ANS
Aquatic Nuisance Species
DIGEST

Volume 3 No. 3 August 1999

FRESHWATER FOUNDATION

Providing current information on monitoring and controlling the spread of harmful nonindigenous species.

Another Invader Attacks the Duluth/Superior Harbor

by Jeanne Rodd

A new invader has been added to Twin Port harbor's collection of aquatic nuisance species. On June 25, while inspecting the harbor at Duluth, MN and Superior, WI for zebra mussels, Minnesota Sea Grant's Exotic Species Information Center Coordinator, Doug Jensen discovered four rusty crayfish (*Orconectes rusticus*). The discovery was made on the Minnesota side of the St. Louis River estuary near the Bong Bridge. Rusty crayfish were found on screens that guard an electric plant's intake pipes.

Upon making this discovery, Minnesota Sea Grant staff launched a sampling of 80 other locations throughout the harbor. Results of the sampling yielded rusty crayfish near the Blatnik Bridge. Three other native crayfish species were also discovered.

At this early stage, the Minnesota Sea Grant staff cannot determine if this is an isolated occurrence or if the crayfish have settled into the area. Jensen stated that, based on the samplings, this may be a recent introduction, as rusty crayfish were found in just two areas. However, he explained, research to establish a population baseline has not been done, so it's difficult to speculate on the status of the infestation. If the rusty crayfish were to become established in the harbor, significant ecological problems could arise. Rusty crayfish have the potential to displace native crayfish, reduce fish populations by eating eggs, and devastate both submergent and emergent aquatic vegetation. A rusty crayfish infestation may also threaten the water recreation and fishing industry. Swimmers have a particular aversion to the pinching claws of the rusty crayfish.

Rusty crayfish *continued on page 30*

Rusty crayfish *(Orconectes rusticus)*

Model Guidance on ANS Legislation, Regulation and Policy: A Step Forward in the Prevention and Control of Great Lakes Biological Invaders

by Katherine Glassner-Shwayder, Project Manager, Great Lakes Commission

This article is taken from ANS Update, Volume 5, Number 2, published by the Great Lakes Panel on Aquatic Nuisance Species and the Great Lakes Commission.

The Great Lakes Panel on Aquatic Nuisance Species takes aim at closing the door on Great Lakes biological invaders with implementation of its recently completed policy document titled *Legislation, Regulation and Policy for the Prevention and Control of Nonindigenous Aquatic Nuisance Species: Model Guidance for Great Lakes Jurisdictions.* The model guidance, approved by the Great Lakes Panel, is a tool kit from which states, provinces, tribal authorities, and local entities can select the legislative, regulatory and policy provisions best suited to address ANS problems.

The impetus for development of this regional model was the lack of interjurisdictional consistency in laws, regulations and policies directed at ANS prevention and control efforts. "Regional policy to help prevent ANS introduction and spread is needed immediately to respond to the increased likelihood of introductions due to the increase in international and domestic trade and travel," says Jay Rendall, Panel member representing the Minnesota Department of Natural Resources. "The model guidance is a good start at familiarizing the governing agencies in the Great Lakes region and elsewhere on ways to respond proactively to ANS problems."

Model Guidance *continued on page 35*

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Bighead Carp Threatens Missouri River Fisheries

by Sally J. Schrank

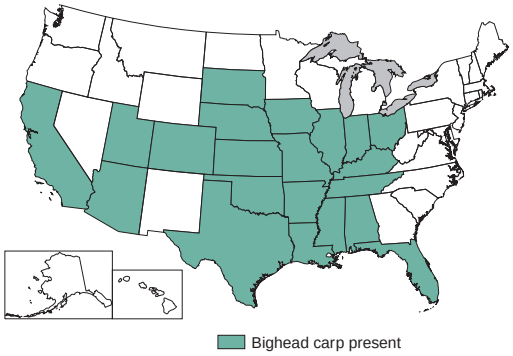

Figure 1. Distribution of bighead carp in the United States, modified to include South Dakota.

The bighead carp, (*Hypopthalmichthys nobilis*) is a large-bodied planktivore native to eastern China. In 1973, a fishery introduced bighead carp into Arkansas in an attempt to improve water quality in fish production ponds (Freeze and Henderson 1982). In 1974, after concern was raised over this exotic, regulations were mandated to restrict bighead carp stocking into Arkansas public waters, and the control of accidental introductions was investigated (Freeze and Henderson 1982). Similarly, in Kansas the importation and possession of bighead carp were prohibited in 1978 (Mosher 1989). Despite these regulations, bighead carp found their way upstream into the Mississippi and Missouri river systems. Currently, bighead carp are present in 19 states (Figure 1; Fuller et al. 1999). Its presence is likely to have a negative impact on native **planktivores** [bigmouth buffalo (*Ictiobus cyprinellus*) and paddlefish (*Polyodon spatula)]* through competition and disruption of the food web (Pfleiger 1997).

Reproduction

Spawning habits of bighead carp in river ecosystems of the U.S. have not been documented; however Asian and European populations have been extensively studied. In Asia, bighead carp generally spawn between April and June with a peak in late May (Verigin et al. 1978; Jennings 1988). Spawning typically occurs at the confluence of two rivers, behind sandbars, stonebeds, or islands. These areas are characterized by rapid current (> 0.8 m/s) and mixing of water (Huet 1970). During rising water levels, bighead carp often migrate upstream to spawn (Verigin et al. 1978). They produce eggs that are semi-buoyant and require a current to float (Soin and Sukhanova 1972; Pfleiger 1997). One day after fertilization, larval bighead carp hatch and enter the ichthyoplankton drift (Etnier and Starne 1993). Seven days after hatching, bighead carp larvae migrate to shore (Jennings 1988). Flood plains associated with rising water levels provide nursery areas for larval and juvenile bighead carp (Huet 1970). Optimum water temperature for spawning is 22-26ºC, and must be greater than 18ºC (Verigin et al. 1978; Jennings 1988). Bighead carp often have two or three spawning periods per year (Jennings 1988). For example, Pfleiger (1997) reported capturing a 7.6 cm (age-0) bighead carp in mid August and a 2.5 cm (age-0) bighead carp in mid September in the Missouri River, suggesting an extended spawning period or multiple spawning.

Bighead carp reach sexual maturity at ages three through nine years, depending on environmental conditions. Researchers in Asia and Europe have documented average weight and length of sexually mature individuals as being 50-70 cm and 5-10 kg, respectively. Males generally mature one year earlier and at smaller sizes than females (Jennings 1988). Fertility increases with increasing age and body weight and is directly related to growth rate (Verigin et al. 1990). Vinogradov et al. (1966) found that first-time spawners average 288,000 eggs. Sukhanova (1966) documented that bighead carp produce 478,000-549,000 eggs; however, an 18.5 kg female is capable of producing 1,100,000 eggs (Jennings 1988).

Feeding and Food Habits

Numerous authors report that bighead carp are opportunistic feeders, characterized by planktonic and **benthic** feeding, depending on food availability. Intestinal contents of bighead carp

words in **bold type are defined in the glossary on page 28*

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indicate that their feeding methods are filter feeding throughout the water column and detrital debris from the **substrate** (Cremer and Smitherman 1980; Opuszynski 1981; Spataru et al. 1983; Burke et al. 1986; Opuszynski et al. 1991; Dong and Li 1994). Cremer and Smitherman (1980) concluded that the quantity and diversity of zooplankton in the intestines of bighead carp indicates active feeding in all layers of the water column. Dong and Li (1994) documented that bighead carp remain in areas with high zooplankton density; however, they do not actively select feeding areas. They also describe the presence of taste buds in the epithelial of the filtering organ, which may aid bighead carp in identifying areas with a high density of zooplankton. Lazareva et al. (1978) concluded that bighead carp will switch to phytoplankton when zooplankton are limiting.

Feeding time of this species varies by location. For example, bighead carp feed for 18 hours a day in July and August in China (Jennings 1988). Whereas, Moskul (1977) found that feeding peaked at 2000 hours and was lowest at 0600 hours. Sifa et al. (1980) documented that feeding times may be a function of light intensity, dissolved oxygen, and temperature.

Several researchers have studied the diet of bighead carp; however, most of the work has been conducted in aquaculture experiments. For example, bighead carp raised in aquaculture ponds with high densities of zooplankton fed primarily on zooplankton (Voropaev 1968; Spataru et al. 1983; Burke et al. 1986). Opuszynski (1981) found that when bighead carp were raised alone in aquaculture ponds, 86% of their diet was zooplankton, including cladocera and copepoda. Somewhat contrary, Cremer and Smitherman (1980) found that the diet of bighead carp raised in aquaculture ponds consisted of 26% zooplankton, 69.3% **detritus**, and 7.1% phytoplankton.

The food size consumed by bighead carp is related to **gill raker** spacing, the average width being 84 µm (Cremer and Smitherman 1980; Spataru et al. 1983; Opuszynski et al. 1991; Opuszynski and Shireman 1991). Opuszynski et al. (1991) reported that bighead carp consumed food particles about four times smaller than gill raker width. Jennings (1988) documented the presence of a translucent mucous coating on the gill rakers of bighead carp that trapped particles smaller than the width of the gill rakers.

Missouri River

The Missouri River, from St. Louis, MO, to Sioux City, IA, has been modified by channelization and bank stabilization projects since 1900. These projects were undertaken to provide navigation channels, flood control, irrigation, and hydro-power. The impact of these projects has had detrimental effects on the natural flow regime, aquatic habitats, and species assemblages within the mainstem and tributaries of the Missouri River (Pfleiger and Grace 1987). For example, 16 fish species historically found in the Missouri River have been classified as endangered, threatened, or rare by state and federal agencies (SAST 1994). The Missouri River was listed as North America's most endangered river in 1997 (American Rivers 1997). Since 1940, a decrease in turbidity and change in flow regime increased abundance of pelagic planktivores and sight feeding carnivores (Pfleiger and Grace 1987). It is likely that bighead carp could have negative impacts on other planktivores in the Missouri River, such as bigmouth buffalo (*Ictiobus cyprinellus*) and paddlefish (*Polyodon spathula)* (Pfleiger 1997). Paddlefish populations have been declining in major river systems since 1900 due to over exploitation, habitat alteration, and habitat destruction (Russell 1986; Graham 1997). Thus, competition with bighead carp could further impact paddlefish populations (Pfleiger 1997).

Dispersal

Upstream dispersal of bighead carp in the Mississippi River and its tributaries has been documented. Freeze and Henderson (1982) reported the collection of a single adult in 1981 from the Ohio River in Kentucky. By 1982, adult bighead carp were present in the Missouri River, and in the Mississippi River as far north as Illinois (Jennings 1988; Pfleiger 1997). Pfleiger and Grace (1987) speculated on the potential establishment of bighead carp in the Missouri River due to their presence in the Mississippi River. The first evidence of bighead carp reproduction in the Mississippi River was the collection of age-0 fish between 1992 and 1994 by Tucker et al. (1996). Bighead carp reproduction in the Missouri River was documented in August 1989 (Pfleiger 1997) and Kubisiak (1997) captured juvenile bighead carp (<150 mm) in areas of the lower Missouri River. Several bighead carp (578-988 mm) have been sampled from tributaries in the lower Missouri River (P. J. Braaten, Kansas State University, personal communication). Tibbs and Galat (1997) found bighead carp proto-larvae, meso-larvae, and meta-larvae in scour habitats of the lower Missouri River.

The limits of bighead carp expansion in the U.S. are unknown. Impoundments may impede river dispersal; however a large flood could negate this type of confinement. Additional introductions into rivers, lakes, and reservoirs, released from U.S. aquaculture facilities are possible. The potential impact of this exotic planktivore released into river, lake, or reservoir ecosystems of the U. S. could be detrimental to native fish.

Future Action

To determine the extent of impact of species such as bighead carp on non-sport fish and sport fish, a multi-state-agency asian carp study is proposed for the Missouri River. This study will examine bighead carp population characteristics including; current distribution, food habits, recruitment, growth mortality, rate of expansion and range limitations, in the lower Missouri River (i.e., Gavins Point tail waters to the confluence with the Mississippi River). Data collection and analysis will be conducted by U.S. Geological Survey - Biological Resources Division (BRD) Cooperative Research Units in South Dakota, Iowa, Kansas, and Missouri. Cooperating federal and state agencies will also take part in the study. This data is necessary in predicting the effects of bighead carp on sport fish and non-sport fish species and developing management and control strategies.

Final products of the study will include:

- a distribution map with current and predicted distributions of bighead carp for the Missouri River basin,
- a report on population characteristics of all Asian carp in the lower Missouri River with possible management strategies and,
- a report on food habitats of bighead carp in the lower Missouri River and predictions regarding impacts on native fishes.

For more information on bighead carp or the proposed impact study please contact; Sally J. Schrank, Division of Biology, Kansas State University, Manhattan, KS 66506-3501, (785) 532-6172, sjsally@ksu.edu or Linda Drees, U.S.Fish and Wildlife Service, 785-539-3474X20, Linda_Drees@fws.gov

***Carp** continued on page 28*

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Glossary

benthic:
Occuring at the bottom of a body of water.

gill raker:
Any of the bony processes on a gill arch that divert solid substances away from the gills.

planktivore:
A species whose diet is composed of plankton.

carapace:
The bony case or shield covering the back of an animal.

substrate:
The base on which an organism lives.

detritus:
Loose material, such as rock fragments or organic particles, that results from disintegration.

Upcoming Meetings

National ANS Task Force Meeting
August 18-19, 1999
Olympia, Washington
Contact: Sharon Gross
(703) 358-2308 or sharon_gross@fws.gov

Western Regional Panel ANS Fall Meeting
October 5-6, 1999
Austin, Texas
Contact: Bill Harvey, TXFWD; (512) 389-4642
or Linda Drees; (785) 539-3474, ext. 20

Southeast ANS Conference
October 12-14, 1999
Charleston, South Carolina
Contact: Janice Conner; (803) 737-0800 for registration forms and details. Visit the conference web site at :
<http://www.dnr.state.sc.us/water/envaff/aquatic/ansconference.html>

Send meeting announcements to:

Jeanne Rodd, ANS Digest
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Deadline for the next issue is September 1, 1999

News from the Great Lakes Panel on Aquatic Nuisance Species

ANS UPDATE

Spring/Summer 1999 Volume 5, No. 2

Great Lakes Panel Update

The draft ANS Action Plan has been revised and is under review by the Panel membership and will be submitted for formal approval at the Panel's fall meeting. Staff is preparing recommendations for Great Lakes ballast water research based on input received at the April 29 symposium held in Duluth, Minn. The final document to be presented for Panel approval next fall, will provide a detailed ballast water research agenda for the Great Lakes Basin. **Contact:** Katherine Glassner-Shwayder, Great Lakes Commission, 734-665-9135, shwadyer@glc.org.

News from Around the Basin

ILLINOIS: The annual meeting of International Association for Great Lakes Research (IAGLR), held in late May at Case Western Reserve, featured papers from the latest in round goby research and identified related research priorities. Conference sponsors included IL-IN Sea Grant, Ohio DNR, Ohio Sea Grant and IAGLR. The state ANS management plan is completed and will be sent in July to constituents for comments. *Contact:* Pat Charlebois, IL-IN Sea Grant, 847-872-0140, p_char@ix.netcom.com.

INDIANA: Information will be evaluated on the design and feasibility of a fish barrier for Bixler Lake (Noble County in northeast Ind.) to prevent carp from moving into the lake from downstream areas. Modifications to the outlet structure of Pine Lake (LaPorte County) are being considered to protect downstream areas from zebra mussel colonization. **Contact:** Randy Lang, 317-232-4094, lang@dfw.dnr.state.in.us.

MICHIGAN: The Office of the Great Lakes received a final report titled Analysis of Laws and Policies Concerning Exotic Invasions of the Great Lakes prepared by Eric Reeves, Commander, U.S. Coast Guard (Ret.). The report was commissioned pursuant to Michigan's ANS State Management Plan. **Contact:** Mark Coscarelli, 517-335-4227, cosarem@ state.mi.us.

MINNESOTA: State statutes have been changed to prohibit the harvest of live bait from infested waters, with an exception to allow harvest from Eurasian watermilfoil waters by permit (after required annual ANS training for permittees). The DNR provided ANS training for several bait dealers this spring, which was considered valuable by the dealers. The DNR plans to inspect boats entering and leaving several noninfested waters this summer to raise awareness of ANS threats and related state laws. The DNR is developing an enforcement plan to provide the conservation officers with information on ANS threats and enforcement priorities for their districts. **Contact:** Jay Rendall, MN DNR, 651-297-1464, jay.rendall@ dnr.state.mn.us.

NEW YORK: Two ANS research projects will be conducted at Cornell University, based on a cooperative agreement that was signed between the U.S. Fish &Wildlife Service (U.S. FWS) and the DEC to facilitate the transfer of funds. Dr. Edward Mills is investigating the ecological relationships between zebra mussels and quagga mussels, and the consequences of zebra mussel displacement by quagga mussels in Lake Ontario. Dr. Robert Johnson is investigating the efficacy of Eurasian watermilfoil control by aquatic weevils and moths. **Contact:** Bill Culligan, NYS DEC, 716-366-0228, nysdecdk@netsync.net.

OHIO: The DNR's ANS Advisory Team and Steering Committee are currently reviewing existing state ANS laws, rules and regulations in comparison with the Great Lake Panel's model guidance. Based on their reviews and input, changes may be recommended to the appropriate agencies. **Contact:** Randy Sanders, OH DNR, 614-265-6344, randy.sanders@ dnr.state.oh.us.

WISCONSIN: The DNR, with assistance from volunteers, will be sampling over 100 lakes for zebra mussels this summer. In 1998, zebra mussels were discovered in seven inland lakes in the state. As of April 1998, the DNR has had the authority to close waters to bait harvest if they are infested with invasive species. It is expected that the DNR will receive $50,000 in state funds between 1999 and 2001 to fund information and education activities related to zebra mussels and other aquatic nuisance species. The state ANS management plan is nearly complete and soon will be sent out for public review. **Contact**: Ron Martin, WI DNR, 608-266-9270, martinr@dnr.state.wi.us.

Washington Watch

Both House and Senate Appropriations committees have begun to a and mark appropriations bills. House and Senate allocations differ considerably; most notable for ANS programs are likely to be the allocations for Interior (House mark a 19 percent cut below FY1999, Senate mark a 4 percent cut) and Commerce, Justice, State and Judiciary (House mark a 7.5 percent cut below FY 1999, Senate mark a 1 percent increase).

The House Appropriations Subcommittee on Transportation has marked up its Transportation Appropriations bill, which will include funding for U.S. Coast Guard ballast water regulation efforts. Despite an overall cut of nearly 10 percent to the Senate Transportation Appropriations allocation, the bill includes level funding ($3 million) for the Coast Guard's Ballast Water Guidelines and Prevention Program and increased funding (at least $1.5 million) for Coast Guard research relating to ballast water exchange verification.

For the Energy and Water Development Appropriations Committee, overall cuts resulted in a bill with relatively few earmarks for specific ANS programs and almost no funding for new initiatives. The bill does not provide funding for the Corps' Zebra Mussel Control Program (ANS Public Facility Research and Development) and only $100,000 for completion of the dispersal barrier in the Chicago Ship and Sanitary Canal (the Corps' project estimates place total federal cost at an additional $300,000). The Senate bill does provide a substantial increase for Aquatic Nuisance Plant Control (research authorized under the Rivers and Harbors Act) from $3 million to $5 million, but accompanying report language shifts the program away from its research framework in favor of cost-shared "on-the-ground" control efforts. The committee recommends that "the Corps place a higher priority on actual plant harvesting and eradication... that be undertaken only when a local sponsor agrees to provide 50 percent of the cost of the work." **Contact:** Rochelle Sturtevant, Senate Great Lakes Task Force, Northeast Midwest Institute, 202-224-1211, rochelle_sturtevant@levin.senate.gov.

National ANS Task Force

The ANS Task Force meeting is scheduled for Aug. 18-19, 1999 in Olympia, Wash. A field trip is planned for Aug. 17 to visit ballast water facilities on a vessel and a local shell fish aquaculture business. Gary Edwards, ANS Task Force Co-Chair representing the U.S. FWS, recently transferred to Alaska. His replacement is Cathleen Short, serving as U.S. FWS Assistant Director of Fisheries. In addition, the ANS Task Force Executive Secretary, Robert Peoples, has retired and has been replaced by Sharon Gross of the U.S. FWS. **Contact:** Sharon Gross, 703-358-2308, sharon_gross@fws.gov.

Upcoming Events

Meeting of the Great Lakes Panel on Aquatic Nuisance Species, Oct. 19-20, 1999, Chicago, Ill. **Contact:** Katherine Glassner-Shwayder, Great Lakes Commission, 734-665-9135, shwayder@glc.org.

Meeting of the ANS Task Force, Aug. 18-19, 1999, Olympia, Wash. **Contact:** Sharon Gross, 703-358-2308, sharon_gross@ fws.gov.

Meeting of the Western Regional Panel on ANS, Oct. 5-6, 1999, Austin, Texas. **Contact:** Linda Drees, USFWS, 785-539-3474, Ext. 20, linda_drees@fws.gov.

On The Bookshelf

Legislation, Regulation and Policy for the Prevention and Control of Nonindigenous Aquatic Nuisance Species: Model Guidance for Great Lakes Jurisdictions. June 1999. Publication of the Great Lakes Panel on Aquatic Nuisance Species. **Contact:** Katherine Glassner-Shwayder, Great Lakes Commission, 734-665-9135, shwayder@glc.org.

Abstracts: International Zebra Mussel and Aquatic Nuisance Species Conference. April 1999 . Minnesota Sea Grant Program publication X60. **Contact:** Doug Jensen, MN Sea Grant, 218-726-8712, <R>djensen1@d.umn.edu.

Help Prevent the Spread of Aquatic Exotic Plants and Animals. IL-IN Sea Grant brochure. 1998. **Contact:** Robin Goettel, IL-IN Sea Grant, 217-333-9448, goettel@uiuc.edu.

Full copies of the *ANS Update*, a quarterly newsletter prepared by the Great Lakes Panel on Aquatic Nuisance Species, are available upon request from the Great Lakes Commission. The feature article of this issue (Vol. 5, No. 2) is authored by Katherine Glassner-Shwayder, Project Manager, Great Lakes Commission, and is titled, *Model Guidance on ANS Legislation, Regulation and Policy: A Step Forward in the Prevention and Control of Great Lakes Biological Invaders.* **Contact:** Katherine Glassner-Shwayder, Great Lakes Commission, 734-665-9135, shwayder@glc.org.

Rusty crayfish *continued from page 25*

The Spread

Rusty crayfish are native to streams in the Ohio, Kentucky, Illinois, Indiana and Tennessee regions. They are currently found in non-native regions of Michigan, Massachusetts, Missouri, Iowa, Minnesota, New Mexico, New Jersey, Pennsylvania, Wisconsin, New York and all New England states except Rhode Island. (Figure 1) Also, many areas of Ontario, Canada have become home to this non-native species.

Rusty crayfish were first observed in Minnesota in 1967 at Otter Creek in the southern part of the state. A statewide study in 1990 showed rusty crayfish in 11 counties, and 19 different lakes and streams. To date, rusty crayfish have been discovered in at least 41 lakes and rivers in Minnesota.

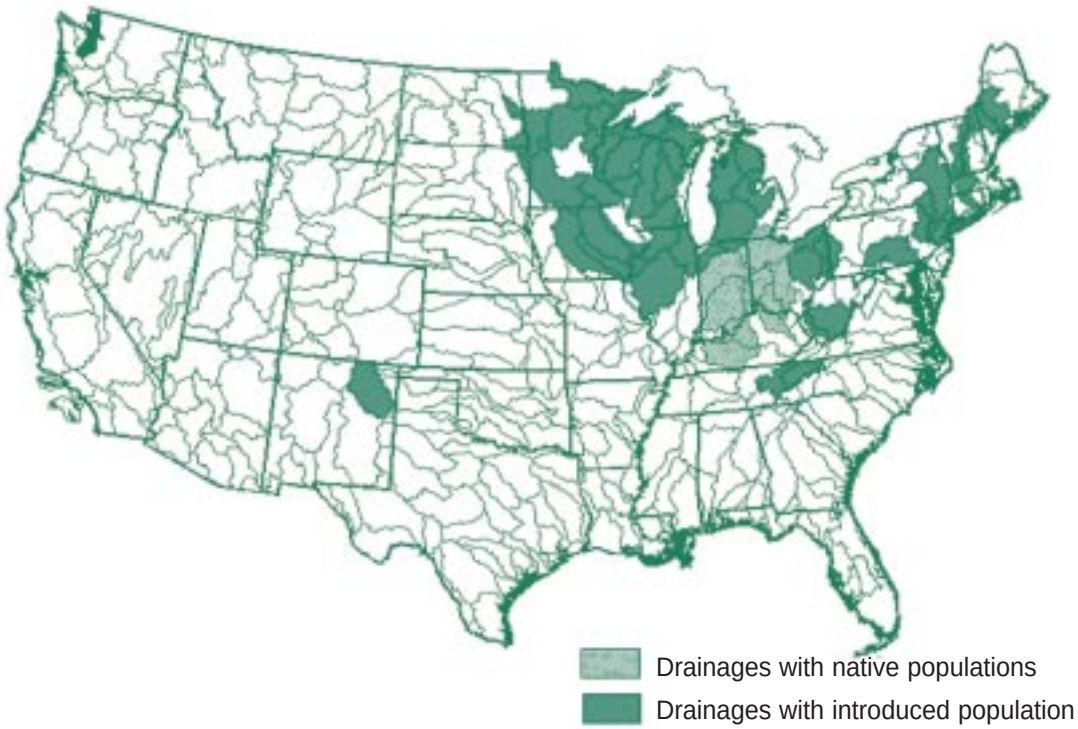

Figure 1. Rusty crayfish distribution mapped by USGS 6-digit drainages.
Data Source: Chris Taylor - Illinois Natural History Survey.
Map produced by: Nonindigenous Aquatic Species Program, USGS, Gainesville, FL. March 1999.

The spread of the rusty crayfish in Minnesota is probably due to non-resident anglers who brought them north from their native lands for use as bait. As populations increased, rusty crayfish were harvested for the regional bait market and for biological supply companies. These activities perhaps helped to spread the species further. Rusty crayfish can also move short distances by crawling across flooded areas during periods of high water.

According to Jensen, the rusty crayfish were probably introduced into the Duluth-Superior harbor from anglers' bait buckets or through releases by students or teachers after a study. Rusty crayfish also could have come from the ballast water in Great Lakes ships, which is often the route by which exotic species enter the harbor.

How to Identify

The rusty crayfish is a crustacean resembling a small lobster. This species has a few identifying characteristics which distinguish it from native crayfish species. The adult species is a rusty color, with dark spots located on each side of their **carapace**. The spots are located as though you picked up the crayfish with paint on your forefinger and thumb. These spots may be absent or faint on rusty crayfish from some waters. The claws of the rusty crayfish are larger than its body and have dark tips. When the claw is closed, an oval opening is created between the pinchers. These characteristics are primarily found in adult species, making the young rusty crayfish difficult to identify.

Crayfish have a hard outside skeleton. This jointed exoskeleton provides protection and allows movement, but limits growth. As a result, the crayfish regularly gets too big for its skeleton, sheds it, and grows a larger one. This molting process occurs six to ten times during the first year of rapid growth, but less often during the second year. For a few days following each molt, crayfish have soft exoskeletons and are more vulnerable to predators. Rusty crayfish reach maturity at an average length of one and three-eighths inches, but can reach a maximum length of about four inches.

Life Cycle

The average life expectancy of a rusty crayfish is three to four years. Therefore, rapid high-volume reproduction is important for the continuation of the species. Many crayfish become sexually mature and mate in the October or November after they are born, but fertilization and egg laying usually occur the following spring. The fertilized eggs are attached to the female's swimmerets on the underside of her jointed abdomen. There, the 80 to 575 eggs change from dark to translucent as they develop. The eggs hatch in three to six weeks, depending on water temperature. The newly hatched crayfish stay attached to its mother until shortly after their third molt.

Rusty crayfish *continued on next page*

Rusty crayfish *continued from previous page*

It is not necessary to introduce both a female and male crayfish to begin a new infestation. A female-carrying sperm is able to begin a population if released into a suitable environment. In addition, rusty crayfish in captivity reproduce readily so females used as fishing bait or in a classroom have the potential to increase the population.

Behavior

Rusty crayfish often conceal themselves under rocks or logs in lakes, ponds or streams. They inhabit both calm water and areas of fast moving water. Rusty crayfish are considered opportunistic feeders, often feeding at night on algae, snails, worms, leeches, aquatic insects, detritus, fish eggs, and small fish.

Rusty crayfish may eat twice as much as native crayfish because they have a higher metabolic rate and appetite. This enables the rusty crayfish to grow faster and larger and helps them to avoid fish that otherwise eat crayfish. Rusty crayfish also feed longer and can attain high population densities faster. The rusty crayfish's general feeding habits allow it to compete for food with many different aquatic organisms, including juvenile fish.

The Threat

Rusty crayfish have the potential to cause a variety of economic and environmental impacts when introduced to a non-native area. Because of their aggressive nature and voracious appetite, rusty crayfish often displace native crayfish populations, creating less food for fish. Large populations of rusty crayfish can quickly decimate submerged aquatic vegetation. This event can have profound negative effects on water quality, and fish and wildlife habitat. The damage to aquatic vegetation can have an increased negative impact in relatively unproductive northern lakes, where beds of aquatic plants are not abundant. Submerged aquatic plants are vitally important in these areas as they provide habitat for invertebrates, shelter and nesting substrate for fish, and erosion control.

It has also been suggested that rusty crayfish harm fish populations by eating fish eggs. No scientific studies directly link fishery declines with crayfish egg predation. However, observations and circumstantial evidence gathered by Wisconsin fishery managers suggest that bluegill and northern pike populations frequently decline following introduction of rusty crayfish. The primary cause of this decline probably was due to the decrease in abundance and diversity of aquatic plants. It is impossible to predict the effect of a rusty crayfish invasion to a new water body. However, rusty crayfish clearly have the potential to upset the balance of an aquatic ecosystem.

Regulations

Department of Natural Resources regulations state that it is illegal, in both Minnesota and Wisconsin, to introduce crayfish into any waterbody. According to Wisconsin DNR regulations, crayfish may only be used as bait in the Mississippi River and the Great Lakes. In addition, Minnesota regulations state that it is illegal to sell live crayfish as bait or for aquarium use or to transport live crayfish, except with written permission from the DNR.

Control

Presently chemical eradication of the rusty crayfish is not a viable means of control. Crayfish-killing chemicals do exist but are not approved, nor are they able to kill the rusty crayfish specifically. Approved pesticides that will kill the rusty crayfish will kill other animals, including fish.

Researchers have suggested that nuisance populations of rusty crayfish are the result of poor fishery management and that by restoring a healthy population of bass and sunfish, rusty crayfish would not be as disruptive in some lakes. Maintaining a healthy and diverse aquatic environment also allows the rusty crayfish's native predators, such as the mink, raccoon, otter, and muskrat, to naturally control the pest.

The best method of control is to prevent the rusty crayfish from being introduced to non-native areas. Jensen believes educating anglers, bait dealers, boaters, and teachers about the threats posed by rusty crayfish will reduce the risk of spreading the exotics to new areas.

For More Information

For further information on rusty crayfish or to report sightings, contact Doug Jensen, Exotic Species Information Center Coordinator, at 218-726-8712 or djensen1@d.umn.edu.

A fact sheet describing biology and impacts of rusty crayfish is also available from Minnesota Sea Grant. For a free copy of *Rusty Crayfish: A Nasty Invader* contact Minnesota Sea Grant at 218-726-6191 or visit their web site at <http://www.d.umn.ed./seagr/>

Compiled by Jeanne Rodd from information obtained from Doug Jensen, Minnesota Sea Grant, "Rusty Crayfish: A Nasty Invader" by Jeff Gunderson, Minnesota Sea Grant and "Invasive Crayfish Discovered in St. Louis Bay," released by Minnesota Sea Grant.

An Alarming Side Note

The discovery of the rusty crayfish in the Duluth/Superior harbor was made while Minnesota Sea Grant's Doug Jensen was conducting an inspection for zebra mussels. While investigating the finding further, Jensen found round gobies *(Neogobius melanostomus)* present in all 80 samplings and three-spined sticklebacks *(Gasterosteus aculeatus)* present in reproducing numbers.

A recent inspection of zebra mussels in the harbor by Dr. Mary Balcer, co-director of the Lake Superior Research institute at the University of Wisconsin- Superior, yielded 2600-6000 zebra mussels per square meter. Dr. Balcer also noted that 80% of zebra mussels survived the past winter.

USGS Develops a Drainage-Based System to Track ANS Introductions

by Pam Fuller

The U.S. Geological Survey (USGS) Nonindigenous Aquatic Species (NAS) Program has tracked the distribution of introduced species for more than 20 years.

This effort began with foreign fishes in Florida and later expanded to include aquatic nuisance species nationwide. The tracking database contains locational and temporal data for introductions and spread. This data is generally derived from literature, museum collections, state monitoring programs, and reports from professionals at state and federal agencies. Analysis of this data can be helpful in displaying any patterns that may be present in introductions of aquatic nuisance species and developing a management plan to prevent spread.

To produce maps and perform analysis, all data are referenced geographically at the finest scale possible (state, county, drainage, waterbody, point). Data reported in the literature range from state or regional lists of introduced species to exact time, date, and location of collections or releases. Often, vague locality reports make it difficult to obtain accurate answers in fine-scale analysis.

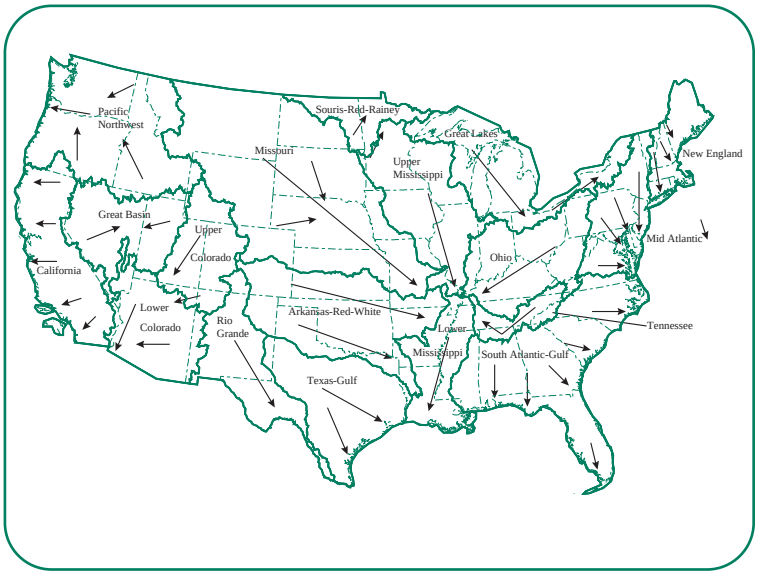

Figure 1. Map of the continental United States showing the major basins and the direction of water flow in each.

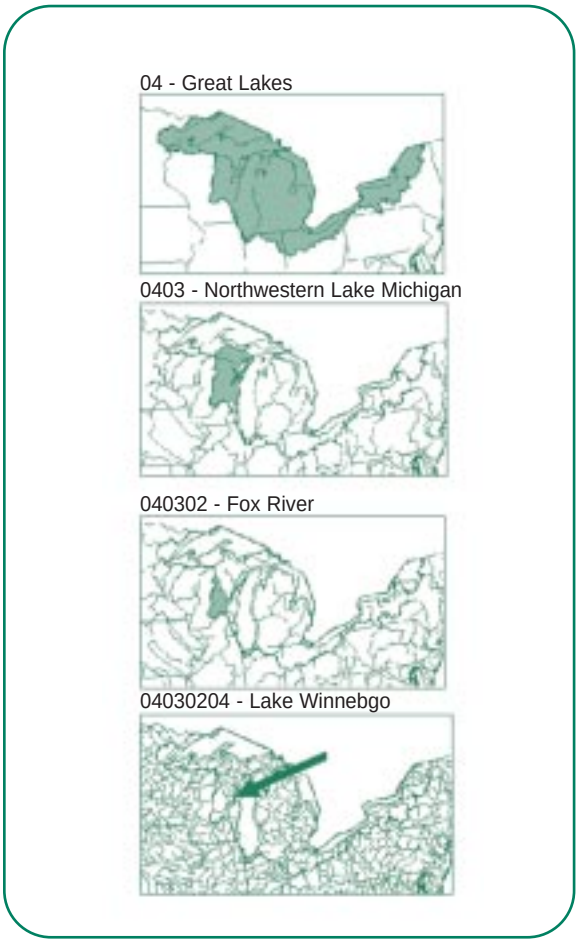

Figure 2. An example of the hierarchical HUC system. Hydrologic unit codes with more digits allows for more precisely locating and hence georeferencing a site. Lake Winnebago belongs within all of the HUCs shown.

Hydrologic Unit Codes

Hydrologic units are a hierarchical series of drainages set up by the U.S. Geological Survey in 1972. Boundaries are determined by the topography of the area, which in turn, defines the direction of water flow. Each hydrological unit is assigned a unit code (HUC) to identify the hydrologic area. The largest scale units have two digits (Figure 1) and each successive level is a smaller section of the 2-digit HUC, until an 8-digit HUC is reached. Many states are currently refining the 8-digit HUC system to a 14-digit HUC, allowing for a finer scale analysis.

This HUC system divides the United States into 21 regions (2-digit) (Figure 1), 222 subregions (4-digit), 352 accounting units (6-digit), and 2,262 cataloguing units (8-digit) (Figure 2). Each hydrologic unit is assigned an 8-digit attribute code that uniquely identifies each of the four levels of classification within four two-digit fields. A complete listing of all the hydrologic numbers and names can be found in the publication "Hydrologic Unit Maps" (U.S. Geological Survey 1982). An example is shown here (Table 1 and Figure 2) using hydrologic unit code 04030203.

Table 1.

Level	Code	Description
Region	04	Great Lakes
Subregion	0403	Northwestern Lake Michigan
Accounting Unit	040302	Fox River, Wisconsin
Cataloging Unit	04030204	Lake Winnebago, Wisconsin

Drainage-Based System *continued on next page*

Drainage-Based System *continued from previous page*

The Importance of Hydrologic Unit Codes

Identifying susceptible regions of aquatic nuisance invasions can be invaluable in protecting the area or in knowing where to set up monitoring programs. The locations of species occurrences are commonly kept by political boundaries such as state and county — a meaningless designation to an aquatic organism. To complicate matters, rivers often form political boundaries between counties and states, causing the river to be associated with two states. Conversely, a state or county can be part of multiple major drainages like Colorado. (Figure 1) Depending on the area of introduction, the introduced species may be in a watershed with access to the interconnected waterways of the Colorado, Rio Grande, Missouri, or Arkansas River basins.

Unless there is a dramatic habitat change or physical barrier, downstream areas are at high risk of infestation by the introduced species. However, upstream areas may also be at risk if the organism is either mobile or can be transported upstream by another means, such as a barge, boat, carried on fish or turtles, or by bait bucket release. In comparison, adjacent drainages are less at risk because most aquatic organisms, except for some amphibians, usually do not move over land to invade the next water body.

When Drainage Divisions Are Breached

An exception to the idea of adjacent drainages being less of a risk is when the drainages have headwaters that are separated by little distance. In these cases, organisms can disperse during "stream capture" events that may connect or redirect the stream channel between the two drainages. Some areas are more prone to this than others based on geology and topography. One of the most susceptible regions is in northwestern Virginia between the James drainage on the Atlantic Slope and the Kanawha (New) drainage of the Ohio basin. Numerous fish species are thought to have entered the upper New through stream capture from the James (Gilbert 1980; Jenkins and Burkhead 1994; Fuller et al. 1999), always in the same direction. Conversely, no stream captures have occurred in the opposite direction, from the New into the James. Stream capture is, in this case, a one-way event.

Construction of canals is another event that has caused previously separate drainages to become connected. Canal construction boomed in the mid to late 1800s and early 1900s, especially in the eastern United States. Today, canals connect the Atlantic to the Great Lakes (the Erie canal), the lower Great Lakes to the upper Great Lakes (the Welland Canal), the Great Lakes to the Ohio Basin, and the Great Lakes to the Mississippi Basin (the Fox-Wisconsin Canal and the Chicago Shipping Canal). The latter has had a significant effect on the spread of several introduced species.

One of the most recent and well-known examples of this event is the zebra mussel's spread from the Great Lakes to the Mississippi River via the Chicago Shipping and Sanitary Canal. Knowing this, the canal is also the route targeted to prevent downstream spread by the round goby and other exotics to the Mississippi basin (Keppner and Theriot 1997). Unlike areas of stream captures, canal connections provide a two-way route for migrations. Not only have species migrated from the Great Lakes to the Mississippi, several fish species (alewife *Alosa pseudoharengus*, skipjack herring *Alosa chrysochloris*, and gizzard shad *Dorosoma cepedianum*) have entered the Great Lakes from the Mississippi River basin via the Chicago Shipping Canal (Fuller and Williams, in prep.). Another case of a canal connecting two distinct drainages is the Panama Canal that connects the Atlantic Ocean to the Pacific Ocean. To date, the pipefish *(Oostethus brachyurus lineatus)* is the only documented species introduced via this route (Chickering 1930). The low number is likely due to the presence of freshwater in the central portion of the canal.

Patterns of Introductions

Using hydrologic units to document introductions can be helpful in displaying any patterns that may be present. When mapped at the 2-digit HUC level, the region with the most fish species introduced, by far, is the South Atlantic-Gulf (Figure 3). Many of these introductions can be attributed to tropical fish farms in Florida and the warm climate which allow some tropical and warm water species to survive. The California region ranks second, largely due to the number of marine species (>40) that were stocked into the Salton Sea, mostly without success. The Souris-Red-Rainy and Alaska regions rank low, probably due to the cold climate and the low human population density.

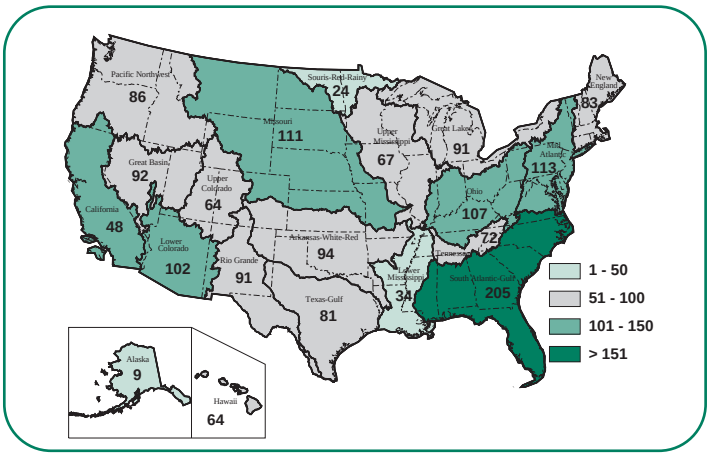

Figure 3 Number of fish species introduced into USGS 2-digit HUC regions. Fuller et al. 1999.

Drainages "hot spots" with the most fish species introduced are the upper Tennessee (TN, NC), Kanawha (WV), and South Florida (FL). Other drainages with high numbers of introductions include Oahu (HI), lower Colorado-Lake Mead (UT, AZ, NV), East Texas Coastal (TX), Chowan-Roanoke (VA, NC), Sacramento (CA), South California Coastal (CA), Rio Grande headwaters (CO), the South Platte (CO, WY, NE), Susquehanna (NY, PA), Potomac (WV, VA), Edisto (SC), and the Salton Sea (CA). The east coast in general is quite high, the central region is fairly low. With this knowledge, management plans need to be aggressive in high introduction areas to prevent future introduced species.

Drainage-Based System *continued on next page*

Drainage-Based System *continued from previous page*

Illustrating Native vs. Introduced Range

Mapping with hydrologic units is useful to demonstrate an aquatic species' native and introduced distribution (Figure 4). The flathead catfish is an example of a species that is native to one part of the country but introduced to another. They are native to interior and central Gulf drainages east to the Mobile Basin but have been introduced into drainages on the eastern Gulf and Atlantic Slope. These drainages are separated from the native river systems by a topographical ridge or drainage divide. The native drainages flow to the south and/or west, whereas the drainages with introductions flow to the east or southeast. Therefore, the catfish would not have had access to Atlantic Slope rivers without human intervention.

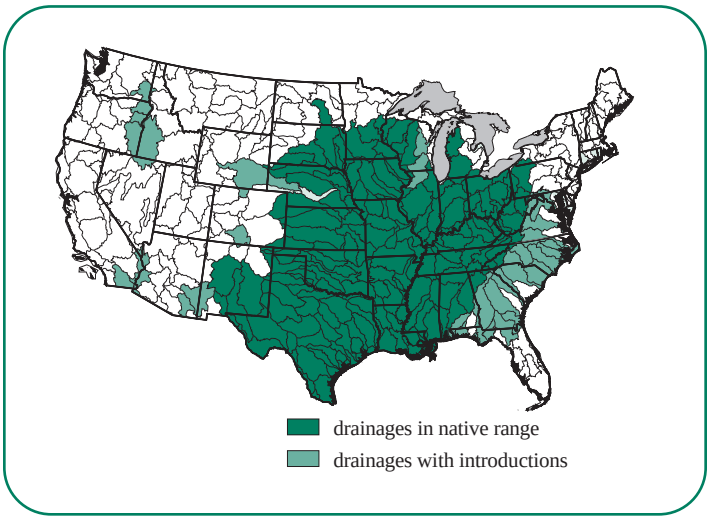

Figure 4. Distribution of flathead catfish by 6-digit HUCs.

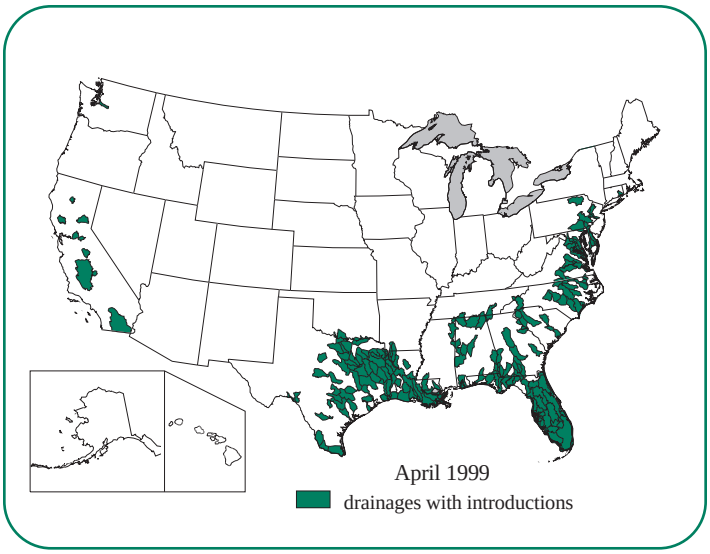

Figure 5. Drainages (8-digit HUC) with hydrilla.
Map produced by C. Jacono, USGS, Gainesville.

Risk Assessment

The distribution of hydrilla (*Hydrilla verticillata*), an exotic aquatic plant, in the U.S. is a good example of how the 8-digit HUC map may be used to assess risks to other drainages (Figure 5) . However, the map alone is not enough to determine the drainage at risk. Interpretation of this map for at-risk areas requires that the user be familiar with the area and the direction of waterflow. With this knowledge, areas adjacent to and downstream from infested waterways can be periodically surveyed for spread.

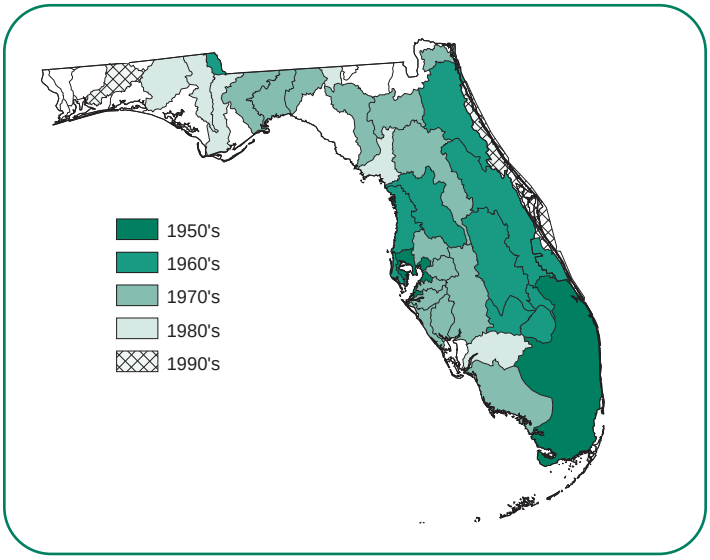

Figure 6. Spread of hydrilla through Florida drainages.
Map produced by C. Jacono, USGS, Gainesville.

Analysis of hydrologic unit codes can also be used to track spread over time through drainages. Hydrilla was first discovered in South Florida and the Tampa area (Figure 6). In the past several decades it has spread to nearly every drainage in the state. The remaining uninfested drainages either do not have public boating areas or are blackwater streams that lack suitable habitat.

Conclusion

One of the major problems facing modeling or Geological Information System analysis of aquatic introductions is the lack of a meaningful definable unit for georeferencing occurrences. Using hydrologic units will help overcome this problem since they are based on direction of water flow rather than political boundaries. It is important to track aquatic introductions relative to drainages because they can be used to differentiate native and introduced distributions, look for patterns in introductions, assess risk potential to a drainage, and target monitoring efforts. Adopting the use of hydrologic unit codes may encourage resource managers to start thinking in terms of drainages and direction of water flow.

Drainage-Based System *continued on next page*

Drainage-Based System *continued from previous page*

WATERSHED WEB SITES

For more information on HUCs an watersheds see the following web sites:

- EPA's Locate your Watershed
  <http://www.epa.gov/surf2/locate/>
  Enter your zip code to find your watershed or watersheds.

- EPA's Surf your Watershed
  <http://www.epa.gov/r10earth/gisapps/basinmethod.html>
  Select a drainage and map it.

- EPA Office of Water
  <http://www.epa.gov/OWOW/watershed>
  Information on watershed protection.

- National Watershed Network
  <http://www.ctic.purdue.edu/Watershed/US_Watersheds_8digit.html>
  Watershed locater and information.

- USGS Water Resources Division
  <http://water.usgs.gov>
  A great resources for a variety of water topics.

- USGS Geographic Names Information System (GNIS)
  <http://www-nmd.usgs.gov/www/gnis/gnisform.html>
  Here you can find the location of a lake and through a link to the EPA Surf Your Watershed site, find out what HUC it is in.

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Model Guidance *continued from page 25*

The primary building blocks of the model guidance include:

- designation of management authority;
- a four-tiered classification system for nonindigenous aquatic species (prohibited, regulated, unregulated and unlisted species) and criteria to guide in the classification process;
- designation of infested waters and activities subject to regulated/prohibited activities in infested waters;
- permit and regulatory protocol pertaining to beneficial uses of nonindigenous aquatic species;
- inspection of recreational vehicles/equipment and beneficial use operations;
- establishment of enforcement authority and related penalties; and,
- protocol for an ANS emergency action plan.

Among others, the guidance suggests rules covering the transport of watercraft from infested waters. Boats must be properly drained, and any visible plants, animals and mud must be removed before the vessel is launched elsewhere. Another suggested regulation prohibits the diversion, appropriation, and interstate transport of water taken from infested waters. Provisions pertaining to the movement of high-risk fishing gear from infested waters to uninfested waters call for the decontamination of gear with removal of plant material, animals and mud, along with freezing, drying, or use of separate gear as alternatives.

Operations involving aquatic nuisance species for beneficial uses, such as the live-bait industry, aquaculture trade, and the horticultural business are also addressed in the guidance. Panel Chair Gary Isbell, of the Ohio DNR, points out that "although implementation of the model's provisions may not be popular with everyone, it is a critical move to strengthen ANS prevention and control measures in the Great Lakes region and beyond."

The model guidance is not presented as an "all or nothing" proposition, but rather as a map to guide Great Lakes jurisdictions toward achieving a higher level of consistency regarding their legislative, regulatory and policy mandates to prevent ANS introductions and dispersal. A multi-watershed, interjurisdictional approach is essential in addressing the insidious problems caused by invasive species since they are coming from other parts of the country as well as waters around the world.

Panel Vice Chair Ron Martin, of the Wisconsin DNR, views this policy document as "providing an opportunity for more regulatory consistency in laws and polices directed at ANS prevention and control; and at the same time, allowing each jurisdiction the flexibility to select from the guidance the provisions that best suit individual jurisdictional needs." The Panel's work on the model guidance reflects the long-standing commitment of this regional body to mitigate problems stemming from biological invasions in Great Lakes waters.

The model guidance, approved by the Great Lakes Panel, is available for $10 upon request. It is also accessible on the Great Lakes Panel's publications page (<http://www.glc.org/ans/anspubs.html>). This initiative is funded by a grant from the National Oceanic and Atmospheric Administration and the Michigan Department of Environmental Quality, Coastal Management Program. **Contact:** Katherine Glassner-Shwayder, Great Lakes Commission, 734-665-9135, shwadyer@glc.org.

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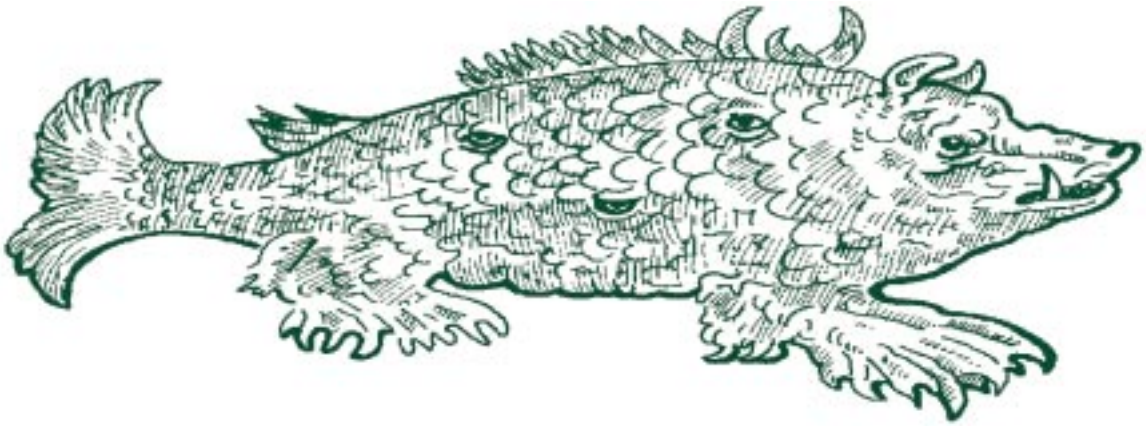

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