)

International Laws and Treaties

International agreements signed by the United States government are considered law at the federal level. A small number of treaties signed by the US, as well as some international agreements under the auspices of the United Nations may affect Tennessee's strategies to prevent and control aquatic invasive species. These are summarized in Appendix D of this plan.

Table 2. Federal Agencies Responsibilities in Transport of Live Aquatic Products
(Adapted and updated from Olson and Linen 1997 and Washington State Aquatic Nuisance Species Management Plan, September 2001.)

	Restrict Movement Into U.S	Restrict Interstate Movement	Regulate Product Content or Labeling
Plants	APHIS	APHIS	APHIS
	DOD	AMS	AMS
	Customs Border Protection	DEA	
Fish	FWS	FWS	FWS
	Customs Border Protection		
	USCG		
Invertebrates	APHIS	APHIS	FWS
	FWS	FWS	
	ARS		
	PHS		
	Customs Border Protection		
	USCG		

Table 3. List of abbreviations and descriptions of authority referenced in Table 2.	
Organization	**Description**
APHIS EXPLANATORY NOTE: Under the legislation that created the Dept. of Homeland Security, APHIS maintained responsibility for establishing the regulations that govern the importation of agricultural and forest products, and Customs Border Protection became responsible for conducting the actual inspections at ports of entry. APHIS retained inspections authority for propagative plant material.	The Animal and Plant Health Inspection Service, U.S. Department of Agriculture, has broad mandates related to the importation and interstate movement of foreign plant pests and exotic species, under the Plant Protection Act of 2000 and several related statues. The primary concern is species that pose a risk to agriculture crops and protection of natural resources and the environment. In cooperation/coordination with Customs Border Protection, restricts the movement of foreign plant pests and pathogens into the country by inspecting, prohibiting, or requiring permits for the entry of agricultural products, seeds, live plants and animals, and forest products such as lumber and wood packing material. Restricts interstate movements of agricultural plant pests and pathogens by requiring movement permits and imposing domestic quarantines and regulations when necessary. Restricts interstate transport of noxious weeds under the Federal Noxious Weed Act.
AMS	The Agricultural Marketing Service, U.S. Department of Agriculture, works closely with states in regulating interstate seed shipments. Regulations require accurate labeling and designation of “weeds” or “noxious weeds” conforming to the specific state's guidelines.
ARS	The Agricultural Research Service, U.S. Department of Agriculture, the research branch of USDA, conducts and funds research on the prevention, control, or eradication of harmful nonnative species often in cooperation with APHIS. Projects include aquaculture techniques and disease diagnosis and control.
DEA	The Drug Enforcement Agency restricts imports of a few nonnative plants and fungi because they contain narcotics substances.
DOD	The Department of Defense has diverse activities related to nonnative species. These relate to its movements of personnel and cargo and management of land holdings. Armed forces shipments are not subject to APHIS inspections. Instead, the DOD uses military customs inspectors trained by APHIS and the Public Health Service.
FWS	The Fish and Wildlife Service, U.S. Department of the Interior, has responsibility for regulating the importation of injurious fish and wildlife under the Lacey Act. Maintains a limited port inspection program. In 1990, FWS inspectors inspected 22 percent of the wildlife shipments at international ports of entry. Interstate movement of state–listed injurious fish and wildlife is a federal offense and therefore potentially subject to FWS enforcement. Also provides technical assistance related to natural resource issues and fish diseases to state agencies and the private sector (aquaculture in particular). Helps control the spread of fish pathogens.
NOAA and NMFS	The National Oceanic and Atmospheric Association and National Marine Fisheries Service, U.S. Department of Commerce, inspect imported shellfish to prevent the introduction of nonnative parasites and pathogens. Cooperative agreements with Chile and Australia; Venezuela has requested a similar agreement.
PHS	The Public Health Service, U.S. Department of Health and Human Services, regulates entry of organisms that might carry or cause human disease.
CBP	Customs Border Protection, U.S. Department of Homeland Security. CBP personnel inspect passengers, baggage, and cargo at U.S. ports of entry to enforce homeland security regulations and the regulations of other federal agencies. They inform interested agencies when a violation is detected and usually detain the suspected cargo for an agency search.
USCG	The Coast Guard, U.S. Department of Homeland Security, was given certain responsibilities under the Nonnative Aquatic Nuisance Prevention and Control Act of 1990, relating to preventing introductions (mostly dealing with ballast water exchange).

V. Strategies and Action Items

The goal of the Tennessee Aquatic Nuisance Species Management Plan, to manage ANS in Tennessee to minimize adverse impacts on native species, water quality, and economics, can be achieved through actions supporting two objectives.

Objective 1: Prevention of new ANS

To keep out any nonnative invasive species in Tennessee and to prevent existing invasive species from spreading to other watersheds in Tennessee.

Strategy 1

Education/Public Awareness: Educate about the harmful effects of ANS and how to prevent introductions and spread.

* Strategy 1A. Promote ANS awareness within the public school system.

Actions

1A1. Develop and publish instructional materials such as workbooks, PowerPoint presentations, and instructional DVD's.
1A2. Work with and encourage educational groups such as the TSTA (Tennessee Science Teachers Association) and Project CENTS (Conservation Education Now for Tennessee Students) to promote ANS awareness. Add ANS awareness to TN Content Standards for Science Curriculum.

* Strategy 1B. Create an educational campaign focusing on informing the general public about ANS.

Actions

1B1. Develop pamphlets, posters, and fliers for general distribution promoting ANS awareness, i.e., SARP.
1B2. Build and maintain an ANS Website.
1B3. Utilize mass media such as TV, e.g., TN Wildside, newspaper, magazine, and radio to promote ANS awareness.
1B4. Develop partnerships with watershed associations for education at local level.

* Strategy 1C. Develop an educational program that specifically targets users most likely to encounter or spread ANS.

Actions

1C1. Incorporate ANS prevention training in boating safety and education classes.
1C2. Continue to develop and include ANS information within the TWRA fishing regulations guide.
1C3. Post signs at boat docks, boat ramps and kiosks utilizing resources available through programs such as "Stop Aquatic Hitchhickers" http://www.protectyourwaters.net/.
1C4. Provide organized fishing clubs with general prevention procedures recommended by

"Stop Aquatic Hitchhikers" to prevent the spread of ANS.
1C5. Utilize Habitatitude program to educate aquarium and water garden wholesalers, retailers and hobbyists.

* Strategy 1D. Actively promote ANS awareness within the commercial aquatic industry.

Actions

1D1. Include ANS prevention in training for barge pilot licensing.
1D2. Explore methods to assure that educational material be provided to consumers of products of the aquatic pet and water garden industries. (Might require legislation and/or partnership.)
1D3. Work with bait industry to prevent distribution of ANS.
1D4. Develop and provide educational material such as HACCP (Hazard Analysis Critical Control Point) to the aquaculture industry through the TSA (Tennessee Aquaculture Association).
1D5. Cooperate with and provide educational material to commercial fishermen.

Strategy 2

Early Detection: Develop an early detection plan to promptly identify, eradicate, or contain pioneering ANS populations.

* Strategy 2A. Develop "in house" programs that would aid in the early detection of ANS.

Actions

2A1. Train field personnel and resource managers to correctly identify, collect and record essential data on ANS species encountered.
2A2. Develop reporting protocol to submit ANS records to central authority (ANS Coordinator).
2A3. Instruct field survey units to incorporate an "ANS Watch" during routine fish, benthic, mussel, and plant surveys.
2A4. Conduct periodic fish, benthic, crayfish, mussel, and plant surveys targeting specific ANS likely points of introduction, e.g., trout tailwaters streams for the New Zealand mud snail.
2A5. Utilize HACCP (Hazard Analysis and Critical Control Point) training at state and federal hatcheries and during stocking activities.

* Strategy 2B. Foster public involvement in ANS detection.

Action

2B1. Encourage and provide a method for citizens to report occurrences of ANS, e.g., hotline.

* Strategy 2C. Monitor commercial trade and recreational use of ANS.

Actions

2C1. Work with the commercial fishing industry to detect ANS occurrences through training (ANS Coordinator).
2C2. Develop plans to monitor the pet trade, bait, and water garden industries to prevent

distribution of ANS (ANS Coordinator).
2C3. Monitor bait used for striped bass tournaments; encourage use of native species of bait.

* Strategy 2D. Foster interagency cooperation in monitoring ANS.

Action

2D1. Conduct cooperative surveys with local, state, and federal agencies to detect new or expanding populations of ANS (ANS Coordinator).

Strategy 3

Information Management: Coordinate the compilation and management of ANS information.

* Strategy 3A. Identify ANS that pose an immediate threat to aquatic resources of the state.

Actions

3A1. Hire statewide ANS Coordinator.
3A2. Incorporate ANS occurrences into the Tennessee Aquatic Database System (TADS).
3A3. Maintain a priority list of ANS (ANS Coordinator).
3A4. Search existing collections and data bases for recent and historic records of ANS (ANS Coordinator).
3A5. Coordinate and share all ANS data at the local, regional, as well as national level (ANS Coordinator).

* Strategy 3B. Create a repository and documentation process for all ANS occurrences in Tennessee watersheds.

Action

3B1. Ensure submission of voucher specimens to appropriate institutions (museum collections and herbaria) (ANS Coordinator).

* Strategy 3C. Monitor ANS vectors.

Action

3C1. Maintain a list of ANS pathways (bait distribution, fish culture and distribution, water garden and aquatic pet industries etc.) (ANS Coordinator).

* Strategy 3D. Use current technology to monitor changes in ANS occurrence.

Action

3D1. Continue to develop GIS distribution analysis.

* Strategy 3E. Provide comprehensive information on current ANS activities.

Action

3E1. Ensure good dissemination of information by producing an ANS annual report (ANS Coordinator).

Strategy 4

Regulation: Support existing regulations and enact new legislation to control the collection, cultivation, distribution, importation, possession, propagation, purchase, sale, transport and introduction of ANS in Tennessee.

* Strategy 4A. Identify legislation that controls ANS and parties responsible for administering such legislation.

Actions

4A1. Maintain a comprehensive list of all current state and federal laws regulating ANS (ANS Coordinator).
4A2. Determine a clear line of regulatory authority for ANS groups (plants and animals). (Also supports tasks in Objective 2, Strategy 1A)

* Strategy 4B. Determine actions implemented by border states to control ANS.

Action

4B1. Evaluate existing regulations of border states that share drainages with Tennessee and coordinate actions when possible (ANS Coordinator).

* Strategy 4C. Ensure that regulations are in keeping with current ANS trends and threats.

Actions

4C1. Continue to update the "Banned in Tennessee" species list (ANS Coordinator).
4C2. Conduct a comparative analysis study for an "Approved Species" list verses the "Banned in Tennessee" list (ANS Coordinator).

Strategy 5

Research: Support research on ANS and develop a system to effectively disseminate ANS information among managing agencies and academic institutions.

* Strategy 5A. The economic impact of ANS in Tennessee is undetermined - Conduct research to fully understand the potential impacts of ANS to Tennessee.

Actions

5A1. Fund economic and ecological impacts research of ANS in Tennessee.
5A2. Evaluate the cost/benefit of control or eradication of priority ANS.

* Strategy 5B. In order to control ANS in Tennessee, protocols and methods need to be developed to effectively manage or eradicate ANS with minimum impact to native ecosystems.

Actions

5B1. Fund research to develop effective methods of control or eradication of priority ANS.
5B2. Carefully evaluate potential harm to non-target species by chosen control methods (ANS Coordinator).
5B3. Fund laboratory studies to determine potential for competitive exclusion of ANS by native species and vice-versa.
5B4. Monitor ANS research projects of other states (ANS Coordinator).
5B5. Continue to support research relating to threatened and endangered species restoration (e.g., Barrens Topminnow).
5B6. Support research to determine limiting factors for growth and survival of priority ANS.

Objective 2 – Management of existing ANS

To manage priority invasive species in Tennessee in order to minimize their impact on native species, economics, and water quality.

Strategy 1

Rapid Response: Develop a rapid response plan to control or eradicate detected priority ANS populations.

* Strategy 1A. Assemble an interdisciplinary committee to complete the following actions.

Actions

1A1. Create a permanent mechanism to apply control and eradication methods developed through research where ANS populations pose risk to ecology and economies of Tennessee (Interdisciplinary committee led by ANS Coordinator).
1A2. Identify existing agency expertise and resources that can respond to new or expanding ANS populations (Interdisciplinary committee led by ANS Coordinator).
1A3. Identify ANS impacting native rare and endangered species (Interdisciplinary committee led by ANS Coordinator).
1A4. Identify actions to eradicate or control pioneering ANS populations (Interdisciplinary committee led by ANS Coordinator).
1A5. Establish rapid response mechanism and pre-approved permits necessary for rapid eradication (e.g. herbicide or pesticide application, habitat alteration etc.) (Interdisciplinary committee led by ANS Coordinator).

Strategy 2

Enforcement

* Strategy 2A. Identify all legalities and enforcement issues associated with ANS.

Actions

2A1. Identify all affected law enforcement divisions, what role they will play and who will be the contact person (Law Enforcement Divisions).
2A2. Coordinate enforcement cases between agencies (Law Enforcement Divisions).
2A3. Examine case histories of successful prosecutions in other states (Law Enforcement Divisions).

* Strategy 2B. Maintain a high level of control in regulating ANS.

Actions

2B1. Conduct surveys to track range expansion of established or naturalized populations of priority ANS.
2B2. Enforce existing laws pertaining to ANS.

Strategy 3

Intrastate/Interstate/International Cooperation: Collaborate on ANS projects with all managing agencies and user groups at local, state, regional, and national levels.

* Strategy 3A. Ensure all governing agencies are aware of jurisdictions and responsi-

bilities in managing ANS.

Actions

3A1. Continue a comprehensive review of each managing agency's rules and regulations to ensure cross-compliance (ANS Coordinator).

Strategy 4

National Environmental Policy Act (NEPA) Compliance: Ensure compliance with NEPA.

* Strategy 4A. Ensure that all agency responses to ANS meet requirements under NEPA.

Action

4A1. Frequently review NEPA policy in order to maintain continuity and proper authority in managing ANS (ANS Coordinator).

* Strategy 4B. Ensure that all consultation with governing agencies is conducted in ANS management issues and that public and private sectors are informed and allowed to comment on proposed actions.

Actions

4B1. Develop plans and coordinate responses with full partner participation, including reviews of state and federal air, water, wetland, wildlife, and endangered species regulations.
4B2. Coordinate public input as appropriate or required by law. Prepare alternatives analysis based on best available scientific data.
4B3. Evaluate potential for third-party water projects in Tennessee or adjoining states to impact distribution or abundance of ANS in Tennessee.

Strategy 5

Restore Native Species

* Strategy 5A. Address native species impacts resulting from ANS.

Actions

5A1. Support restoration of native species into areas where ANS have caused or coincided with decline.
5A2. Establish threshold criteria for reintroduction of native species of proper genotype.
5A3. Maintain database of restoration sites and periodically survey to determine success.

* Strategy 5B. Be proactive in preventing ANS from impacting Threatened or Endangered species or their habitat.

Actions

5B1. Periodically monitor populations of rare and endangered species currently impacted by ANS (e.g., current project to protect barrens topminnow; see Appendix A).
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Implementation Table

The following table is a summary of the strategies and actions. It is the opinion of the TANSTF that Strategy 3A1 (Hire statewide ANS Coordinator) should be one of the first actions to be funded and implemented. The order in which the actions of this plan will be implemented will ultimately depend on available funding, resources, and priority circumstances as they develop.

Goal: To manage ANS in Tennessee to minimize adverse impact on native species, water quality, and economics.

Objective 1: Prevention of new ANS:

Strategy 1. Education/Public Awareness: Educate about the harmful effects of ANS and how to prevent introductions and spread
Strategy 2. Early Detection: Develop an early detection plan to promptly identify, eradicate, or contain pioneering ANS populations
Strategy 3. Information Management: Coordinate the compilation and management of ANS information
Strategy 4. Regulation: Support existing regulations and enact new legislation to control the collection, cultivation, distribution, importation, possession, propagation, purchase, sale, transport and introduction of ANS in Tennessee
Strategy 5. Research: Support research on ANS and develop a system to effectively disseminate ANS information among managing agencies and academic institutions

Strategies and Actions		Current Status	Fund Source	Implementing Agency	Cooperating Agency	Recent Efforts	Planned Efforts and Funding				
Number	Description						FY07	FY08	FY09	FY10	FY11
Strategy 1A. Promote ANS awareness within the public school system											
1A1	Develop and publish instructional materials such as workbooks, PowerPoint presentations, and instructional DVDs	Unfunded		TWRA	TSTA, TVA, TDOE	0	5k	10k	20k	20k	20k
1A2	Work with and encourage educational groups such as the TSTA (Tennessee Science Teachers Association) and Project CENTS (Conservation Education Now for Tennessee Students) to promote ANS awareness. Add ANS awareness to TN Content Standards for Science Curriculum	Unfunded		TWRA	TDEC, TVA, TDA, TDOE	0	2k	2k	2k	2k	2k
Strategy 1B. Create an educational campaign focusing on informing the general public about ANS											
1B1	Develop pamphlets, posters, and fliers for general distribution promoting ANS awareness, i.e., SARP	Partially Funded	AGFC	TWRA		yes	5k	10k	20k	20k	20k
1B2	Build and maintain an ANS Website	Unfunded		TWRA		0	10k	5k	5k	5k	5k

Strategies and Actions		Current Status	Fund Source	Implementing Agency	Cooperating Agency	Recent Efforts	Planned Efforts and Funding				
Number	Description						FY07	FY08	FY09	FY10	FY11
1B3	Utilize mass media such as TV, e.g. , TN Wildside, newspaper, magazine, and radio to promote ANS awareness	Unfunded		TWRA	TDEC, TVA	yes	1k	1k	1k	1k	1k
1B4	Develop partnerships with watershed associations for education at local level	Unfunded		TVA	TWRA, TDEC, TDA	0					
Strategy 1C. Develop an educational program that specifically targets users most likely to encounter or spread ANS											
1C1	Incorporate ANS prevention training in boating safety and education classes	Unfunded		TWRA	TVA, Bass Pro Shops	0	1k		1k		1k
1C2	Continue to develop and include ANS information within the TWRA fishing regulations guide	Funded	TWRA	TWRA		yes	Continue current efforts				
1C3	Post signs at boat docks, boat ramps and kiosks utilizing resources available through programs such as "Stop Aquatic Hitchhikers" http://www.protectyourwaters.net/	Partially Funded	USFWS USCG	TWRA	TDEC, TVA	yes		5k		5k	
1C4	Provide organized fishing clubs with general prevention procedures recommended by "Stop Aquatic Hitchhikers" to prevent the spread of ANS	Partially Funded	USFWS USCG	TWRA	TVA	yes	1k		1k		1k
1C5	Utilize Habitatitude program to educate aquarium and water garden wholesalers, retailers and hobbyists	Partially Funded	USFWS	TDA	Habitatitude TWRA	0		2k		2k	
Strategy 1D. Actively promote ANS awareness within the commercial aquatic industry											
1D1	Include ANS prevention in training for barge pilot licensing	Unfunded	?	USCG	USACE		?	?	?	?	?
1D2	Explore methods to assure that educational material be provided to consumers of the aquatic pet and water garden industries	N/A		TDA	Habitatitude TWRA	0		X		X	
1D3	Work with bait industry to prevent distribution of ANS			TWRA	Bait industry		X		X		X
1D4	Develop and provide educational material such as HACCP (Hazard Analysis Critical Control Point) to the aquaculture industry through the TSA (Tennessee Aquaculture Association)	Unfunded		TDA	TWRA, USFWS	0	2k	2k	2k	2k	2k

Strategies and Actions		Current Status	Fund Source	Implementing Agency	Cooperating Agency	Recent Efforts	Planned Efforts and Funding				
Number	Description						FY07	FY08	FY09	FY10	FY11
1D5	Cooperate with and provide educational material to commercial fishermen	Unfunded		TWRA	TDA, USFWS	0	2k	2k	2k	2k	2k
Strategy 2A. Develop "in house" programs that would aid in the early detection of ANS (Coordinate w/ Obj. 2, Strategy 1)											
2A1	Train field personnel and resource managers to correctly identify, collect and record essential data on ANS species encountered	Unfunded		TWRA	TDEC, TVA, THP, USACE,US FWS, USGS TDA, TNC	0	10k	10k	10k	10k	10k
2A2	Develop reporting protocol to submit ANS records to central authority (ANS Coordinator)			TWRA	TVA, TDEC		Implemented by ANS Coordinator				
2A3	Instruct field survey units to incorporate an "ANS Watch" during routine fish, benthic, mussel, and plant surveys	Funded	TWRA	TWRA	TVA, TDEC, USFWS, USGS	yes	Conducted by field survey units, begin FY08 w/ 2A1, 2A4				
2A4	Conduct periodic fish, benthic, crayfish, mussel, and plant surveys targeting specific ANS likely points of introduction, e.g., trout tailwaters streams for the New Zealand mud snail	Unfunded		TWRA	TVA, TDEC, USFWS, USGS	yes	Conducted by field survey units, begin FYO8 W/ 2A1, 2A3				
2A5	Utilize HACCP (Hazard Analysis and Critical Control Point) training at state & federal hatcheries and during stocking activities	Unfunded		TWRA USFWS		0	1k	1k	1k	1k	1k
Strategy 2B. Foster public involvement in ANS detection											
2B1	Encourage and provide a method for citizens to report occurrences of ANS, i.e., hotline	Partially Funded	USFWS, USGS	TWRA	USGS, MRBP, USFWS	Yes[1]	1k	1k	1k	1k	1k
Strategy 2C. Monitor commercial trade and recreational use of ANS											
2C1	Work with the commercial fishing industry to detect ANS occurrences through training	Unfunded		TWRA		0	Implemented by ANS Coordinator				
2C2	Develop plans to monitor the pet trade, bait, and water garden industries to prevent	Unfunded		TDA		0	Implemented by ANS Coordinator				

[1] USFWS and USGS currently have in place a 24/7 real person hotline to report ANS occurrences. Although still under development, this system will be linked to a list of contacts and responders within Tennessee. (David Britton, USFWS, Pers. Comm.).

Strategies and Actions		Current Status	Fund Source	Implementing Agency	Cooperating Agency	Recent Efforts	Planned Efforts and Funding				
Number	Description						FY07	FY08	FY09	FY10	FY11
	distribution of ANS										
2C3	Monitor bait used for striped bass tournaments; encourage use of native bait	Unfunded		TWRA		yes	3k	3k	3k	3k	3k
Strategy 2D. Foster interagency cooperation in monitoring ANS											
2D1	Conduct cooperative surveys with local, state, and federal agencies to detect new or expanding populations of ANS	Unfunded		TWRA, ANS Coordinator	TVA, TDEC		5k	5k	5k	5k	5k
Strategy 3A. Identify ANS that pose an immediate threat to aquatic resources of the state											
3A1	Hire statewide ANS Coordinator	Unfunded		TWRA	TDEC	0	88k	67k	71k	75k	80k
3A2	Incorporate ANS occurrences into the Tennessee Aquatic Database System (TADS)	Funded		TWRA		0	Implemented by ANS Coordinator				
3A3	Maintain a priority list of ANS (ANS Coordinator)			TWRA		yes	Implemented by ANS Coordinator				
3A4	Search existing collections and data bases for recent and historic records of ANS	NA		TDEC	TWRA, TVA	0	Implemented by ANS Coordinator				
3A5	Coordinate and share all ANS data at the local, regional, as well as national level			TWRA		0	Implemented by ANS Coordinator				
Strategy 3B. Create a repository and documentation process for all ANS occurrences in Tennessee watersheds											
3B1	Ensure submission of voucher specimens to appropriate institutions, i.e., museum collections and herbaria	Partially Funded		TDEC	TWRA, TVA, USFWS	yes	Submitted by field survey units				
Strategy 3C. Monitor ANS vectors											
3C1	Maintain a list of ANS pathways, e.g., bait distribution, fish culture and distribution, water garden and aquatic pet industries etc.			TWRA	TDA, TDEC	yes	Implemented by ANS Coordinator				
Strategy 3D. Use current technology to monitor changes in ANS occurrence											
3D1	Continue to develop GIS analysis & maps	Partially Funded		TWRA	TVA. TDEC	yes	0	2k	2k	2k	2k
Strategy 3E. Provide comprehensive information on current ANS activities											
3E1	Ensure good dissemination of information by producing an ANS annual report (ANS Coordinator)			TWRA		0	Implemented by ANS Coordinator				
Strategy 4A. Identify legislation/regs that control ANS and parties responsible for administering such legislation											

Strategies and Actions		Current Status	Fund Source	Implementing Agency	Cooperating Agency	Recent Efforts	Planned Efforts and Funding				
Number	Description						FY07	FY08	FY09	FY10	FY11
4A1	Maintain a comprehensive list of all current state and federal laws regulating ANS			TWRA		yes					
4A2	Determine a clear line of regulatory authority for ANS groups (plants and animals) See also Obj. 2, Strategy 1A			TWRA	TDEC, TDA, USFWS	yes		x			
Strategy 4B. Determine actions implemented by border states to control ANS											
4B1	Evaluate existing ANS regulations of border states that share drainages with Tennessee and coordinate actions when possible			TWRA	MRP, USGS, USFWS		Implemented by ANS Coordinator				
Strategy 4C. Ensure that regulations are in keeping with current ANS trends/threats											
4C1	Continue to update the "Banned in Tennessee" species list			TWRA	TDA, TDEC	yes					
4C2	Conduct a comparative analysis study for an "Approved Species" list verses the "Banned in Tennessee" list	Funded		TWRA	TDA, TDEC	yes					
Strategy 5A. The economic impact of ANS in Tennessee is undetermined - Conduct research to fully understand the potential impacts of ANS to Tennessee											
5A1	Fund economic and ecological impacts research of ANS in Tennessee	Unfunded		TWRA	Universities				30k		
5A2	Evaluate the cost/benefit of control or eradication of priority ANS	Unfunded		TWRA	Universities					30k	
Strategy 5B. In order to control ANS in Tennessee, protocols and methods need to be developed to effectively manage or eradicate ANS with minimum impact to native ecosystems											
5B1	Fund research to develop effective methods of control or eradication of priority ANS	Unfunded		TWRA	TVA, USFWS	yes					30k[2]
5B2	Carefully evaluate potential harm to non-target species by chosen control methods	Unfunded		TDEC	TWRA		Implemented by ANS Coordinator				
5B3	Fund laboratory studies to determine potential for competitive exclusion of ANS by native species and vice-versa	Unfunded		TWRA, TDEC	Universities			10k			
5B4	Monitor ANS research projects of other states	Unfunded		TWRA, TDEC			Implemented by ANS Coordinator				

[2] Recommend the ANS Coordinator use funds in partnership with neighboring states or other parties seeking similar research.

Strategies and Actions		Current Status	Fund Source	Implementing Agency	Cooperating Agency	Recent Efforts	Planned Efforts and Funding				
Number	Description						FY07	FY08	FY09	FY10	FY11
5B5	Continue to support research relating to threatened and endangered species restoration	Funded	TWRA, USFWS, TTU, AAFB	USFWS	TWRA, USFWS, TTU, AAFB	yes					
5B6	Support research to determine limiting factors for growth and survival of priority ANS	Unfunded		TWRA, TDA	MRBP						

Objective 2 – Management of existing ANS:

Strategy 1. Rapid Response: Develop a rapid response plan to control or eradicate detected priority ANS populations.
Strategy 2. Enforcement
Strategy 3. Intrastate/Interstate/International Cooperation: Collaborate on ANS projects with all managing agencies and user groups at local, state, regional, and national levels
Strategy 4. NEPA (National Environmental Policy Act) Compliance: Ensure compliance with NEPA
Strategy 5. Restore Native Species

Strategies and Actions		Current Status	Fund Source	Implementing Agency	Cooperating Agency	Recent Efforts	Planned Efforts and Funding				
Number	Description						FY07	FY08	FY09	FY10	FY11
Strategy 1A. Assemble an interdisciplinary committee to complete the following actions (Coordinate with Obj. 1, Strategy 4A2.)											
1A1	Create a permanent mechanism to apply control and eradication methods developed through research where ANS populations pose risk to ecology and economies of Tennessee			TWRA	TVA. TDEC, USFWS		Implemented by ANS Coordinator, to begin FY08				
1A2	Identify existing agency expertise and resources that can respond to new or expanding ANS populations			TWRA	TVA. TDEC, USFWS		Continued by ANS Coordinator, begun with management plan				
1A3	Identify ANS impacting native rare and endangered species			TWRA	TVA. TDEC, USFWS		Implemented by ANS Coordinator, utilize state CWCS, to begin FY08				
1A4	Identify actions to eradicate or control pioneering ANS populations			TWRA	TVA. TDEC, USFWS		Implemented by ANS Coordinator, to begin FY08				
1A5	Establish rapid response mechanism and pre-approved permits necessary for rapid eradication (e.g. herbicide or pesticide application, habitat alteration etc.)			TWRA	TVA. TDEC, USFWS		Implemented by ANS Coordinator, to begin FY08				
Strategy 2A. Identify all legalities and enforcement issues associated with ANS											
2A1	Identify all affected law enforcement divisions, their roles with ANS and contact persons.			TWRA	TDEC, TDA		Law Enforcement Divisions				
2A2	Coordinate enforcement cases between agencies			TWRA	TDEC, TDA		Law Enforcement Divisions				
2A3	Examine case histories of successful prosecutions in other states			TWRA	TDEC, TDA		Law Enforcement Divisions				

Strategies and Actions		Current Status	Fund Source	Implementing Agency	Cooperating Agency	Recent Efforts	Planned Efforts and Funding				
Number	Description						FY07	FY08	FY09	FY10	FY11
Strategy 2B. Maintain a high level of control in regulating ANS											
2B1	Conduct surveys to track range expansion of established or naturalized populations of priority ANS	Partially Funded	TWRA	TWRA	TVA. TDEC, USFWS	yes	Conducted by field survey units				
2B2	Enforce existing laws pertaining to ANS			TWRA	TDEC, TDA		Law Enforcement Divisions				
Strategy 3A. Ensure all governing agencies are aware of jurisdictions and responsibilities in managing ANS.											
3A1	Continue a comprehensive review of each managing agencies' rules and regulations to ensure cross-compliance			TWRA		yes	Continued by ANS Coordinator, continuing from management plan				
Strategy 4A. Ensure that all agency responses to ANS meet requirements under NEPA											
4A1	Frequently review NEPA policy in order to maintain continuity and proper authority in managing ANS			TDEC			Implemented by ANS Coordinator				
Strategy 4B. Ensure that all consultation with governing agencies is conducted in ANS management issues and that public and private sectors are informed and allowed to comment on proposed actions											
4B1	Develop plans and coordinate responses with full partner participation, including reviews of state and federal air, water, wetland, wildlife, and endangered species regulations	Ongoing	Depends upon plan or reg	TWRA	TDEC, TDA, USFWS, TVA, USACE	yes	Implemented by ANS Coordinator				
4B2	Coordinate public input as appropriate or required by law. Prepare alternatives based on best available scientific data		Depends upon plan or reg	TWRA	TDEC, TDA, USFWS, TVA, USACE	yes		Implemented by ANS Coordinator with partners			
4B3	Evaluate potential for third-party water projects in Tennessee or adjoining states to impact distribution or abundance of ANS in Tennessee			TWRA	TVA, TDEC, TDA SARP, SEAFWA, EPA			Implemented by ANS Coordinator with partners			
Strategy 5A. Address native species impacts resulting from ANS											
5A1	Support restoration of native species into areas where ANS have caused or coincided with decline (e.g. Barrens Topminnow)	Partially Funded [3]	USFWS	USFWS	USFWS, GSMNP	yes			X	X	X

[3] The USFWS is currently funding efforts to eradicate Western Mosquito Fish (*Gambusia affinis*) from populations of the State and Federally listed Barrens Topminnow (*Fundulus julisia*)

Strategies and Actions		Current Status	Fund Source	Implementing Agency	Cooperating Agency	Recent Efforts	Planned Efforts and Funding				
Number	Description						FY07	FY08	FY09	FY10	FY11
5A2	Establish threshold criteria for reintroduction of native species of proper genotype	Unfunded		TWRA, TDEC			Consult with regional experts, i.e., ichthyologist and geneticist				
5A3	Maintain database of restoration sites and periodically survey to determine success	Partially Funded		TWRA	TWRA, TDEC, TVA		ANS Coordinator in conjunction with field survey units				
Strategy 5B. Be proactive in preventing ANS from impacting Threatened or Endangered species or their habitat											
5B1	Periodically monitor populations of rare and endangered species currently impacted by ANS (e.g. barrens topminnow) for early detection and rapid response	Partially Funded	USFWS	USFWS, TWRA	TTU	yes	Conducted by field survey units				

Implementation Table Abbreviations: Tennessee Wildlife Resources Agency (TWRA), Tennessee Science Teachers Association (TSTA), Tennessee Valley Authority (TVA), Tennessee Department of Education (TDOE), Tennessee Department of Environment and Conservation (TDEC), Tennessee Tech University (TTU), The Nature Conservancy (TNC), Arkansas Game and Fish Commission (AGFC), United States Coast Guard (USCG), United States Army Corp of Engineers (USACE), Tennessee Department of Agriculture (TDA), Mississippi River Basin Panel (MRBP), Mississippi Regional Panel (MRP), Arnold Air Force Base (AAFB), Great Smoky Mountains national Park (GSMNP).

VI. Program Monitoring and Evaluation

The goal of the Tennessee Aquatic Nuisance Species Management Plan, to manage ANS in Tennessee to minimize adverse impacts on native species, water quality, and economics, can be achieved through actions supporting two objectives. This section of the plan lays out the methods through which Tennessee will measure the success or failure of this management plan.

A word about performance measurement: Measuring performance of any program or activity can be divided into "output measures" and "outcome measures." Output measures could be described as "counting widgets," while outcome measures examine the degree to which a program has accomplished its goal(s). Typically, "outputs" help to achieve the desired "outcomes."

In Tennessee's ANS management plan, the two Objectives can be viewed as the desired outcomes of this plan. These require measurement. Under each of these two objectives, multiple strategies describe the actions the task force believes will help to reach the objectives. These may change over the years. They can be viewed as the widgets, or outputs. It is necessary to measure delivery of the widgets to ensure that Tennessee is fully implementing the strategies that will help achieve the objectives.

Primary Responsibility

Ultimate responsibility for determining whether or not this plan has adequately achieved its objectives should rest with the Tennessee Wildlife Resources Commission (TWRC), the lead agency in developing and implementing the plan. Because of the distribution of authorities and jurisdictions currently established in Tennessee, this responsibility is actually shared. While the TWRC has statutory jurisdiction over the animal portion of the plan, the Commissioner of the Department of Environment and Conservation has major responsible for water quality, and the Commissioner of the Department of Agriculture, addresses the plant and aquaculture issues in a limited fashion. As the lead agency, the TWRC may wish to consider in the future establishing an independent board, working group, or some other committee structure from these and other stakeholders to share the responsibility.

The Commission or other body, however, will require information on which to base such evaluation of the plan. The ANS Coordinator, when that position is established, will be the most logical source of that information. He or she should assemble and present an evaluation compiled from resulting data of activities and monitoring conducted by program area staff in the appropriate divisions of TWRA, TDEC, and TDA. Monitoring and evaluation should be associated with all strategies implementing this plan.

When to Evaluate

Initially, evaluations should be submitted at the end of years 1 and 2, and should probably be limited to the "indicator actions" (described below) approach. Deeper assessments should occur in the latter three years of the plan, when the biological and social quantitative methods should be employed, provided baseline data and funding are available.

How to Evaluate

Recognizing the potentially high cost of a thorough assessment, the Task Force proposes a three-fold approach to monitoring and evaluating the actions listed in this plan. The ANS coordinator in cooperation with the TWRC/TWRA will be responsible for selecting and combining these three methods and applying them to specific goals and objectives.

1. Indicator actions

In this approach, evaluators select a representative group of actions as indicative of management plan progress. The degree to which those "indicator actions" acquire funding and are executed in their entirety is the degree to which success is declared. Advantages of this approach are that it is straightforward, inexpensive, and may be implemented in the early years of plan execution. The disadvantages are that it is based upon a small sample, does not address the larger issue of invasive species spread, and may not satisfy the public's right to know the "bottom line:" are we better off now than when this effort commenced?

2. Quantitative biological measures

In this approach, field work is conducted to answer questions such as:

- Has the range of a particular species expanded?
- Have new invasive species arrived?
- Have ecological costs of the impact of certain species increased or spread?
- Biologically speaking, is this problem greater than it was five years ago?

Advantages of this approach include its scientific and quantitative nature, and it addresses fundamental questions rather than bureaucratic ones. Disadvantages include its costliness, its highly focused nature (the range of one species may be reduced while another's may expand), and the need to wait until the end of the five-year cycle for actions to take potential effect. It may also be "setting the bar too high" to expect to control or eliminate certain species. Existing monitoring activities of stakeholder agencies may help to provide a portion of the necessary monitoring data if tasks to record ANS occurrences are added to existing protocols.

3. Quantitative social measures

In this approach, surveys are conducted among stakeholders to answer such questions as:

- Can you define the term “invasive species?”
- Have you seen posted signs about invasive species at boat ramps and docks?
- Do you wipe off your outboard motor and hull upon extracting it from the water?

VII. Glossary

Terms used in the Tennessee Aquatic Nuisance Species Management Plan.

Acclimatization - A process of adaptation of introduced species and their offspring in a new environment.

Aquatic plant - A plant that naturally grows in water, saturated soils, or seasonally saturated soils, including algae, submersed, floating leaved, free floating or emergent plants.

Aquatic species - All organisms living at least partially in a water environment. Usage commonly refers to aquatic plants such as water hyacinth and salvinia, fish, and invertebrates, but also includes mammals such as nutria. For purposes of the management plan, species that arrived through aquatic pathways (such as the Formosan termite) are considered aquatic species.

Aquatic Nuisance Species (ANS) - A nonindigenous species that threatens the diversity or abundance of native species or the ecological stability of infested waters, or commercial, agricultural or recreational activities dependant on such waters (National Invasive Species Act of 1996 P.L. 104-332)

Alien species - With respect to a particular ecosystem, any species, including its seeds, eggs, spores, or other biological material capable of propagating that species, that is not native to that ecosystem (Executive Order 13112).

Bait - Any species (fish, insect, invertebrate) sold for use as bait for recreational fishing.

Biological diversity (biodiversity) - The variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are a part; this includes diversity within species, between species and of ecosystems.

Control [noxious weed] - To destroy the above ground growth of noxious weeds that prevents the maturation and spread of noxious weed propagating parts from one area to another.

Cryptogenic species - A species that is not demonstrably native or introduced.

Criteria - The principles or standards that a thing is judged by (Illustrated Oxford Dictionary 1998).

Cultivar - A plant that was selected from a population of plants because it has desirable characteristics, and is cultivated and given a specific name.

Ecosystem - A community of plants, animals and other organisms that are linked by energy and nutrient flows and that interact with each other and with the physical environment.

Established - The condition of growing in a particular location (not the same as naturalize).

Habitat - Area where a species has the necessary food, water, shelter, and space to live and reproduce.

Hybrid - Offspring resulting from a cross between two different species, or genetically distinct individuals within the same species, that may be naturally occurring or the result of controlled crosses, or being genetically modified.

Indigenous species - Organisms naturally occurring in a specific geographic area or ecosystem. Synonym includes native species.

Injurious [re: state noxious weeds] - The negative economic, physical, aesthetic, environmental, and other effects an uncontrolled plant may have in completing its life cycle.

Intentional introduction - An introduction made deliberately by humans, involving the purposeful movement of a species outside of its natural range and dispersal potential. Such introductions may be authorized or unauthorized.

Introduced species - An organism that has been brought into an area where it does not normally occur. Most introductions are caused by human activity. Introduced species often compete with and cause problems for native species. An introduced species is not necessarily an invasive species. Also called exotic, nonnative, or alien species.

Introduction
The intentional or unintentional escape, release, dissemination, or placement of a species into an ecosystem as a result of human activity (Executive Order 13112).

Invasive species - A species that is nonnative to the ecosystem under consideration and whose introduction causes or is likely to cause economic or environmental harm, or harm to human health. Invasive species tend to grow rapidly and spread easily, and frequently outcompete native species for space and resources. An invasive species may be introduced or may spread outside its normal range through natural processes. An alien [nonnative / exotic / introduced] species whose introduction does or is likely to cause economic or environmental harm or harm to human health (Executive Order 13112).

Native species - A species naturally present and reproducing within the state or that naturally expands from its historic range into this state.

Naturalize - To establish a self-sustaining population of exotic species in the wild outside of its natural range.

Nonindigenous species - With respect to a particular ecosystem, any species that is not naturally found in that ecosystem. Species introduced or spread from one region of the U.S. to another outside their normal range are non-indigenous, as are species introduced from other countries or continents.

Nonnative species / exotic species / introduced species - A species occurring outside its natural range.

Noxious species - A plant species that is undesirable because it is troublesome and difficult to control. Not to be confused with species declared noxious by law (see noxious weed).

Noxious weed - A plant defined by law as being especially undesirable, troublesome, and difficult to control.

Noxious weed (state) - An annual, biennial, or perennial plant that the State designates to be injurious to public health, the environment, public roads, crops, livestock, or other property.

Nuisance species - A species that threatens the diversity or abundance of native species or the ecological stability of an infested area, or that threatens commercial, agricultural, aquacultural or recreational activities dependent on such an area.

Parasite - An organism living in or on another organism.

Pathogen - A specific agent causing disease. May be a bacteria, virus, or fungus.

Pathway - The means by which species are transported from one location to another. (ANS Task Force, Pathway Ranking Guide, 2005).

Plant pest - Includes, but is not limited to, an invasive species or any pest of plants, agricultural commodities, horticultural products, nursery stock, or noncultivated plants by organisms such as insects, snails, nematodes, fungi, viruses, bacterium, microorganisms, mycoplasma-like organisms, weeds, plants, and parasitic plants.

Prohibited invasive species - An invasive species, plant or animal that has been designated as a prohibited exotic species by the State.

Quarantine - Enforced isolation or restriction of free movement of plants, plant material, animals, animal products, or any article or material in order to treat, control, or eradicate a plant pest or animal population.

Range - The known geographical distribution of a plant or animal.

Regulated nonquarantine pest - A plant pest that has not been quarantined by state or federal agencies and whose presence in plants or articles may pose an unacceptable risk to nursery stock, other plants, the environment, or human activities.

Re-introduction - To establish a species in an area which was once part of its historical range from which it has been extirpated.

Restricted noxious weed - Plants are designated by the State as a restricted noxious weed because the only feasible means of control is to prohibit the importation, sale, and transportation in the state.

Significant damage or harm - A level of adverse impact that results in economic damage, injury, or loss that exceeds the cost of control of a plant or animal.

Species - A group of organisms that differ from all other groups of organisms and that are capable of breeding and producing fertile offspring. This is the smallest unit of classification for plants and animals.

Terrestrial plant - A plant that can grow in soils that are seasonally saturated or drier than seasonally saturated, but not in soils that are permanently flooded.

Terrestrial species - Organisms living primarily on land.

Unintentional introduction - An accidental movement of a species into a new habitat outside of its native range, often as a result of a species utilizing humans or animals as vectors for dispersal.

Variety - A subdivision of a species having distinct, uniform, though often inconspicuous difference, and typically breeding true to that difference.

Watershed- The dividing ridges separating drainage basins (USGS), but in recent usage synonymous with drainage basin.

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*Washington State Aquatic Nuisance Species Management Pla*n, September 2001, available online at http://wdfw.wa.gov/fish/nuisxsum.htm, accessed 11/20/06.

Appendix A. Aquatic Nuisance Species of Concern in Tennessee

Animals

The descriptions of animal species of concern, listed below in alphabetical order by type, include both common and scientific name. The scientific name consists of the genus and species, and can be helpful in locating additional information in books and taxonomic manuals, published scientific papers, and on the Internet. Each species account also includes pictures to help identify the animal. The credit below each photo identifies the photographer or source of each picture. The **Description and Biology** section provides information on the physical characteristics of the animal, which are helpful for identification and to understand the species' life cycle and habitat. The section entitled **Distribution** provides information about the animal's native range, how and when it was first introduced outside of its native range, and its current distribution in the United States and Tennessee. **Harmful Impacts** describes potential or known problems that the introduced species can cause to native species, ecological systems, the economy, or directly to humans.

The primary source used to write most of the following animal descriptions is Simmons, J.W. 2007. Accounts of Resident or Potential Aquatic Nuisance Fish, Mollusks, and Crayfish in Tennessee with Notes on Biology, Distribution and Potential Impacts. Tennessee Valley Authority, Aquatic Monitoring and Management, Chattanooga, TN. Sources for each species are included for the use of those managing ANS in Tennesee. The species description for the big claw crayfish was not included in the TVA report. The description was preprated by Carl E. Williams, Tennessee Widlife Resources Agency, Morristown, TN. Use the **References** and **Additional Web Resources** sections for additional information.

Animals - Vertebrates - Fishes

<u>Aelwife and Blueback Herring</u>

Alewife
Alosa pseudoharengus

Blueback Herring
Alosa aestivalis

Photos by Jim Negus, Tennessee Wildlife Resources Agency

Description and Biology - The **alewife** is a slender, laterally compressed fish that is greenish-grey from a dorsal view fading to silver on the sides. Eye diameter is greater than the length of the snout and the peritoneum (membrane lining the abdominal cavity) is pale to pinkish grey. The dorsal margin of the lower jaw is abruptly turned upward. This species is very similar in appearance to the blueback herring. The **blueback herring** has an eye diameter less than or equal to snout length and the peritoneum is black. Blueback herring have a blue sheen dorsally compared to the grayish-green of the alewife. Both of these species are anadromous species (migrate to freshwater to spawn), native to the Atlantic Coast. When not on spawning migrations, adults of both species congregate over the Continental shelf off New England (Neves, 1981). Young alewives and blueback herring feed primarily on diatoms and copepods and when entering saltwater consume plankton, small shrimp, and small fish. Both species can reach lengths around 14 inches and landlocked populations in Virginia live 3-4 years (Jenkins and Burkhead, 1993).

Distribution - The **alewife** is native to the Atlantic coast from South Carolina to Newfoundland. Many landlocked populations have been established. This species spread through the Great Lakes via the Welland Canal. Alewife have been introduced into Colorado, Georgia, Illinois, Indiana, Kentucky, Maine, Massachusetts, Michigan, Minnesota, Nebraska, New Hampshire, New York, Ohio, Pennsylvania, Tennessee, Vermont, Virginia, West Virginia, and Wisconsin (Fuller et al., 1999). Most introductions have been intentional for use as a forage species. In Tennessee, this species was initially stocked in Watauga and Dale Hollow reservoirs but has spread downstream in the tailwaters (Etnier and Starnes, 1993). The illegal introduction of this species in Norris Reservoir, Dale Hollow and possibly other Tennessee reservoirs is believed to be the cause of recruitment failure in walleye, *Sander vitreus*.

Blueback herring are native to the Atlantic coast from Nova Scotia to Florida. Landlocked populations have been introduced in Georgia, New York, North Carolina, Tennessee, Texas, Vermont, and Virginia (Fuller et al., 1999; TVA, unpub. data). The TVA collected the first East Tennessee specimens of blueback herring from Melton Hill Reservoir in the fall of 1998 and has since observed them in Tellico and Boone. Blueback herring have been suspected of causing problems with the largemouth bass fisheries in Lake Burton and Nottely Reservoir in Georgia and with the walleye fishery in Hiwassee Reservoir of North Carolina. The method of introduction into these systems is thought to have been via anglers using live bait or intentional stocking as a forage species.

Harmful Impacts - Blueback herring and alewife introductions have had negative impacts on reservoir fisheries in several states. Blueback herring introduction into Lake Burton, Georgia coincided with decreased abundance of black crappie, *Pomoxis nigromaculatus*, largemouth bass, *Micropterus salmoides*, and white bass, *Morone chrysops* (Rabern, 2000). Following the introduction of alewife in several Tennessee reservoirs and the introduction of blueback herring in Hiwassee Reservoir, North Carolina, recruitment failure in walleye was documented (Schultz, 1992; Wheeler et al., 2004a). Wheeler et al. (2004b) documented high predation of fish eggs by blueback herring, predominately white bass eggs, but little evidence of larval fish predation. In contrast, alewives in Claytor Lake, Virginia ate larvae of several fishes including white and largemouth basses (Kohler and Ney, 1980). Additionally, landlocked populations of alewives feed heavily on zooplankton and may compete with other planktivores, especially larval fishes. Alewives and blueback herring contain thiaminase, an enzyme that destroys thiamine, a crucial enzyme for egg development and survival of many fishes. Low thiamine levels in eggs may result from spawning females feeding extensively on alewife, which may be the cause of Early Mortality Syndrome (EMS). EMS occurs during the sac-fry stage and effects 100% of the fry from an individual female. Salmonid and walleye fisheries have suffered in the Great Lakes from EMS and research is ongoing to determine the relationship between forage high in thiaminase and EMS (Marcquenski and Brown, 1997).

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Additional Web Resources

Blueback herring:
http://nas.er.usgs.gov/queries/FactSheet.asp?speciesID=488

http://www.tnfish.org/InvasivesExotics/BluebackHerring.htm
Alewife:
http://www.invasivespeciesinfo.gov/aquatics/alewife.shtml

http://nas.er.usgs.gov/queries/FactSheet.asp?speciesID=490

http://www.in.gov/dnr/invasivespecies/ALEWIFE.pdf

http://www.columbia.edu/itc/cerc/danoff-burg/invasion_bio/inv_spp_summ/alewife.html

Asian Carp- (Grass, Bighead, Silver, Black)

These four species were imported into the United States for use in the aquaculture industry and escaped into the wild or have been intentionally released for use as biological control agents. Wild populations have quickly increased their distribution and abundance, which may result in serious ecological and economic consequences.

Grass Carp

Other Common name: White Amur
Ctenopharyndogon idella

Photo by Jim Negus, Tennessee Wildlife Resources Agency

Description and Ecology - Grass carp are silver to pale grey in color, have large scales, large grooved pharyngeal teeth, and the anal fin is positioned close to the caudal fin. Adult individuals feed primarily on aquatic vegetation where they can consume several pounds per day. Growth is rapid and individuals can reach lengths greater than 4 feet and can weigh over 50 pounds. Fecundity is high; large females can produce over a million ova. Eggs drift before hatching and long reaches of flowing river are required for reproduction (Etnier and Starnes, 1993).

Distribution - Grass Carp are native to large rivers of eastern Asia. This species has been introduced throughout the United States for biological control of nuisance aquatic plants in ponds and lakes in every U.S. state except Alaska, Maine, Montana, Rhode Island, and Vermont (Fuller et al., 1999). It was first imported to the United States in 1963 to aquaculture facilities in Auburn, Alabama and Stuttgart, Arkansas, for research in the control of aquatic vegetation. During the past few decades, this species has spread rapidly as a result of widely scattered research projects, stockings by federal, state, and local government agencies, release by individuals and private groups, escapes from farm ponds and aquaculture facilities, and natural dispersal from introduction sites (Fuller et al., 1999).

Harmful Impacts - Grass carp have been known to clean entire lakes of all aquatic plants and then consume organic detritus and animal material. Negative impacts on native fauna include interspecific competition for food with invertebrates and fishes; significant changes in the composition of macrophyte, phytoplankton, and invertebrate communities; interference with reproduction and decreases in refugia of other fishes; enrichment and eutrophication of lakes by expelling undigested plant material; disruption of food webs and trophic structure; and introduction of nonnative parasites and disease. It is believed that grass carp imported from China were the source of introduction of the Asian tapeworm, *Bothriocephalus opsarichthydis* (Fuller et al., 1999).

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Additional Web Resources

http://nas.er.usgs.gov/queries/FactSheet.asp?speciesID=514

http://www.fws.gov/midwest/News/documents/AsianCarp.pdf

Bighead Carp *Hypophthalmichthys nobilis* (top of photo)
Silver Carp *Hypophthalmichthys molitrix* (two fish at bottom of photo)

Photo by Tennessee Wildlife Resources Agency

Description and Ecology - Silver carp have a ventral keel that extends forward past the pelvic fin base, gill rakers that form a compact mass covered by a net-like matrix, and they lack scattered dark blotches on the body (Etnier and Starnes, 1993). Both the silver carp and bighead carp have small scales and an unusual eye position that is on the antroventral portion of the head. Silver carp are pelagic filter feeders with highly specialized gill rakers capable of filtering particles as small as 4 microns (Cremer and Smitherman, 1980). They primarily feed on nanno and phytoplankton and detritus in the range of 17-50 microns. This species can reach a length greater than 3 feet and can weigh up to 60 pounds (Etnier and Starnes, 1993). Other aspects of its biology are similar to bighead carp.

Bighead carp have a ventral keel which extends forward only to the base of the pelvic fins, gill rakers that are long and slender, and scattered dark blotches which often occur on the body (Etnier and Starnes, 1993). This species is also a pelagic filter feeder but their food consists of somewhat larger items such as zooplankton, clumps of algae, and insect larvae. It is capable of switching to phytoplankton and detritus if zooplankton is scarce (Cremer and Smitherman, 1980). Bighead carp can reach lengths of 3 feet and can weigh up to 90 pounds. Fecundity of both the bighead and silver carp is high. They can spawn several times a year and require stretches of free-flowing river for egg development. Eggs suspend in the current and hatch about 1 day after fertilization.

Distribution - Silver Carp are native to eastern Asia in the lower Amur River and other lowland rivers in China. In the United States, silver carp have been reported from Alabama, Arizona, Arkansas, Colorado, Florida, Illinois, Indiana, Kansas, Kentucky, Louisiana, Missouri, and Tennessee (Fuller et al., 1999). Initial introductions were in Arkansas in the 1970s where it was used in municipal sewage lagoons (Robison and Buchanan, 1988). Wild populations were probably the result of escape from aquaculture facilities or contaminated grass carp shipments (Fuller et al., 1999).

Bighead carp are native to large rivers of eastern China. It has been documented in Alabama, Arizona, Arkansas, California, Colorado, Florida, Illinois, Indiana-Kentucky border (Ohio River), Iowa, Kansas, Louisiana, Missouri, Mississippi, Ohio, Oklahoma, Tennessee, Texas, and West Virginia (Fuller et al., 1999). This species was first introduced into the U.S. by an Arkansas fish farmer who wanted to use them to improve water quality in aquaculture ponds. By the early 1980s, wild individuals were collected from the Ohio and Mississippi rivers, which were probably the result of escapes from aquaculture facilities. Other introductions were probably the result of contaminated grass carp shipments or illegal stockings (Fuller et al., 1999).

Harmful Impacts - Silver and bighead carp may compete for food with native planktivores including paddlefish, bigmouth buffalo, gizzard shad, larval fishes of many species, and freshwater mussels (Pflieger, 1997; Laird and Page, 1996). The noise of boat motors induce silver carp to leap out of the water, which causes potential for human injury or fatality. Commercial fishermen have abandoned fishing sites on the Missouri River due to the high numbers of Asian carp in their nets (USFWS, 2002). Asian carp currently pose the greatest immediate threat to the Great lakes. Bighead and silver carp are in the Illinois River which is connected to the Great lakes via the Chicago Sanitary and Ship Canal. If these species become established in the Great Lakes, serious economic and ecological consequences could result (USFWS, 2004).

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U.S. Fish and Wildlife Service. 2002. Asian carp fact sheet. La Crosse Fishery Resource Office, Onalaska, Wisconsin. http://wwwaux.cerc.cr.usgs.gov/MICRA/Asian%20Carp%20Brochure%20MICRA.pdf

Additional Web Resources

http://www.glfc.org/fishmgmt/carp.php

http://massbay.mit.edu/seafood/bigheadcarp.pdf

http://fisc.er.usgs.gov/Carp_ID/html/hypophthalmichthys_nobilis.html

http://www.epa.gov/glnpo/invasive/asiancarp/

http://wwwaux.cerc.cr.usgs.gov/MICRA/Asian%20Carp%20Key%20MICRA.pdf

Black Carp
Other common names: snail carp, black amur, Chinese roach
Mylopharyngodon piceus

Photo by Leo Nico, U.S. Geological Survey

Description and Ecology - The black carp is a bottom-dwelling molluscivore that has been used by U.S. fish farmers to control disease-carrying snails in aquaculture ponds. Although their primary diet consists of mussels and snails, they will also consume freshwater shrimp, crayfish, and insects (USFWS, 2002a). This species is blackish-grey dorsally, fading to white ventrally. Fins are dark and body is elongate and laterally compressed. This species resembles the grass carp but the gill rakers are fused and hardened for use in crushing shells of mollusks and crustaceans (USFWS, 2002b). This species can grow to lengths greater than 4 feet and can weigh more than 80 pounds (Fuller et al., 1999). This species has been proposed as a biological control for the introduced zebra mussel, *Dreissena polymorpha,* but there is no experimental evidence that indicates black carp would be effective in controlling zebra mussels. Black carp do not have jaw teeth and their mouths are relatively small, therefore, it is unlikely that these fish are capable of breaking apart zebra mussel rafts (Nico and Williams, 1996).

Distribution - The black carp is native to most drainages of eastern Asia. In the U.S., wild individuals have been collected in Arkansas, Illinois, Louisiana, and Missouri (Nico and Fuller, 2006). This species was first brought into the U.S. in the early 1970s as a contaminant in imported grass carp shipments that were sent to a private fish farm in Arkansas (Nico and Williams, 1996). During the 1980s black carp were imported as a food fish and as a biological control agent to combat the spread of yellow grub, a trematode parasite in cultured catfish, in aquaculture ponds (Nico and Williams, 1996). The first known record of an introduction of black carp into open waters occurred in Missouri in 1994 when thirty or more black carp along with several thousand bighead carp escaped into the Osage River, Missouri River drainage, when high water flooded hatchery ponds at an aquaculture facility near Lake of the Ozarks (Nico and Williams, 1996).

Harmful Impacts - At all life stages, black carp will compete for food with native species. There is high potential that black carp could have serious impacts to native mussel and snail populations; many of which are threatened or endangered. Black Carp are host to many parasites, flukes, bacteria, and viral infections that are likely to infect sport, food, or rare fish species (USFWS 2002a).

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Additional Web Resources

http://nas.er.usgs.gov/queries/FactSheet.asp?speciesID=573

http://www.flmnh.ufl.edu/fish/organizations/sfc/carpcolor2004.html

Asian swamp eel
Other common names: Asian rice eel, ricefield eel, rice paddy eel
Monopterus albus

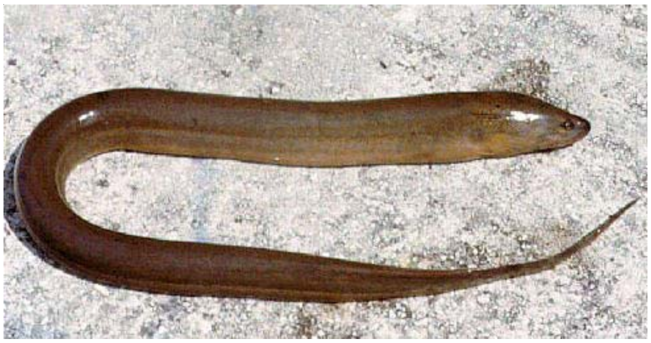

Photo by Leo Nico, U.S. Geological Survey, Gainesville, FL

Description and Biology - The Asian swamp eel has an elongated, finless, snake-like body, small eyes, and can grow up to 3 feet and weigh up to a pound. This species is among the most highly derived of air breathing fishes. Swamp eels have highly modified gill structures that function like a lung. They stick their snouts above the water surface, take in large amounts of air and hold it in their gill chamber for several minutes, exchanging carbon dioxide for oxygen before they have to rise to take another breath. Additionally, they can respire through their skin. They can survive in swamps with anoxic conditions and can tolerate long drought periods by living in damp areas. Under captive conditions, a swamp eel survived out of water for seven months on a damp towel at room temperature with no food. Swamp eels live in burrows that may extend several feet back into a bank and reside in a cavity above the water level where they are not susceptible to predators. Most individuals are born as females but sex reversal can occur as they age, insuring that only a few individuals are needed to colonize new areas. This species is highly mobile and can travel considerable distances over land to find new breeding and feeding areas. Swamp eels feed on land and in the water where they are voracious predators. If a prey item is too large for its mouth, the eel will spin rapidly around the prey until it is broken into smaller pieces (Starnes et al., 1998).

Distribution - This species is native to Asia and possibly northeastern Australia. This species was introduced to Oahu, Hawaii, prior to 1900 presumably by Asian immigrants as a food fish.
It has been introduced to several waterways in Florida and to three spring-fed impoundments in the Chattahoochee River drainage near Atlanta in Roswell, Georgia, probably from aquarium release (Fuller et al. 1999). **Note**: The Georgia population is probably a different species in the genus *Monopterus* based on recent genetic analysis (Straight et al. 2005).

Harmful Impacts - The potential for this species to have serious ecological impacts to native fauna is large. Because populations have only been established since the 1990s, impacts are currently unknown. In its native habitats, this species feeds on fish, prawns, crayfish, snails, adult and larval insects, adult and juvenile frogs, and frog eggs (Liem, 1987).

Stomach contents of individuals from the Roswell, Georgia population were examined and were comprised mostly of aquatic invertebrates, mollusks, and amphipods, but some fish were also present (Freeman and Burgess, 2000). Starnes et al. (1998) noted that captive individuals would eat one minnow or night crawler after another. Straight et al. (2005) suggested that this species may be impacting other insectivorous fish and invertebrates through competition for food resources at the Georgia locality. The Georgia population has survived air temperatures below freezing and ice cover over the ponds, proving that they are cold tolerant and cooler temperatures may not limit their dispersal. In Florida, this species has been found in close vicinity to the Everglades National Park and has the potential to further interrupt the ecological processes of this ecosystem (USGS data).

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http://www.uga.edu/water/GWRC/Papers/StraightC_GWRCpaper.pdf

http://www.columbia.edu/itc/cerc/danoff-burg/invasion_bio/inv_spp_summ/Monopterus_albus.html

http://nas.er.usgs.gov/queries/FactSheet.asp?SpeciesID=974

http://www.sherpaguides.com/georgia/atlanta_urban_wildlife/rice_eel/

http://biology.usgs.gov/invasive/CaseFiles/AsianSwampEel.htm

Brook stickleback
Other common name: five-spined stickleback
Culaea inconstans

Photo by Konrad Schmidt, Minnesota Division of Natural Resources

Description and Biology - The brook stickleback is mottled in color and breeding males become dark with copper or orange tinges. This species reaches a maximum size of 3.5 inches, reaches sexual maturity by one year, and lives up to three years. Five dorsal spines are usually present, thus the name “stickleback”. They occupy streams, swamps, and vegetated bays of larger lakes and can tolerate low dissolved oxygen concentrations. Males construct nests composed of plant material and defend the nest, eggs, and developing young. Diet includes small crustacea, insect larvae, snails, small annelids, water mites, and fish eggs. (Etnier and Starnes, 1993)

Distribution - This species is native to the Atlantic and Arctic drainages from Nova Scotia to the Northwest Territories within the Great Lakes- Mississippi River basins south to southern Ohio and New Brunswick, and west to Manitoba and eastern British Colombia. Documented occurrences outside of its native range have been recorded from Alabama, California, Colorado, Connecticut, Kentucky, Maine, Montana, New Mexico, Oklahoma, Pennsylvania, Tennessee, and Utah (Fuller et al., 1999). Introductions have resulted from escape from hatchery facilities, contaminated sport fish stockings, and bait bucket releases. This species commonly occurs in shipments of bait minnows from the Midwest, usually mixed with fathead minnows (*Pimephales promelas*) (Etnier and Starnes, 1993).

Harmful Impacts - Impacts of introduction on native fauna are largely unknown. Woodling (1985) noted that this species preys on fish eggs and is aggressive.

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Additional Web Resources

http://nas.er.usgs.gov/queries/FactSheet.asp?speciesID=701

Common Carp
Other common names: German carp, European carp, mirror carp, leather carp, koi
Cyprinus carpio


"Mirror" carp


"Typical" carp

Photos by Jim Negus, Tennessee Wildlife Resources Agency

Description and Biology

The common carp is a large high-backed minnow with a large serrated spine at the front of the dorsal and anal fins and has barbells on the upper jaw. This species is typically brassy to yellowish with yellow-orange lower fins, but several other varieties exist. Genetic mutants are frequently seen that have only a few large scales ("mirror carp") or lack scales entirely ("leather carp"). Ornamental varieties have been bred to be orange, red, black, or white (Etnier and Starnes, 1993). Common carp average 1 to 2 feet in length and can weigh over 50 pounds. Carp are omnivores and consume vascular plants, algae, invertebrates, and occasionally small fish (Etnier and Starnes, 1993). Common carp are extremely fecund; large females may produce over 2 million eggs per season, depositing them on submerged vegetation (Mansueti and Hardy, 1967). This species inhabits ponds, lakes, reservoirs, and pools and backwaters of streams. It is very tolerant of turbidity, low dissolved oxygen, high water temperatures, and heavily polluted water (Jenkins and Burkhead, 1993). Carp are eaten by many people and large numbers are caught and sold annually by commercial fisherman (Etnier and Starnes, 1993). In other parts of the world, the carp is considered a sport fish due to its large size and aggressiveness.

Distribution - The common carp is native to Asia, was cultured in Europe in the 13th century, and occurred throughout Eurasia by the 19th century. The exact native range is unknown because it was spread as early as Roman times (Courtenay et al., 1984). This species occurs in every state except Alaska (Fuller et al., 1999). During the late 1800s private individuals and federal and state agencies began to actively stock common carp as a food fish throughout much of the United States. Records from the early 1880s indicate that common carp stocked in farm ponds frequently escaped into open waters as a result of dam breaks or flood events (Smiley, 1886). By 1885, the U.S. Fish Commission was actively stocking lakes and rivers throughout the country; often the fish were released from railroad tank cars at bridge crossings directly into streams (McDonald, 1887). As a result of subsequent population growth and dispersal, common carp have spread into available habitats throughout the United States.

Harmful Impacts - In their review of the literature, Richardson et al. (1995) concluded that common carp have had adverse effects on biological systems including destruction of vegetated breeding habitats used by both fish and birds, and an increase in turbidity. This fish stirs up the bottom during feeding, resulting in increased siltation and turbidity which can degrade clean substrates (needed for spawning) and smother fish eggs (Etnier and Starnes, 1993). This feeding behavior also destroys rooted aquatic plants that provide habitat for native fish species and food for waterfowl (Dentler, 1993). Laird and Page (1996) stated that common carp may compete with ecologically similar species such as carpsuckers and buffalo fish.

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Additional Web Resources

http://nas.er.usgs.gov/queries/FactSheet.asp?speciesID=4

http://nis.gsmfc.org/nis_factsheet.php?toc_id=183

http://www.issg.org/database/species/ecology.asp?si=60&fr=1&sts=

Flat Bullhead
Ameiurus platycephalus

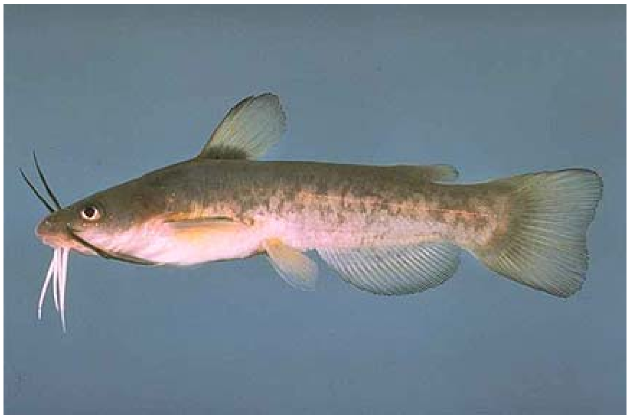

Photo by Robert E. Jenkins, Noel M. Burkhead. http://www.cnr.vt.edu/efish/. Used by permission.

Description and Biology - The flat bullhead is dark dorsally, upper side is yellow-brown with mottling fading to creamy-white, and underside is white. This species has a prominent dark spot at the base of the dorsal fin. It has a flat predorsal and head profile and has a larger eye than most other bullheads. The flat bullhead can live 5-7 years and can reach length just under one foot. It occurs in medium to large rivers, ponds, and reservoirs. Spawning occurs in June and July. This species is omnivorous but the majority of its diet is comprised of aquatic invertebrates and fish. It is similar in appearance to the brown bullhead (*A. nebulosus*) and the snail bullhead (*A. brunneus*). Maxillary barbels of the snail bullhead are completely black whereas the maxillary barbels of the flat bullhead are bicolor. The brown bullhead has black chin barbels, dark fins, and a dirty white to yellow underside.
(Etnier and Starnes, 1993; Jenkins and Burkhead, 1994)

Distribution - The flat bullhead is native to the Atlantic Coast drainages from Roanoke River, Virginia, south through the Altamaha River drainage, Georgia, where it occurs both in the Piedmont and Coastal Plain. This species has been collected outside of its native range in Georgia in the Chattahoochee River drainage (Couch et al., 1995), introduced into the French Broad, Little Tennessee, and Hiwassee river basins in North Carolina (Menhinick, 1991), and two individuals were collected in the upper James River in Virginia (Jenkins and Burkhead, 1994).

Harmful Impacts - Impacts to native fauna in areas where this species has been introduced are unknown.

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Additional Web Resources

http://nas.er.usgs.gov/queries/FactSheet.asp?speciesID=737

Margined Madtom
Noturus insignis

Photo by Robert E. Jenkins, Noel M. Burkhead. http://www.cnr.vt.edu/efish/. Used by permission.

Description and Biology - The margined madtom is gray to tan in color, has dark margins on the dorsal, caudal, and anal fins, and does not exhibit blotching on the body as found on many other madtom species. Chin barbels are white, snout barbels are dusky brown. Madtoms can be distinguished from other catfish by the attached adipose fin that is continuous with the caudal fin whereas in other catfish, only a portion of the adipose fin is connected to the body. This species occurs in large, moderate gradient streams and rivers, feeds primarily on aquatic insects, and is most active at night. The margined madtom is one of the larger madtom species; adults can reach lengths greater than 6 inches. (Etnier and Starnes, 1993; Jenkins and Burkhead, 1994)

Distribution - The margined madtom is indigenous to Atlantic slope drainages from the Altamaha in Georgia, north to at least the lower Hudson in New York and in the New River drainage (Ohio River system) in Virginia and West Virginia (Jenkins and Burkhead, 1994). This species has been introduced outside of its native range in Maryland, Massachusetts, Michigan, New Hampshire, New York, North Carolina, Pennsylvania, Tennessee, Virginia,and West Virginia (Fuller et. al. 1999). Madtoms are frequently used as bait for smallmouth bass and most introductions are believed to be a result of angler bait bucket release.

Harmful Impacts - Although impacts to native fauna are currently unknown, the scarcity of stonecat (*Noturus flavus*) in the upper Holston River system may be related to the introduction of margined madtom in this system (Etnier and Starnes, 1993). Both of these species use similar habitats which include nesting habitats.

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Additional Web Resources

http://nas.er.usgs.gov/queries/FactSheet.asp?speciesID=748

Redbreast Sunfish
Lepomis auritus

Photo: Jim Negus, Tennessee Wildlife Resources Agency

Description and Biology - Adult redbreast sunfish have pale to bright orange coloration on the breast and belly and typically exhibit bright blue vermiculations on the cheek below the eye. Margins of the soft dorsal fin and caudal fin are usually yellow to orange. The pectoral fin is relatively short and if extended, does not reach past the eye. The black ear flap becomes long in adults and lacks a pale border. Large bluegill sunfish have similar yellow or orange coloration on the breast but lack blue vermiculation on the cheek and have a much longer pectoral fin. Redbreast sunfish can reach lengths greater than seven inches. They occur in a variety of habitats from small creeks to large rivers and reservoirs. This species feeds primarily on insects but a small portion of its diets consists of crustaceans and small fish (Etnier and Starnes, 1993).

Distribution - Redbreast sunfish are native to the Atlantic Slope drainages from New Brunswick south and to the Gulf Slope drainages west to the Apalachicola River Basin. This species has been introduced or introduced outside of its native range in Alabama, Arkansas, Georgia, Kentucky, Louisiana, New York, North Carolina, Oklahoma, Pennsylvania, Tennessee, Texas, Virginia, and West Virginia (Fuller et. al, 1999). Most introductions were intentional for sport fishing. The late 1920s and early 1930s were active periods of sunfish stocking by the U.S. Fish Commission which may have been the initial vector for introductions outside of the native range for this species (Jenkins and Burkhead, 1993).
In Tennessee, this species is well established in the Conasauga River system and throughout the Tennessee River drainage. Occurrences have also been documented in the upper Cumberland River drainage and in the Forked Deer and Big Sandy river systems in west Tennessee (Etnier and Starnes, 1993).

Harmful Impacts - In east Tennessee, this species is believed to have caused the decline or extirpation of many native longear sunfish populations through direct competition (Etnier and Starnes, 1993). Longear sunfish populations have been completely replaced by redbreast sunfish in the Tennessee River drainage in North Carolina. Both of these species occupy a very similar ecological niche.

References

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Additional Web Resources

http://nas.er.usgs.gov/queries/FactSheet.asp?speciesID=379

Round Goby
Neogobius melanostomus

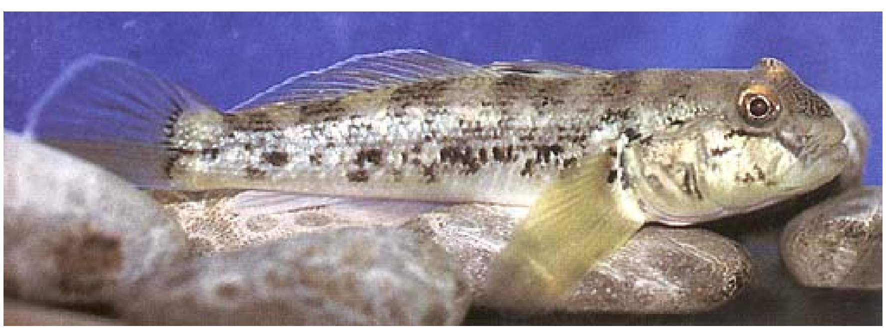

Photo by David Jude, Center for Great lakes Aquatic Sciences

Description and Biology - The round goby is a bottom dwelling fish with a large head, resembling a tadpole and can grow to a size up to 10 inches. Young round gobies are solid slate gray. Older fish are blotched with black and brown, have a greenish dorsal fin with a black spot, and have distinctive raised eyes. Round gobies look similar to sculpins, a native, bottom-dwelling fish that is mottled brown in color. Gobies are the only fish that have fused pelvic fins which form a suctorial disk that allows them to stay on the bottom in fast current (see illustration below). This is the easiest way to distinguish a goby from a sculpin. They have the ability to survive in poor water quality conditions and to feed in complete darkness. Gobies have a long spawning period (April through September) and prefer rocky or gravel substrates. Females produce 300 to 5,000 eggs which are deposited in nests and are often guarded by the male. They are aggressive fish and voracious feeders, often eating the eggs and larvae of native fish. They will vigorously defend spawning sites in rocky habitats, restricting access of native species to prime spawning areas. Females mature at 1 to 2 and males at 3 to 4. (Marsden and Jude, 1995)

Distribution

The round goby is native to marine and freshwater environments in Eurasia including the Black Sea, Caspian Sea, and Seas of Azov and tributaries (Miller, 1986). Nonindigenous North American occurrences: After first being discovered in 1990 along the St. Claire River (a Canadian river north of Detroit), gobies have now been found in all of the Great Lakes and many major tributaries within the boundaries of Michigan, Illinois, Indiana, Ohio, Pennsylvania, Wisconsin, Minnesota, New York, and Ontario (Fuller et al., 1999). They now have access to America's largest watershed through the Grand Calumet River (which begins at Lake Michigan near Chicago and connects with the Mississippi River).

Round gobies were introduced into the Great Lakes via transoceanic freighter ballast water from the Black and Caspian seas and continue to spread by freighters operating in the Great Lakes.

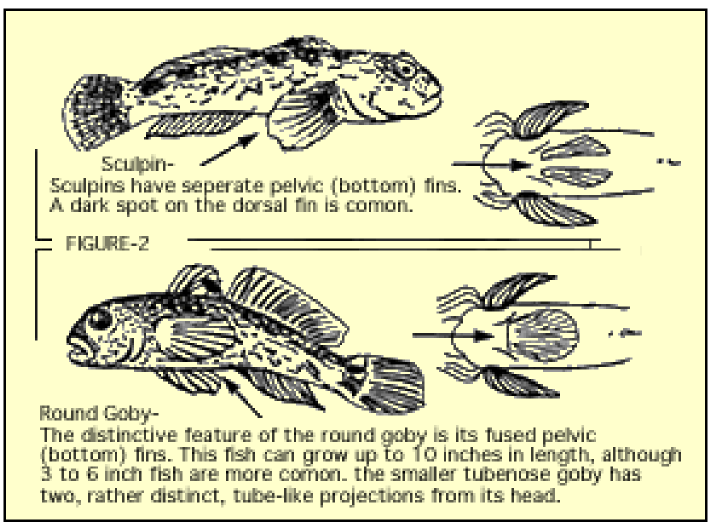

Illustration: Marsden and Jude, 1995. http://www.seagrant.umn.edu/exotics/goby.html

Harmful Impacts - The round goby has been found to prey on darters, other small fish, and lake trout eggs and fry in laboratory experiments. Mottled sculpins (*Cottus bairdi*) have been particularly affected since the establishment of this species due to competition for habitat and food (Marsden and Jude, 1995). In Calumet Harbor, mottled sculpin recruitment failure has been documented since the introduction of the round goby (Janssen and Jude, 2001). Adult round gobies eat up to 78 zebra mussels a day, but it is unlikely that gobies alone will have a detectable impact on the zebra mussel population (Fuller et al., 1999). Zebra mussels may offer an unexploited food resource that could fuel a round goby population explosion (Vanderploeg et al., 2002). The invasion of round gobies into Lake Erie has had very real economic impacts. Ohio enacted a closed season on the smallmouth bass fishery in Lake Erie during May and June to protect smallmouth bass recruitment. Male smallmouth bass guard nests and are effective in keeping round gobies away. When males are removed, round gobies immediately invade and have been shown to eat up to 4,000 eggs within 15 minutes. The months of May and June normally account for 50 percent of the total smallmouth catch in Lake Erie so there will be a considerable loss in funds generated by recreational anglers (National Invasive Species Council, 2004).

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Additional Web Resources

http://www.tnfish.org/InvasivesExotics/RoundGoby_USGS.pdf

http://nas.er.usgs.gov/queries/FactSheet.asp?speciesID=713

Rudd
Scardinius erythrophthalmus

Photo by Noel M. Burkhead, U.S. Geological Survey

Description and Biology - The rudd is a silvery/golden deep-bodied minnow with a strong downward curve in the lateral line. It has a keel present along midline of belly from anus forward to pelvic fin bases. The rudd is similar to the golden shiner (*Notemigonus crysoleucas*), but the rudd has scales on the keel on midline of belly and adult individuals have bright red fins (See Pflieger, 1997 for more separating characters). Adults are commonly 8 to 12 inches long and maximum size reported within its native range is about 16 inches and 4.4 pounds. The rudd feeds on zooplankton, aquatic insects, crustaceans, filamentous algae, aquatic plants, and occasionally on small fish and fish eggs. This species is very fecund; a single female may produce more than 200,000 eggs. Individuals reach sexual maturity by age 2 or 3 and can live up to 17 years. (Pflieger, 1997)

Distribution - The rudd is native to Europe and central Asia and was initially introduced to the United States as an ornamental in the early 1900s. In recent times, this species has been reared by fish farmers and sold as bait in Arkansas, Virginia, and elsewhere (Pflieger, 1997; Jenkins and Burkhead, 1993; Fuller et al., 1999). Bait bucket releases are probably the primary mechanism for introductions. The rudd has been introduced in Alabama, Arkansas, Colorado, Connecticut, Kansas, Massachusetts, Maine, Missouri, Nebraska, New Jersey, New York, Oklahoma, Pennsylvania, South Dakota, Texas, Vermont, Virginia, West Virginia, and Wisconsin (Fuller et al., 1999).

Harmful Impacts - The impact of introduction of this species on native fauna is largely unknown. Burkhead and Williams (1991) were successful in breeding the rudd and golden shiner in a laboratory environment. This could have genetic integrity implications to native golden shiner populations. Additionally, the rudd competes with native fishes for invertebrate food sources.

References

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Additional Web Resources

http://digital.library.okstate.edu/OAS/oas_htm_files/v70/p37nf.html

http://nas.er.usgs.gov/queries/FactSheet.asp?speciesID=648

http://nematode.unl.edu/rudd.htm

http://sgnis.org/search/nnmark2.asp?IN=Keyword&PR=B&FOR=EUROPEAN_RUDD

Ruffe
Other common names: Eurasian ruffe, pope
Gymnocephalus cernuus

Photo by Konrad P. Schmidt, Minnesota Division of Natural Resources

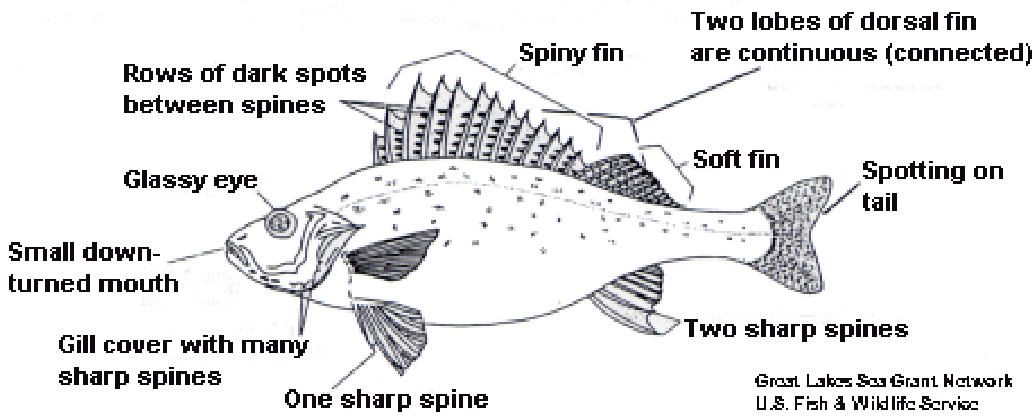

Illustration: Great Lakes Sea Grant Network and U.S. Fish and Wildlife Service

Description and Biology - The ruffe is a perch-like fish that resembles a yellow perch with walleye markings. Its continuous dorsal fin helps distinguish this species from young walleye. Adult ruffe average five to six inches in length but they can reach lengths up to 10 inches. The ruffe can tolerate and thrive in a wide range of temperatures and habitats. This species has high fecundity; an average female can produce 13,000 to 200,000 eggs per season, thus populations can explode quickly. Average life span of females is seven years, while males typically live three to five years. In Europe, the ruffe is found in fresh and brackish waters. In rivers, the ruffe prefers slower-moving water; in lakes, it prefers turbid areas and soft bottoms, usually without vegetation. The ruffe is a nocturnal feeder and has a well developed sensory system to detect predators and prey. In Europe, the ruffe is known to eat fish eggs, but the majority of its diet consists of benthic aquatic invertebrates. (Minnesota Sea Grant, 1994)

Distribution - The ruffe is native to northeastern France, England, most of Siberia, and the Baltic Sea and tributaries (Minnesota Sea Grant, 1994). North American nonindigenous occurrences: The ruffe was first collected in North America in 1986 from the St. Louis River at the border of Minnesota and Wisconsin. It then spread in Lake Superior and into several tributaries of the lake. In 1994, it was found in Saxon Harbor, Wisconsin and in Michigan at the mouths of the Black and Ontonagon rivers. In 1995, it was collected in Lake Huron at the mouth of the Thunder Bay River. This species was probably unintentionally introduced with discharged ship ballast water and may have been spread through the Great Lakes by intra-lake shipping (Fuller et al., 1999).

Harmful Impacts - The ruffe has quickly become the dominant species in the St. Louis River estuary (McLean, 1993). Based on bottom trawl samples, ruffe make up an estimated 80% of fish abundances in the southwestern regions of Lake Superior (Leigh, 1998). The population in Duluth Harbor was estimated at two million adult fish in 1991 and was the most abundant species of the 60 fish species found there (Ruffe Task Force, 1992). Yellow perch (*Perca flavescens*), emerald shiners (*Notropis atherinoides*), and trout-perch (P*ercopsis omiscomaycus*) have all declined since the introduction of this fish into the Great Lakes Region (McLean, 1993). The ruffe has affected fish populations in other areas where introduced. In Scotland, native perch populations declined, and in Russia whitefish numbers have declined because of egg predation by ruffe (McLean, 1993). Ogle et al. (1995) found that ruffe inhabiting the St. Louis estuary prey heavily on benthic insects which suggests that ruffe compete for food with yellow perch, trout-perch, and other native benthic-feeding fishes.

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Additional Web Resources

http://nas.er.usgs.gov/queries/FactSheet.asp?speciesID=7

http://www.invasivespeciesinfo.gov/aquatics/ruffe.shtml

http://www.anstaskforce.gov/spoc/ruffe.php

http://ag.ansc.purdue.edu/EXOTICSP/ruffe.htm

Silversides

Inland Silverside
Menidia beryllina

Inland Silverside snout shape

Brook Silverside (Similar species)
Labidesthes sicculus

Brook Silverside snout shape

All photos by Jim Negus, Tennessee Wildlife Resources Agency

Description and Biology - The inland silverside is a small fish with a compressed, elongate body bearing a bright silvery lateral stripe. It is similar in appearance to the brook silverside but lacks a beak- like snout and has much larger dorsolateral scales. For additional morphological differences (i.e. predorsal scale number, anal fin ray number) see Etnier and Starnes, 1993. This species occurs in brackish costal waters and freshwater rivers and reservoirs. It occurs in large schools and feeds near the surface. Stomach contents of specimens collected from the Mississippi River in west Tennessee contained midge larvae, mayfly larvae, and fallen terrestrial insects. Inland silversides live up to two years and reach lengths of 125 mm (about 5.5 inches) (Etnier and Starnes, 1993). Females have high reproductive potential; a single large female may produce over 150,000 eggs in 100 days which is equivalent to 6 or 8 times her body weight (Hubbs, 1976).

Distribution - The inland silverside is native to costal and freshwater habitats from Massachusetts to Mexico occurring inland up the Mississippi River to Illinois, in the Arkansas and Red Rivers, and in the Rio Grande (Boschung and Mayden, 2004). This species has been introduced outside of its native range in California, Arkansas, Missouri, New Mexico, Oklahoma, and Texas where it was intentionally stoked as forage for sport fish in most locations (Fuller et al., 1999). In Tennessee, this species has quickly invaded the Tennessee and Cumberland river systems. In the Tennessee River system, individuals were first collected in Kentucky and Pickwick reservoirs in 1993, Wilson and Wheeler reservoirs in 1994, Guntersville reservoir in 2002, Nickajack reservoir in 2001, and Chickamauga, Watts Bar, Fort Loudon, and Tellico reservoirs in 2004 (TVA, unpubl. data). This species was first collected in the Cumberland River from Barkley Reservoir in the early 1990s and has been collected frequently since 1999 in Barkley and Old Hickory reservoirs (TVA, unpubl. data). This invasion may be occurring naturally from the Ohio River or this species may have entered the system through the Tennessee-Tombigbee Waterway. The second route may be unlikely since this species has not been collected very far inland in the Mobile Basin in Alabama (Boschung and Mayden, 2004).

Harmful Impacts - Introduced populations of inland silversides in Oklahoma almost completely replaced brook silversides (Gomez and Lindsay, 1972; Moyle 1976). In a California lake, inland silversides displaced several other fish species through competition for food including the now extinct Clear Lake splittail, *Pogonichthys ciscoides* (Cook and Moore, 1970). The effect of the inland silverside invasion on native aquatic fauna in the Tennessee and Cumberland rivers is currently unknown. TVA samples since 2001 in Kentucky reservoir lacked brook silversides but contained inland silversides, with the exception of 2005 samples in which inland silversides were more abundant. Similarly, higher densities of inland silversides than brook silversides were encountered in Wheeler reservoir during 2001 and 2005, and the 2003-2004 samples yielded only inland silversides. Since first being detected in Guntersville reservoir, inland silversides have been more abundant in samples than brook silversides. In Barkley and Old Hickory reservoirs, densities of inland silversides were higher than brook silversides in samples collected since 2001. Although more time is needed to fully understand impacts to brook silverside populations (and other species whose ecological niche may overlap at some life stage) in the Tennessee and Cumberland rivers, trends indicate that brook silversides are being affected by this invader.

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Snail Bullhead
Ameiurus brunneus

Photo: Florida Fish and Wildlife Conservation Commission. Used with permission.

Description and Biology - The snail bullhead is mottled olive-brown to gray-brown on the back and sides with a white underside. This species has a dark spot at the base of the dorsal fin which is less distinct and may be less frequently present than in the flat bullhead (*Ameiurus platycephalus*). Maxillary barbels are completely dark and fins are usually lighter in color than the rest of the body. The snail bullhead can attain a length of one foot and feeds on insect larvae, snails, minnows, filamentous algae, and aquatic macrophytes. It occurs in medium to large streams and rivers where spawning is thought to occur during May and early June. It is similar in appearance to the flat bullhead but the flat bullhead has bicolor maxillary barbels. (Jenkins and Burkhead, 1993)

Distribution - The snail bullhead is native to the Atlantic Slope from the Pee-Dee River basin beginning in southern Virginia, south to the Altamaha River basin in Georgia and in the middle St. Johns River drainage in Florida. It is native to the Gulf Slope in the Apalachicola River basin in Georgia, Alabama, and Florida (Page and Burr, 1991). This species has been introduced outside of its native range in the Etowah River system in Georgia, in the Dan

River system in Virginia and North Carolina, and in the Little Tennessee and Hiwassee River basins in North Carolina (Fuller et al., 1999).

Harmful Impacts - Impacts to native fauna are unknown in areas where this species has been introduced.

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Additional Web Resources

http://www.flmnh.ufl.edu/fish/freshwater/ictaluridae/snailbullhead.htm

http://nas.er.usgs.gov/queries/FactSheet.asp?speciesID=728

<u>Snakeheads</u>

Two distinct genera:
Channa (snakeheads of Asia, Malaysia, and Indonesia- 26 species)
Parachanna (African snakeheads- 3 species)

Photo: U.S. Geological Survey- Florida Integrated Science Center

Description and Biology - Snakeheads have somewhat elongated and cylindrical bodies with a flattened head. They have large scales on top of their heads with eyes located in a dorsolateral position on the anterior part of the head. Dorsal and anal fins are elongated and the caudal fin is rounded. The mouth is terminal and large with a protruding lower jaw, which is toothed, often containing canine-like teeth. The only North American native species that snakeheads could be confused with is the bowfin (*Amia calva*). The pelvic fin of the snakehead is located almost directly below the pectoral fin, whereas the pelvic fin of the bowfin is located much more posterior in the belly region. Additionally, the anal fin of the bowfin is much shorter than that of a snakehead. Snakeheads are air breathing fishes that have the ability to travel over land to colonize new areas. Snakeheads have very little if any tolerance for saltwater, but can tolerate a wide range of pH. Snakeheads inhabit small to large streams, rivers, ponds, reservoirs, and lakes within their native and introduced ranges. Many species nest in dense aquatic vegetation and all species exhibit parental care. Many species can attain a size of several feet in length. Juveniles eat zooplankton, insect larvae, small crustaceans, and small fishes. Adults become voracious predators and consume fish, crustaceans, frogs, reptiles, small birds, and mammals. (Courtenay and Williams, 2004)

Distribution - Species and species complexes of the genus *Channa* are native from southeastern Iran and eastern Afghanistan eastward through Pakistan, India, southern Nepal, Bangladesh, Myanmar, Thailand, Laos, Malaysia, Sumatra, Indonesia, Vietnam, Korea, and China northward into Siberia. Most of these species occur in tropical to subtropical regions, although a few species can tolerate colder climates and one species can live beneath ice in the northern part of its range. The three species of *Parachanna* are native to Africa and occur in tropical climates (Courtenay and Williams, 2004). Five species of snakeheads (all in the genus *Channa*) have been reported from open waters of the United States (California, Florida, Hawaii, Maine, Maryland, Massachusetts, North Carolina, Rhode Island, Tennessee, and Wisconsin), and three became established as reproducing populations in Florida, Maryland, and Hawaii (Courtenay and Williams, 2004; TWRA news release, 2006). Introductions are believed to have been the result of aquarium releases or intentional releases for a sport or food fish.

Harmful Impacts - The predatory nature of snakeheads indicates that their introduction could negatively impact populations of native fishes through direct predation, competition for food resources, and alteration of food webs. Larger species of snakeheads are considered to be top predators in their native ranges. Snakeheads are very protective of their young, thus enhancing survival beyond early life history stages and suggesting the possibility of eventual dominance in suitable waters. Economic impacts to the recreational fishing industry could be substantially detrimental over time. There are no waters in the United States that, based on temperature, would preclude some member(s) of the family Channidae from becoming established. (Courtenay and Williams, 2004)

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Additional Web Resources

http://fisc.er.usgs.gov/Snakehead_circ_1251/html/channa_argus.html

http://www.invasivespeciesinfo.gov/aquatics/snakehead.shtml

http://www.issg.org/database/species/ecology.asp?si=380&fr=1&sts

http://nas.er.usgs.gov/queries/FactSheet.asp?speciesID=2265

Mosquitofish

Western Mosquitofish
Gambusia affinis

Eastern Mosquitofish
Gambusia holbrooki

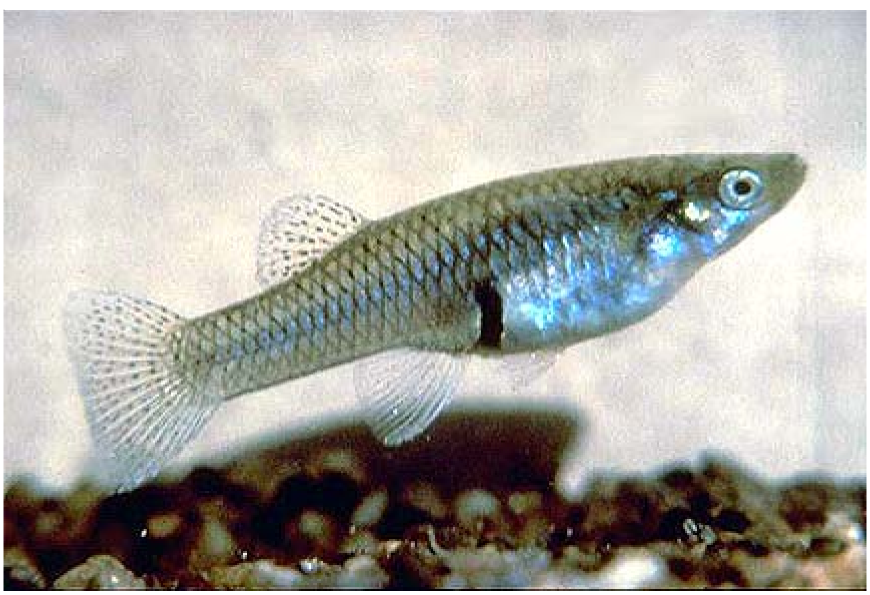

Photo by Noel M. Burkhead and Robert E. Jenkins. http://www.cnr.vt.edu/efish/. Used by permission.

Description and Biology - The western and eastern mosquitofish are very similar in appearance and only differ by dorsal and anal fin ray counts and the structure of the male gonopodium (Etnier and Starnes, 1993). Mosquitofish have large cycloid scales outlined with dark pigment, a silver belly, and are pale yellow over the rest of the body. The body and caudal fin are often speckled with black. The mosquitofish has an upturned mouth, allowing it to be an effective surface feeder. Females reach lengths of 65 mm (2.5 inches) while adult males are much smaller and only attain a size of 35 mm (1.4 inches). The lifespan of the mosquitofish averages about a year. These fish are livebearers and a single female can produce 3 or 4 broods a year. Sperm is transferred by internal fertilization from the male gonopodium where it is stored within the female and used to fertilize repeated broods. Reproductive success is generally very high due to parental care and high tolerance to elevated water temperatures, low oxygen, and poor water quality. Preferred habitat includes shallow waters of swamps and lakes and sluggish backwaters of creeks and rivers (Etnier and Starnes, 1993). Mosquitofish feed on aquatic and terrestrial insects, microcrustaceans, small snails, and larval fish, including their own young (Barkinol, 1941).

Distribution - The western mosquitofish was probably native to the coastal plain from western Alabama northward to southern Illinois, and westward into eastern Mexico where the extent of its range is uncertain (Rauchenberger, 1989). The eastern mosquitofish is native on the Atlantic slope from the Delaware River drainage south to the tip of Florida Peninsula and west into at least eastern Alabama (Jenkins and Burkhead, 1993). Exact determination of native range is difficult because these two species have been widely dispersed by humans as a biological control agent for mosquitoes (Fuller et al., 1999). Mosquitofish have been stocked outside of their native range in Alabama, Alaska, Arizona, California, Colorado, Connecticut, Florida, Hawaii, Idaho, Illinois, Indiana, Iowa, Kansas, Kentucky, Massachusetts, Michigan, Minnesota, Mississippi, Misouri, Montana, Nebraska, Nevada, New Jersey, New Mexico, New York, North Carolina, Ohio, Oregon, Pennsylvania, Tennessee, Texas, Utah, Virginia, Washington, West Virginia, Wisconsin, Wyoming, and probably other states (Fuller et al., 1999).

Harmful Impacts - Although mosquitofish prey on mosquito larvae and are widely introduced as mosquito control agents, critical reviews of the world literature on mosquito control have not supported the view that mosquitofish are very effective in reducing mosquito populations or in reducing the incidence of mosquito borne diseases (Courtenay and Meffe, 1989; Arthington and Lloyd, 1989). Mosquitofish introductions can lead to algal blooms when they eat the zooplankton grazers (Hurlbert et al., 1972) or cause an increase in mosquitoes if they eat the invertebrate predators (Hoy et al., 1972). Mosquitofish are extremely aggressive and can affect native fishes through direct competition and often attack, kill, or eat other fishes. The mosquitofish is responsible for the population reduction of the threatened Railroad Valley springfish, *Crenichthys baileyi*, in Nevada, the local elimination of the endangered Sonoran topminnow, *Poeciliopsis occidentalis*, in Arizona, and the elimination of the least chub, *Iotichthys phlegethontis*, in several areas in Utah (Deacon et al., 1964; Meffe et al., 1983). The greatest threat to imperiled Barren's topminnow (*Fundulus* *julisia*) populations in Tennessee is the presence or potential for colonization of mosquitofish in the few springheads where this species occurs. Goldsworthy and Bettoli (2005) stated that the primary mechanism in reproductive failure of the Barren's topminnow was mosquitofish predation on larvae and juveniles.

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http://www.discoverlifeinamerica.org/atbi/species/animals/vertebrates/fish/Poeciliidae/G_holbrooki.shtml

White Catfish
Ameiurus catus

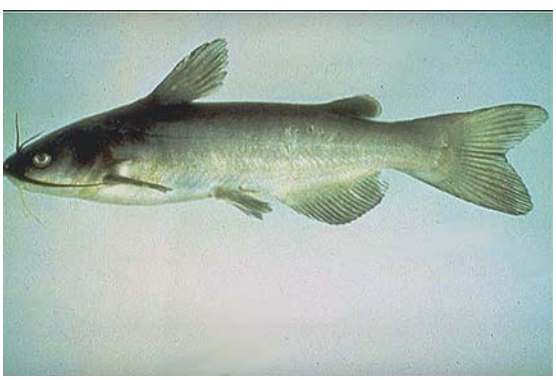

Photo by Robert E. Jenkins, Noel M. Burkhead. http://www.cnr.vt.edu/efish/. Used by permission.

Description and Biology - White catfish are grey dorsally and white ventrally. They have a moderately forked tail and adults are often heavy bodied and robust. Channel catfish (*Ictalurus punctatus*) have similar features but grow much larger. White catfish feed on fish, insects, and occasional consume plant material. This species reaches lengths of almost 2 feet and can weigh up to 10 pounds. Refer to Etnier and Starnes, 1993 and Jenkins and Burkhead, 1994 for additional information.

Distribution - This species is native to the Atlantic and Gulf Slope drainages from New York to the Apalachicola basin in Florida, Georgia, and Alabama, and the Florida panhandle. This species has been introduced outside of its native range in Alabama, Arkansas, California, Connecticut, Florida, Illinois, Indiana, Kentucky, Massachusetts, Mississippi, Missouri, Nevada, North Carolina, Ohio, Oregon, Pennsylvania, Rhode Island, Tennessee, and Washington (Fuller et. al, 1999). Most introductions have been intentional for sport fishing and food. In the Tennessee River drainage, this species has been introduced into the upper French Broad and Pigeon rivers.

Harmful Impacts - Currently, impacts of introduced populations on native catfishes and other aquatic species are unknown. This species was thought to be responsible for the disappearance of Sacramento perch, *Archoplites interruptus*, in Thurston Lake, California (McCarraher and Gregory, 1970).

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Additional Web Resources

http://nas.er.usgs.gov/queries/FactSheet.asp?speciesID=729

Yellow Perch
Perca flavescens

Photo by Jim Negus, Tennessee Wildlife Resources Agency

Description and Biology - The yellow perch is a percid that is gold in color with dark, distinct vertical lateral bars. The anal fin is orange-red on the leading margin, nearly all of the pelvic fin is orange-red, and the pectoral fin is amber. Yellow perch reach lengths up to one foot and maximum life span is at least eight years. This species inhabits both cool and warm water lakes and rivers where it is often associated with rooted vegetation in still water areas. It can also tolerate salinity in brackish waters. Spawning occurs in late winter to early summer (depending on water temperature) where females lay strands of eggs ranging from 2,000 to 157,600 eggs. A large portion of the adult diet consists of crayfish and small fish; smaller individuals consume aquatic insects, crustaceans, mollusks, and fishes. (Etnier and Starnes, 1993; Jenkins and Burkhead, 1993)

Distribution - Yellow perch are native from the middle Mackenzie drainage in Canada southeast through the northern states east of the Rocky Mountains (lower Hudson Bay to the Great Lakes- St. Lawrence and upper Mississippi basins) and to the Atlantic Slope drainages south to South Carolina (Etnier and Starnes, 1993; Jenkins and Burkhead, 1993). This species has been introduced outside of its native range into Alabama, Arizona, Arkansas, California, Colorado, Connecticut, Florida, Georgia, Idaho, Illinois, Indiana, Iowa, Kansas, Kentucky, Maine, Maryland, Massachusetts, Minnesota, Mississippi, Missouri, Montana, Nebraska, Nevada, New Jersey, New Mexico, New York, North Carolina, North Dakota, Ohio, Oklahoma, Oregon, Pennsylvania, South Carolina, South Dakota, Tennessee, Texas, Utah, Vermont, Virginia, Washington, West Virginia, and Wyoming (Fuller et al., 1999). This species was introduced for food and sport fishing beginning in the late 1800's by the U.S. Fish Commission. It is established in most areas where it has been introduced, but has been extirpated in Arkansas (Fuller et al., 1999).

Harmful Impacts - Yellow perch are known to compete for food resources with trout and likely prey on young trout (Coots, 1966). Conversely, yellow perch have been valuable forage for walleye in Georgia reservoirs (Rabern, 1998).

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Additional Web Resources

http://nas.er.usgs.gov/queries/FactSheet.asp?speciesID=820

Invertebrates - Mollusks

Asian Clam
Corbicula fluminea

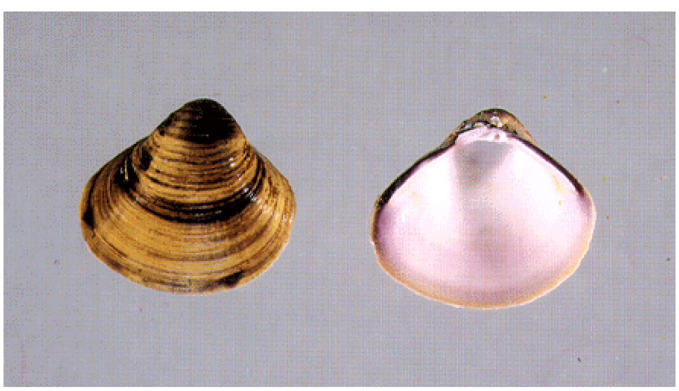

Photo by Kevin Cummings, Illinois Natural History Survey

Description and Biology - The Asian clam is a small, filter feeding bivalve that rarely exceeds 1.5 inches in length (typically, adult individuals are about the size of a nickel). The periostracum (outer shell surface) is light yellow in younger individuals and generally becomes dark brown to black in older individuals. The shell nacre (inside surface of the shell) is white to light purple in color. Growth periods are indicated by prominent rings of the external shell surface. There are three cardinal teeth present below the beak of each valve and two straight lateral teeth on each side of the individual valve. Native freshwater mussels only have one set of lateral and pseudocardinal teeth per valve. Unlike native North American freshwater mussels, larvae of this species are free swimming and do not require a host for development (Parmalee and Bogan, 1998). The Asian clam is hermaphroditic and is capable of self-fertilization. Larvae are brooded in the parent's gills and are released through the excurrent siphon into the water column as active post-larval juveniles. A single, prolific clam can release hundreds or even thousands of juveniles per day, up to 70,000 per year. Asian clams can reach densities of 10,000 to 20,000 per square meter (Balcom, 1994). This species occurs in substrates of silt, sand, and gravel in creeks, rivers, reservoirs, and ponds.

Distribution - The Asian clam is native to southeast China, Korea, and in the Ussuri Basin, southeastern Russia. The Asian clam was first collected in the United States along the banks of the Columbia River, Washington in 1938 (Burch, 1944). Since this first introduction, it is now found in 38 states and the District of Columbia (Foster et al., 2006). In Tennessee, the Asian clam is found in almost every river and reservoir with the exception of a few high gradient creeks and streams in the Blue Ridge and on the Cumberland Plateau (Parmalee and Bogan, 1998). This species was thought to enter the United States as a food item used by Chinese immigrants. Current methods of introduction include bait bucket introductions, accidental introductions associated with imported aquaculture species, and intentional introductions by people who buy them as a food item in markets (Devick, 1991; Counts, 1986).

Harmful Impacts - The greatest ecological impact of the introduction of this species is competition for habitat and food with native bivalves. The Asian clam's greatest economic impact in North America has been biofouling, especially of power plant and industrial water systems, where annual U.S. costs for control, repair, or replacement were estimated in 1986 at 1 billion dollars (Isom, 1986). Juvenile clams are carried into raw water system intakes, pass traveling screens and tertiary strainers, and settle in low-flow areas. After settlement, the juvenile clams grow rapidly and foul small-diameter components, such as narrow gage lines, heat exchange/condenser tubing, fire protection lines and course strainers. Empty clam shells can also lodge in small-diameter components.

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Additional Web Resources

http://nas.er.usgs.gov/queries/FactSheet.asp?speciesID=92

Channeled Apple Snail
Pomacea canaliculata

Photo by Bill Frank, http://www.jaxshells.org/sjrwmd.htm. Used by permission.

Description and Biology - The channeled apple snail is a large, globular snail that can reach lengths greater than 3.5 inches. The shell contains 5 to 6 whorls which are separated by a deep, indented suture. Shell color is generally brownish or greenish, often with spiral banding patterns around the whorls, while some aquarium bred animals are bright golden yellow. The presence of the channeled apple snail in the wild is often first noted by observation of their bright pink egg masses laid on solid surfaces up to about 20 inches above the water surface. Clutch size can be up to 1000 eggs, but averages 200-300. A new clutch can be laid every few weeks. This species is a voracious herbivore and will consume almost any plant. This species lives up to 4 years and reaches sexual maturity in 3 months to 2 years, depending on ambient temperature regime. (Cowie, 2005)

Distribution - The channeled apple snail is widely distributed in the lentic habitats throughout the Amazon Inferior Basin and the Plata Basin: Southeast Brazil, Argentina, Bolivia, Paraguay and Uruguay (Albrecht et al., 1996). It has been introduced throughout southeast Asia and has become a major crop pest, particularly in rice fields. Introductions in the U.S. have been detected in Alabama, Arizona, California, Georgia, Hawaii, Texas, Florida, and Indiana (Howells, 2005; Indiana DNR, 2005; USGS, 2006). It has been introduced through aquarium releases.

Harmful Impacts - The channeled apple snail is a major crop pest in southeast Asia (primarily in rice) and Hawaii (taro), and poses a serious threat to many wetlands around the world through potential habitat modification and competition with native species. In the Philippines, it is considered the number one rice pest and has caused huge economic losses. In southeast Asia, introductions of this species are linked with the decline of native apple snails. Rice crops in Texas and California may soon become threatened by introduced populations of this species (Cowie, 2005).

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Additional Web Resources

http://www.jaxshells.org/sjrwmd2.htm

http://nis.gsmfc.org/nis_factsheet.php?toc_id=154

http://nas.er.usgs.gov/queries/FactSheet.asp?speciesID=980

http://www.applesnail.net/content/species/pomacea_canaliculata.htm

Chinese Mystery Snail
Cipangopaludina chinensis

Other common names: Asian Mystery Snail; Chinese Mystery Snail; Chinese Apple Snail; Asian Apple Snail

Photo: Martin Kohl. Used by permission

Description and Biology - The shell of the Chinese mystery snail is smooth and is a uniform light to dark olive-green, lacking color bands. Black pigmentation rims the entire lip and somewhat within the aperture. Large specimens reach 65 mm (2.5 inches) in length; their shells have 6 or 7 whorls. This species feeds on periphyton (diatoms; other algae), phytoplankton, and detritus and is most often found in slow moving streams, ponds, or lake margins where there is some vegetation and a substrate of mud (Clench and Fuller, 1965).

Distribution - This species is native to Burma, Thailand, South Vietnam, China, Korea, and Asiatic Russia in the Amur region, Japan, the Philippines, and Java (Pace, 1973). This species has become widespread in scattered locations, mostly ponds, lakes, and reservoirs, but sometimes also colonizing river systems, from California to British Columbia and Florida to Maine and Quebec. This snail was first found in North America in Chinese markets in San Francisco, California in 1892. By 1911, they were established in the region between San Jose and San Francisco, and were collected in the Sacramento-San Joaquin Delta by 1938. They were found in Boston, Massachusetts in 1915 and in 1950, Florida reported finding a population. By 1965, Chinese mystery snails were established on the west and east coasts as well as in some of the Gulf States like Texas. Lake Michigan and Lake Erie populations were reported in 1965. Most introductions are believed to be a result of aquarium release. (Fofonoff et al., 2003) . This invasive species has been found in Watauga Lake, located in Centennial Park, Nashville, TN.

Harmful Impacts - This species can serve as a vector for various parasites and diseases which can infect human beings (Pace, 1973). Additionally, introduced populations compete with native snails for food and space.

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Pace, G.L. 1973. The freshwater snails of Taiwan (Formosa). Malacological Review Supplement 1. Pages 1-117.

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http://nas.er.usgs.gov/queries/FactSheet.asp?speciesID=1044

http://invasions.si.edu/nemesis/CH-TAX.jsp?Species_name=Cipangopaludina+chinensis

http://nis.gsmfc.org/nis_factsheet.php?toc_id=125

http://www.in.gov/dnr/fishwild/fish/ais/snail.htm

New Zealand Mud Snail
Potamopyrgus antipodarum

Photos: U.S. Geological Survey, Gainesville, Florida.

Description and Biology - The New Zealand mud snail is a very small aquatic snail that can reach lengths up to 12 mm (~0.5 inch) but most mature individuals are less than 5 mm (~0.2 inch) long. The shell is elongated and coils to the right, typically forming 5-6 whorls. The shell is light to dark brown in color. Populations consist of asexually reproducing females that clone themselves and retain the embryos inside their shell until they are mature. This reproductive strategy allows this species to rapidly colonize new areas. New Zealand mud snails can tolerate a wide range of habitats, including brackish water, and are found on various types of substrates, usually in high densities. This species can tolerate a wide range of water temperatures, except freezing, and can survive periods of desiccation. This snail feeds on diatoms, plant and animal detritus, and attached periphyton.
(Benson, 2006; Oregon Sea Grant, 2006; Montana State University, 2006)

Distribution - This species is native to freshwater streams and lakes of New Zealand and adjacent islands. It has been introduced and naturalized in Australia and Europe. The New Zealand mud snail was first discovered in the U.S. in the middle portion of the Snake River in Idaho in 1987 (Benson, 2006). By 1995, it was known from Idaho, Wyoming, and Montana, and by 2005, it had spread to Arizona, Utah, Nevada, Colorado, Oregon, Washington, and California (Montana State University, 2006). This rapid range expansion is probably the result of snail-hitchhikers attached to boots, waders, hats, etc. (Oregon Sea Grant, 2006).

Harmful Impacts - The New Zealand mud snail is established in 10 western U.S. states including three national parks. In suitable habitats, this snail reaches densities greater than $100,000/m^2$ and has been reported to approach densities as high as $750,000/m^2$ in sections of rivers in Yellowstone National Park. This species has also been shown to drastically alter primary production in some streams (Montana State University, 2006). Certain types of aquatic invertebrates (mayflies, stoneflies, and caddisflies), which are the primary food base for trout, appear to be declining in abundance at sites where mud snails now account for more than 50% of the relative abundance of aquatic invertebrates. Mud snails are a poor substitute for the traditional food base, yielding as little as 2% of their nutritional value when eaten by trout (Yellowstone National Park, 2006). This species could cause serious problems for entire fish communities if aquatic invertebrate communities are reduced. Introductions may also have implications to native snails through direct competition.

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Montana State University. 2006. New Zealand mudsnails in the western USA. http://www.esg.montana.edu/aim/mollusca/nzms/

Amy Benson. 2006. Potamopyrgus antipodarum. USGS Nonindigenous Aquatic Species Database, Gainesville, FL.http://nas.er.usgs.gov/queries/FactSheet.asp?speciesID=1008

Additional Web Resources

http://www.protectyourwaters.net/hitchhikers/mollusks_new_zealand_mudsnail.php

http://cars.er.usgs.gov/mudsnail5.pdf

http://www.issg.org/database/species/ecology.asp?si=449&fr=1&sts=sss

http://cars.er.usgs.gov/pics/nonindig_mud_snail/nonindig_mud_snail.html

Zebra Mussel
Dreissena polymorpha

Photos: Top left- U.S. Geological Survey; top right and bottom left- Ontario Ministry of Natural Resources; bottom right- Illinois Natural History Survey

Description and Biology - The zebra mussel is a small mussel, reaching a maximum length of about 40 mm (1.5 inches). Shell color can be cream colored without banding but typically patterned with irregular, usually parallel, black or brown bands. Shell nacre (inside surface) is bluish white (Parmalee and Bogan, 1998). This species is capable of attaching itself to a hard surface using adhesive secretions called byssal threads, which can often be seen when the shell is removed from a surface. Eggs are fertilized after they are expelled into the water column. Females generally reproduce in their second year. Reproduction usually occurs in the spring or summer, depending on water temperature. Optimal temperature for spawning is 14-16 ^{o}C. Over 40,000 eggs can be laid in a reproductive cycle and up to one million in a spawning season. After the eggs are fertilized, the larvae (veligers) emerge within 3 to 5 days and are free-swimming for up to a month. Downstream dispersal of larvae is facilitated by flow. Zebra mussels are filter feeders and individuals are capable of filtering about one liter of water per day, feeding primarily on algae. The life span of this species is variable, but can range from 3-9 years. (Benson and Raikow, 2006)

Distribution - Zebra mussels are native to the Black, Caspian, and Azov Seas. They were first discovered in North America in 1988 in the Great Lakes. The first account of an established population came from Canadian waters of Lake St. Clair, a water body connecting Lake Huron and Lake Erie. By 1990, zebra mussels had been found in all the Great Lakes. The following year, zebra mussels escaped the Great Lakes basin and found their way into the Illinois and Hudson rivers. The Illinois River was the key to their introduction into the Mississippi River drainage which covers over 1.2 million square miles. By 1992, the following rivers had established populations of zebra mussels: Arkansas, Cumberland, Hudson, Illinois, Mississippi, Ohio, and Tennessee. By 1994, the following states had reported records of zebra mussels within their borders or in water bodies adjacent to their borders: Alabama, Arkansas, Illinois, Indiana, Iowa, Kentucky, Louisiana, Michigan, Minnesota, Mississippi, Missouri, New York, Ohio, Oklahoma, Pennsylvania, Tennessee, Vermont, West Virginia, and Wisconsin. Since 2002, this species has been found in Connecticut, Virginia, Nebraska, and South Dakota (Benson and Raikow, 2006). A release of larval mussels during the ballast exchange of a commercial cargo ship traveling from the north shore of the Black Sea to the Great Lakes has been deduced as the likely vector of introduction to North America (McMahon 1996). Its rapid dispersal throughout the Great Lakes and major river systems was due to the passive drifting of the larval stage, and its ability to attach to boats navigating these lakes and rivers. Overland dispersal has been via boats and boat trailers (Benson and Raikow, 2006).

Harmful Impacts - Zebra mussels are notorious for their biofouling capabilities by colonizing water supply pipes of hydroelectric and nuclear power plants, public water supply plants, and industrial facilities. The colonies constrict flow, therefore reducing the intake in heat exchangers, condensers, fire fighting equipment, and air conditioning and cooling systems. Navigational buoys have been sunk under the weight of attached zebra mussels. Fishing gear can be fouled if left in the water for long periods. Deterioration of dock pilings has increased when they are encrusted with zebra mussels. Continued attachment of zebra mussel can cause corrosion of steel and concrete affecting its structural integrity. Zebra mussels can have profound effects on the ecosystems they invade. Large populations of zebra mussels in the Great Lakes and Hudson River reduced the biomass of phytoplankton and zooplankton significantly following invasion. Reductions in zooplankton biomass may cause increased competition, decreased survival, and decreased biomass of planktivorous and larval fish (Benson and Raikow, 2006). Other effects include the extirpation of native freshwater mussels through epizootic colonization (Schloesser *et al.*, 1996; Baker and Hornbach, 1997). Zebra mussels restrict valve operation, cause shell deformity, smother siphons, compete for food, impair movement and deposit metabolic waste into mussels. Freshwater mussels have been extirpated from Lake St. Clair and have almost disappeared in western Lake Erie.

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http://www.issg.org/database/species/ecology.asp?si=50&fr=1&sts=sss

http://nas.er.usgs.gov/taxgroup/mollusks/zebramussel/

http://www.protectyourwaters.net/hitchhikers/mollusks_zebra_mussel.php

http://www.nationalatlas.gov/dynamic/dyn_zm.html#

http://www.invasivespeciesinfo.gov/aquatics/zebramussel.shtml

Invertebrates - Crustaceans

Bigclaw Crayfish
Orconectes placidus

Photo by Keith A. Crandall.

Description and Biology - The bigclaw crayfish is typically tan to pale green with a pair of dark saddles on the carapace. The fingers of the chelae (claws) are long and usually exhibit orange tips bordered by a dark submarginal band. The bigclaw crayfish is commonly found beneath rocks, leaf litter, and undercut banks in the riffles and pools of small streams to large rivers.

Distribution - The bigclaw crayfish is native to portions of Illinois, Kentucky, Alabama, and Tennessee. In Tennessee it naturally occurs in the lower reaches of the Cumberland and Tennessee river systems as well as the Barren River system from the western edge of the Cumberland Plateau, Nashville Basin, and Highland Rim provinces. Introduced populations have been documented in the eastern portion of the state from the Obed River (Emory River system in Cumberland County) and in Cove Creek (Clinch River system in Campbell County). This species is considered an aquatic invasive species in areas of Tennessee where it has been accidentally or deliberately introduced.

Harmful Impacts - Sometimes a species that is native to certain areas of a state becomes invasive when introduced into another area. Harmful impacts sometimes occur because the introduced species has dominating physiological characteristics plus a lack of natural predators to control population growth in the existing ecological systems of the new habitat. The bigclaw crayfish is competing with and displacing native crayfish species historically known to occur within portions of the Obed River (Roger Thoma, 2005. unpubl. data). The same impact to the native crayfish fauna within the Cove Creek drainage in Campbell County is presumed to be occurring as well. Impacts on other aquatic organisms resulting from bigclaw crayfish introductions are currently unknown.

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Cumberland Crayfish
Cambarus (Puncticambarus) cumberlandensis

Photo: G. Whitney Stocker

Description and Biology - The Cumberland crayfish is reddish-brown dorsally with green chelae (pinchers). Two rows of tubercles are present on the palm of the chelae which is typical for members of the subgenus *Puncticambarus*. Male gonopods are sickle-shaped as they are for all members of the genus *Cambarus*. See Hobbs and Bouchard (1973) for species description.

Distribution - This species is an inhabitant of streams in the Cumberland Plateau and Highland Rim physiographic provinces of Tennessee and Kentucky. It is native to the Cumberland River system from Jellico Creek, Scott County, Tennessee downstream to and including the Roaring River, Jackson County, Tennessee; and Green River system in Adair and Metcalf counties, Kentucky. It has been introduced into the Caney Fork River system in Dekalb County, Tennessee (Hobbs, 1989).

Harmful Impacts - Impacts of introduced population to native fauna, especially other crayfish, are currently unknown (C. Williams, TN Wildlife Resources Agency, Pers. Comm. 2006).

References

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Additional Web Resources

http://iz.carnegiemnh.org/NewAstacidea/species.asp?g=Cambarus&s=cumberlandensis&ssp=

http://nas.er.usgs.gov/queries/FactSheet.asp?speciesID=205

Red Swamp Crawfish
Procambarus (Scapulicambarus) clarkii

Photo: Teresa Worst, North Carolina Division of Water Quality

Description and Biology - The red swamp crayfish is a large dark red to almost black crayfish with long slender chelae (pinchers), nearly obliterated areola (midsection of back), and rostrum with marginal tubercles or spines. Chelae have many bright red tubercles and carapace may have scattered cream colored tubercles. Male gonopods have four short, bladelike terminal processes that do not strongly curve laterally from the midline. Adults are typically 2.2 to 4.7 inches long (Pflieger, 1996). This species occurs in streams, ditches, swamps, and sloughs where it has been found over mud or sand in close proximity to organic debris. The red swamp crayfish occurs in burrows during the winter and may burrow during dry periods to escape desiccation (Pflieger, 1996).

Distribution - The native range of the red swamp crayfish is along the Gulf Coastal Plain from Escambia County, Florida (Florida panhandle) west to northeastern Mexico, and northward along the Mississippi River to southern Illinois and Ohio (Hobbs, 1989; Pflieger, 1996). Economically, the red swamp crayfish is the most important crayfish in North America due to its value for human consumption. Most aquaculture production is in Louisiana, but this species has been widely introduced (Pflieger, 1996). Huner (1986) listed introduced populations in Arizona, California, Georgia, Hawaii, Idaho, Indiana, Maryland, Nevada, New Mexico, North Carolina, Ohio, Oregon, and South Carolina. This species has also been introduced into Alaska, Maine, New York, and Virginia (Benson, 2006). Introductions are planned or have been made in several Central and South American countries and in Africa for food (Hobbs, 1989).

Harmful Impacts - Introduced populations of the red swamp crayfish have reduced the value of the freshwater habitats in which it occurs by consuming invertebrates and macrophytes, and degrading river banks by its burrowing activity (Holdich, 1999). In North Carolina, red swamp crayfish introductions have eliminated native crayfish species at several locations (Cooper, et al., 1998). First records of this species in North Carolina were in the 1980s and since then populations at several sites have experienced massive explosions in numbers and biomass (Cooper, et al., 1998; Fullerton and Watson, 2001). Introductions are the result of escape from aquaculture facilities and bait bucket introductions. Probable impacts to native fauna include destruction of aquatic vegetation, direct competition with native crayfishes, and predation on other aquatic species including aquatic and semi-aquatic snails and larval fish (Cooper, 2005).

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Additional Web Resources

http://animaldiversity.ummz.umich.edu/site/accounts/information/Procambarus_clarkii.html

http://www.issg.org/database/species/ecology.asp?si=608&fr=&sts=sss

http://nas.er.usgs.gov/queries/FactSheet.asp?speciesID=217

Rusty Crayfish
Orconectes (Procericambarus) rusticus

Photo by Carl Williams, Tennessee Wildlife Resources Agency

Description and Biology - Rusty crayfish can be recognized by the rust or maroon-colored splotches that are found on both sides of the crayfish mid-section. The spots are located between the attachment areas of the tail and pinchers (chelae) to the body (carapace). Note- These spots may not always be present or well developed. The claws of this species are often grayish-green to reddish-brown in color and usually have black bands on the tips. For additional identifying characteristics, refer to Gunderson, 1999. Rusty crayfish inhabit lakes, ponds, and streams that contain water year-round and utilize rocks, logs, or other debris for cover. This species inhabits both pools and fast water areas of streams and do not generally dig burrows other than small pockets under rocks and other debris. It can live 3-4 years. Rusty crayfish feed on a variety of aquatic plants, aquatic invertebrates, leeches, clams, other crustaceans, detritus, fish eggs, and small fish (Gunderson, 1999).

Distribution - The rusty crayfish is native to the tributaries of the Ohio River in southwestern Ohio, northern Kentucky, and southeastern Indiana. It has been spread, primarily through baitbucket releases, as far north as Maine and Ontario, south to Tennessee, and west to New Mexico (Hobbs and Jass, 1988). Initially, the rusty crayfish was introduced to the northern part of the Great Lakes region by fishermen who used them as bait. As the population of rusty crayfish increased, they were harvested for use as fish bait and sold to biological supply companies. This provided impetus to breeding rusty crayfish, and subsequently, releasing them, intentionally or otherwise, into non-native waters.

Harmful Impacts - This species is particularly destructive since it feeds heavily on aquatic plants which are important habitat for other invertebrates (food for fish and waterfowl), shelter for fish, nesting substrate for fish, and aid in erosion control (Gunderson, 1999). When introduced, negative impacts include destruction of aquatic vegetation, direct competition of various kinds with native crayfishes, possible hybridization, and predation on other aquatic species (Lodge et. al, 2000; Hobbs et. al, 1989). In the Tennessee River system, introduced populations are well established in the Clinch, Holston, and Nolichucky river systems (Williams and Bivens, 2001). It has also been collected in the Little Tennessee River system in Tennessee (Tellico River) and North Carolina (tributary to Little Tennessee River arm of Fontana Reservoir) (Williams and Bivens, 2001; Cooper, 2002). In Tennessee, it is expanding its range and may be replacing some native species, such as *Orconectes forceps* (Williams and Bivens, 2001).

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Williams, C. E., and R.D. Bivens. 2001. Annotated list of the crayfishes of Tennessee. Tennessee Wildlife Resources Agency report, Nashville. 25 pp.

Additional Web Resources
http://iz.carnegiemnh.org/crayfish/NewAstacidea/species.asp?g=Orconectes&s=rusticus&ssp=

http://www.issg.org/database/species/ecology.asp?si=217&fr=1&sts=

http://nas.er.usgs.gov/queries/FactSheet.asp?speciesID=214

Virile Crayfish
Other common name: northern crayfish
Orconectes (Gremicambarus) virilis

NOTE: Picture is of preserved specimen, body color of live individual will vary.
Photo by Jeff Simmons, North Carolina Wildlife Resources Commission

Description and Biology - The virile crayfish is large; adults range from 2 to 5 inches and males grow larger than females. The carapace (body) is usually reddish-brown or olive-brown in color. The abdomen is brownish-green with two lengthwise rows of black blotches. The chelae (claws) can be green or blue and often have a conspicuous white outer margin. Typically, chelae have blackish specs and fingers can have orange or orange-red tips. The virile crayfish can be found in rivers, streams, and ponds with abundant cover such as slab rocks, logs, or deposits of organic debris. It is typically most abundant in streams and rivers that are warm, moderately turbid, and without strong base flow. This species is not a burrowing species, but will dig horizontal tunnels into stream banks to mate and brood eggs. (Pflieger, 1996)

Distribution - The virile crayfish is native as far north as Hudson Bay. Southward, it occurs from New England to western Montana and through the Missouri, Mississippi and Ohio river basins to Oklahoma and northern Arkansas. It has been widely introduced outside of its native range (Pflieger, 1996). Most introductions have probably been the result of bait bucket releases. In Tennessee, this species has been introduced to the Nolichucky, French Broad, and Holston river systems, as well as a tributary to Watts Bar Reservoir. It is well established in Douglas Reservoir and its tributaries. Impacts to native crayfish in these systems are currently unknown (Williams and Bivens, 2001).

Harmful impacts

Negative impacts include destruction of aquatic vegetation, direct competition of various kinds with native crayfishes, possible hybridization, and predation on other aquatic species (Cooper, 2005). In a stream in Maryland, this species displaced two native crayfish species within one year after being introduced (Schwartz, et al., 1963).

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Additional Web Resources

http://www.issg.org/database/species/ecology.asp?si=218&fr=1&sts=sss

http://nas.er.usgs.gov/queries/FactSheet.asp?speciesID=215

http://www.usgs.gov/invasive_species/plw/crayfish.html

White River Crawfish
Procambarus (Ortmannicus) acutus

Photo: J.W. Simmons, North Carolina Wildlife Resources Commission

Description and Biology - The White River crayfish ranges in color from dark red to brown and has long slender chelae (pinchers). The rostrum (portion of the carapace between the eyes) is pointed with small marginal spines or tubercles. The sides of the carapace have many small tubercles resulting in a granular texture. Male gonopods are stalk like. Adults range in size from 2.6 to 4.9 inches long. This crayfish is most often found in standing water habitats in sloughs, marshes, lakes, and streams (Pflieger, 1996).

Distribution - This species is native to the coastal plain and piedmont from Maine to Georgia, from the Florida panhandle to Texas, and from Minnesota to Ohio in the southern Great Lakes (Hobbs, 1989). This species has been introduced outside of its native range in Florida, Georgia, Tennessee, North Carolina, Connecticut, Massachusetts, Rhode Island, and Maine (Benson, 2006). In North Carolina, this species has been introduced into the Watauga and Pigeon River systems within the Tennessee River basin (Cooper, 2006). This species has also been introduced into Lick Creek in the Nolichucky River system in Greene County, TN (Williams and Bivens, 2001). Mode of introductions is presumed to be from bait bucket release.

Harmful Impacts - Impacts that introduced populations have on native fauna are currently unknown.

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Additional Web Resources

http://nas.er.usgs.gov/queries/FactSheet.asp?speciesID=216

http://iz.carnegiemnh.org/NewAstacidea/species.asp?g=Procambarus&s=acutus&ssp=acutus

Plants

The descriptions of plant species of concern in Tennessee are listed alphabetically below according to plant type. They include the common name, scientific name and the plant family. Although the scientific name, which consists of the genus and species, is Latin in origin and difficult to pronounce, it is helpful in locating additional information in books, taxonomic manuals, published papers and on the Internet. To help identify the species, each entry also includes a digital image and a **Description** section to help identify the species by the morphological characteristics (e.g. shape, color, size, etc.) of stems, leaves, flowers and other plant parts. The **Habitat/Biology** section provides information about where the plant grows, how it reproduces, and its impacts on the environment. Information concerning the plant's geographic origin, first introduction into the United States and current national and Tennessee distribution is found in the **Distribution/Introduction** section. The **Pathways for Spread** describes methods of introduction into Tennessee or ways by which the species could be spread in waterways and aquatic environments of this State.

A majority of the plant descriptions follows Webb (2007) and included in this report are **References** for use by those managing ANS in Tennessee. Those species not described by Webb (2007) were prepared by Terri Hogan, National Park Service, Murfreesboro, TN, and include peppermint, reed canarygrass, spearmint, and watercress. The description of the nonvascular plant was prepared by Frank Fiss, Tennessee Wildlife Resources Agency, Nashville, TN. The taxonomic manuals used for preparation of this document acan be found in **Reference Manuals** at the end of the plant descriptions.

Vascular Plants

Most of the plants of concern for aquatic invasive species management in Tennessee are vascular species. Vascular plants have specialized vascular tissue (xylem and phloem) for the transport of water and nutrients and include the ferns, gymnosperms, and flowering plants. The TANSTF has artificially grouped the vascular species into major categories called growth forms. The growth forms are defined by whether or not the flowering and vegetative parts of the plant grow above or below the surface of the water and whether the plant is rooted in the sediments. The major growth form groupings used in this document are submersed, emergent, and free-floating.

Vascular-Submersed Plants

Submersed plants are generally rooted in the bottom sediments of a waterbody. Their stems and most leaves occur beneath the surface of the water. The flowers and flowering stalks of some species may extend a few centimeters above the surface of the water or may be entirely submersed. Submersed plants grow at depths ranging from a few centimeters to a few meters (as is the case with hydrilla).

Common Name – Brazilian elodea
Scientific Name - *Egeria densa L.*
Family - Hydrocharitaceae

Photo by W. T. Haller, University of Florida/IFAS Center for Aquatic and Invasive Plants. Used with permission.

Photo by A. Murray, University of Florida/IFAS Center for Aquatic and Invasive Plants.
Used with permission.
Egeria densa (left) compared to Hydrilla verticillata (right)

Description - *Egeria densa* is a submersed bottom-rooted perennial with adventitious roots; stems are 1 to 3 mm thick and often branching. The leaves are generally in whorls of 4 (occasionally in whorls of 3 or 5) except at “double nodes” (where two nodes are nearly superimposed, resulting in 2 times the number of leaves at sterile nodes) which occur at 6 to 12 nodal intervals along the stem. Bud development, lateral branching, and adventitious root development occur in the region of double nodes. Leaves are bright green, flaccid, sessile, 1 to 3 cm long or sometimes longer, 1.5 to 4.5 mm wide with finely toothed margins. Only plants with male flowers are known from the United States. The male flowers are from upper leaf axils and on stalks up to 8 cm long that raise the flowers slightly above the water surface. The flowers have 3 green sepals that are 2 to 4 mm long, 3 white petals that are 8 to 10 mm long and 9 stamens. Seed are not formed in populations in the United States because of an absence of female plants.

Habitat/Biology – The stems of *E. densa* can branch profusely about 0.5 m above the bottom and form a canopy and surface mat that excludes light to other submersed plants. *Egeria densa* in Lake Marion, SC, is reported to exhibit a bimodal biomass curve (Getsinger and Dillon 1984) with peak biomass in July, followed by a decline during the early fall, another but lesser biomass peak in December followed by another decline in late winter and the early spring months. Because only plants with male flowers occur in the United States, all reproduction is vegetative from stem fragments or growth from root crowns. Fragments 7.5 mm long or longer with double nodes can produce adventitious roots and lateral branches and are able to develop into new plants. Brazilian elodea over winters as a root crown (a portion of stem with a double node and adventitious roots that anchors the plant on the bottom) from which new growth originates during the late spring months (Getsinger and Dillon 1984).

Although Brazilian elodea has caused major use conflicts in reservoirs along the Santee-Cooper River system (Getsinger and Dillon 1984) in South Carolina (e.g., Lake Marion where *E. densa* at one time colonized 8,000 ha), it has not been a major "weed" in reservoirs of the TVA system. *Egeria densa* grows in ponds, reservoirs, and pools of streams.

Distribution/Introduction – *Egeria densa* is native to Brazil, Uruguay and Argentina in South America (Cook and Urmi-Konig 1984). The first known record of *E. densa* in the United States is from Long Island, New York, and dates to 1893 (Cook and Urmi-Konig 1984). Brazilian elodea naturalized in the New England states by the 1920s to 1930s and is now widespread in the United States (http://plants.usda.gov/java/profile?symbol=EGDE; Cook and Urmi-Konig 1984) from New Hampshire south to Florida and west to Nebraska and Utah. It also occurs in the far western states (California, Oregon, and Washington) (http://www.wapms.org/plants/egeria.html).

Brazilian elodea was probably introduced into the United States as an "oxygen producer" in fish bowls and in small ponds where hobbyists grew and cultured fish. It is reported to have been commercially available as early as 1915 (Countryman 1970). Once naturalized, it spread by flow, possibly by waterfowl and by intentional plantings. *Egeria densa* is also frequently used as an experimental laboratory plant and cultivation for this purpose could have aided its spread.

Egeria densa is documented in Tennessee from eight widely scattered counties of middle and eastern Tennessee (http://tenn.bio.utk.edu/vascular/vascular.html). The earliest collection of *E. densa* in the University of Tennessee Herbarium (TENN) is from 1946 from a pond in Knox County. Although occasionally observed in a few of the large TVA reservoirs along the Tennessee River in Alabama and Tennessee, *E. densa* occurs only in small and widespread populations. It is more frequent in ponds, small lakes, and pools of streams but currently is not reported to have any large-scale negative impacts on recreational use in Tennessee waters or its native biota.

Pathways for Spread – Once established in a waterbody or drainage, Brazilian elodea can spread by flow that distributes fragments and possibly by waterfowl. A likely pathway for introduction of *E. densa* is in water discarded from aquariums or outflows from ornamental ponds. As is the case with most submersed plants, fragments on boat trailers and propellers of motors are another method of spread; however, this is not considered a major pathway of spread for Brazilian elodea in Tennessee because the plant currently is not widespread or documented to grow in large populations in areas with high boating use.

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http://www.issg.org/database/species/ecology.asp?si=289&fr=1&sts=

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http://el.erdc.usace.army.mil/pmis/plants/html/egeria_d.html

Common Name – Curly-leaved pondweed, curly pondweed
Scientific Name - *Potamogeton crispus L.*
Family - Potamogetonaceae

Photo by Vic Ramey, University of Florida/IFAS Center for Aquatic and Invasive Plants. Used with permission.

Description – Curly-leaved pondweed is a submersed, bottom-rooted, rhizomatous perennial with flattened stems. Leaves are alternate, linear-oblong (2 to 10 cm long and up to about 1 cm wide), sessile, with finely toothed, wavy margins. A thin sheath (stipule) occurs above each leaf but disintegrates as plants mature. A few leaves at stem apices often thicken during the late spring months to form vegetative reproductive structures known as turions. Flowers are born on short stalks (peduncles) 2 to 7 cm long that originate from the axils of upper leaves. The fruits are clustered into a spike up to 2 cm long at the apical end of the peduncle. Each fruit (achene) is about 4 to 6 mm long and has a distinct, erect beak.

Habitat/Biology – *Potamogeton crispus* grows in a wide variety of habitats including streams, rivers, reservoirs, ponds and springs. Curly-leaved pondweed has been characterized as a "cold water plant" and generally begins growth in the fall, persists during the winter months, and undergoes rapid growth in the spring when it obtains peak biomass in advance of most other submersed plants. Biomass then declines as water temperatures increase. Vegetative buds known as turions form in late spring and persist in a dormant state during the summer months until the cooler fall months when the turions "germinate" (i.e., begin growth). It appears that high spring biomass of *P. crispus* is from regrowth of turions or underground vegetative structures (e.g., rhizomes) rather than seed which have not been observed to germinate (Cypert 1967; Sastroutomo 1981; Tobiessen and Snow 1984; Nichols and Shaw 1986).

Curly-leaved pondweed is widespread in the Tennessee River system, especially in coldwater streams and tail waters just downstream of dams. Although curly-leaved pondweed has restricted boat travel in Reelfoot Lake during some years (Cypert 1967), the species is not reported to negatively impact recreational use in reservoirs along the Tennessee River. *Potamogeton crispus* is frequent in spring outflows in the Tennessee River drainage in northern Alabama and likely colonizes similar sites in Tennessee.

Distribution/Introduction – Curly-leaved pondweed is native to Eurasia (Stuckey 1979) and was first collected in the United States in the mid 1800s from Delaware and Pennsylvania. By about 1900 curly-leaved pondweed was established from Massachusetts west to New York and south to eastern Virginia (Stuckey 1979). *Potamogeton crispus* is currently widespread and has been documented in most states of the continental United States (Haynes and Hellquist 2000). Although the route of introduction into the United States is speculative, it seems most likely that it was introduced as an ornamental in water gardens or aquariums. It then was presumably spread by migrating waterfowl, intentional plantings for wildlife habitat, natural flow, and possibly in water used to move hatchery stock (Tehon 1929; Stuckey 1979).

Curly-leaved pondweed was collected in the Tennessee River system as early as 1943 from Guntersville Reservoir in northeastern Alabama. The earliest known collection of *P. crispus* in Tennessee was in 1946 from along the Clinch River just downstream of Norris Dam (Stuckey 1979). *Potamogeton crispus* is documented from 13 counties in Tennessee (http://tenn.bio.utk.edu/vascular/vascular.html) with collections primarily from rivers and streams, TVA reservoirs, and Reelfoot Lake where it was observed as early as 1959 (Cypert 1967).

Pathways for Spread – Natural flows that distribute turions and vegetative fragments are likely the major pathway for spread once curly-leaved pondweed is established. Waterfowl may also spread the curly-leaved pondweed to other waterbodies (Tehon 1929). As is the case with most submersed plants, fragments on boat trailers and propellers of motors are another potential means of spread.

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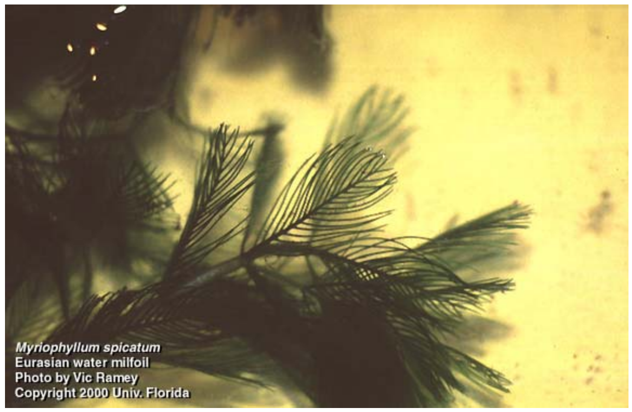
Common Name – Eurasian watermilfoil
Scientific Name - *Myriophyllum spicatum* L.
Family - Haloragaceae



Photos by A. Murray and Vic Ramey, University of Florida/IFAS Center for Aquatic and Invasive Plants. Used with permission.

Description - Eurasian watermilfoil is a submersed, bottom-rooted perennial, generally with multiple stems that arise from root crowns. Stems are branched with the leaves typically in whorls of 4, each “feather-like”, 1.5 to 4.0 cm long with 12 to 24 finely dissected segments on each side of a central axis. Male and female flowers are on an emergent spike that extends a few cm above the surface of the water. The lower flowers of the emergent spike are pistillate, upper flowers staminate with both flowers subtended by a small bract. Staminate flowers are small, with 4 pinkish petals and 8 yellowish stamens; pistillate flowers lack a perianth but have four pinkish stigmas. The fruit is 4-lobed, each of the four segments having small tubercules.

Biology/Habitat – Although Eurasian watermilfoil forms viable seed, its primary method of spread is by fragmentation. Fragments may be formed by mechanical breakage associated with boat traffic, flow, and wave action and by autofragmentation that occurs after flowering and also near the end of the growing season. Eurasian watermilfoil may also spread a few meters from established colonies by stolons that extend horizontally along the bottom (Smith and Barko 1990; Madsen and Smith 1997). Eurasian watermilfoil begins its growth earlier in the growing season than most other species of submersed macrophytes and branches near the surface to form a dense canopy that prevents light penetration and functions to exclude other species of submersed plants (Nichols and Shaw 1986). This frequently results in monospecific colonies of Eurasian watermilfoil. In Tennessee, this species is established primarily in reservoirs of the Tennessee River system at depths up to about 12 feet. Because Eurasian watermilfoil produced high populations of nuisance mosquitoes, adversely impacted boating and various types of water-based recreation, restricted access to ramps and other facilities, and degraded aesthetics in areas of developed shoreline, this species was the primary focus of TVA’s aquatic plant management activities during the late 1960s until the mid 1980s (Bates *et al.* 1985) when several other species established in shallow water areas of developed shoreline.

Distribution/Introduction – The native range of Eurasian watermilfoil includes Europe, Asia, and northern Africa (Aiken *et al.* 1979; Couch and Nelson 1985). Herbarium records indicate that Eurasian watermilfoil was introduced into the United States in the early 1940s (Couch and Nelson 1985). Eurasian watermilfoil is now widespread in the eastern United States (http://nas.er.usgs.gov/taxgroup/plants/docs/my_spica.html) from the New England states west to Minnesota and south to Florida and Texas with populations also occurring in several of the western states (Arizona, California, Oregon, Washington). This species was first introduced into the Tennessee River system about 1953 in Watts Bar Reservoir (Smith *et al.* 1967). In slightly more than a decade, Eurasian watermilfoil spread throughout much of the Tennessee River system and by the late 1960s colonized about 25,000 acres in eight reservoirs in the TVA system (Smith 1971). Eurasian watermilfoil is documented from 15 counties in Tennessee (http://tenn.bio.utk.edu/vascular/vascular.html) with populations (current or historical) in Kentucky, Nickajack, Chickamauga, Watts Bar, Fort Loudoun Reservoirs along the Tennessee River, Tellico Reservoir on the Little Tennessee River and from Melton Hill Reservoir on the Clinch River. Populations of Eurasian watermilfoil in most of these reservoirs have declined significantly since the late 1970s and late 1980s. Eurasian water-milfoil is also well established in the Holston River downstream of Cherokee Dam to near Knoxville and in a few miles of the Elk River downstream of Tim's Ford Dam.

Pathways for Spread – The primary method of spread of Eurasian watermilfoil from waterbody to waterbody is by fragments on boat trailers and propellers of motors. Once established within a waterbody or drainage, milfoil can rapidly spread by fragments that are dispersed by flow and wave action.

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Common Name – Hydrilla
Scientific Name - *Hydrilla verticillata* (L.f.) Royle
Family - Hydrocharitaceae

Photos by Vic Ramey, University of Florida/IFAS Center for Aquatic and Invasive Plants. Used with permission.

Description - Hydrilla is a submersed, rhizomatous, bottom rooted perennial with branching stems. Small, pea-like tubers 5 to 10 mm long form at the ends of spreading stolons or rhizomes in bottom sediments. Leaves along lower stems are opposite or in whorls of 3 with the number of leaves in whorls typically increasing to 5 to 7 along the upper portion of stems. Leaves are 2 to 4 mm wide and 0.6 to 2 cm long with toothed margins and small spines along the mid vein on the underside of the leaf. Female flowers are small (4 to 8 mm wide) with 3 white sepals and 3 translucent petals that are on thin stalks from the axils of upper leaves that are near the surface of the water. Male flowers, if present, are small (2 to 3 mm wide), with 3 whitish red or brown sepals and 3 whitish or reddish petals and 3 stamens. The male flowers are free-floating after release from a small pouch-like structure in the axils of upper leaves.

Note - Two forms of hydrilla are found in Tennessee: a dioecious form that has male and female flowers on separate plants and a monoecious form that has male and female flowers on the same plant. In the case of the dioecious form, only the female plants are know from Tennessee and thus have no capability for forming seed as is the case with the monoecious form.

Biology/Habitat - Hydrilla spreads primarily by fragmentation and but can survive draw downs and other adverse conditions as a tuber. Stems of hydrilla branch near the water surface and form a dense canopy that can “shade out” other species of submersed plants. As a result of light exclusion of other species and other physiological characteristics that provide a selective advantage (Langeland 1996), hydrilla frequently forms dense, monospecific stands. Because hydrilla has a lower light requirement than most other species of submersed plants, it grows at greater depths and has been observed to reach the surface in 15 feet of water during “good growing” years. In Guntersville Reservoir in northeastern Alabama, hydrilla has replaced Eurasian watermilfoil in many areas and continues to expand into habitat formerly colonized by Eurasian watermilfoil. In Tennessee, hydrilla is only known to grow in reservoirs and small lakes but in other regions of the United States it grows in small rivers, springs, ponds, canals, and natural lakes (Langeland 1996). Thus, hydrilla is adapted to a much wider variety of aquatic habitats than it currently grows in Tennessee.

Because hydrilla can form dense surface mats, has a very high biomass, and produces large numbers of fragments, it can negatively impact boating, various types of water-based recreation, access to ramps and other facilities, aesthetics and water quality, and clog screens at water intakes (Langeland 1996). A cyanobacterium that grows on the leaves of hydrilla also has been implicated as the cause of avian vacuolar myelinopathy (AVM), a disease that has killed waterfowl and eagles in some states of the southeastern United States (Wilde *et al.* 2005).

Distribution/Introduction – Hydrilla is widely distributed in the Old World in eastern Asia, Australia and portions of Africa and Europe and is thought to have originated in the warmer regions of Asia (Cook and Luond 1982). It was first discovered in the United States in 1960 in Florida (Haller 1976; Langeland 1990, 1996) where it was likely introduced as a result of activities associated with the aquarium industry. It is now widespread in the eastern United States from Texas to New England with populations in California and Washington (http://nas.er.usgs.gov/taxgroup/plants/docs/hy_verti.html; Madeira *et al.* 2000).

This species was first documented in the Tennessee River system in Guntersville Reservoir in northeastern Alabama in 1982 and first collected in Tennessee in 1988 in Chickamauga Reservoir (Webb and Bates 1989). In Tennessee, hydrilla is well established in Nickajack, Pickwick, and Kentucky Reservoirs along the Tennessee River and in some watershed lakes near Reelfoot Lake in extreme northwestern Tennessee (personal communication Paul Brown, TWRA). Both the dioecious and monoecious forms of hydrilla grow in Nickajack Reservoir while only the dioecious form has been observed in Pickwick and Kentucky reservoirs. In the past, small populations of the dioecious form also occurred in Chickamauga Reservoir (Tennessee River), Tellico Reservoir (Little Tennessee River) and in a small sinkhole pond connected to Melton Hill Reservoir (Clinch River), but these populations have not been observed in recent years. Several thousand acres of the dioecious form of hydrilla occur in Guntersville Reservoir along the Tennessee River in northeastern Alabama.

Pathways for Spread – The primary method of spread of hydrilla from one waterbody to another is by fragments on boat trailers and propellers of motors. Once established within a waterbody, hydrilla can rapidly spread by fragments that are dispersed by flow and wave action. Hydrilla can also be spread as an aquarium plant or as a contaminant growing with other aquatic species that are sold as ornamentals for water gardens.

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Common Name – Spiny-leaf naiad or brittle naiad
Scientific Name - *Najas minor L.*
Family - Najadaceae

 

Photo Credit: APIS™, U. S. Army Engineer Research and Development Center (ERDC), Vicksburg, MS

Description - Spiny-leaf naiad is a submersed, bottom-rooted annual, with a bushy appearance as a result of profuse branching from the upper portion of the stem. The leaves are opposite to sub-opposite, stiff and recurved in late growing season, 0.5 to 3.5 cm long and about 1 mm or less in width. Leaf margins have 7 to 15 conspicuous teeth per side and an expanded sheath at the base of each leaf. Male flowers and female flowers are on the same plant, both flowers inconspicuous, small, 1 or 2 in leaf axils, and lacking sepals and petals. Male flowers have a single stamen and female flowers a single pistil and both are surrounded by a thin sheath. The fruit is greenish and slightly curved. The seeds, one per fruit, also are slightly curved, 1.5 to 3.0 mm long with rectangular areolae in longitudinal rows.

Habitat/Biology – Spiny-leaf naiad is an annual species that regrows from seed and is most common in reservoirs and ponds. In some TVA reservoirs with prolific growth of spiny-leaf naiad, the seed bank is millions of seeds per hectare (Webb and Bates 1989). Because spiny-leaf naiad regrows from seed, this species is adapted to colonization of drawdown zones of reservoirs that are dewatered during the winter months. The seed tolerates drying and freezing conditions that often eliminate perennial species that regrow from underground vegetative parts. Spiny-leaf naiad is reported to be tolerant of eutrophic conditions (Wentz and Stuckey 1971), which is a probable factor in its spread.

Although spiny-leaf naiad often grows in monospecific stands, in the TVA reservoir system it is frequently mixed with other species such as *Najas guadalupensis, Potamogeton pusillus,* and *Chara* spp. Because spiny-leaf naiad grows in shallow water areas in dense colonies, it can adversely impact water quality and various types of water-based recreation and access to ramps and other facilities in areas of developed shoreline. During the late summer months, spiny-leaf naiad undergoes a natural "breakup" and stems with leaves float to the surface to form dense, free-floating mats that frequently become covered with algae and produce a smelly odor. Spiny-leaf naiad was one of the primary species that TVA managed with herbicides in the 1970s through the early 1990s. Populations of spiny-leaf naiad undergo dramatic fluctuations in the TVA reservoir system (Peltier and Welch 1970) and tend to be most abundant during years of low flow and clear water (i.e., drought years).

Distribution/Introduction – *Najas minor* is an Old World species (Haynes 1977) that was first documented from the northeastern United States in the 1930s and may have been introduced by shipping or possibly as an aquarium introduction (Clausen 1936). Spinyleaf naiad is widespread in the eastern United States from Illinois to New York, south to Florida and west to Arkansas (Haynes 1979, 2000). The species was first documented in the Tennessee River system in the 1940s (Merilainen 1968) from Nickajack Reservoir (then Hales Bar Reservoir) and Guntersville Reservoir in northeastern Alabama. *Najas minor* is widely distributed in Tennessee (http://tenn.bio.utk.edu/vascular/vascular.html) and is documented from 17 counties. All of the main stem TVA reservoirs along the Tennessee River have or in the past have had populations of spiny-leaf naiad. Historically, the largest populations have been in Chickamauga Reservoir which had more than 2,000 ha of spiny-leaf naiad in the 1980s.

Pathways for Spread – Once established in a waterbody, spiny-leaf can spread by seed that remain attached in the leaf axils of floating fragments. Seed in the substrate may also be carried and moved to other areas by flow and wave action. Waterfowl feeding on spiny-leaf naiad also probably carry the seed to other waterbodies (Merilainen 1968). As is the case with most submersed plants, fragments on boat trailers and propellers of motors are another means of spread.

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Vascular – Emergent Plants

Emergent plants are rooted in the bottom sediments. Their stems, leaves, and flowers extend well above the surface of the water. Emergent plants generally grow in shallow water of wetlands and along the shoreline of streams, ponds, and reservoirs.

Common Name – Alligatorweed
Scientific Name - *Alternanthera philoxeroides* (Mart.) Griseb.
Family - Amaranthaceae

Photo Credit: APIS™, U. S. Army Engineer Research and Development Center (ERDC), Vicksburg, MS
Photo by Vic Ramey, University of Florida/IFAS Center for Aquatic and Invasive Plants. Used with permission.

Description – Alligatorweed is an herbaceous perennial with hollow, decumbent and/or upright stems that are 0.3 to 1 m tall. The stems root at the nodes and are often branched and interwoven to form mats that float on the water. Leaves are opposite, sessile or with short, winged petioles that clasp the stem. Leaf blades are linear-elliptic in shape (4 to 10 cm long and 0.5 to 2 cm wide) with entire margins. The inflorescence is head-like, with numerous, small, white flowers arranged in a spike-like head that is terminal on the stem or on an axillary stalk that is up to about 5 cm in length. Mature seed are not reported as being formed in the Tennessee Valley and other areas of the southeastern United States.

Biology/Habitat –In areas with permanent standing water, plants root in wet or moist soils along shoreline areas and send out horizontal stems that float on the surface of the water. The stems with lateral branches are often interwoven to form dense, floating mats that may extend 50 feet or more into open water at some sites (Penfound 1940; Spencer and Coulson 1976). Alligatorweed frequently occurs in large, monospecific colonies, or in some cases may be mixed with Uruguayan waterprimrose which has a similar growth form. *Alternanthera philoxeroides* also can grow on moist soil and out-compete native wetland species that are of value to waterfowl and other wetland wildlife. Alligatorweed has not been documented to produce viable seed in the United States; thus, all reproduction is by vegetative means with each node having the potential to produce a new plant (Penfound 1940; Spencer and Coulson 1976).

In the Tennessee Valley, alligatorweed is most common along reservoirs of the Tennessee River in inlets and in the extreme upstream portion of embayments and shoreline areas that are protected from wave action. Rainfall events that result in higher than normal water levels and high flows have been observed to move large colonies from embayments to main channel areas where they are dispersed downstream. Over time, alligatorweed is expected to colonize a much wider variety of aquatic, wetland, and moist soil habitats in Tennessee. In addition to replacing native species and restricting boating and access for fishing, alligatorweed provides a good habitat for mosquito production (Penfound 1940).

Populations of alligatorweed in warmer portions of the southeastern United States have been significantly reduced by the introduction of South American insects that feed on the leaves and stems of alligatorweed (Spencer and Coulson 1976; Buckingham 1996). These natural herbivores of alligatorweed do not over winter in the Tennessee Valley and thus are ineffective in controlling alligatorweed in this region of the southeastern United States.

Distribution/Introduction – *Alternanthera philoxeroides* is native to South America and was introduced into the United States in the 1890s probably in ballast (Zeiger 1967; Buckingham 1996). It is widespread in the southeastern United States from Virginia to Florida, west to Texas and Oklahoma and north to Kentucky and Illinois. Populations of alligatorweed also occur in some western states such as California (http://plants.usda.gov/java/profile?symbol=ALPH).
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Alligatorweed was first reported from the Tennessee River system in the mid 1930s from along TVA reservoirs in northern Alabama where it possibly was introduced through shipping (Penfound 1940). The species is now common along all the TVA reservoirs in the Tennessee River in northern Alabama (Pickwick, Wilson, Wheeler, Guntersville), and has spread to several other reservoirs of the TVA system in Tennessee including Pickwick, Kentucky, Nickajack, and Chickamauga reservoirs. Alligatorweed is documented from 13 counties (http://tenn.bio.utk.edu/vascular/vascular.html) in Tennessee most of which contain impounded waters of the Tennessee River.

Pathways for Spread – While the first introductions of alligatorweed into the United States and possibly the Tennessee River system was by commercial shipping (Zeiger 1967; Penfound 1940), currently the most common method of spread is by fragments and floating mats that are distributed by flow. Alligatorweed may also be spread by fragments on boat trailers and propellers of motors and as a contaminant (Wofford and Dennis 1976) in containerized nursery stock.

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Common Name – Asian spiderwort, aneilema, marsh dew-wort
Scientific Name - *Murdannia keisak* (Hasskarl) Hand.-Mazz.
Synonym – *Aneilema keisak* Hasskarl
Family - Commelinaceae

Photo by ©G.A. Cooper. Courtesy of Smithsonian Institution, Department of Systematic Biology-Botany. USA, NC, Raleigh, Springmoor.

Description – *Murdannia keisak* is an herbaceous annual with decumbent and trailing stems that root at the lower nodes. The leaves are alternate, linear-lanceolate, 2 to 7 cm long and up to about 2 cm wide with leaf bases that clasp the stem. Flowers are solitary or in a few-flowered clusters at the end of the stem or from the upper leaf axils. Each flower has 3 sepals, and 3 pinkish to purple to whitish petals up to about 8 mm long. The fruit is a capsule with 3 locules, each with 3 to 6 seed that are 1.5 to 3 mm long. Flowering occurs in the late summer to fall.

Habitat/Biology – Asian spiderwort is an annual plant that frequently grows in monospecific colonies and forms dense mats that exclude many species of native plants. In Tennessee, the species is most common along the margins of inlets and embayments of the large reservoirs along the Tennessee River where it grows rooted in moist soil near the level of full summer pool or in a few inches of water. During high rainfall events, mats may be dislodged by rapid increases in water levels and/or moved by high flows. Several thousand seed per meter square are produced in areas with dense growth (Dunn and Sharitz 1990); thus, the species presumably has a large seed bank that functions to maintain populations on an annual cycle. In other areas of the Southeast (Faden 2000; http://www.dcr.state.va.us/dnh/fsmuke.pdf), *M. keisak* is reported to grow in a wider variety of habitats including wet ditches and marshes and along the margins of lakes, ponds, swamps, creeks, and various aquatic and wetland habitats. It is expected to colonize similar areas in the Tennessee in the future.

Distribution/Introduction – *Murdannia keisak* is native to eastern Asia (Dunn and Sharitz 1990; Faden 2000) and likely was introduced into the United States with rice cultivation in coastal regions of the southeastern United States. The earliest known collections of *M. keisak* in the United States are from Louisiana in the late 1920s and from South Carolina in

1935. Most collections of *M. keisak* prior to the 1950s were from coastal regions of the southeastern United States (Dunn and Sharitz 1990). Since that time, the species has rapidly expanded its range and now occurs from Maryland south to Florida and west to Louisiana and north to Kentucky. Asian spiderwort is also reported from along the extreme downstream portion of the Columbia River in Washington and Oregon (Faden 2000).

Asian spiderwort was first collected in Tennessee in 1976 along Watts Bar Reservoir and by the late 1970s was documented from other reservoirs (e.g., Chickamauga, Ft. Loudoun) of the Tennessee River, from Melton Hill Reservoir along the Clinch River, and from reservoirs along the Tennessee River in northern Alabama (Dennis *et al.* 1980; Webb and Bates 1990). *Murdannia keisak* is documented from 10 counties in Tennessee (http://tenn.bio.utk.edu/vascular/vascular.html), most of which border or include the Tennessee River or its major tributaries. It also occurs along smaller rivers such as the Buffalo and likely has a wider distribution in Tennessee than current collections indicate.

Pathways for Spread –Once established within a waterbody, Asian spiderwort can spread by vegetative fragments and seed that are distributed by flow. This can result in a rapid downstream spread of the species. The seeds of *Murdannia keisak* are reported as an important food item for waterfowl (Dunn and Sharitz 1990) which may account for its rapid spread in the mid to late 1900s from coastal regions to the interior portions of the southeastern United States.

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Common Name – Common reed
Scientific Name- *Phragmites australis* (Cav.) Trin. ex Steudel
Synonym - *Phragmites communis* Trin.
Family - Poaceae

Photos by A. Murray, University of Florida/IFAS Center for Aquatic and Invasive Plants. Used with permission.

Description – *Phragmites australis* is a tall (2 to 4 m in height), colonial, perennial grass with course stems and stout, creeping rhizomes and/or stolons. The stem is leafy throughout with leaves that are up to 6 dm long and 1 to 4 cm wide with long acuminate blades and overlapping leaf sheaths. The ligule consists of a ring of short stiff hairs. The infloresence is a terminal and much-branched, dense panicle that is tawny, to purplish to silver in color and 2 to 4 dm long. Spikelets are 3 to 7 flowered with unequal glumes and long silky hairs that exceed the florets. Disarticulation is above the glumes and below each floret. Seeds are produced in some populations but are reported to have low viability in many instances.

Note - A non-native, aggressive strain of *P. australis* has been introduced into North America (Saltonstall 2002) and is reported to differ from the native strain of *P. australis* in the northeastern United States in characters such as the color, texture, and density of the stems, density of the inflorescence, flowering time, leaf color and some other characteristics (see http://www.invasiveplants.net/phragmites/morphology.htm).

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Biology/Habitat – Once established, *P. australis* can form large colonies and grow as monospecific stands. Rhizomes that grow beneath the soil surface or stolons that creep along the soil surface result in rapid lateral expansion of colonies. The role of seed in the spread of *P. australis* is difficult to assess due to conflicting and variable reports relating to seed set and viability (Tucker 1990). However, it is clear that rhizome fragments and other vegetative structures such as stolons can function to form new colonies when transported by natural events or human activities. With viable seed, the species could also be spread by birds, mammals, wind, and by flow.

Common reed grows in moist soils and areas with slight inundation such as marshes and along the margins of lakes, ponds, streams, swamps, and in brackish marshes in coastal regions. It grows (Batterson and Hall 1984; Marks *et al.* 1994) on a wide variety of substrates, tolerates both alkaline and acidic conditions, and can grow in areas with a salinity of 15 to 20 ppt (parts per thousand). Because of the ability of common reed to sequester nutrients and grow in saturated soils, it is frequently used in constructed wetlands to remove nutrients and other pollutants. One of the greatest negative impacts of *P. australis* is the displacement of natural wetland plant community types which frequently also reduces the biodiversity of associated animal communities.

Distribution/Introduction – *Phragmites australis* has a world wide distribution and is known from every continent except Antarctica (Tucker 1990). The species is native to the United States with established populations reported from most states (http://plants.usda.gov/java/profile?symbol=PHAU7). A non-native strain or genotype (termed haplotype M, see Saltonstall 2002) has been introduced into the United States, and at many sites in the northeastern United States has replaced natural mixed wetland communities and even the native genotypes of *P. australis.* The introduced genotype is thought to be of Eurasian origin and was likely introduced during the early part of the 19th century in shipping ballast dumped at coastal ports in the northeastern United States. From the region of introduction, the non-native genotype has spread into the interior, far western regions, and a few areas of the southeastern United States. Its spread is postulated to have been aided by the construction of railroads and highways (Saltonstall 2002).

Specimens of *P. australis* deposited in the herbarium of the University of Tennessee (TENN) document populations of common reed from nine counties in Tennessee (http://tenn.bio.utk.edu/vascular/vascular.html). Sharp *et al.* (1956) attribute *P. communis* (=*P. ausrtalis*) to "West Tennessee" but note the species to be "localized and rare". The earliest collection date for any of the specimens currently at TENN is 1982, suggesting that the species has only recently become widely established in Tennessee. Several of the specimens were collected along highways or railroad tracks and less commonly in wet areas of old fields or beaver swamps. *Phragmites australis* has also been observed growing in ash ponds at several TVA coal-fired steam plants and at a single site along Tellico Reservoir (David Webb, TVA, personal communication). At present, it is unknown as to whether populations of *P. australis* in Tennessee are a native or introduced genotype.

Pathways for Spread – At present, the most common pathways for the establishment of *P. australis* in Tennessee seem to be related to human activities such as highway construction, transport of materials along railroads, and activities associated with the use of coal at power generating facilities. *Phragmites australis* is also frequently recommended for constructed wetlands which could provide an additional pathway for introduction. The species apparently produces few viable seed; thus, the species is most likely spread from vegetative propagules (e.g., rhizomes, stolons) that can be transported by water flow or human activities.

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Common Name – Dwarf water clover
Scientific Name - *Marsilea minuta* L.
Family - Marsiliaceae

Photo by Vic Ramey, University of Florida/IFAS Center for Aquatic and Invasive Plants. Used with permission.

Description – This non-flowering fern, dwarf water clover, has fleshy, horizontal rhizomes that have roots at the nodes and internodes. Foliage, appearing as a “four-leaf clover” due to four leaflets that are borne at the end of an 8 to 22 cm long petiole, arises at a node. The leaves sometimes float on the water or are emergent and extend to about 15 cm above the water. The sporocarps are borne on slightly curved to upright stalks that are 6 to 11 mm long and attached at the base and junction of the leaf petiole and rhizome. Sporocarps are about 2.5 to 5 mm long, oval to oblong, and often bean-shaped.

Note – The genus *Marsilea* is easily recognized by its “four-leaf clover” foliage; however, identification to the species level is often difficult without sporocarps (Jacono and Johnson 2006). It is likely that any population of *Marsilea* growing in aquatic and wetland habitats in Tennessee is a non-native species and every effort should be made to collect voucher specimens with detailed locality information.

Habitat/Biology - Dwarf water clover grows along the margins of ponds, ditches, streams and wetlands. It reproduces vegetatively from rhizomes and can also reproduce sexually and form spores. *Marsilea minuta* can form monospecific colonies in shallow water and in moist soil along the margins of ponds and other moist habitats (http://nas.er.usgs.gov/taxgroup/plants/docs/marsilea/marsilea.html). To date, the impact of *M. minuta* on native plant communities in the United States has not been documented, but *M. minuta* is a major weed in rice paddies in southeast Asia (Jacono and Johnson 2006)

Distribution/Introduction - *Marsilea minuta* is reported as a native plant from Africa, India, and Southeast Asia (http://www.ars-grin.gov/cgi-bin/npgs/html/taxon.pl?423469) and has been introduced and is widely distributed outside of its native range (Jacono and Johnson 2006), presumably because of its use as an ornamental in water gardens. Dwarf water clover was first collected in the United States in Florida in 1992 and is now documented from

Georgia and Tennessee (Jacono and Johnson 2006). At present, the only known population of *M. minuta* in Tennessee is from Hamilton County (http://tenn.bio.utk.edu/vascular/vascular.html) where it was first collected in 2000. The habitat is the margin of a sink-hole pond that has no outflow and that fluctuates with water levels in Chickamauga Reservoir.

Pathways for Spread – Because the water clovers are frequently promoted and sold as ornamentals for water gardens, that trade is the most likely pathway for the introduction and spread of *M. minuta* in Tennessee. Once established in a waterbody or drainage, vegetative fragments and spores can be spread by flow and possibly by waterfowl.

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http://tenn.bio.utk.edu/vascular/database/vascular-database.asp?CategoryID=Pteridophytes&FamilyID=Marsileaceae&GenusID=Marsilea&SpeciesID=minuta

Common Name – Parrot's feather
Scientific Name - *Myriophyllum aquaticum* (Vell.) Verdc.
Synonym - *Myriophyllum brasiliense* Camb.
Family - Haloragaceae

Photos by Vic Ramey, University of Florida/IFAS Center for Aquatic and Invasive Plants. Used with permission.

Description - *Myriophyllum aquaticum* has relatively stout, emersed and submersed stems that are simple or sparsely branched. Emersed stems can grow 0.5 m above the surface of the water. Adventitious roots form at the nodes of the underwater stems and anchor the plant to the bottom or to exposed mud. Leaves in whorls of 4 to 6 occur along both emersed and submersed stems. Submersed leaves are 1.5 to 3 cm long with 20 to 36 narrow, linear segments per leaf. The emersed leaves are stiff, gray-green in color, feather-like, 2 to 5 cm long, with 6 to 18 divisions per leaf. Flowers (pistillate only in the United States) are borne in the leaf axils of the emersed leaves and are small, with whitish to pinkish stigmas that appear as a tuft in the leaf axils. Flowering occurs in the spring.

Habitat/Biology – Parrot's feather typically grows in shallow water or may be rooted in mud along the shoreline of lakes, ponds, small streams, swamps and other aquatic habitats. The stems are often intertwined and form a mat with the emersed stems sometimes growing up to about 0.5 m above the water surface. Since only the pistillate plants occur in the United States, seed are not formed and all reproduction is vegetative from fragments. Plants over winter and regrow from rhizomes attached to the mud by adventitious roots (Sutton 1985).

Although widespread in Tennessee, parrot's feather is not known to cause major problems related to recreational use in contrast to other milfoils such as *M. spicatum* which has large-scale negative impacts to recreational use in large reservoirs. *Myriophyllum aquaticum* can form monospecific stands and exclude some native species and also restrict flow in drainage ditches and small streams.

Distribution/Introduction – Parrot's feather is native to South America and was introduced into the United States in the late 1800s, probably as an ornamental in aquariums, water gardens, fountains and greenhouses (Nelson and Couch 1985; http://www.ecy.wa.gov/programs/wq/plants/weeds/aqua003.html). By the 1980s it was widespread in the United States (Nelson and Couch 1985) from New York, south to Florida and west to Texas and Oklahoma and is also established in several of the western states (Arizona, California, Oregon, Washington).

Myriophyllum aquaticum is reported as growing in Tennessee in the early 1940s (Nelson and Couch 1985) and currently is documented from 17 counties across the State from eastern to western Tennessee (http://tenn.bio.utk.edu/vascular/vascular.html). Parrot's feather is frequent in springs and outflows which are characterized by cold water with some flow. It is also found in a variety of aquatic habitats (e.g., ponds, swamps, margins of streams and small rivers). Parrot's feather is uncommon in TVA reservoirs, and when present, usually occurs in small and localized populations where springs or their outflows enter reservoirs. A remnant population of parrot's feather occurs in the tail waters of Tellico Reservoir (Little Tennessee River) a couple of miles downstream of Chilhowee Dam.

Pathways for Spread – Because *M. aquaticum* does not form seed in the United States, vegetative fragments are the method of spread. Fragments, or in some cases mats of parrot's feather, are distributed by flow. *Myriophyllum aquaticum* is frequently used as an ornamental in water gardens and ornamental pools and can "escape" or be discarded into natural aquatic habitats. In rare instances, parrot's feather may be moved from one waterbody to another as fragments on propellers or boat trailers but this is not considered a major pathway for spread in Tennessee.

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Common Name – Pale yellow iris
Scientific Name – *Iris pseudacorus* L.
Family – Iridaceae

Photos by Vic Ramey and A. Murray, University of Florida/IFAS Center for Aquatic and Invasive Plants. Used with permission.

Description – *Iris pseudacorus* is a rhizomatous perennial plant. Leaves are stiff and erect basally, arching distally, and broadly ensiform arising from stout, extensively radially spreading, densely crowded rhizomes. Leaves are 4 to 8 dm long and 2 to 3 cm wide. Stems are 0.5 to 1.2 m tall and shorter than or equaling the leaves. Flowers measure 7 to 9 cm across. Petals are erect, 2 to 3 cm long and 4 to 5 mm wide and are bright yellow or cream colored and linear to narrowly fiddle-shaped. Sepals are golden-yellow to cream colored and spreading. They measure 5 to 8 cm long and 3 to 5 cm wide with short broad claws which are flecked with brown. The fruit is an elongate capsule, 5 to 8.5 cm long. Valves are widely spreading at maturity. Seeds are brown, corky and angular.

Habitat/Biology – In the United States, this species grows in shallow water or wet soil including swamps, wet meadows, marshes, ditches, pond banks, and along streams (Godfrey and Wooten 1979, Kral specimens collected in 1971 and 1974). It grows in both fresh and brackish water. Other wetland communities where this species commonly occurs include meadows, fens, swamps, reed bed, saltmarshes, and in permanently wet sand dunes (Sutherland 1990). It can quickly colonize sediments and litter around the margins of standing or sluggish, mesotrophic and eutrophic waters (Tu 2003). When used as a landscaping plant along bodies of water, it commonly spreads along riverbanks and streambanks, lake or pond edges, or into marshlands. Plants form large clonal populations through radial spread of rhizomes which are also drought tolerant (Sutherland 1991, Jacono 2007).

Pale yellow iris reproduces both sexually and asexually from rhizomes. Germination rate from freshly collected seed ranged from 48% in seed collected in the British Isles (Sutherland 1990) to 62% in seed collected from a swamp in north Florida (Jacono 2007). The clonal nature of this species results in a dense rhizome mat that can prevent the germination and seedling growth of other plant species (Tu 2003) and allows it to outcompete native plants (Raven and Thomas 1970).

Distribution/Introduction –*Iris pseudacorus* is native to Europe and the British Isles, North Africa and the Mediterranean region (Cody 1961). It occurs in all European countries except Iceland (http://www.issg.org/database/species/distribution.asp?si=873&fr=1&sts=tss). *Iris pseudacorus* was likely introduced to the United States in the 1800s as an ornamental plant and is still widely used in landscape plantings. It is also used for erosion control, sewage treatment, and in other constructed wetlands in North America. It is documented from 40 of the continental United States except for Alaska, Arizona, New Mexico, Colorado, Wyoming, South Dakota, North Dakota, Iowa, and Oklahoma (http://plants.usda.gov/).

Specimens of *Iris pseudacorus* from 12 Tennessee counties are housed at the University of Tennessee herbarium (http://tenn.bio.utk.edu/vascular.html). Tennessee counties in the Tennessee River Basin where this species occurs include Johnson, Carter, Sullivan, Unicoi, Greene, Claiborne, Campbell, and Knox in northeastern Tennessee and Lawrence in south central Tennessee. Counties with this species in the Ohio River Basin are Fentress, Robertson, and Cheatham counties. The earliest collection date of specimens in the University of Tennessee herbarium is 1952. This specimen was collected along the Nolichucky River in Unicoi County. As five of the specimens in the herbarium were collected in the 1950s, it seems likely that this species was established at several localities in Tennessee by that time.

Pathways for Spread – Pale yellow iris is sold as an ornamental and is widely available commercially. It has also been tested for removal of heavy metals (Mungar *et al*. 1997), removal of nutrients from urban waste water (Ansola *et al*. 1992), and for erosion control. In addition to being spread by humans, pale yellow iris spreads downstream through transport of both rhizomes and seed (Sutherland 1990).

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Common Name – Peppermint
Scientific Name – *Mentha X piperita* L. (pro sp.)
Family – Lamiaceae

Photo by Robert H. Mohlenbrock @ USDA-NRCS PLANTS Database / USDA NRCS. 1995. Northeast wetland flora: Field office guide to plant species. Northeast National Technical Center, Chester, PA.

Description – Peppermint is an introduced, naturally occurring sterile hybrid of two nonnative Eurasian mint species, *Mentha aquatica* and *M. spicata*. It is a rhizamatous perennial with stems 3 to 10 dm long. Stems may be glabrous, glandular, or with recurved hairs. Unlike *Mentha spicata* L., leaves of this species have definite petioles that are 5 to 8 mm long (petioles have been seen as short as 4 mm and as long as 16 mm). Leaves are 3 to 7 cm long and often more than half as wide. Blades are variable in shape and may be ovate, lance-ovate, lanceolate, or elliptic. They are shortly and broadly cuneate or rounded basally and acute to occasionally obtuse apically. Leaf margins are sharply serrate, glabrous and smooth on upper surfaces, and sparsely pubescent on the veins of the lower surfaces. The inflorescence of this species are much like those of *M. spicata*. Flowers are numerous and crowded in dense terminal spikes that usually are 2 to 7 cm in length (they have been recorded at 10 cm) and are usually over 1 cm across at anthesis. Flower spikes may be interrupted to continuous. Bracts subtending the cymes are lance-attenuate, glandular, glabrous or sometimes with few irregularly spaced hairs on the margins. The calyx, including the lobes, commonly measures (1.7) 3 to 4 mm long (it can be as small as 1.7 mm). The tube is narrowly campanulate, nerved but not ribbed, with subulate lobes that are much shorter than the tube. Calyx lobe margins are ciliate. The corolla is lavender.

Habitat/Biology – *Mentha* X *piperita* is cultivated and sporadically naturalized throughout much of North America where it is found in wet places, brooksides, meadows, margins of ponds and lakes, thickets, and ditches (Godfrey and Wooten 1981). This species of garden mint is likely more common in the wild than spearmint (Grieve 1971) and is the one that is most frequently and abundantly naturalized in the southeastern United States (Godfrey and Wooten 1981). Within the state of Tennessee, specimens of peppermint have been collected from a boggy creek bottom, areas of wet or swampy soils, along brooks and creeks, and within developed areas including railroad embankments and among commercial buildings. Like *Mentha spicata*, peppermint is known for the ease of growing it from cuttings. It spreads aggressively vegetatively, forming monoculture stands and crowding out native vegetation.

This species is considered to be an invasive plant that threatens native plant communities. It is listed as such by a number of organizations such as Tennessee Exotic Pest Plant Council, Delaware Natural Heritage Program, and Kentucky Exotic Pest Plant Council.

Distribution/Introduction – This species' native range is uncertain. However, it was known to the Greeks and Romans, and cultivated by the Egyptians (Grieve 1971). It is mentioned in Icelandic pharmacopeias of the 13th century (Grieve 1971). It came into general use in Western Europe in approximately the middle of the 13th century and was cultivated commercially in England by approximately 1750 (Grieve 1971). Spearmint and peppermint are among the world's most popular flavorings and are grown as crops on a large scale for leaf and oil production in Europe, the United States, the Middle East, Brazil, Paraguay, Japan, and China (Bown 2001). This species was introduced as a crop in the United States in approximately 1855 (Grieve 1971). At the present time, it is widespread in the United States being found in all states except North and South Dakota, Wyoming, New Mexico, Arizona, and Hawaii (http://plants.usda.gov/java/profile?symbol=MEPI).

Peppermint is well represented in Middle and East Tennessee and is documented from one West Tennessee County, Carroll County. Gattinger (1901) notes the presence of *Mentha* X *piperita* L. outside of cultivation in Tennessee. Four Tennessee specimens at Gray and New York Botanical Gardens Herbaria were collected in 1897 and 1898. Two 1897 specimens, one at Gray Herbarium and the other at the New York Botanical Gardens, were likely collected by Gattinger while working on his 1901 flora. Ten of the University of Tennessee specimens were collected between 1934 through 1941 suggesting this species was actively collected to rebuild the herbarium after it burned and that it was relatively common in the state by that time. Currently, *M.* X *piperita* is documented from 43 Tennessee counties, most of which are in middle or eastern Tennessee.

Pathways for Spread – Like *Mentha spicata*, this species was introduced for medicinal and culinary use, and is actively spread by humans. Medicinal uses include antiseptic, digestive aid, anodyne, antispasmodic, carminative, cholagogue, diaphoretic, stomachic, tonic, and vasodilator (http://www.pfaf.org/database/). It is also used to treat fevers, headaches, and digestive disorders (http://www.pfaf.org/database/). Resent research points to antioxidant properties as well (Dorman *et al*. 2003). Peppermint is also spread by flows that transport rhizomes.

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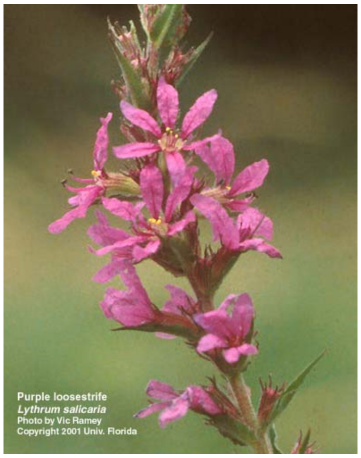
Common Name – Purple loosestrife
Scientific Name - *Lythrum salicaria* L.
Family - Lythraceae



Photos by Vic Ramey, University of Florida/IFAS Center for Aquatic and Invasive Plants. Used with permission.

Description – Purple loosestrife is a stout, erect, perennial up to 2 m tall that grows from a stout rootstock that has numerous, lateral roots. A few to 50 stems may grow from a single rootstock of mature plants. The stem is square; the leaves are opposite or in whorls of 3, pubescent, stalkless, heart-shaped or rounded at the base. Leaves are lanceolate to occasionally linear in shape, 2 to 10 cm long and 0.5 to 1.5 cm wide with entire margins. Numerous, small, showy flowers, occur in clusters in the axils of leaves or bracts at the end of stems and branches, producing an inflorescence with a spike-like appearance. Each flower has 5 or 6 petals that are reddish-purple. The fruit is a capsule, 3 to 4 mm wide, containing numerous, tiny seeds.

Note - *Lythrum virgatum L.* is similar in many respects to *Lythrum salicaria* but differs in being glabrous throughout and having leaves that narrow at the base.

Biology/Habitat – Purple loosestrife spreads primarily by seed. A mature plant with multiple stems from a single rootstock may produce in excess of 2 million seed per plant during a single growing season. The seed are reported to be viable for at least 3 years with a germination rate of approximately 80 percent; thus, purple loosestrife is capable of building a large seed bank that can persist for several years and germinate under favorable conditions or when perturbations occur in native plant communities. Once established, lateral spread from the peripheral roots of the primary rootstock seems to be limited to about 0.5 meter (Thompson *et al.* 1987; http://www.npwrc.usgs.gov/resource/plants/loosstrf/index.htm).

In Tennessee, purple loosestrife grows in a wide variety of open, wetland habitats, along reservoir and stream margins, and other open, moist site areas. In several regions, such as the northeastern and midwestern United States, purple loosestrife grows in monospecific stands in wetlands and frequently displaces many native plants that results in negative impacts to most species of native wildlife (Thompson *et al.* 1987). Although purple loosestrife occurs in high densities in a few localized areas in Tennessee, it has not yet spread and negatively impacted wetlands to the extent it has in some other regions of the United States.

Distribution/Introduction – Purple loosestrife, a native of Eurasia, was reported in literature as growing in the United States in the early 1800s. However, it was the mid to late 1800s before this species was well established in wetland and waste sites in Massachusetts, New York, Pennsylvania, and New Jersey (Stuckey 1980). It is likely that introduction of purple loosestrife into the United States occurred on multiple occasions (Stuckey 1980; Thompson *et al.* 1987) by a variety of methods (ship ballast, on sheep and shipments of raw wool, intentional plantings in herbal and ornamental gardens).

By the mid 1980s, purple loosestrife was established in most states of the United States north of the 35th parallel from the Atlantic to the Pacific coasts (Thompson *et al.* 1987). The species is most abundant in states of the northeastern United States and the mid western states in the Great Lakes region. Purple loosestrife has continued to spread since the mid 1980s and the general consensus is that with exception of Florida, there are established populations of purple loosestrife in every state of the continental United States (http://www.nps.gov/plants/alien/fact/lysa1.htm). The first know collection of purple loosestrife in Tennessee was in 1899 from Knox County (Stuckey 1980). Beginning in 1981 (Patrick *et al.* 1983; Bowen 1995), several collections of purple loosestrife have been made in eight counties in Tennessee (http://tenn.bio.utk.edu/vascular/vascular.html) from the margins of streams and small rivers, reservoirs, and wetland areas.

Pathways for Spread – Water is the primary dispersal mechanism for seed produced by mature plants, and in some cases, for small, recently germinated seedlings. Some seed dispersal also is likely in mud that adheres to wildlife, livestock, and the tires of vehicles and hulls of small boats. In rarer instances, purple loosestrife may spread from broken stems and branches that are transported by water and take root in wetlands or other habitats with moist substrate. Because of its aesthetic qualities, purple loosestrife is planted intentionally from seed or as containerized nursery stock.

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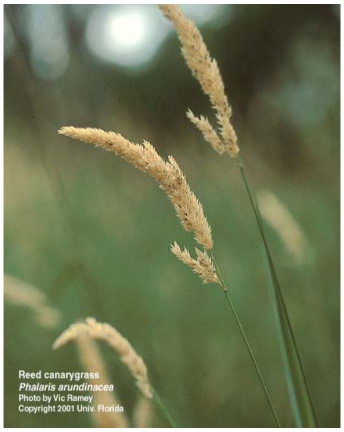
http://cars.er.usgs.gov/Region_4_Report/html/vascular_plants.html

Common Name – Reed canarygrass
Scientific Name – *Phalaris arundinacea* L.
Family – Poacea



Photos by Vic Ramey, University of Florida/IFAS Center for Aquatic and Invasive Plants. Used with permission.

Description – *Phalaris arundinacea* is a colonial cool-season perennial grass. This species spreads by rhizomes to form a thick, fibrous root mass and resulting dense tussock that measures between 1 and 2 m in diameter. Culms are stout and leafy throughout, growing from 0.8 to 1.5 (2.0) m tall. Basal leaf sheathes are glabrous. The leaf-blades are flat, 0.2 to 2 cm wide and up to 0.5 m long. Ligules are 2.5 to 6 mm in length and membranous. The panicle is dense and cylindrical in shape, measuring 7 to 15 cm long. Panicle color ranges from light green, purplish, whitish-green to tawny brown at maturity. Glumes may be glabrous or pubescent and measure 3 to 5 mm long. Most spikes are composed of three florets two of which are infertile and reduced to linear trichome covered scales that are 1.5 to 2 mm long. Spikelets are 3.5 to 5 mm long with short, less than 1 mm long, pubescent pedicels. Paleas are 2-nerved and whitish in color with scarious margins. Seeds are usually less than 2 mm long and circular in cross-section (Lyons 1998). This species is known for its seedheads that shatter easily, breaking up at maturity above the glumes.

Reed canarygrass is highly variable morphologically. More than 10 infraspecific categories have been described based on characteristics such as the coarseness, earliness amount of branching, leaf color, size, shape and density of inflorescences (Piper 1942, Lyons 1998). Native and introduced ecotypes do not appear to be distinguishable morphologically (Anderson, 1961).

Biology/Habitat – This species occurs within riparian and streamside corridors. It is found on streambanks, lake-shores, low woods, sloughs, and other wetland community types. Reed canarygrass is adapted to wide extremes of soil moisture (Zeiders and Sherwood 1985) and is likely to be a competitive dominant under a wide variety of hydrologic regimes (Kercher and

Zedler 2004). It is relatively drought tolerant and also succeeds well in soils disturbed by agriculture (Piper 1942).

This species reproduces both by seed and rhizomes. Seeds are produced in early summer and some germinate soon after ripening (Apfelbaum and Sams 1987, Leck 1996). Leck (1996) found good germination in a variety of flooding regimes and that dry conditions do not appear to adversely affect germinability. This species also forms a persistent seedbank (Leck 1996). Reed canarygrass is highly productive vegetatively (Piper 1942) quickly outcompeting other species when it is introduced to an area. Plants introduced to a site spread rapidly through rhizome sprouts to form dense monospecific stands within one growing season (Apfelbaum and Sams 1987, Barnes 1999). In a study conducted over two growing seasons, this species demonstrated rapid growth in the first two years after germinations allocating resources to rapid above ground growth in the first four months after which resource allocation was found to shift to roots (Adams and Glatowitsch 2005). This strategy permits *P. arundinacea* to outcompete natives for space and light, resulting in the formation of huge colonies that can quickly dominate wetlands.

There are a variety of environmental effects that result from this species' rapid and vigorous growth. It impedes water flow, alters soil hydrology, promotes silt deposition, and may increase soil erosion (Lyons 1998). It appears to inhibit establishment of understory trees (Fierk and Kauffman 2006) and poses a direct threat in western states to federally threatened annual aquatic plant species *Howellia aquatilis* (Lesica 1997; NatureServe 2007). However, one of the most deleterious effects is that on native plant diversity within plant communities where it occurs. Reed canarygrass excludes native species due to its large size and dense clonal growth (Barnes 1999) causing declines in wetland species within several years following its introduction (Apfelbaum and Sams 1987). Studies have shown a correlation between presence and abundance of *P. arundinacea* and decreased understory species diversity and total species richness at sites where it occurs (Barnes 1999, Kercher *et al.* 2004, Fierke and Kauffman 2006, Schooler *et al.* 2006). According to Barnes (1999), it is likely that the aggressive behavior of reed canarygrass observed over a 15-year period along the Chippewa River was due to the aggressive introduced ecotypes and agricultural strains dominating within wetland plant communities (Barnes 1999).

Distribution/Introduction – *Phalaris* is found on Greenland and on all continents except Antarctica (Anderson 1961). It was first cultivated in England before 1824 and was in cultivation in Germany by about 1850 (Piper 1942). Non-native ecotypes were introduced to the United States as a forage and hay crop in the mid-1800s (Piper 1942). Although *P. arundinacea* is considered to be native to northwestern North America, its current wide distribution within the continent is believed to be primarily the result of introductions in agricultural areas of non-native ecotypes or strains that have been selected and bred for vigorous growth (Anderson 1961, Apfelbaum and Sams 1987).

Reed canarygrass is documented from 18 counties in Tennessee (http://tenn.bio.utk.edu/vascular/database). They include Obion and Chester counties in the Coastal Plain Physiographic Province; Stewart, Montgomery, and Robertson counties in the Western

Highland Rim; Scott, Fentress, Cumberland, Bledsoe, and Grundy counties in the Cumberland Plateau Physiographic Province; Johnson, Carter, and Unicoi in the Blue Ridge Physiographic Province; and Knox, Sevier, Blount, and Monroe counties with major waterbodies in the Ridge and Valley Physiographic Province. Gattinger (1901) remarks on the presence of ribbon grass, a horticultural variety of *P. arundinacea*, in gardens, noting "the genuine *Phalaris arundinacea* I have never seen in Tennessee spontaneous." The earliest specimens of this species at the University of Tennessee Herbarium were collected in the mid-1960s, strongly suggesting that this species was introduced to Tennessee around that time. One recent study in a wetland in Johnson County, Tennessee, where *Phalaris arundinacea* covers large areas, suggests introduction for forage (Foster & Wetzel 2005).

Pathways for Spread – *Phalaris arundinacea* has been spread throughout the United States through its use as hay and forage (Piper 1942), gully erosion control (Baltensperger and Kalton 1958), ditchbank and sediment stabilization (Figiel *et al.* 1995), and in constructed wetlands. It has also been suggested as a potential biofuel source in several states (Powlson *et al.* 2005). Propagules are spread primarily through movement of soil infested with rhizomes. However, seed and rhizomes may also be transported by water through flooding and stream flow.

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Common Name – Spearmint
Scientific Name – *Mentha spicata* L.
Family – Lamiaceae

#1 #2

Photo #1 by ©J.S. Peterson. USDA NRCS NPDC. USA, CA, Berkeley, UC Botanical Garden. March 24, 2004.
Photo #2 by Robert H. Mohlenbrock @ USDA-NRCS PLANTS Database / USDA NRCS. 1995. *Northeast wetland flora: Field office guide to plant species*. Northeast National Technical Center, Chester, PA.

Description – Spearmint is perennial with slender subterranean rhizomes. Stems are erect, simple or variously branched. Plants are mostly 5 to 8 dm tall, essentially glabrous but may be sparsely pubescent or glandular. Although uncommon, these plants have been seen as small as 3 dm and as tall as 12 dm. Leaves are sessile or less frequently with petioles 1 to 2 mm long. Leaves are 2 to 7 cm long by 0.7 to 2.5 cm wide. They may be lanceolate, lance-ovate, ovate or elliptic in shape, are rounded to obtuse basally, and acute to acuminate apically with serrate margins. They are glabrous and smooth above and sparsely pubescent to hirsute on the veins beneath. The inflorescence is branching. Flowers are crowded in slender terminal spikes that are continuous or sometimes interrupted below. They are 3 to 7 cm long (occasionally to 12 cm) and usually less than 1 cm across at anthesis. Bracts subtending the cymes are lance-subulate and glandular-dotted with evenly ciliate margins. The calyx, including the lobes, is 1.5 to 3 mm long. The calyx tube is campanulate, ribbed and grooved with subulate and hispid-ciliate lobes that are about as long as the tube. The corolla measures 2 to 4 mm long and is whitish, lavender, pale violet, or pinkish in color.

Habitat/Biology –According to Godfrey and Wooten (1981), this species is cultivated and sporadically and widely naturalized in North America, occupying wet places, bogs, seepage areas, about ponds, creek banks, and in ditches. In Tennessee, *Mentha spicata* has been collected from creek bottoms and edges, lake sides, low wet areas, and roadsides. This species is known for the ease of growing it from cuttings. It spreads aggressively vegetatively, forming monoculture stands and crowding out native vegetation.

Mentha spicata is considered to be an invasive plant that threatens native plant communities throughout the world. It is listed on weed lists in Australia, the United Kingdom, mainland Europe and the United States (http://tncweeds.ucdavis.edu/global/australia/ger.html). It is listed as an invasive plant by a number of organizations within the United States, including the Maryland Native Plant Society, New Jersey Native Plant Society, Wisconsin Department of Natural Resources, Tennessee Exotic Pest Plant Council, and Delaware Natural Heritage Program.

Distribution/Introduction – *Mentha spicata* has been in cultivation for many centuries and its nativity is uncertain. However, Grieve (1971) suggests that it is native to the Mediterranean region and was introduced to Britain by the Romans. By the 9th century, this species was being cultivated in Convent gardens in England (Grieve 1971). Both spearmint and peppermint are among the world's most popular flavorings and are grown as crops on a large scale for leaf and oil production in Europe, the United States, the Middle East, Brazil, Paraguay, Japan, and China (Bown 2001). Currently, spearmint is distributed throughout the globe. It probably was introduced to the United States by the mid-1700s (Grieve 1971) and is now found in every state in the United States except for South Dakota (http://plants.usda.gov/java/profile?symbol=MESP3).

The earliest collection date found for specimens of *M. spicata* in Tennessee is 1934 which postdates the fire that destroyed the University of Tennessee Herbarium in the early 1930s. However, Gattinger notes the presence of *Mentha spicata* L. outside of cultivation in Tennessee in his 1901 flora. He probably collected a specimen in the course of his work which would have been lost in the herbarium fire. Based on herbaria records, this species does not appear to be as common in Tennessee as *Mentha* X *piperita*. However, *M. spicata* is still widely and sporadically scattered throughout the state. It has been collected from 15 counties in Tennessee. It is found within each of the three major watersheds of Tennessee: the Tennessee, Ohio, and Lower Mississippi.

Pathways for Spread – This species was introduced for medicinal and culinary use. It has been used medicinally as an antiemetic, antispasmodic, stomachic, carminative, diuretic, poultice to relieve bruising, restorative, stimulant, and for cancer treatment (http://

www.pfaf.org/). Research on uses of this plant continues to this day. It has been tested for its potential usefulness in relieving the symptoms of irritable bowel syndrome (Vejdani *et al.* 2006) and for its antioxidant properties (Dorman *et al.* 2003). It is also noted for its antibacterial and antiseptic properties. Recent research has found mosquito repellant and mosquito reproduction retardant properties as well (Tripathi *et al.* 2004).

Mentha spicata is actively spread by humans. It also spreads widely by seed and rhizomes.

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Common Name – Uruguayian waterprimrose
Scientific Name - *Ludwigia hexapetala* (Hook. & Arn.) Zardini, Gu, & Raven
Family - Onagraceae

Photo by A. Murray, University of Florida/IFAS Center for Aquatic and Invasive Plants. Used with permission.

Synonyms – *Ludwigia uruguayensis* (Cambess.) Hara; *Ludwigia grandiflora* (Michx.) Greuter & Burdet *subsp. hexapetala* (Hook. & Arn.) Nesom & Kartez

Description – *Ludwigia hexapetala* is a mat-forming, perennial that is rooted in mud or shallow water and has long, decumbent stems that float on or just below the surface of the water. Leaves of early season growth are compacted to form floating rosettes, each leaf is sub-orbicular to spatulate in shape, shiny, glabrous, and from the nodes of the horizontal floating stem. Later season growth has upright stems (up to 1 m tall) from the nodes. Leaves of upright stems are obviously alternate, lanceolate to oblanceolate in shape, and 3 to 6 cm long and 2 cm or so in width. The ascending stems are sparsely to densely pubescent, becoming reddish and woody with age. Flowers are solitary on stalks from the upper leaf axils and have 5 or occasionally 6, large, yellow petals that are up to 3 cm long. The fruit is a cylindrical capsule up to about 2 cm long, containing numerous seeds.

Habitat/Biology – Uruguayian waterprimrose is typically rooted along the shoreline and sends out horizontal stems that branch and form mats. These mats may extend 30 feet or more from the shoreline and completely colonize narrow pockets and sloughs. *Ludwigia* *hexapetala* frequently forms monospecific colonies and in the TVA reservoirs is often mixed with alligatorweed which has a similar growth form. During periods of high flow or wind, vegetative fragments and large mats of *L. hexapetala* may be dislodged and moved to open water areas where flow and/or prevailing winds then move them to new areas. *Ludwigia hexapetala* can also reproduce from seed that can be dispersed by flow and presumably by waterfowl and aquatic mammals.

Ludwigia hexapetala colonizes a variety of habitats including swamps, ditches, open water areas of marshes, shoreline areas of lakes and ponds, and margins of streams. Dense mats of *L. hexapetala* can restrict flow in streams and drainage ditches and hinder access to shoreline areas and the upstream ends of shallow sloughs.

Distribution/Introduction – *Ludwigia hexapetala* is native to South America including Uruguay (Zardini *et al.* 1991) and questionably to portions of the southeastern United States. If native to portions of the southeastern United States, the species has been introduced and has established far outside of it native range and is currently widespread from New York south to Florida, west to Oklahoma and Texas and north to Missouri and Kentucky. Populations of *L. hexapetala* also are established in the western United States (http://cars.er.usgs.gov/Nonindigenous_Species/R5finalreport.pdf) in California, Oregon, and Washington.

The first known collection of *L. hexapetala* in Tennessee is from along the Cumberland River drainage in 1968 (Chester and Holt 1990). The species currently is documented by voucher specimens from four counties (http://tenn.bio.utk.edu/vascular/vascular.html) in Tennessee, three of which are from along the Cumberland drainage (including populations along Lake Barkley and in Land Between the Lakes) in the northwestern portion of central Tennessee. Uruguayian primrose also occurs along the Holston River where it was observed in the early 1970s and along Ft. Loudoun Reservoir (Tennessee River) where it was observed in the early 1980s (Webb and Bates 1989). *Ludwigia hexapetala* is common along the Wheeler and Guntersville reservoirs in northern Alabama which could provide a propagule source for movement to downstream reservoirs such as Pickwick and Kentucky.

Pathways for Spread – The species can spread by seed, vegetative fragments and floating mats distributed by downstream flow. It seems likely that the seed of *L. hexapetala* also may be carried to other waterbodies and drainages by waterfowl. Because of its large, showy, yellow flowers, *L. hexapetala* is sometimes sold as an ornamental (http://www.nwcb.wa.gov/weed_info/Ludwigia_hexapetala.html) for water gardens.

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http://www.awc-america.com/plant_id_utility/plants/ludhex.html

Common Name – Watercress
Scientific Name – *Nasturtium officinale* Ait. f.
Family – Brassicaceae
Synonyms – ***Rorippa nasturtium-aquaticum*** (L.) Hayek

#1 **#2**

Photo #1by Robert H. Mohlenbrock @ USDA-NRCS PLANTS Database / USDA NRCS. 1995. *Northeast wetland flora: Field office guide to plant species*. Northeast National Technical Center, Chester, PA.
Photo #2 by Brother Alfred Brousseau. Courtesy of St. Mary's College of California. ©St. Mary's College of California.

Description - Watercress is a partly floating perennial plant with succulent, decumbent, much branched stems. It is stoloniferous and freely roots into the substrate at the nodes. Leaves are 2 to 15 cm long and 2 to 5 cm wide. They are alternate and compound with 3 to 12 glabrous leaflets that are variable in shape which may be ovate, elliptic, orbicular, or lanceolate. Leaflet margins may be undulate, crenate, or entire. Petioles partially clasp the stem. The inflorescence is in compact terminal racemes. The four petals are white, entire, and 3 to 5 mm long. The stigma is 2-lobed and capitate. Siliques are slender and beaked measuring 1 to 2.5 cm long, the beak to 1 mm long. Seeds are many and arranged in two rows. They are approximately 1 mm in length, lustrous, reddish brown, prominently reticulate, ovoid to obovoid in outline and flattish and lenticular in profile.

Biology/Habitat – This species is found primarily in cool, flowing waters in streams, springs, seeps, clear water of sluggish streams, and brooks. Herbarium labels from Tennessee specimens note collections from brooks, stream banks, streams, an open creek bank, shallow water of intermittent stream, a rich sandy creek bank in woods, and low wet woods. Watercress spreads by seed and stem fragmentation. Roots often loosen from the substrate to form large, dense floating mats of plants (Godfrey and Wooten 1981) that exclude light from other submerged plants.

This species grows both upward and outward from the roots, extending lateral branches that form dense, leafy monospecific stands which alter the function and flow in shallow streams (Howard-William *et al.* 1982, Jacono 2001). The effect of watercress' outward growth into the stream channel is exacerbated by the trapping of suspended materials among the roots (Howard-William *et al.* 1982). As a result, the stream's water level increases in the summer, leading to flooding and creating a growth promoting feedback loop by improving site conditions for watercress (Howard-William *et al.* 1982). Other changes in the hydrologic cycles of wetland ecosystems also occur as a result of this growth habit (Howard-William *et al.* 1982, Les and Mehrhoff 1999).

Watercress is also very successful at sequestering nitrogen regardless of ambient nitrogen levels (Robinson and Cumbus 1977, Howard-William *et al*. 1982). The lateral spread demonstrated by this species appears to be an adaptation to utilize greater volume for nutrient uptake in a stream system (Howard-William *et al.* 1982). *Nasturtium officinale* has chemical defenses to protect its nitrogen rich young leaves against herbivory (Newman *et al.* 1992, Newman *et al.* 1996). The ability to sequester nitrogen and protect nitrogen-rich leaves from herbivory as well as a very fast growth rate give this species a competitive advantage over native species.

Distribution/Introduction – The origin of this species is generally recognized as Eurasian. The native range appears to include Asia, Europe, and Africa but it is widely naturalized throughout the globe (http://www.ars-grin.gov/cgi-bin/npgs/html/taxon.pl?25072). Watercress was established in the US by the mid 1800s as a submersed plant in cold water streams and springs (Les and Mehrhoff 1999). It is now widespread in the United States having been found in all of the continental states except for North Dakota and is found in eight Canadian provinces. It is considered native to one Alaska province (http://plants.usda.gov/).

Watercress has been in Tennessee since the late 1800s. One specimen at the University of Tennessee is dated 1896. Gattinger (1901) notes *N. officianale* as being found in brooks and streams in the state and sometimes in cultivation suggesting that it was fairly common in the wild by that time. Some early collections are located at the New York and Missouri Botanical Gardens are dated 1898. In the early 1930s, the University of Tennessee herbarium burned, including all specimens except those on loan. As a consequence, nearly all specimens collected in Tennessee before that time have been destroyed. There are 10 specimens of this species at the University of Tennessee herbarium that were collected in the mid-1930s suggesting that the species was relatively common and quickly collected in an effort to rebuild the herbarium. Specimens of this species were collected during a 1956 thesis study of the vascular aquatic vegetation of the Cumberland Plateau (Robinson and Shanks 1959). As a part of that study, *N. officinale* was documented from the following Tennessee counties: Anderson, Blount, Grainger, Hawkins, Knox, Lawrence, Lincoln, and Roan (Robinson and Shanks 1959). Currently, the Ohio and Tennessee river watersheds are well represented within the range of watercress in Tennessee which is documented from 46 counties in the state (http://tenn.bio.utk.edu/vascular/). Specimens have been collected from Johnson County (Chester *et al.* 1997) in the east to Stewart in the west (Joyner and Chester 1994) and from Pickett County in the north (Chester *et al.* 1997) to Lawrence County in the south (Robinson and Shanks 1959). The species is absent west of the Tennessee River.

Pathways for Spread – *Nasturtium officinale* is widely used as a fresh salad green or steamed green for its spicy, peppery flavor. It is a good source of vitamins A and C, along with niacin, ascorbic acid, thiamine, riboflavin, and iron (Stephens 1994) and has a long history of medicinal use for a variety of ailments. It is still grown commercially in the United States for food and as an ornamental for water gardens. In the wild, it is spread by seed and rooting stem fragments.

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Vascular - Free-Floating Plants

Free-floating plants typically are not rooted in the bottom sediments, although they are sometimes stranded on mud. They float on the surface of the water and are moved by wind and water currents. The leaves or fronds of free-floating plants may be flat and float parallel to the surface of the water (as is the case with duckweeds) or the leaves may extend above the water surface by as much as a meter (as is the case with water hyacinth).

Common Name – Dotted duckweed
Scientific Name - *Landoltia punctata* (G. Mey.) Les & D. J. Crawford
Synomym – *Spirodela punctata* (G. Mey.) C. H. Thompson
Family - Lemnaceae

Photos by Vic Ramey and Ann Murray, University of Florida/IFAS Center for Aquatic and Invasive Plants. Used with permission.

Description – *Landoltia punctata* is a free-floating aquatic plant consisting of small, flattened fronds. The fronds are slightly egg- to kidney-shaped, 2 to 5 mm long, 1 to 3 mm wide, bright green on the upper surface and usually reddish on the lower surface. Roots are usually 2 to 5 in number, rarely 1, and located near the center of the frond and hang downward. Vegetative reproduction is by budding of small daughter plants from lateral pouches at the base of the frond. Flowers are very small, rarely seen, from lateral pouches and only visible through a good hand lens or dissecting scope.

Note - *Landoltia punctata* generally has more than one root per frond which distinguishes it from the various species of *Lemna*, and usually has less than 5 roots per frond which distinguish it from *Spiriodela polyrhiza*. *Landoltia* also lacks the prominent dot on the upper surface of the frond that is generally visible on *S. polyrhiza* (http://www.mobot.org/jwcross/duckweed/duckpix.htm).

Habitat/Biology – As is the case with other species of Lemnaceae, dotted duckweed can rapidly reproduce by vegetative budding (i.e., daughter plants originate from lateral pouches at the base of the frond) and carpet the entire water surface (Daubs 1965; Landolt 1986). Wind may move the plants to one side of a waterbody, resulting in a mat of plants that may be a few centimeters in thickness. Dotted duckweed and other species of duckweed frequently grow intermixed and are most often found in quiet or sluggish waters of swamps, sloughs, oxbow lakes, ponds, and drainage ditches. Although various species of duckweed occur in small populations in the large reservoirs along the Tennessee River, they rarely negatively impact reservoir use.

Distribution/Introduction – *Landoltia punctata* is native to Australia and Southeast Asia (Landolt 1986) and was possibly introduced into the United States with the stocking of ornamental fish (e.g., goldfish) or as an “escape” from an aquarium (http://nas.er.usgs.gov/taxgroup/plants/docs/la_punct.html). The first collection of *L. punctata* in the United States was from a pond in Missouri in 1930. The species is now widely distributed from Massachusetts and Pennsylvania south to Florida and west to Texas and Oklahoma. It also occurs in Arizona, California and Oregon (http://nas.er.usgs.gov/taxgroup/plants/docs/la_punct.html).

Apparently there are no voucher specimens in the University of Tennessee herbarium or other herbaria within the State that document the occurrence of *L. punctata* in Tennessee; thus, the species is not included in the checklist of vascular plants for Tennessee. Landolt (1986) attributes *L. punctata* to Lake County which is in extreme northwestern Tennessee. Lake County is one of two counties that include Reelfoot Lake where large colonies of several genera of duckweed (*Spirodela, Lemna, Wolffia, Wolfiella*) grow in profusion. Because dotted duckweed resembles some species of native duckweed (i.e., *Spirodela polyrhiza* and *Lemna spp*.) that are common and widespread in Tennessee, it may have been overlooked by botanical collectors.

Pathways for Spread – The most likely pathways for the introduction and spread of dotted duckweed are wholesale growers or retail stores that distribute plants for aquariums or water gardens and in water used to transport ornamental fish. Once established within a waterbody or drainage, *L. punctata* can be moved downstream by flow. Waterfowl and aquatic mammals such as beavers may also transport dotted duckweed for short distances.

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http://www.mobot.org/jwcross/duckweed/duckpix-S_punctata.htm

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http://plants.usda.gov/java/profile?symbol=LANDO2&format=Print&photoID=

Common Name – Giant salvinia
Scientific Name - *Salvinia molesta* Mitchell
Family - Salviniaceae

Photo by A. Murray, University of Florida/IFAS Center for Aquatic and Invasive Plants. Used with permission.

Description – *Salvinia molesta* is a free-floating fern that has a horizontal stem that floats just beneath the surface of the water. Three leaves are produced at each node, two of which are emergent and floating, and a third that is much divided and appearing as cluster of thin roots that hang in the water. Floating leaves are green, 1.5 to 3.5 cm long, and oblong to ovate in shape. The upper leaf surface has a prominent midrib and a velvety appearance due to several rows of hairs. Each hair branches into four terminal prongs that rejoin at the tip to resemble a tiny "eggbeater". Chains of small egg-shaped sporocarps develop on the underwater leaf.

Habitat/Biology – *Salvinia molesta* is considered one of the world's worst weeds and typically inhabits slow moving streams, ditches, swamps, rice fields, ponds, lakes and reservoirs. It reproduces vegetatively by self-induced fragmentation and can rapidly cover the water surface. With continued growth, it can form multi-layered mats that have been reported to be a meter in thickness (Oliver 1993; http://salvinia.er.usgs.gov/). Mats shade out submersed plants, impede access, negatively impact fish and wildlife habitat, alter water quality, and can clog water intakes used for irrigation, drinking water supplies, and power generation (http://www.invasive.org/biocontrol/2FloatingFern.html).
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Distribution/Introduction – Giant salvinia is native to South America in the coastal region of southern Brazil (Oliver 1993; http://salvinia.er.usgs.gov/). Since the 1930s, it has been introduced by man's activities (i.e., as a botanical curiosity in water gardens, an aquarium plant, and a contaminant in nursery stock) to numerous other areas including Sri Lanka, South Africa, India, Southeast Asia, the Indonesian area, New Guinea, Australia, New Zealand, and the United States. The first report of *S. molesta* growing outside of cultivation in the United States was in 1995 in South Carolina. By 2005 *S. molesta* was reported from several states from Virginia south to Florida and west to Texas and from California and Arizona. More recently, it has been reported from other states such as Massachusetts and New York (http://salvinia.er.usgs.gov/).

There are no known populations of *S. molesta* in Tennessee. An assessment of the potential range (http://salvinia.er.usgs.gov/html/predicted_range.html) of establishment of *S. molesta* by the U. S. Geological Survey (USGS) indicates that *S. molesta* is likely to become a problem species in the southeastern United States in areas of the Atlantic and Gulf Coastal Plain. If introduced, Sa*lvinia molesta* possibly could persist in USDA Hardiness Zone 7a, which includes some portions of Tennessee; however, it is unclear as to whether populations will persist through the winter months, be confined to restricted microhabitats, or "reach problem status" during years with mild winters.

Pathways for Spread – The mostly likely pathway for the introduction of *Salvinia molesta* into Tennessee is by the aquarium or water garden industry as an ornamental or specimen plant or as contaminant in aquatic nursery stock or with fishes that are stocked for ornamental purposes.

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http://salvinia.er.usgs.gov/html/cultivation.html

http://salvinia.er.usgs.gov/html/predicted_range.html

http://salvinia.er.usgs.gov/salvinia.pdf

http://salvinia.er.usgs.gov/html/s_molesta_biology.html

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http://plants.usda.gov/java/profile?symbol=SALVI2

http://plants.ifas.ufl.edu/salmol.html

Common Name - Water hyacinth
Scientific Name - *Eichhornia crassipes* (Mart.) Solms-Laub.
Family - Pontederiaceae

Photo Credit: APMIS™, U.S. Army Engineer Research and Development Center (ERDC), Vicksburg, MS. Used with permission.

Description – *Eichhornia crassipes* is floating plant that is sometimes found stranded and rooted in mud. The leaves are in clusters or rosettes; each leaf with a petiole up to 30 cm long that usually has an inflated or bulbous base to help give the plant buoyancy. Leaf blades are ovate to broadly elliptic, thickened, glossy green and up to about 15 cm wide. Daughter plants originate from a mother plant and are connected by a short stolon. The inflorescence is a spike up to 30 cm long, with numerous flowers, each flower with six lavender to bluish petals with the uppermost petal having a bright yellow splotch. The fruit is a three-celled capsule, each cell containing numerous seeds.

Habitat/Biology – Water hyacinth grows in a variety of habitats including canals, ditches, swamps, ponds, lakes, and sloughs and slack water along rivers. In Florida, water hyacinth is reported to reproduce primarily by vegetative means but can also reproduce from seed that sink to the bottom and remain dormant until exposed by periods of drought (Hoyer *et al.* 1996). Vegetative reproduction is primarily from "daughter plants" that are connected to the "mother plant" by horizontal stolons. Under ideal growing conditions, the number of hyacinth plants can double every two weeks. A few individuals can generate enough plants to cover the surface of an acre in a single growing season (Penfound and Earle 1948). Because water hyacinth in deeper water areas is not anchored to the substrate, flow and wind can move large numbers of plants and compact them into dense mats.

Distribution/Introduction – *Eichhornia crassipes* is native to South America and is thought to have been introduced into the United States in 1884 at the Cotton Exposition in New Orleans where the plants were distributed as souvenirs (Sculthorpe 1967). Self- sustaining populations of water hyacinth occur in the Atlantic and Gulf Coastal Plains from southeastern Virginia south to Florida and west to Texas with populations also in California and Arizona (http://nas.er.usgs.gov/taxgroup/plants/docs/ei_crass.html). In some states of the more temperate portions of the United States, water hyacinth grows well during the summer months but generally does not persist through the winter (http://nas.er.usgs.gov/taxgroup/plants/docs/ei_crass.html).

Water hyacinth has periodically been observed during the summer months in several of the reservoirs along the Tennessee River (David Webb, TVA, personal communication) and in ponds with spring outflows and small lakes. The plants of water hyacinth in the reservoirs likely represent intentional introductions or entered the reservoir as a result of overflows from ornamental ponds and water gardens. Water hyacinth has not been observed to over winter in any of these reservoirs but has been observed to regrow from vegetative parts (i.e., stolons) in spring fed ponds and swamps in central Tennessee and northern Alabama (Troy Goldsby, Aqua Services, Inc., personal communication; David Webb, TVA, personal communication). These populations could be extirpated by a harsh winter unless they are able to regrow from seed. *Eichhornia crassipes* is reported from three counties (http://www.bio.utk.edu/herbarium/vascular/vascular.html) in Tennessee and likely will be reported from additional counties in the near future.

Pathways for Spread - Because of its showy flowers and waxy foliage, water hyacinth is sometimes sold at flea markets and retail outlets that supply ornamentals for water gardens. Thus, the water garden industry is the most common pathway for the introduction of water hyacinth into Tennessee. *Eichhornia crassipes* grown in private water gardens often gets into waterbodies and natural wetlands as a result of intentional introductions by owners trying to reduce overcrowding or during times of outflow. Plants of water hyacinth also have been introduced into Pickwick Reservoir in northeast Mississippi by barge traffic from the Tennessee-Tombigbee Waterway. Once established within a waterbody or drainage, *E. crassipes* can be moved downstream by flow.

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http://el.erdc.usace.army.mil/aqua/apis/biocontrol/html/waterhya.html

Common Name – Water lettuce
Scientific Name - *Pistia stratiotes* L.
Family - Araceae

Photos by A. Murray, University of Florida/IFAS Center for Aquatic and Invasive Plants. Used with permission.

Description – *Pistia stratioites* usually floats on the water's surface except when stranded on mud. Leaves are in clusters or rosettes and appear as an open head of lettuce, gray-green in color with prominent parallel veins, obovate to spatulate in shape and up to about 15 cm long, spongy at the base and covered with a dense, soft pubescence. The roots are numerous, feather-like and hang from the base of the rosettes. Smaller daughter plants originate from and are connected to the primary rosette (mother plant) by a short stolon. Male and female flowers are on the same plant, surrounded by sheath, inconspicuous and hidden in the leaf axils.

Habitat/Biology - Water-lettuce grows in lakes, ponds, canals, ditches, and slack water along rivers and streams and can form floating mats that cover the surface of the water (Stoddard 1989; Thompson 2000). Reproduction is primarily vegetative (Dray and Center 1989: http://aquat1.ifas.ufl.edu/pisstr.pdf) from offsets (daughter plants) on short stolons that originate from a larger, primary rosette (mother plant). Dray and Center (1989) also have documented that *P. stratioites* in Florida can form viable seed.

Distribution/Introduction – *Pistia stratoites* is widespread in tropical and subtropical regions of the world including portions of the southeastern United States, Mexico and Central America, South America, Asia, Africa and Australia (Thompson 2000). It is unclear as to whether *P. stratiotes* is native to the United States (Thompson 2000); however, it was noted in Florida in the late 1700s where it was reported by William Bartrum to exist in large colonies along the St. John's River (http://aquat1.ifas.ufl.edu/pisstr.pdf). Water lettuce has persistent populations in much of Florida and the southern portion of Louisiana and Texas. It is reported from several other western and eastern states but these collections probably represent seasonal introductions and most do not persist through the winter months (Thompson 2000).

Water lettuce has been observed during the summer months in several of the TVA reservoirs (e.g., Nickajack, Guntersville, Ft. Loudoun) but is not known to persist through the winter months (David Webb, TVA, personal communication). The source of the plants in the TVA reservoirs is presumably from water gardens or ornamental ponds. Based on the distribution of persistent populations of water lettuce in the eastern United States, it seems that the potential for water lettuce to over winter in a vegetative state in the Tennessee Valley is unlikely and less than water hyacinth; however, if water lettuce in the Tennessee Valley were to produce seed, populations might persist from seed germination in small areas under specialized conditions.

Pathways for Spread - The water garden industry and the use of water lettuce in water gardens and ornamental ponds is the most likely pathway for the introduction of *P. stratiotes* into Tennessee. *Pistia stratoites* grown in private water gardens can get into waterbodies and natural wetlands as a result of outflows or by the intentional introduction by owners trying to reduce overcrowding. Once established within a waterbody or drainage, *P. stratiotes* can be moved downstream by flow.

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Nonvascular Plants

Nonvascular plants have no true roots, stems, or leaves. The lobes (rounded parts) of the some nonvascular plants may look like leaves, but they are not true leaves because they have no xylem or phloem. Non-vascular plants include two distantly related groups, Bryophytes (mosses, liverworts, hornworts) and algae. The TANSTF has identified one alga among the species of concern.

Nonvascular - Algae

Algae are one of the largest groups of nonvascular plants. They can be unicellular, colonial, filamentous, or in some cases, resemble vascular plants in size and form. Algae are generally classified into major groupings based on the type of pigment used to capture light and the type of food reserve.

Common Name - Didymo, Rock Snot
Scientific Name - *Didymosphenia geminata*
Family - *Gomphonemataceae*

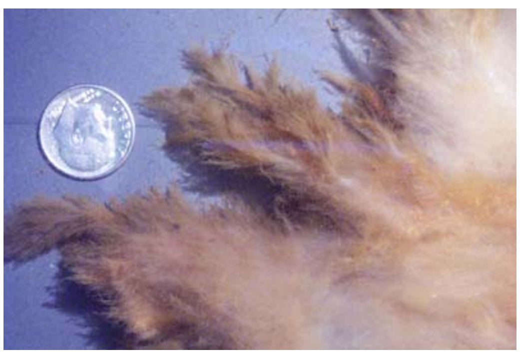


Photo Credit: Photos by Tyler F. Baker, Tennessee Valley Authority, Aquatic Monitoring and Management, Chattanooga, TN. Used by permission

Description - Didymo is a single-celled freshwater diatom that can be identified with a microscope by its bottle-like shape, very large size compared to other diatoms (> 100 µm long and >35 µm), and prominent stria (regular lines of holes) that radiate from the center of the cell (Kilroy 2004). Another diagnostic feature of didymo is the presence of long branched mucilage stalks that are exuded from the smaller end of the cell (Round et al.

1990). These stalks are known for their great length and thickness relative to the size of the cell. The stalks allow didymo to attach to substrate or plants. Didymo cannot be observed by the naked eye until large colonial masses are formed.

Biology/Habitat - Didymo populations grow by vegetative cell division. Each half of the cell creates another half cell within the confines of its rigid cell walls. The slight size restriction for each successive division results in a gradual reduction in cell size as the population expands. Each branch in the mucilage stalk represents a point at which the cells divided. Didymo uses sexual reproduction at some point to exchange genetic material and to restore their maximum cell size. Little is known about generation times for diatoms, but many have rapid (<30 h) generation times at temperatures between 12 and 20 ^{o}C (Kilroy 2004). Kilroy (2004) notes that a cell division every 30 h would be sufficient to rapidly expand the colonies to large sizes.

Large colonies of didymo cover the bottom of rivers appearing like a felt carpet, tufted masses, or even a white strand of toilet paper. Colonies of didymo are white to brown and not slippery to the touch, and feel like wet wool. Excessive growths (> 1 mile) of didymo are most common in sunny, open rivers with stable flows of water that are 3 to 72 inches deep with moderate to high velocity (EPA 2007).

Distribution/Introduction - Didymo is native to northern Europe and northern North America, typically in boreal or montane regions. According to the Global Invasive Species Database (2007) didymo has been found in New Zealand, United States, Canada, Faroe Islands, Norway, Svalbard, United Kingdom, Ireland, Sweden, Finland, France, Spain, Switzerland, Turkey, Ukraine, Poland, Romania, Hungary, Iceland, Russian Federation, Kyrgyzstan, Kazakhstan, China, Mongolia, and Pakistan.

The alga is native to North America, but recently has exhibited characteristics of an invasive species. This has raised questions among scientists as to whether the diatoms are becoming more tolerant of some environmental factor that used to limit their expansion, or perhaps an environmental change has helped their spread (Spalding 2005). Excessive blooms have been reported in several western states, Arkansas, and eastern Tennessee. Many of these blooms are located in popular trout fisheries.

At present the known distribution of didymo in Tennessee is the Clinch River downstream of Norris Dam, South Holston River below South Holston Dam, Watauga River below Wilbur Dam, and Holston River below Cherokee Dam.

Large blooms of didymo can adversely affect freshwater fish, plant and invertebrate species by reducing the number of suitable habitats and excluding the growth of other diatoms (Biosecurity NZ 2005). Direct human impacts are limited to eye irritation in swimmers (Kilroy 2004) and contamination of fishing tackle. Anglers also are concerned that it may potentially reduce the number of fish available to catch.

Blooms also degrade the aesthetics of rivers. As the mats peel away from the substrate they are sometimes mistaken for toilet paper, leading to concerns about possible upstream sewage discharges. A combination of poor fishing and poor aesthetics could drastically reduce the economic value of destination fisheries in Tennessee. There are also reports of didymo blocking or fouling water intakes (Kilroy 2004).

However, these impacts are new and require more study. In the four Tennessee trout tailwaters where didymo has been observed in large blooms (> 1 mile), TWRA has not observed substantial decreases in trout populations that can be directly attributed to didymo. Likewise TVA (Charlie Saylor, personal communication) has not observed substantial changes in density or composition of macroinvertebrate fauna.

Pathways for Spread - The presence of didymo in popular trout fisheries suggests that anglers may be unintentional vectors for the spread of this diatom in the United States. Specifically, didymo may be transferred on fishing tackle, boats, or boots among popular waterbodies. Cleaning all angling equipment after each use is suggested as a method to reduce spread.

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Appendix B. Ranking Considerations

ANS–TN – Aquatic Plants Ranking Considerations for each Criterion

1. Ecological Impacts – Assessment of potential to have an impact on aquatic ecosystems based on literature, discussions with colleagues, and personal field observations and experience. Some of the species are "linked" to a specific habitat (e.g., water cress, peppermint with springs and outflows from springs), so the assessment should relate to the primary habitat where the species is currently established, or in some cases where it is likely to establish in the foreseeable future: **3** = High ecological impact, **2** = Intermediate ecological impact, and **1** = Low ecological impact.

2. Current Distribution and Status - The species were evaluated from an overview of documented distribution in Tennessee, where **3** = Widespread, **2** = Intermediate spread, and **1** = Localized. Distribution data for the various species were primarily obtained from the website of the herbarium of the University of Tennessee - http://tenn.bio.utk.edu/vascular/vascular.html

3. Trend in Distribution and Abundance – Value based on the committee's (J. Ranney, A. Self, D. Webb) estimate of change in each invasive species population over the next 10 years: **3** = Species has a high potential to expand in distribution and abundance; **2** = Species has an intermediate potential to expand in distribution and abundance; and **1**= Distribution and abundance not expected to change to any large extent.

4. Management Difficulty – Several questions were considered in the ranking. Are multiple treatments required to control this species? Are proven management techniques available? Can colonization sites be easily accessed for treatment? The ratings focused primarily on the use of herbicides to manage the listed species: **3** = Repetitive and ongoing treatments are required, or technology for management has not been demonstrated in the field, or colonization sites are very difficult to access; **2** = Intermediate rank between **3** and **1**; **1**= Technology has been demonstrated that can manage the pest plant with a few treatments with a high expectation of success and the colonization sites/habitat is readily accessible with "conventional equipment."

ANS-TN – Aquatic Animals Ranking Considerations for each Criterion

The committee considered the following factors when ranking the economic and biological impacts of certain aquatic animals that are or might become ANS in Tennessee during the next 10 years.

1. Ecological Impacts

- Impact on ecosystem processes and system-wide parameters
- Impact on ecological community structure
- Impact on ecological community composition
- Impact on individual native plant and animal species
- Conservation significance of the threatened communities and threatened native species.

2. Current Distribution and Status

- Current range size in region
- Proportion of current range where species is negatively impacting biodiversity
- Proportion of region's biogeographic units invaded
- Diversity of habitats or ecological systems invaded in region.

3. Trend in Distribution and Abundance

- Current trend in total range within region
- Proportion of potential range currently occupied
- Long-distance dispersal potential within region
- Inherent ability to invade conservation areas or other native species habitats
- Similar habitats invaded elsewhere
- Reproductive characteristics

4. Management Difficulty

- General management difficulty
- Minimum time commitment
- Impacts of management of native species
- Accessibility of invaded areas

5. Economic Impact

- Commercial fishing
- Recreational boating
- Sport fish angling
- Tourism
- Pet and food industries

Pathways – TN Ranking Procedure, Linking Species and Pathways

The TANSTF listed all of the existing or potential pathways for the spread of ANS in the state. Task force members initially prioritized the pathways by placing checkmarks under all pathways that might be associated with each species. The pathways with the most checkmarks (direct score) were considered to be the most important.

These ranks were verified by developing a weighted score. The direct score for each pathway was multiplied by the species score (based on the species priority ranking). The resulting ranks are below.

Pathway Priority Summary Sheet

Direct Score	Pathway	Weighted Score	Pathway
176	Natural Waterways	1657.91	Natural Waterways
127	Accidental Stocking	1192.31	Accidental Stocking
123	Canals (Waterways)	1172.97	Canals (Waterways)
108	Intentional Stocking	1006.36	Intentional Stocking
93	Flood (Pond Breach)	873.12	Flood (Pond Breach)
91	Water Gardens	827.81	Water Gardens
83	Aquarium Pet Trade	761.73	Aquarium Pet Trade
78	Bait bucket	739.06	Bait Bucket
78	Dike Failure	727.64	Dike Failure
67	Live Wells	649.84	Live Wells
67	Waterfowl	630.54	Waterfowl
57	Boat Trailers	585.00	Boat Trailers
52	Propellers	573.68	Propellers
51	Hatcheries	476.3	Hatcheries
50	Retail Bait Distr.	449.51	Retail Bait Distr.
41	Aquac. Transport	411.18	Aquac. Transport
41	Aquac. Wholesale	387.5	Pet Trade Transport
40	Wholesale Bait Distr.	377.33	Wholesale Bait Distr.
40	Pet Trade Transport	375.79	Aquac. Wholesale
37	Tournament Bait Dist	341.50	Tournament Bait Dist.
31	Commercial Barges	311.85	Commercial Barges
29	Tow Boats	299.52	Tow Boats
28	Fishing Gear-Users	279.98	Fishing Gear-Users
0	Fishing Gear-Retail	0	Fishing Gear-Retail

With the exception of four of the lower ranked pathways (aquaculture transportation, aquaculture wholesale, pet trade transportation, and wholesale bait distribution), the rankings were the same. The 25 pathways were further categorized into ten sub-headings listed below:

1) Waterways
   a) Natural
   b) Canals

2) Fish/Plant Stocking
   a) Intentional
   b) Accidental

3) Pond Breaches
   a) Floods
   b) Dike failure

4) Aquatic Pet Trade
   a) Aquarium
   b) Water garden
   c) Transport

5) Bait Distribution
   a) Tournament
   b) Bait dealers
   c) Bait buckets

6) Recreational Boaters
   a) Live wells
   b) Boat trailers
   c) Bait bucket
   d) Propellers
   e) Boat Hulls

7) Commercial Shipping
   a) Barges
   b) Tow boats

8) Waterfowl

9) Aquaculture Industry
   a) Hatcheries
   b) Wholesale
   c) Transport

10) Fishing Gear
   a) Users

Appendix C. Summary of Relevant State Laws and Rules

The following sections of state statutes and rules are applicable to the prevention and management of Aquatic Nuisance Species in Tennessee. Some of the statutes and rules apply broadly to all types of nuisance species, both terrestrial and aquatic. All are found in the Tennessee Code Annotated (TCA)*.

*TCA 70-2-212. Stocking of Wildlife-Inspections-Charges.
-(a) Stocking of wildlife is declared to be a prerogative of the state. All persons desiring to stock wildlife shall first obtain a permit from the executive director of Tennessee Wildlife Resources Agency (TWRA).

-(b) The TWRA has the power to inspect all live fish entering the state, regardless of their source, and to destroy any shipment found to be diseased without incurring any liabilities for so doing.

*TCA 70-2-213. Permits for Scientific Purposes.
-(a) The TWRA director has the power, at the executive director's discretion, to grant permission, under the executive director's seal, to any reliable person to take, capture and transport in Tennessee, wild birds, and nests and eggs, and wild animals and fish, when taken for purely scientific purposes.

*TCA 70-2-221. Fish Dealers License.
-(c) The TWRA is empowered to inspect any shipment of live minnows, and if found diseased, may cause the shipment to be destroyed without being liable for damage for such destruction.

*TCA 70-4-107. Hunting and Fishing Seasons-Bag and Creel limits- Non-protected Wildlife.
-(4) The Tennessee Wildlife Resources Commission shall annually publish a list of such wildlife as are deemed destructive and/or not to be protected by law.

*TCA 70-4-113. Use of Bait, Pitfalls and Certain other Devices in Taking Birds and Animals Prohibited.
-(b) The TWRA executive director or the executive director's designees may use any chemical, biological substance, poison or device under controlled conditions to capture or kill any bird or animal for scientific, propagating, enforcement, humane or rescue purposes or when it is considered necessary by the executive director to reduce or control any species that may be detrimental to human safety, health or property.

*TCA 70-4-119. Taking of Aquatic Animal Life Other Than Game Fish-Possession of Commercial Fishing Gear on Contaminated Waters-Use of Explosives, Electrical Devices or Poisons

-(a) The taking of fish, mussels, turtles and other aquatic animal life, other than those species designated as game fish, from the waters of this state is not permitted except in accordance with the following provisions:

-(1) Any and all varieties of fish, mussels, turtles and other aquatic life may be sold commercially, subject to limitations prescribed by the Wildlife Resources Commission.

-(c)(1) It is unlawful to use or possess dynamite, electrical devices, explosives, chemicals, lime or poison to kill or stun fish, or to attempt to do so.

-(4) The TWRA executive director, or the executive director's designated agents, may use any substance or chemical or device to stun or kill fish for scientific, propagating, enforcement or rescue purposes, and may use poison in certain waters or lakes of the state where it is necessary to remove or eradicate undesirable species of fish from the waters.

*TCA 70-4-201. Possession of or Traffic in Protected Wildlife Illegal.
-(a) It is unlawful for any person, firm, or corporation, any restaurant, club, or hotel in this state to barter, sell, transfer or offer for sale, or to purchase, or offer to purchase, any of the wildlife except as provided within this title or in rules and regulations promulgated by the commission.

*TCA 70-4-401. Prohibited Acts.
-(a) It is unlawful for any person to possess, transport, export, buy, sell, barter, propagate or transfer any wildlife, whether indigenous to this state or not, except as provided by this part and rules and regulations promulgated by the Tennessee Wildlife Resources Commission pursuant to this part.

*TCA 70-4-403. Classifications of Wildlife.
-(2) Class II- This class includes native species, except those listed in other classes.

-(5) Class IV- This class includes such species that the Commission, in conjunction with the Commissioner of Agriculture, may designate by rules and regulations as injurious to the environment.

*TCA 70-4-410. Propagation of Class I or Class II Wildlife.
-(a) Before any person may engage in the business of propagating or otherwise obtaining Class I or Class II wildlife for sale, barter or trade, whether indigenous to this state or not, such person must obtain and possess a permit for each propagating location.

*TCA 70-4-412. Release of Wildlife.
-It is unlawful to release any class of wildlife in Tennessee except in accordance with the rules and regulations promulgated by the Tennessee Wildlife Resources Commission.

*TCA 70-5-106. Establishment of Fish Preserves-Powers of Commission.
-(c) The Tennessee Wildlife Resources Commission has the power and authority to close the waters against fishing of all kinds, and to reopen the same for fishing when it deems the water has been closed a sufficient time for restocking.

*TCA 70-6-101. Enforcement Authority.
-(a) The officers of the TWRA or officers of any other state agency or of the federal government who are full-time wildlife enforcement personnel designated by the executive director, shall enforce all laws now enacted or that may hereafter be enacted for the propagation and preservation of all wildlife in this state, and shall prosecute all persons, firms, and corporations who violate any such laws.

-(b)(1) It is the duty of every person participating in the privileges of taking or possessing such wildlife as permitted by this title to permit the executive director or officers of the Tennessee Wildlife Resources Agency to ascertain whether the requirements of this title are being faithfully complied with, including the possession of a proper license.

*TCA 70-6-102. Each Unlawful Taking and Device deemed Separate Offense.
-Each wild animal, wild bird, wild fowl, or fish caught, taken, killed, captured, destroyed, shipped, offered or received for shipment, transported, bought, sold, or bartered, or had in possession, and each trap, snare, net, or other device used or attempted to be used in violation of the provisions of this title constitutes a separate offense.

Proclamation 99-6, Taking, Possessing, and Selling of Mussels
-Individuals must possess a license to buy or sell mussels in Tennessee. This is enforced by the TWRA. The TWRA also regulates waters from which mussels may be harvested, and closes some waters from harvest; it specifies species that may be harvested, sizes, and seasons for harvest; it regulates mussel harvesting gear.

Proclamation 06-22, Commercial Taking of Fish and Turtles (Statewide)
-Allows the taking and selling of bighead, silver, grass, and common carp.

Rules and Regulations, Chapter 1660-1-15, Animal Importation
-Individuals must possess an importation permit. Each request to import will be considered on its own merits, taking into consideration human health and safety, competition with or effect on native species, prolific breeders, and agricultural pests.

Rules and Regulations, Chapter 1660-1-18, Rules and Regulations of Live Wildlife
-Allows for the possession of triploid grass carp and goldfish, but lists zebra mussels, black carp, blueback herring, ruffe, bighead carp, silver carp, snakehead fish, New Zealand mud snail, round goby, rudd, and swamp eels as Class V wildlife (injurious to the environment).

Rules and Regulations, Chapter 1660-1-26, Rules and Regulations For Fish Farming, Catch-Out Operations, and Bait Dealers
-Identifies approved species for fish farming.

Appendix D. Summary of International Laws and Treaties Relevant to Aquatic Invasive Species

Codex Alimentarius Commission
The United Nations' Food and Agricultural Organization (FAO) and the World Health Organization (WHO) created the Codex Alimentarius Commission (Codex) in 1962,[1] to encourage fair international trade in food while promoting the health and economic interests of consumers.[2] In the United States, Codex activities are coordinated by the USDA, EPA, and Food and Drug Administration.[3]

One of the Codex' specialized committees, the Committee on Import/Export Inspection and Certification Systems,[4] oversees matters that may involve aquatic invasive species by applying standards that protect consumer health in the area of food safety. The standards apply to specific food commodities, pesticide and drug residues, food contaminants and additives, labeling, and food safety.[5] Introduction or transport of a species is subject to the Codex if it threatens food safety or the international food trade.

Convention on Biological Diversity
The Convention on Biological Diversity (CBD) recognizes the importance of "ecological, genetic, social, economic, scientific, educational, cultural, recreational, and aesthetic" values of biological diversity throughout the world.[6] Countries have rights over their own biological resources, but also have the responsibility of conserving them and using them in a sustainable manner.[7] A fundamental requirement for the conservation of biological diversity is in-situ conservation.[8] The CBD recognizes the need to "prevent the introduction of and control or eradicate those alien species which threaten ecosystems, habitats, or species."[9] The CDB has a program to target introduction of invasive species.[10] The Global Invasive Species Programme works with the CBD to provide expertise through the CBD's Subsidiary Body on Science, Technology, and Technical Assistance.[11] Although the United States has not ratified this agreement, many of the country's trading partners have.

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[1] See Food Safety and Inspection Service, U.S. Codex Office, Codex Alimentarius Commission. Retrieved 19 October 2006 from http://www.fao.org/docrep/008/y7867e/y7867e07.htm#bm07/.
[2] See id.
[3] See id.
[4] See FAO/WHO Food Standards, Codex Alimentarius. Retrieved 19 October 2006 from http://www.codexalimentarius.net/web/standard_list.do?lang=en.
[5] See id.
[6] Convention on Biodiversity, June 5, 1992, Preamble.
[7] See id.
[8] In situ conservation means "the conservation of ecosystems and natural habitats and the maintenance and recovery of viable population of species in their natural surroundings and, in the case of domesticated or cultivated species, in the surroundings where they have developed their distinctive properties." Id. Article 2.
[9] Id. Article 2(h).
[10] See Convention on Biodiversity, Alien Species Introduction. Retrieved 10 October 2006 from http://www.biodiv.org/programmes/cross-cutting/alien/default.aspx.
[11] See id.

Convention on International Trade in Endangered Species of Wild Flora and Fauna
The purpose of The Convention on International Trade in Endangered Species of Wild Flora and Fauna (CITES) is to foster international cooperation in order to protect certain species of flora and fauna from over-exploitation through international trade.[12] CITES divides species of wild flora and fauna into three appendices. Trade of any species in Appendices I, II, or III is prohibited, except in accordance with provisions set forth in CITES.[13] Trade of species included in Appendices I, II, and III are regulated through a system of import, export, and re-export permits.[14] Appendix I includes species threatened with extinction that are or may be affected by trade. Trading members of these species are the most strictly regulated in order not to further endanger their survival.[15] For these species, trade is authorized in only "exceptional" circumstances.[16]

Appendix II includes species that currently are not threatened with extinction, but would become so threatened without strict regulation.[17] Appendix II also recognizes that trade in other species also must be regulated in order to effectively protect species included in Appendix II.[18]

Appendix III includes all species that any Party to CITES declares to be subject to regulation within its jurisdiction to prevent or restrict exploitation, and "as needing cooperation of other parties in the control of trade."[19]

Office of International Epizootics
The Office of International Epizootics (OIE) is an international organization created by agreement in 1924 to guarantee the transparency of animal diseases worldwide; to collect, analyze, and disseminate veterinary scientific information; to provide expertise and promote international solidarity for the control of animal diseases; and to guarantee the sanitary safety of world trade by developing sanitary rules for international trade in animals and animal products.[20]

The OIE collects and disseminates information through cooperation between member countries. Each member reports to the OIE animal diseases that it identifies within its territory.[21] The OIE thereby disseminates this information to other members so that each may act upon this information accordingly.[22] The OIE provides technical support to Member Countries that request assistance in controlling and eradicating animal

[12] See Convention on International Trade of Endangered Species of Wild Flora and Fauna, March 3, 1973, Preamble.
[13] See id. Article II.4.
[14] See id. Article III.2, III.3, and III.4. See also Article IV.2, IV.3, IV.4, and IV.5, plus Article V.2, V.3, and V.4.
[15] See id. Article II.1.
[16] Id.
[17] See id. Article II.2(a).
[18] See id. Article II.2(b).
[19] See id. Article II.3.
[20] See Office of International Epizootics, What is the OIE? Retrieved 19 October 2006 from http://www.oie.int/eng/OIE/en_oie.htm.
[21] See id.
[22] See id.

diseases.[23] The OIE also creates "normative documents relating to rules that member countries can use to protect themselves from diseases without setting unjustified sanitary barriers."[24] Such normative documents include the International Animal Health Code[25] and Manual Standards for Diagnostic Tests and Vaccines.[26] While the OIE generally focuses on issues such as livestock diseases and developing standards for diagnostic tests and vaccines, it recently has started to focus on diseases affecting wildlife, including aquatic species, by publishing its International Aquatic Animal Health Code.[27]

International Plant Protection Convention

The purpose of the International Plant Protection Convention (IPPC) is to prevent the introduction and spread of pests of plants and plant products and to promote appropriate control measures.[28] The IPPC was adopted in 1951 and was revised in November 1997. Under the IPPC, each contracting party agrees to cooperate with each other to prevent the introduction of plant pests and diseases and prevent their spread across national boundaries.[29] There is a structure to disseminate information on import restrictions, requirements, prohibitions, and regulations to all contracting parties and regional plant protection organizations.[30] The IPPC makes a key contribution to biosecurity in reducing the risks of introduction of plant pests that may affect agriculture and the environment.[31] The US Department of Agriculture uses the guidelines provided by the IPPC for conducting risk analysis and enforcing US importation laws and regulations.

North American Free Trade Agreement

The main objectives of the North American Free Trade Agreement (NAFTA) are to eliminate trade barriers and to promote fair competition between the Parties to the Agreement.[32] NAFTA requires that each Party to the greatest extent practicable, participate in international and North American standardizing organizations, such as the Codex, OIE, IPPC, and North American Plant Protection Organization, to promote the development and periodic review of international standards, guidelines and recommendations.[33]

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[23] See id.

[24] See id.

[25] See Office of International Epizootics, Terrestrial Animal Health Code 2003. Retrieved 19 October 2006 from http://www.oie.int/eng/OIE/en_oie.htm.

[26] See Office of International Epizootics, Manual Standards for Diagnostic Tests and Vaccines 2000. Retrieved 19 October 2006 from http://www.oie.int/eng/OIE/en_oie.htm.

[27] See Office of International Epizootics, International Aquatic Animal Health Code 2002. Retrieved 19 October 2006 from http://www.oie.int/eng/OIE/en_oie.htm.

[28] See International Plant Protection Convention, December 6, 1951, current text adopted in 1979, Article I.1.

[29] See International Plant Protection Convention, 1997 Revision. Retrieved 19 October 2006 from https://www.ippc.int/servlet/CDSServlet?status=ND0xMzI5MiY2PWVuJjMzPSomMzc9a29z.

[30] See id. Information Exchange. Retrieved 19 October 2006 from https://www.ippc.int/servlet/CDSServlet?status=ND0xMzM2MyY2PWVuJjMzPSomMzc9a29z.

[31] See id. IPPC and Biosecurity. Retrieved 19 October 2006 from https://www.ippc.int/servlet/CDSServlet?status=ND0xMzMzOCZjdG5faW5mb192aWV3X3NpemU9Y3RuX2luZm9fdmlld19mdWxsJjY9ZW4mMzM9KiZzaG93Q2hpbGRyZW49dHJ1ZSYzNz1rb3M~.

[32] See North American Free Trade Agreement, 17 December 1992, Article 102.

[33] See NAFTA Agricultural Fact Sheet, Retrieved 19 October 2006 from http://www.fas.usda.gov/itp/policy/nafta/sanitary.html.

Chapter 7 relates to invasive species. It allows each Party to adopt sanitary or phytosanitary measures necessary for the protection of human, animal, or plant life or health in its territory. Such measures may be more stringent than international standards, guidelines, or recommendations. Such measures should be based on research and risk assessment. However, measures should not arbitrarily or unjustifiably discriminate against another Party's goods. Furthermore, in conducting risk assessments in order to determine appropriate measures of protection, one of the factors that the Parties must take into account is "the prevalence of relevant diseases or pests, including the existence of pest-free or disease-free areas or areas of low pest or disease prevalence."[34]

World Trade Organization Agreement on the Application of Sanitary and Phytosanitary Measures

The Sanitary and Phytosanitary Measures Agreement (SPS Agreement) is a supplement to the World Trade Organization Agreement. It encourages Members to adopt measures necessary to protect human, animal or plant life or health.[35] However, such measures should not arbitrarily or unjustifiably discriminate against Members that experience the same conditions in their territories or be disguised as a restriction on international trade.43[36] The SPS Agreement also encourages Members to use other international guidelines, such as the Codex, OIE, and IPPC44 to promote within these organizations the development and periodic review of standards, guidelines, and recommendations with respect to all aspects of sanitary and phytosanitary measures.[37] The SPS Agreement Members should conduct scientific research and collect evidence in order to set appropriate levels of sanitary and phytosanitary protection with the least impact on international trade.[38] Such evidence includes the prevalence of specific diseases or pests, existence of pest-free or disease-free areas, relevant ecological and environmental conditions, and quarantine or other treatment.[39]

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[34] See text of treaty. Retrieved 19 October 2006 from http://www-tech.mit.edu/Bulletins/nafta.html.
[35] See Agreement on Sanitary and Phytosanitary Measures, 15 April 1994. Preamble.
[36] See id. Article 5.5
[37] See id. Preamble. See also Article 3.4
[38] See id. Article 5.4
[39] See id. Article 5.2

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Appendix E. Animals and Plants Prohibited in Tennessee

Animals

In Tennessee, it is unlawful to possess or transport live specimens of the following animals:
Bighead carp (*Aristichthys nobilis*)
Black carp (*Mylopharyngodon piceus*)
Blueback herring (*Alosa aestivalis*)
New Zealand mud snail (*Potamopyrgus antiposdarum*)
Round goby (*Neogobius melanostomus*)
Rudd (*Scardinius erythrophthalmus*)
Ruffe (*Gumnocephalus cernua*)
Silver carp (*Hypophthalmichthys molitrix*)
Snakeheads (all members of the Family *Channidae*)
Swamp eels (all members of the Family *Synbranchidae*)
Zebra mussels (*Dreissena polymorpha*)

Plants

In Tennessee, the following plants are considered pest plants. Effective June 28, 2007, these plants, or parts thereof that might be used for propagation are injurious to the agricultural. Horticultural, silvicultural or other interests of the state.

Amur honeysuckle, shrub honeysuckle (*Lonicera maackii*)
Autumn olive (*Elaegnus umbellata*)
Bell's honeysuckle (*Lonicera x bella*)
Chinese privet (*Ligustrum sinense*)
Cogongrass (*Imperata cylindrica*)
Common privet, European privet (*Ligustrum vulgare*)
Giant salvinia (*Salvinia molesta*)
Mimosa (*Albizia julibrissin*)
Morrows bush honeysuckle, Morrow's honeysuckle (*Lonicera morrowii*)
Multiflora rose (*Rosa multiflora*)
Purple loosestrife (*Lythrum salicaria, Lythrum virgatum* and related cultivars)
Thorny olive (*Eleagnus pungens*)
Tropical spiderwort (*Commelina benghalensis*)
Tropical soda apple (*Solanum viarum*)

Appendix F. Public Comments

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